Applying conservation assessment to Australian rivers:

a case study using macroinvertebrates

by

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Statement

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except where acknowledged in the thesis, and to the best of my knowledge and belief, no material previously published or written by another person, except where due reference is made in the text of the thesis.

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Abstract

Interest is growing among river managers in the conservation values of rivers, and in the protection of rivers of high ecological value. But can the concepts of conservation value established for terrestrial ecosystems be transferred to riverine ecosystems? What special features of riverine systems should be addressed in determining approaches to assessment and protection?

The thesis uses a case study of the assessment of conservation values of stream macroinvertebrates to explore these questions. Four conservation criteria widely used in the assessment of flora and fauna of terrestrial ecosystems were used. These criteria are: rarity, diversity (richness), representativeness and biogeographic values.

A field survey of 44 sites in two regions of Tasmania provided data to test these criteria and to evaluate implications for protection of high conservation value sites. The thesis describes the macroinvertebrate assemblages using family level data, and the Plecoptera are analysed at species level. The four conservation criteria are applied to the data and the sites of high conservation value identified.

The conservation assessment process is then subjected to evaluation. A number of issues were identified including: limitations of site-based data; taxonomic issues; distributional information, applying thresholds, integrating with existing data sources including the Monitoring River Health database, and establishing representative assemblages. The assessment process was determined to fulfil most quality standards but fell notably short on an adequate assessment of the conservation values of riverine systems. Implications of the study are discussed within the broader context of conservation assessment and protection for riverine ecosystems in Australia.

Possible strategies available for the protection of sites of high value identified in the field study are identified. A model for the assessment of riverine ecosystems is proposed and future directions in protection are explored.

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Abbreviations and acronyms

AHC	Australian Heritage Commission
ANZECC	Australia and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AUSRIVAS	Australian River Assessment System
CALM	Conservation and Land Management (WA)
CAR	comprehensive, adequate and representative
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organization
DCNR	Department of Conservation and Natural Resources (Vic)
DEST	Department of Environment, Sport and Territories (Commonwealth)
DNRE	Department of Natural Resources and Environment (Vic)
EA	Environment Agency (UK)
EA	Environment Australia (Commonwealth)
EDO	Environmental Defenders Office
EPA	Environment Protection Agency (Queensland)
EU	European Union
GBRMPA	Great Barrier Reef Marine Park Authority
IFC	Inland Fisheries Commission (now Corporation), Tasmania
IUCN	International Union for the Conservation of Nature
JANIS	Joint ANZEECC/MCFFA National Forest Policy Statement Implementation Sub-committee
LWRRDC	Land and Water Resources Research and Development Corporation
MCFFA	Ministerial Council of Forestry, Fisheries and Aquaculture
MRHI	Monitoring River Health Initiative (Australia)
NSESD	National Statement on Environmentally Sustainable Development (Australia)
PLUC	Public Land Use Commission (Tasmania)
QEPA	Queensland Environment Protection Agency
RFA	Regional Forest Agreement
RIVPACS	River Invertebrate Prediction and Classification System
RPDC	Resource Planning and Development Commission (Tasmania)
SERCON	System for evaluating rivers for conservation (UK)
SDAC	Sustainable Development Advisory Committee (Tasmania)
SSSI	Sites of Special Scientific Interest (UK)
WCMC	World Conservation Monitoring Centre
WHA	World Heritage Area

Chapter 1

Introduction

1.1 The purpose of the study

River management in Australia has historically focused on human, utilitarian, and economic elements of water availability and use (see for example, ARMCANZ &ANZECC 1996). Because of the essential nature of water for the maintenance of life, conservation perspectives are usually subsumed within issues of river health and have been secondary to the use of water as a human resource. Even recent water reform agendas in Australia (COAG 1994) do not reflect any systematic or purposeful recognition of a primary need for river conservation. Acknowledgement of the provision of water for the environment is the only element of water resource planning to address aspects of river conservation, usually taking the form of a minimalist, and often simplistic, approach to the provision of environmental flows. Rivers are considered to include some of the most threatened species and ecosystems (Allan & Flecker 1993) yet the issues of river conservation have been little explored in Australia.

The need for planning for the conservation of other major categories of ecosystem - forests, grasslands, and marine areas - is well established, and to varying degrees enabled through legislative or policy processes (JANIS 1996; ANZECC 1998, 1999 Environment Australia 1997a, 1998). There are no such systematic plans for riverine environments, although there is a growing recognition of the need for such conservation planning (NSW DLWC 1998; European Commission 1999; Dunn 2000).

A central element of conservation assessment is to define the criteria by which the significance of a river or river section is assessed. There is widespread agreement amongst Australian river scientists and managers that the ecological values of rivers should be broadly defined (Dunn 2000), incorporating hydro-geomorphological characteristics, flora and fauna values, river processes and its role within a landscape.

There has not, however, been any attempt to evaluate what commonly applied criteria for conservation values might be most appropriate for river ecosystems. This is especially important given that legislation, policy, and strategies have largely emerged from experience within, and definitions for, terrestrial ecosystems.

The rationale for this study comes from the urgency to determine possible criteria and strategies for river conservation assessment and protection within the Australian context. Although systems for river conservation assessment have been developed elsewhere in the world (O'Keeffe *et al* 1987; Collier 1993a; Boon *et al* 1994; Boon *et al* 1998; US Wild and Scenic Rivers Act 1968) the criteria and processes may not be entirely appropriate in the Australian context. Possible areas of differences include: the nature of riverine systems and scales for assessment; levels of knowledge and extent of comparative databases; perceptions of conservation values and their significance; the political and legislative context, the influence of potential drivers and levels of advocacy for rivers. Institutional issues are the most probable reason for the failure of at least some of the assessment schemes to be systematically implemented, for example in South Africa (J. O'Keeffe pers. comm.) and New Zealand (K. Collier pers. comm.). Neither the US Wild and Scenic Rivers Act nor the SERCON approach of Boon *et al* in Scotland, have led to the systematic protection of river types in those countries.

The primary purpose of the study is to explore the issues of river conservation assessment and protection in an Australian context, using a Tasmanian field study as a test case. Key issues will be addressed using a conceptual framework developed from a critical review of the technical and institutional dimensions of conservation assessment processes. The field study will be used to test the framework and to highlight implications for river conservation policy, river management practice and the scientific basis for conservation assessment of rivers. The thesis will illustrate the fundamental linkages between science, policy, and practice, which are essential if river conservation and protection of Australia's rivers are to be implemented.

1.2 Australia's rivers and their conservation

1.2.1 The conservation significance of Australia's rivers

Aspects of Australia's rivers are of conservation significance on a world scale (DEST

1996; DEST 1997; WCMC 1998). Australian rivers and associated ecosystems are notable for:

- variable and distinctive hydrology
- unusual ephemeral dryland river systems
- inland streams with high natural salinity and turbidity
- internationally significant wetlands
- river systems dependent on distinctive energy sources and food webs derived from sclerophyllous forests
- a very high degree of endemism amongst the flora and fauna, across a wide range of groups and taxonomic levels
- taxa of phylogenetic or biogeographic significance
- many invertebrate taxa of Gondwanan significance
- marsupials and the monotreme *Ornithorhynchus* (platypus) unique to Australia
- significant karst systems and associated biota.

The importance of the biodiversity of Australia's rivers, floodplains, and wetlands is widely acknowledged (DEST 1996; WCMC 1998). Other values are recognized through inscription at international level, such as the World Heritage listing of the wetlands of Kakadu and Franklin River in the Tasmanian Wilderness World Heritage Area, and Ramsar listing of 49 wetlands (few of which are riverine wetlands) in Australia. A preliminary assessment of Australia's biodiversity (DEST 1997) identified four significant themes for wetlands - the high degree of endemism; the unusual composition of the fauna; ancient and relict components of Pangaean and Gondwanan origin; and adaptations to special conditions including salinity, ephemeral water and variable hydrology.

Many invertebrate taxa have links to the ancient southern continent of Gondwana with their closest relatives in South America or New Zealand. There are fewer than expected freshwater fish species, many of which are endemic and apparently evolved from marine forms (DEST 1996). The uniquely Australian platypus *Ornithorhynchus* depends on freshwater habitats. Riparian plants and aquatic macrophytes and Protista also exhibit high levels of endemism and Gondwanic affinities (Tyler 1992).

Australia is the driest of the inhabited continents (Lake 1995; White 2000). It has the lowest percentage of rainfall as run-off, the least amount of water in its rivers, and the most variable rainfall and streamflow in the world (Finlayson & McMahon 1988; Puckridge *et al* 1998). This creates rivers of varied and distinctive hydrology. In addition, inland streams have high natural salinity and turbidity, with the chemistry often dominated by sodium chloride rather than the more usual calcium or magnesium carbonates (DEST 1996). A range of climate from wet tropical to cold temperate provides various temperature regimes for the associated biota.

White (2000) points out that Australia is a very ancient land, moulded over millions of years to become the flattest, driest and most poorly drained landmass on earth. The rivers of the drier inland are very different from those of the northern hemisphere. Only the fringes of the continent and Tasmania have sufficient rainfall and run-off for the typical hydrological cycle to occur. As a consequence, river types vary across the continent: slow-moving lowland rivers, ephemeral dryland rivers, permanent upland streams, and actively eroding watercourses and rivers are all present in the landscape.

Australia's freshwater biota has several distinctive features. A large number of invertebrate species, genera, and some families are endemic to the country or region within it (Zwick 2000; Wilson & Johnson 1999; EA 1997; WCMC 1998). Several groups generally widespread worldwide are absent from Australian rivers, while some families have adapted to a wider range of habitats (Blyth 1983; Lake *et al* 1985; Lake & Marchant 1990; Rutherfurd 1998). The fauna is characterized by flexible life histories probably in response to the extreme variability of climatic influences (Hynes & Hynes 1975; Lake *et al* 1985; Lake 1995; White 2000).

Australia's vegetation also differs from other world environments with evergreen hardwoods generating much of the energy source for many rivers. The different processing characteristics of this energy source create food webs and carbon flows that differ from other river systems of the world. Models of river ecology developed in the Northern Hemisphere are not necessarily applicable to Australia or other southern regions for these reasons (Winterbourn *et al* 1981; Lake & Marchant 1990; Lake 1995; Rutherfurd 1998).

Australia's rivers have high conservation values but these are yet to be protected in any systematic way. 'At the national level there is little direct activity in reserving river conservation areas' (Schofield *et al* 2000). Protection of water quality and quantity may have consequences for conservation of river ecosystems, but this is incidental to the primary purpose for the respective legislation (Schofield *et al* 2000).

1.2.2 Threats to Australian rivers

The status of a river is largely dependent on the state of the catchment. Catchment degradation in many Australian rivers is profound, with extensive salinisation, land clearance, loss of riparian zones and soils, altered hydrological regimes and groundwater stress. Threats to riverine systems themselves are well documented (Lake & Marchant 1990; Boon 1992a; Barmuta *et al* 1992; Collier 1993; Allan & Flecker 1993; Schofield *et al* 2000) and may be direct or indirect (DEST 1996). Direct threats are the result of changes to the river flow through construction of dams, channelization, or inter-basin transfer, the introduction of exotic species, clearance of riparian zones and point source pollution. Indirect threats are impacts on rivers as a result of changes in the catchment such as land clearance, urbanization, afforestation, intensive agriculture and non-point source pollutants such as fertilizers, stock effluent, or pesticides.

All of the classes and types of threats identified (Boon 1992a; Allan & Flecker 1993), with the exception of acid precipitation, are widespread in Australian waters (Barmuta *et al* 1992; DEST 1996). Australian river systems are especially vulnerable to some classes of threat as a consequence of its shallow soils and highly variable flows (White 2000). To overcome this variability in available water supply and to provide a cheap power source, 'pharonic works' (Allan & Flecker 1993) were undertaken which dammed major river systems and captured flows between catchments. Clearance of native vegetation, coupled with drainage of irrigation water, has resulted in widespread salinity problems (DEST 1996; White 2000).

As settlement of Australia progressed and ever more areas were developed for farming, shallow rooting introduced plant species, which are mostly annual in their life-cycle, replaced the deeper rooting, mostly perennial, native species. These caused not only change in the water table but also changed the geomorphic forms of rivers (White 2000). Many of the problems and damage to Australia's river systems can be attributed to a lack of understanding by Europeans of the very different nature of the land, the climate, and the river systems of Australia. 'Our European attitudes have landed us in the present situation where our water and land use practices are unsustainable' (White 2000 p 2).

Other, more subtle impacts on riverine environments are also acknowledged (Zwick 1992; Frissel & Bayles 1996; Kingsford 1999; White 2000). These include loss of connectivity between the river channel and its floodplains, and the fragmentation of habitat. These have particular relevance in Australia where floodplain rivers are characteristic and ancient landforms (White 2000), and where agricultural and forestry activities occur even in headwaters (Lake & Marchant 1990).

1.2.3 Constraints on river conservation and protection in Australia

Constraints on protection of rivers systems in Australia may be classed in three groups: institutional barriers, environmental constraints, and technical constraints.

Institutional barriers stem from the Commonwealth - State - local government responsibilities and relationships, and a raft of consequences of the political and administrative structure (Maher & Associates 2000; Schofield *et al* 2000). At all levels there is a multiplicity of agencies and legislative powers affecting rivers (Clement & Bennett 1998; EDO 1999). Diametrically across these elements, recent community-targeted Commonwealth funding programs have encouraged community groups to take on responsibilities for water quality and catchment management (Schofield *et al* 2000). While catchment management and funding programs for rivers have increased, conservation values appear to play a minor role (Horwitz *et al* 1999).

The lack of understanding of Australian riverine systems and environments, so clearly highlighted by White (2000), is still a pervasive mentality not only among the general public but also at political levels. River conservation has received comparatively little attention by conservation groups until quite recently and appreciation of the wider conservation value of rivers may be masked by the focus on water quality.

Environmental barriers which constrain river conservation have been discussed in section 1.2.2. The very nature of Australia's climate, its dryness and variability of flow, constrain attempts to protect riverine environments when human use of water supplies is essential.

There are specific technical barriers to the assessment and protection of rivers in Australia for their conservation. The level of knowledge of riverine systems is relatively poor, not only in terms of its fauna but also in the characterization of geomorphic features and hydrology. Thus while efforts are now being directed to defining 'environmental flows' as a core plank of water reform, inadequacy of long-term data sets is just one difficulty (Arthington & Zalucki 1998). The use of biotic surrogates for describing and defining riverine communities is constrained by limited knowledge of much of the macroinvertebrate fauna and other elements of the biota, both in taxonomy and ecology (Kitching 1999). As Kitching (1999) has pointed out, conservation of invertebrates is hindered by a number of factors, including the fact that very little is known about them, either taxonomically or ecologically. This issue was raised almost twenty years ago by Taylor (1983) when he referred to it as the 'taxonomic impediment' to understanding arthropod biodiversity in Australia and the issue remains a major concern (Kitching 1999; Horwitz *et al* 1999; Hutchings & Ponder 1999).

A major technical constraint is the absence of any conceptual framework for assessment and protection of river ecosystems (Boon 1992a), a constraint which it is hoped this study will go some way to relieve.

1.2.4 The condition and status of Australia's rivers

The State of the Environment Report (DEST 1996) paints a bleak picture of the environmental status of Australia's rivers. In the 200 years since European settlement, land clearance, water regulation, impacts on water quality, river engineering and introduced species have had a massive impact on natural riverine and floodplain environments. The report suggests that 'most rivers in the lowlands and in agricultural catchments are degraded, with moderate to severe disturbance of riparian and channel habitats as well as increase in salinity, decreases in flow, changes in flow regimes and increased sediment loads' (DEST 1996 p 7.6). Water storage for power generation, water supply, and irrigation has permanently altered the nature of many of the largest rivers. This has had consequences not only for instream processes and biota but also for floodplains and wetlands. Australia has the highest per capita water storage of all countries in an effort to moderate the impact of its variable rainfall on resource security (DEST 1996). The river systems of the more populous coastal plains in all parts of the country exhibit the greatest modifications to the natural condition. Most unregulated rivers occur in sparsely inhabited parts of the country such as far northern and central Australia.

Damage to river and stream ecosystems is geographically widespread and profound in extent (Blyth 1983; Lake & Marchant 1990; White 2000). In Victoria, most streams and rivers exhibit seriously degraded water quality and aquatic life (VSOE 1988). In the South West Drainage Division of Western Australia, for example, there has been extensive impact on river systems (WAWRC 1992), with most dammed for water supply purposes. Changing flow regimes and agricultural activity have resulted in significant salinity problems and eutrophication of waterways. Well-preserved examples exist for only two of eleven representative river types for the area, with very few examples of a further three types. Remaining river types for this Drainage Division have all been substantially modified (WAWRC 1992). In contrast, rivers of the Timor Sea Drainage Division, one of the northern Drainage Divisions with a sparse population, are mostly classed as 'pristine' or near-pristine' (WRCWA 1997). A similar picture emerges from state of environment reports in other states.

In summary, the State of the Environment Report for Australia (DEST 1996) concludes that, in relation to rivers:

> Aquatic habitat quality has deteriorated markedly in areas of agriculture, urban land use and substantial water regulation.
>
> In many parts of Australia (such as the wet tropics and mountainous areas) where such changes have not occurred, aquatic habitat is still of high quality.
>
> The area of natural wetland has significantly reduced since European settlement.
>
> Regulation, physical barriers, erosion, de-snagging, channel modification, introduced species, pollution and algal blooms have all substantially altered and degraded river habitat quality.
>
> The range and abundance of many species of native aquatic biota have declined significantly, to the point where many are threatened and endangered.
>
> The introduction, spread and establishment of a large number of exotic biota... have exerted significant impacts on the biological communities and habitats of inland waters.
>
> (DEST 1996 p 7.33).

The neglect of protection for rivers as ecosystems is not restricted to Australia. Allan and Flecker (1993) suggest that in the 'biodiversity crisis' attention has been focussed on tropical moist forests, with perhaps a growing interest in ocean conservation, but 'freshwater systems have received less attention … and rivers and streams perhaps least of all' (p 32). This neglect, they claim, is despite the fact that 'running waters harbour a diverse and unique panoply of species, habitats, and ecosystems, including some of the most threatened species and ecosystems on earth, and some of those having greatest value to human society' (p 32). Collier (1993) noted a similar discrepancy in New Zealand, where conservation efforts have focussed largely on terrestrial environments and wetlands. Historically in New Zealand efforts to protect rivers were mainly to preserve fishery values and secondary importance was placed on natural values (Collier 1993a, b). Boon (1992a) claims that the focus on river conservation in North America was similarly driven by a desire to protect habitat for sport and commercial fishing.

Australia's distinctive and important rivers and river sections are ecologically significant on a world scale. The destruction of much of the ecological (and human) values of our river systems is all the more disturbing given the distinctive character of Australia's river systems and biota. Much has already been lost - not only loss of biodiversity but also a lost opportunity to develop a better understanding of the complex ecology of many types of Australia's river systems. It is critical and timely that conservation values of rivers are identified and protected both to meet biodiversity commitments and to ensure that the best possible management and use of all water resources can be achieved (White 2000). In a recent assessment of river conservation Schofield *et al* (2000) concluded that 'Australia is now at a critical point in managing its aquatic resources'.

1.2.5 Tasmania's riverine environments

Tasmania's location in the path of predominating westerly winds over the southern ocean coupled with its mountainous topography provides for an extensive system of rivers. It is the most well-watered of any Australian state and has a wealth of freshwater habitats including highland streams, major rivers, natural lakes and artificial impoundments, pools and wetlands. The climate maintains most of these as permanent features of the landscape, though ephemeral streams occur in eastern areas and some larger rivers suffer low or nil flow in summer months as a consequence of regulation and abstraction.

River systems of Tasmania have a number of features that distinguish them from rivers of mainland Australia. The high rainfall spread through out the year in western Tasmania creates a hydrological regime unique in Australia (Hughes 1987; Finlayson & McMahon 1998). Such high rainfall and continuous discharge occurs nowhere else in temperate Australia. Despite its small area, Tasmania has at least four other distinct hydrological regimes with some marked seasonality (Hughes 1987). Rivers in Tasmania are generally less impacted by point source discharge from current industrial developments and alpine streams are mostly undisturbed due to the limited use of highland areas for grazing or agriculture.

Tasmania has some rivers and river sections that have been assessed as being of high value as wild rivers (Tasmanian Regional Forest Agreement 1997). There are still a few rivers, which are unregulated, not subject to abstraction and with undisturbed catchments from headwaters to sea level. This is most unusual in temperate regions on a world scale.

The water chemistry of Tasmania's rivers is diverse, partly owing to the diversity of bedrock geology and river geomorphology. Rivers with a naturally low pH (around 5 - 6) are common, particularly in the west, where they are characteristically brown due to dissolved tannins. Low pH rivers also occur in the granitic rocks of the east. Karstic rocks sustain naturally higher conductivity rivers, attributable to calcium or magnesium ions. Most waterways are clear and well oxygenated, though some are subject to siltation under certain conditions.

The fauna of Tasmania's rivers is highly endemic. Species of the major aquatic insect groups - the Ephemeroptera, Plecoptera, and Trichoptera - are between 70% and 80% endemic to the state (Hynes 1989; Neboiss 1991). Some taxa are locally endemic to a particular region. Crustacean taxa are also highly endemic and often quite restricted in distribution. In addition, the fauna is considered to have distinct Gondwanic affinities and affiliations of biogeographic significance (Hynes & Hynes 1980; Bureau of Flora and Fauna 1988). Controls on the present distribution of some invertebrate groups are believed to relate to recent glacial events (Mesibov 1996). There was recognition of the significance of Tasmania's invertebrate fauna on a world scale at quite an early stage of natural history exploration of the state (Tillyard

1921, 1924, 1936) and it continues to attract research visits especially from taxonomists. However, the level of knowledge of Tasmanian instream communities and dynamics remains limited and patchy (Richardson & Swain 1978; Chilcott 1987; Richardson & Serov 1992; Swain *et al* 1994) and often driven by impact assessment (Lake *et al* 1977; Davies & Nelson 1993, 1994; Davies *et al* 1996).

Tasmania's rivers therefore are generally regarded as of conservation interest, yet the conservation significance has not been systematically assessed, nor have macroinvertebrate communities been characterized, except in a superficial way through the Monitoring River Health Initiative analysis (Oldmeadow *et al* 1998). There is no systematic protection of rivers of high conservation value nor is there protection of a representative selection of river types. Indeed, despite widely held perceptions of clean and healthy rivers, there has been considerable impact on the natural riverine environments. Tasmania's State of Environment report (SDAC 1996) comments that '[f]ew of Tasmania's aquatic ecosystems have escaped alteration since European settlement' (p 3.23) A wide range of impacts is noted including:

> Change to the watertable, salination and organic and inorganic pollution...a result of building dams, forestry, agriculture and quarrying, as well as urban and rural developments (p 3.23)
>
> Most of the large waterbodies in the State have been changed [and] the creation of artificial water storages and the subsequent regulation of river flow has been widespread in Tasmania (p 3.23)
>
> [T]here are localised pressures on inland waters and wetlands...due to historic neglect of the state's environment [or] ongoing human activities. Continuing activities including forest harvesting and sewage effluent discharge, are still causing short- to long-term changes to sections of many catchments (p 3.43).

Private land uses such as agriculture are identified as significant sources of pressure on the state's inland waters with 'diffuse source pollution, swamp drainage and water over-use leading to problems such as groundwater contamination, stream stagnation, salinisation, eutrophication and ecosystem diversity loss' (p 3.43).

Much of Tasmania's rainfall has been captured by the extensive hydro-electricity generating schemes which were developed over a period of some 80 years. Despite the claims of a 'clean' electricity generating system in the state, considerable impact has occurred to many riverine environments. Most of the larger river systems now have substantially altered flow regimes and some systems are also subject to interbasin transfer. Floodplains and wetlands have been inundated to form large dams or impoundments. Dam construction by the Hydro-electric Commission has resulted in the inundation of some 1100 km^2 of river valleys, wetlands and pre-existing lakes (SDAC 1996). This has resulted not only in loss of riverine sections but also has impacted upon riparian vegetation, flow and temperature regimes, and sediment and nutrient distribution downstream of the impoundments.

Withdrawal of water for irrigation purposes has increased, notably in the last twenty years, with the increasing emphasis on diversified cropping, viticulture, and efforts to increase pasture yields. Past efforts to 'improve' agricultural land through river improvement, drainage schemes and riparian clearance have been undertaken in many areas of the state to the detriment of streams, wetlands and native vegetation (SDAC 1996 p 3.32). Despite stream protection claimed (but largely untested) by the Forest Practices Code (Forest Practices Board 2000), headwater catchments are becoming isolated refugial islands (Zwick 1992).

Exotic fish species were first introduced to Tasmania over one hundred years ago. Brown and rainbow trout (*Salmo trutta, Onchorhynchus mykiss*) are widespread in the majority of catchments and lakes (Cadwallader 1996). Carp (*Cyprinus carpio*) and yabbies (*Charax destructor*) have been illegally introduced and efforts are being made to control spread and to reduce the impacts of these species (website of the Inland Fisheries Commission, Tasmania www.ifc.tas.gov.au/carp.html and www.ifc.tas.gov.au/exoticman.html, consulted 22/01/01)

The State of the Environment Report concludes that ' the true condition of the State's inland aquatic environments is still uncertain. However, it is clear that while some areas are in very good condition others are seriously degraded' (SDAC 1996 p 3.43). The Report also recommends the application of the precautionary principle to the management of the state's water resources (p 3.43). Imminent proposals for additional agricultural dam developments will add further pressure on river systems. A system for identification and protection of the conservation values of Tasmania's rivers is therefore urgently needed.

1.3 Biodiversity conservation and reserve planning in Australia

Until the last decade, conservation and protection of natural areas occurred in an *ad hoc* manner at state level. While the Commonwealth government played a role in identification of places of heritage value (Australian Heritage Commission Act 1975) and in matters of national significance such as World Heritage, the protection and management remained with the states. In recent years, the Commonwealth has taken a more purposeful role in bringing about coordinated approaches between all states to the protection of biodiversity (DEST 1996), sustainable development in response to the UN Agenda 21 (NSESD 1992) and water reform (ARMCANZ & ANZECC 1994, 1996). Each of these strategic directions potentially plays a part in protecting riverine values but there is no distinctive driver for river conservation such as the European Union's Habitats Directive (European Commission Directorate-General XI) or forthcoming EU Water Directive (P. Boon, pers. comm. 2000). Australia also lacks legislation equivalent to that protecting the UK Sites of Special Scientific Interest or SSSI's (Boon 1999) at either Commonwealth or state level under which ecosystems or habitats of conservation value may be protected.

Moves for river ecosystem conservation also need the weight of well-resourced and influential agency support and leadership such as that provided by the Nature Conservancy in UK. Such agency leadership for river conservation is lacking in Australia. Endorsement and pressure from non-government organizations (NGO's) has played an important role in pressing the case for conservation of other ecosystems, notably forests, in Australia, but rivers have not attracted the same degree of support.

The principal drivers that could be applied to river conservation in Australia are the biodiversity strategy and water reform. However, such a policy commitment requires a conceptual framework and practical strategies to proceed. Assessment and protection of other ecosystems has proceeded through application of principles of protection for representative areas. This has principally been for terrestrial environments and is sponsored as a key element of the Biodiversity Strategy (1998). Greatest progress has been made in representative reserve systems for forests (Regional Forest Agreements website www.rfa.gov.au consulted 18/01/01), largely driven by high conflict levels between conservation and forestry interests. Planning for a representative reserve system for marine areas (ANZECC 1998, 1999) is also proceeding. Grassland conservation is currently being addressed under the Representative Areas Program, a component of the Biodiversity Strategy (EA 1997; ANZECC 1996). There is no equivalent process in place for river or other freshwater ecosystems.

1.3.1 Requirements for river assessment and conservation

Riverine environments present particular difficulties in both assessment and protection for conservation (Ladle 1991; Ward 1998; Boon 1992a, 2000). Ward (1989) argues that the riverine environment must be considered in four dimensions having longitudinal, lateral, vertical and temporal components implying that not only instream values are important but also the floodplain, catchment and the entire river from source to mouth. Boon (1992a) suggests that this four-dimensional model should be taken to a fifth dimension for the purpose of conservation assessment. This is a conceptual dimension that defines what is important to conserve through 'questions of philosophy, policy and practice' (p 22). The conceptual dimension addresses issues such as what is important to conserve, how can conservation potential of rivers be assessed, and what priorities should be given to different elements of conservation value (Boon 1992a).

The multi-dimensional nature of riverine systems is now well established in the key concepts of river ecology (Carpenter *et al* 1996; Corkum 1999; Boon 2000; Dunn 2000). It is Boon's fifth 'conceptual' dimension on which river conservation debates focus. Almost by its definition, referred to in the previous paragraph, this fifth dimension is inextricably linked with protection and restoration of rivers.

Rivers as ecosystems have a number of distinctive features, which make conservation assessment and protection particularly problematic (Ladle 1991). These ecosystem features include: the longitudinal and directional nature of key system components; the interaction with the tributaries, catchment and floodplain; the extreme patchiness of faunal assemblages within and between the many riverine microhabitats, and issues of scale and delimiting geographically an area for assessment and protection (Downes *et al* 1995; Frissell & Bayles 1996; Carpenter *et al* 1996; Corkum 1999; Ormerod 1999; Moss 2000; Pringle 2000). In like fashion, rivers as management entities have special problems including: the importance of water as a human resource; the non-substitutable nature of this resource; the longitudinal and dynamic nature of the ecosystem; the numerous interests and agencies with an interest in and responsibility for aspects of river management; impact of political boundaries; community expectations for 'free' water supplies and a lack of recognition of the ecosystem services provided by rivers (Ladle 1991; Costanza *et al* 1997; Moss 1999; Pringle 2000; Schofield *et al* 2000; Boon 2000; Cork 2000).

1.4 The imperatives for river assessment and protection in Australia

General Commonwealth and state policy commitments to the protection of biodiversity have yet to be translated into strategy and action with respect to freshwater habitats (Schofield *et al* 2000). Indeed it may be argued that government policies for water reform may be contradictory to biodiversity protection if judgements about environmental needs are based on inadequate ecosystem data.

There are increasing pressures and threats to freshwater systems (DEST 1996; EPA 1999a). While efforts are being made to control some recognized threats to rivers such as discharge of waste, the quantity of water required to sustain a healthy system is under greater pressure. Competition has accelerated for access to and use of water for a variety of human purposes. Water is now recognized as a critical limiting factor in regional development. Many rivers, which remain unregulated or with limited abstraction have been proposed for development and few will remain in natural condition. River systems are not only impacted by direct draw-off but also by use of groundwater and changes in land use.

River systems have distinctive problems, which call for different management strategies compared with land management. The water resource cannot be substituted with any other substance. It is limited in availability and can be uneven in renewal. River systems are linear systems with energy and resources flowing for the major part in a single direction. The cycle, which re-supplies the river environment with nutrients, water and other habitat elements, is complex and often indirect. The needs of rivers have, to a greater degree than terrestrial systems, to be addressed on a wider scale than the immediate geographic locality and management cannot be fixed spatially to a river section. On the Australian mainland these differences in management contexts are exacerbated by traverse of many river systems across state boundaries.

While work is proceeding on assessment on river condition (DNRE 1997; Simpson *et al* 1999; Davies 2000) and rehabilitation (Rutherfurd *et al* 1999), there are no agreed principles and frameworks for conservation assessment and protection for rivers.

1.5 Outline of the methodology and the thesis

The purpose of this study is to explore the issues of river assessment conservation in an Australian setting. The scope is potentially very large: the multi-dimensional and multi-faceted nature of riverine environments; the range of river types and habitats; the political and institutional dimensions and the conceptual parameters of the assessment process. It was therefore necessary to be highly selective in the scope of the study, and to delimit data collection in a number of ways.

In choosing a focus for study, a number of factors were taken into account: available data and ecological frameworks; relevance and familiarity to potential target audiences; manageable field requirements, and potential links with measures for protection. Macroinvertebrate riffle fauna met these requirements and two areas in northern Tasmania were selected for the field study and subsequent exploration of conservation issues. While related conservation values such as fish communities, flora, geomorphological values, maintenance of flood plains, karst and wetlands are recognized as also being of conservation value (Dunn 2000), these were not addressed.

The two study areas were selected because their rivers were unregulated and relatively undisturbed yet there were no protected areas in those regions of the state. One region, the north-west, is thought to be a centre for trichopteran diversity (Neboiss 1981). The north-eastern region was chosen as a study area with some biophysical similarities to the northwestern sites but in a different rainfall regime and in different bioregions. The second region provided an opportunity to explore any bioregional differences between the faunas.

The study draws on general conservation theory to generate criteria for assessment of conservation values of the macroinvertebrate fauna. These criteria were then applied to data collected in a field study in two areas of northern Tasmania to provide an assessment of the conservation values of river macroinvertebrates in these areas. This practical exercise was used as the basis for evaluation of these criteria and the assessment process for river conservation values. Options for protection of macroinvertebrate and other ecological values in these rivers were identified.

The analysis of the field study raised a range of issues, which are clearly generic in the assessment and protection of rivers of conservation values in Australia. These were summarized in a model of river conservation assessment.

The outcomes of the study will be:

- Assessment of the conservation values of stream macroinvertebrates in two comparable areas of northern Tasmania
- Evaluation of the application of conservation criteria to river macroinvertebrates using these values as examples which may be applied more widely in river ecosystems
- Identification of possibilities and gaps in measures for protection of rivers of high conservation value in Tasmania
- A model for conservation assessment of river systems

In Chapter 2, approaches to assessment in rivers are outlined including recent Australian initiatives in the assessment of condition. These are compared with two well-established approaches to river assessment in the Northern Hemisphere. Criteria for conservation value are explored through examples from other types of environments and ecosystems.

Chapter 3 proceeds to define and delimit the conceptual framework for the study and details the methodologies adopted. Subsequent chapters follow two different, but interrelated, strands of analysis: the assessment of riverine macroinvertebrate communities and the conservation values of streams in the study areas, and an evaluation of the assessment process and implications for riverine protection.

Chapter 4 describes the field sites, their macroinvertebrate fauna, and communities. The place of the field sites within the broader context of Tasmanian lotic habitats is considered in Chapter 5, using the Monitoring River Health Initiative data for comparison.

The Plecoptera of the study sites are described and their distributions are analysed in Chapter 6.

In Chapter 7 the data from the field study sites are analysed with reference to conservation criteria to identify sites of special conservation value.

In Chapter 8, principles of conservation assessment are presented and their management in the present study is outlined. Issues which emerge for river conservation assessment are discussed.

Chapter 9 provides the policy and legislative contexts for protection of river systems in Tasmania and shows, using some examples from the field study, that options for protection are very limited. This leads to a discussion on the implications for protection of rivers in Tasmania and elsewhere in Australia and recommendations are made for a strategy to address river protection.

Chapter 10 provides a critique of the assessment process and an analysis of the implications for river conservation assessment. A general model of river conservation assessment is proposed.

In Chapter 11 I summarize my findings and make proposals for river conservation and protection in Australia.

Chapters 3-11 each commence with a brief overview of their contents (italicised).

Chapter 2

Assessing rivers and conservation values: concepts and strategies

2.1 Assessment of rivers in Australia and overseas

The systematic assessment of rivers has been a fairly recent phenomenon in Australia. So far it has been limited to assessing degradation and condition of rivers rather than assessing their conservation value. With the exception of the Monitoring River Health Initiative (Simpson *et al* 1999) and the Wild Rivers project (Stein *et al* n.d.) the assessment protocols have been developed at state level and in particular management contexts.

The Commonwealth Government initiated the Monitoring River Health Initiative (MHRI) in 1993 to develop scientifically based tools to assess and monitor the state of the nation's rivers (Schofield & Davies 1996; Oldmeadow *et al* 1998; Davies 2000). In a collaborative nationwide program, a scheme was to be developed using bio-assessment techniques based on the highly successful RIVPACS (River Invertebrate Prediction and Classification System) approach developed in the UK (Wright *et al* 1989). A standard rapid assessment sampling protocol was developed for Australian conditions with up to four in-stream habitat types sampled at each site for macroinvertebrates (Davies 1994). State agencies undertook selection of sites, nominating 'reference' or least disturbed sites, as well as 'test' sites which were suspected of being impacted and were to be assessed also (Fuller & Read 1997). Sampling of reference sites over the period 1994 - 7 provided data which were to be the foundations of model development. The Monitoring River Health Initiative then developed a protocol based around a predictive model derived from the reference site database, the Australian River Assessment System (AUSRIVAS), which enables comparison of observed with expected macroinvertebrtate community using the predictive model (Davies 2000). AUSRIVAS models were developed for each region and state and for the dominant habitat types of Australian river systems.

Unlike the UK RIVPACS model, which was its precedent, AUSRIVAS relies on family level taxonomic assessment. With greater knowledge of both taxonomy and distribution, the British system uses species level data with confidence (Wright *et al* 1996). The AUSRIVAS models are based on macroinvertebrate data collected from some 1500 reference sites nationally. Each state is now utilising the AUSRIVAS predictive models for bio-assessment of nominated test sites (Davies 2000). The data from reference sites may also be used in other more broadly based riverine assessment programs and projects.

The Wild Rivers Project identified Australian river systems, which have been relatively unchanged since European settlement (Stein *et al* n.d.). This national study, coordinated and undertaken by the Australian Heritage Commission, used input data supplied by the State agencies on various indicators of disturbance. The various data layers are combined using specific decision rules (Stein *et al* n.d.) and converted to an index of 'river wildness' reflecting level of disturbance.

All river sections across Australia have been accorded a score, which can be mapped, giving an overview of the level of disturbance of river systems as measured by the selected criteria. The project used these data in a process to identify 'pristine' and 'near pristine' rivers and draft conservation management guidelines have been developed as a voluntary code for river managers (Kunert & McGregor 1996). The Wild Rivers Index has been used in other assessment processes such as Regional Forest Agreement (Tasmania) and the State of the Rivers project in Western Australia (WAWRC 1992; WRCWA 1997). It is also being incorporated for co-assessment within the AUSRIVAS framework (P. Davies pers. comm.). It was proposed that lists of wild rivers be produced by individual states but there is no strategy for formal protection (Kunert & McGregor 1996).

In the state of Victoria, a project was undertaken to identify least disturbed rivers to be designated under state wild rivers legislation (Land Conservation Council 1991). Eighteen Heritage Rivers were designated for their outstanding natural, cultural, scenic and recreational attributes and 26 Natural Catchment Areas were proclaimed under the Heritage Rivers Act 1992 but, with a change in government, this action was not pursued to full implementation (L. Metzeling pers. comm.). Under a new government, management plans are now being prepared for all heritage rivers and natural catchments as required under the Act (M.Crowe pers. comm.)

An Index of Stream Condition (ISC) has been developed to assess the degradation of the Victoria's waterways (DNRE 1997; Ladson *et al* 1999). Most of Victoria's lowland rivers are affected in some way by human activity. The ISC is a tool to aid integrated management of waterways (Department of Natural Resources and Environment 1997). The assessment is used:

> To benchmark stream condition;
>
> - To aid objective setting for waterway management;
> - To judge the effectiveness of management intervention, in the long term ...;
> - To provide feedback to waterway managers ...;
> - To indicate long-term strategic performance by waterway management authorities.
>
> (Department of Natural Resources and Environment 1997 p 2).

The ISC comprises assessment of hydrology, physical form, streamside zone, water quality and aquatic life. One of the ISC sub-indices is the AUSRIVAS bioassessment 'O/E' (observed over expected) score. Data on key indicators for each of these categories are collected and resulting scores or ratings converted to an index according to set rules or criteria. Descriptive categories are converted to arbitrary numerical values and values for each of the five sub-indices are combined to give an overall numerical value for the ISC.

The ISC is appropriate where there has been extensive modification of catchments from natural condition. The ISC contributes to the broadscale management of waterways by providing an integrated measure of their environmental condition (Ladson *et al* 1999). It is not intended for identification of ecological value, except that a stream which achieves high ISC values would be indicative of a stream with potential conservation value because of its relatively low level of disturbance compared with other sites.

The Stressed Rivers approach was one of the first steps in introducing a series of water reforms in the state of New South Wales. A classification system was devised to enable prioritisation of catchments for immediate management attention (DLWC NSW 1998). This approach again focuses on assessment of damage or threats to riverine environments. The Stressed Rivers approach separates each sub-catchment into one of nine categories based on environmental and hydrological stress. Stresses are assessed on the basis of current water usage and environmental health measures. Possible future levels of hydrological stress are also considered where there are a substantial number of undeveloped water entitlements. This results in a matrix of stress classifications and management categories (Table 2.1).

The Stressed Rivers classification process also attempted to identify all sub-catchments with special conservation value. This included not only many low stress rivers but also some impacted rivers, which had remnant habitats or species of significance. The values identified provided information for the management of those rivers.

Table 2.1 NSW Stressed Rivers matrix

	Environmental stress: LOW	Environmental stress: MEDIUM	Environmental stress: HIGH
Proportion of water extracted: HIGH	Immediate indications are that water extraction is causing a problem. Requires more detailed evaluation	Water extraction is likely to be contributing to environmental stress	Water extraction is likely to be contributing to environmental stress
Proportion of water extracted: MEDIUM	No indication of a problem, low priority for management action	Water extraction is likely to be contributing to environmental stress	Water extraction is likely to be contributing to environmental stress
Proportion of water extracted: LOW	No indication of a problem, low priority for management action	Environmental stress likely to be due to factors other than water extraction. Stress not high so lower priority for management action	Environmental stress likely to be due to factors other than water extraction. Stress high so important to ensure that water extraction is not exacerbating the problem.

In addition, a smaller number of rivers were identified as high overall conservation value, which would justify a higher level of protection. Further refinement of the assessment of conservation value of rivers is being considered (M. Conlon DLWC pers. comm.).

In Western Australia, the Western Australian Water Resources Council (1992) and later the Water and Rivers Commission (1997) have documented the state of the rivers across all drainage divisions of the state. This was assessed by mapping the major forms of degradation to which rivers in the state are subject. These included pastoral land use, clearing for agriculture, introduction of weeds, mining, roads and tracks, dams, erosion and sedimentation.

Information from the Wild Rivers project of the Australian Heritage Commission aimed at identifying rivers in pristine and near-pristine condition was also incorporated.

The WA State of the Rivers assessment (WAWRC 1992; WRCWA 1997) led to the assigning of rivers to one of five categories: A1 Pristine, A2 Near-pristine, B1 Relatively natural, B2 Altered, C Degraded. Rivers in Categories B1 and B2 are considered to have potential for rehabilitation to stable, healthy, functioning ecosystems. These reports have helped the Water and Rivers Commission to focus on the important issues and management objectives, but the location of restoration works has been driven largely by community interest (Traylor pers. comm.1999) More recently, efforts towards a more strategic approach are being pursued through the Waterways WA Program (Klemm *et al* 1999; Sparks 1999). Standard protocols for assessing riparian condition have been developed for both urban and rural stream sections by the WRC.

The assessment of environmental flows is one aspect of river assessment which has received national attention. A strategic framework to achieve an effective and sustainable water industry by the Council of Australian Governments in 1994 laid the foundations for addressing the issue of water allocation in river management. One major recommendation was the introduction of a system of water allocation, which would address water entitlements, water trading, and provision of water for environmental flows. Subsequently, a set of National Principles for the Provision of Water for Ecosystems was produced (ARMCANZ & ANZEEC 1996). This was followed by responses from states and territories to develop practical methods for assessing water requirements for ecosystems, known as environmental flows. A review and evaluation of environmental flow assessment techniques has been undertaken recently (Arthrington & Zalucki 1998). Methods targeting different key ecosystem elements including geomorphology and channel morphology, wetland and riparian vegetation, aquatic invertebrates, freshwater and estuarine fish, and water-dependent wildlife and water quality are evaluated.

Arthrington & Zalucki (1998) have evaluated six methods of environmental flow assessment. Environmental flows assessments may be incorporated into a decision support system process such as the Queensland Water Allocation Management Planning (WAMP) process (Arthington & Zalucki 1998). Other states are seeking to use environmental flows assessment as a key plank of water management planning (for example, Fuller & Read 1997). The assessment of environmental flows presupposes that the ecological value of the river is known and that flow requirements of the ecosystems are also understood.

In 1997 the Queensland Government initiated a process to identify potential water infrastructure projects to support economic development. The Department of Natural Resources prepared an implementation plan known as the Water Infrastructure Planning Development Implementation Plan (WIPDIP). The Environmental Protection Agency (EPA) is working with the Department of Natural Resources and other government agencies to assemble information about conservation priorities and the sustainability of future water resource developments. The EPA's work is termed the Water Resources Environmental Planning (WREP) program for WIPDIP (EPA 1999a, b).

The work on this project is still in a developmental phase with a focus on developing a conceptual framework incorporating description and classification of waterways, conservation value assessment, and sustainability assessment. A protocol for delimiting the river sections for assessment known as the Biological Aquatic System (BAS) on geomorphological, hydrological and biological parameters is also being developed.

There is debate amongst river scientists as to just what constitutes river health (Norris & Thoms 1999). The intensive work in the field of river health using macroinvertebrates to provide predictive models of the state of rivers (Davies 2000) has led to the equating, by many within the river community, of 'healthy rivers' with rivers of 'conservation value'. This assertion is based on the experience of meeting with river managers across Australia and through conducting a survey of river scientists and managers (Dunn 2000). While there may be common elements, it is argued that a 'healthy river', however defined, is neither a necessary nor a sufficient condition for the river to be of high conservation value, except in so far as it is important to conserve the general ecological quality of all rivers.

The early steps towards notions of conservation of rivers in Australia generally focussed only on the assessment of in-stream biota (Blyth 1983; Macmillan 1983; Lake & Marchant 1990; Doeg 1995a, 1995b). Barmuta *et al* (1992) reported on progress towards conservation but this only addressed approaches to assessment and did not demonstrate any progress towards application of the findings of such conservation assessment into mechanisms for protection.

Elsewhere in the world, in addition to assessment of river quality, there have been attempts to develop assessment protocols and some formal protection of high value rivers. The UK has been foremost in developing comprehensive and, recently, integrated, approaches to river assessment.

The River InVertebrate Prediction And Classification System (RIVPACS) is a software package developed by the Institute for Freshwater Ecology in the UK for assessing the biological quality of rivers (Wright 1995). Work commenced in 1977 to develop a classification of un-polluted sites based on the macroinvertebrate fauna and to determine whether the macroinvertebrate fauna at an un-stressed site could be predicted on the basis of physical and chemical characteristics of the river only. The work drew on an extensive database of information about the distribution of fauna and has gone through a number of phases. It has the advantage of using species level taxonomic resolution.

Biological data were collected from hundreds of sites, along with data on environmental variables. These data were classified using two-way indicator species analysis (TWINSPAN) (Hill 1979) into site groups. Multiple discriminant analysis (MDA) was used to find combinations of variables which best predicted the identified groups (Moss *et al* 1987, Wright *et al* 1984, Wright *et al* 1989, Wright 1995). Predicted taxa for any given site could then be generated using 14 environmental variables and the frequency of occurrence of species in these classified groups. The RIVPACS approach has continued to evolve and is now applied in the five-yearly River Quality Surveys (Raven *et al* 1998).

In parallel with RIVPACS, the River Habitat Survey (RHS) is a British system for assessing the character and quality of rivers based on their physical structure (Raven *et al* 1998). Originally focused on providing a detailed information tool, the RHS may be applied to rivers for a variety of management purposes. It has four components: a field survey using a rigorous standard methodology; a computer database for data entry and comparison with other sites; a suite of methods for assessing habitat quality, and a method for describing channel modification. 'Habitat quality is determined according to the occurrence and diversity of habitat features of known value to wildlife, and is derived by comparing observed features at a site with those recorded at sites from rivers of similar character' (Raven *et al* 1998 p 7). Thus the evaluation stage of the assessment is founded upon: knowledge and description of habitat requirements; classification of types of sites or reaches; assumptions concerning distribution and behaviour of rivers and associated flora and fauna; a large database, and a validated methodology. The River Habitat Survey is used in a variety of ways by various agencies and supports legal and political imperatives for river protection.

The third plank in the river assessment strategies in the UK is SERCON (System for Evaluating Rivers for Conservation). SERCON is a broadly based technique for assessing conservation value using six conservation criteria and a criterion for impacts (Boon *et al* 1997; Boon *et al* 1998). The six conservation criteria are: physical diversity, naturalness, representativeness, rarity, species richness and special features (Table 2.2) These criteria have been 'designed so that evaluation can be related to the wider field of nature conservation assessment, (which is) achieved by fitting each attribute into a framework of generally accepted conservation criteria' (Boon *et al* 1997 p 308).

Rivers are evaluated in discrete lengths, normally between 10 and 30 km known as Evaluated Catchment Sections (ECSs). A SERCON evaluation has three stages: field survey using an extended form of the River Habitat Survey, a wide range of other data is collected from available sources, and finally all data are translated into scores ranging between 0 and 5 for each of the attributes using guidance from the SERCON manual. Scores are weighted and combined to provide separate indices of conservation value for each of the six conservation criteria (Boon *et al* 1998). The indices are presented in the form of an A - E assessment of conservation quality, and other data such as region and catchment use are also collected for the overall conservation assessment.

Table 2.2 River attributes assessed by SERCON

Physical Diversity	**Rarity**
Substrates	EC Habitats Directive/Bern Convention Species
Fluvial features	Scheduled species
Structure of aquatic vegetation	EC Habitats Directive Species
	Red Data Book macrophyte species
	Red Data Book invertebrate species
Naturalness	**Species Richness**
Channel naturalness	Aquatic and marginal macrophytes
Physical features of the bank	Aquatic invertebrates
Plant assemblages on the bank	Fish
Riparian zone	Breeding birds
Aquatic and marginal macrophytes	
Aquatic invertebrates	
Fish	
Breeding birds	
Representativeness	**Special Features**
Substrate diversity	Influence of natural on-line lakes
Fluvial features	Extent and character of riparian zone
Aquatic macrophytes	Floodplain: recreatable water-dependent habitats
Aquatic invertebrates	Floodplain: unrecreatable water-dependent habitats
Fish	Invertebrates of river margins and banks
Breeding birds	Amphibians
	Wintering birds on floodplain
	Mammals

Source: Boon *et al* 1997

SERCON had its origins in the work of O'Keeffe *et al* (1987) in South Africa. O'Keeffe surveyed experts in river research and management to determine a suite of criteria for conservation value. For each river, these would be assessed, weighted and a sum total score provided as a summary of conservation value. No assessment process applying this work has been implemented in South Africa. The protocol was refined by Boon *et al* (1994, 1997), notably in providing a score for each criterion rather than a summary total.

In New Zealand, a similar criterion-based approach was explored by Collier (1993a) but in the absence of any provisions or policies for protection of riverine environments, it proceeded no further.

Boon (1992) suggests that three elements are necessary for assessment of conservation value:

- description (to identify the species and habitats of interest),

- classification (to distinguish rivers of different types) and
- assessment (to identify, at least in a semi-objective way, rivers which have greater conservation value than others).

In the UK, classification is provided by the River Habitat Survey, while description and assessment is provided by SERCON. The River Habitat Survey provides an approach to describing physical features of the river corridor for use in wider conservation assessment such as SERCON. The two approaches were being developed concurrently. More recently, work has been proceeding on integrating the two processes to complete the requirements for assessment of conservation value (Boon *et al* 1998; Raven *et al* 1998).

A quite different approach to river conservation assessment is adopted in the United States. This is based on classification into broad categories based on descriptive criteria (Table 2.3). The US Congress may list rivers under the Wild and Scenic Rivers Act after study of the river's eligibility and suitability for classification. Agencies are required to consider and evaluate all rivers for potential designation while preparing broad land and resource management plans. Numerous rivers and river segments have been nominated and legislated at state level. The National River Inventory lists rivers and river segments that appear to meet minimum Act eligibility requirements based on their free-flowing status and resource values, and which are, therefore, afforded some protection from the adverse impacts of federal projects until fully assessed. Study of the rivers applies a common inventory of values through resource assessment (eligibility), assessment of existing conditions and evaluation of alternative management scenarios (suitability).

Eligibility is an evaluation of whether a candidate river is free flowing and possesses one or more outstandingly remarkable value (ORV). If found eligible, a candidate river is analysed as to its current level of development (water resources projects, shoreline development, and accessibility) and a recommendation is made that it be placed into one or more of the classes: wild, scenic, or recreational (www.usbr.gov/laws/wildscen.html).

The different approaches to assessment - detailed criteria and scoring systems (SERCON) compared with broad classification (Wild and Scenic Rivers) - are a parallel of the recent strategies for determining river quality or health in Australia. A criterion-based approach is utilized in the Index of Stream Condition in Victoria while in NSW the Stressed Rivers program adopts a classificatory approach.

Table 2.3 US Wild and Scenic Rivers classification matrix

Attribute	Wild	Scenic	Recreational
Water resource development	Free of impoundment	Free of impoundment	Some existing impoundment or diversion
Shoreline development	Essentially primitive. Little or no evidence of human activity	Largely primitive and undeveloped. No substantial evidence of human activity	Some development. Substantial of human activity.
Accessibility	Generally inaccessible except by trail	Accessible in places by road	Readily accessible by road or rail road.
Water Quality	Meets or exceeds federal criteria or federally approved state standards for aesthetics, and for propagation of fish and wildlife normally adapted to the habitat	No criteria prescribed by the Wild and Scenic Rivers Act.	No criteria prescribed by the Wild and Scenic Rivers Act.

2.2 Defining and assessing conservation value

The Natural Heritage Charter (AHC 1996) explains conservation value or significance in the following way.

> Natural significance means the importance of ecosystems, biological diversity and geodiversity for existence value or for present or future generations in terms of their scientific, social, aesthetic and life-support value (AHC 1996 p 6).

Conservation value is explained in the selection of criteria and attributes. But constructs of 'conservation value' can change over time, and also may be perceived differently in different environmental contexts. Australia has a well-established history of conservation assessment and development of conservation theory even though this is almost exclusively for terrestrial ecosystems. Consideration of what is considered to mark 'conservation value' both in international contexts and in other types of system in Australia can be used to frame a set of proposed conservation criteria for Australian river systems.

Several approaches to conservation assessment for various ecosystems, which have been developed or applied in Australia, are now outlined. Common elements are notable with consistent themes amongst the criteria. These include naturalness or integrity, diversity, richness, habitat for rare and threatened species and representativeness of ecosystem type. Where the criteria are associated with planning for conservation or reservation, selection of representative areas of ecosystem type is a fundamental starting point (EA 1997; Tasmanian RFA 1997).

The Register of the National Estate (RNE) is a listing of places of natural, historic or cultural significance complied and administered by the Australian Heritage Commission. It is proclaimed under a Commonwealth Government Act (the Heritage Act 1974) and only has direct effect on Commonwealth agencies or in situations where Commonwealth legislation is in some way involved.

There are a number of specific criteria against which the value of the place nominated is assessed (Table 2.4). These encompass three aspects of heritage: natural, historic and aboriginal. Despite the interrelationships between these three aspects of heritage, they are generally assessed and listed under these separate classes of heritage in the Register. For places nominated for natural values, only criteria A1 - 3, B1, C1, D1 and E1 apply. Clear scientific evidence of the value must be provided, and as far as possible, comparisons made to show the significance of the place. Benchmark standards such as listing on national rare and threatened species lists apply for some criteria. Decision rules for the threshold for entry in the register include agreement that a place need only reach significance on any one criteria in order to be listed.

Table 2.4 Criteria for entry in the Register of the National Estate

A: Importance in the course or pattern of Australia's natural history
A 1 Importance in the evolution of Australia's flora, fauna, landscapes or climate;
A 2 Importance in maintaining existing processes or systems at the regional or national scale;
A 3 Importance in exhibiting unusual richness or diversity of biotic features or landscapes;
B: Possession of uncommon, rare or endangered aspects of Australia's natural history
B 1 Importance for rare, endangered or uncommon flora, fauna, communities, ecosystems, natural landscapes or phenomena, or as a wilderness
C: Potential to yield information that will contribute to an understanding of Australia's natural history
C 1 Importance for yielding information that will contribute an understanding of Australia's natural or cultural history, by virtue of its use as a research site, teaching site, type locality, reference or benchmark site
D: Importance in demonstrating the principal characteristics of a class of Australia's natural places or environments
D 1 Importance in demonstrating principal characteristics of the range of landscapes, environments or ecosystems, the attributes of which identify them as being characteristic of their class.
E: Importance in exhibiting particular aesthetic characteristics valued by a community or cultural group
E 1 Importance for a community for aesthetic characteristics held in high esteem or otherwise valued by the community.

Source: Australian Heritage Commission

National Estate criteria are increasingly being used as a framework for assessment of natural heritage in other contexts, perhaps because they have been widely used and applied to a wide range of system types and at different scales. A notable use of this framework is the assessment of forest values in the Regional Forest Agreements (www.rfa.gov.au).

The Regional Forest Agreements being progressively negotiated for all major forest areas across Australia are an attempt to ensure protection of the full suite of forest values while at the same time, providing for security of access to forests for timber production. The basis of decision-making on areas to be reserved for forest protection lies in the assessment process of three key forest-related criteria: biodiversity, old-growth forest, and wilderness (JANIS 1996). The design of areas of forest for reservation is based on three principles (Table 2.5).

Table 2.5 Principles for forest reserves

The CAR principles:
Comprehensiveness - the forest reserve system includes the full range of forest communities recognised by an agreed national scientific classification at appropriate hierarchical levels.
Adequacy - the forest reserve system should ensure the maintenance of ecological viability and integrity of populations, species and communities.
Representativeness - those sample areas of the forest that are selected for inclusion in reserves should reasonably reflect the biotic diversity of the communities.
Criteria
Biodiversity
Old-Growth
Wilderness

Source: JANIS 1996

The three criteria are expanded by expert technical committees in the region concerned to list particular aspects or expressions of those values. Thus for the Tasmanian Regional Forest Agreement, the list of natural values identified by the technical committees and considered in the assessment process is shown in Table 2.6. Notations after each value donate its location within the criteria of the Register of the National Estate, shown in Table 2.4.

International Conventions are also a source of guidance on conservation value. Of particular relevance are the Ramsar convention (Convention on Wetlands of International Significance www.ramsar.org) and the IUCN's World Heritage Convention (www.unesco.org/whc/nwhc/).

Table 2.6 Conservation criteria for the Tasmanian Regional Forest Assessment

Biodiversity - related values
Flora and fauna species at the limit of their natural range (A1)
Disjunct populations of flora and fauna species(A1)
Centres of endemism (A1)
Phylogenetically primitive species of flora and fauna (A1)
Biogeographically relictual species of flora and fauna (A1)
Species refugia (arising from past processes) (A1)
Species refugia (arising from present processes)(A2)
Important fauna habitat (A2)
Remnant vegetation patches (A2)
Places important for primary and secondary vegetation succession (A2)
Flora and fauna species and community richness (A3)
Rare (including uncommon), vulnerable and endangered species and communities (B1)
Uncommon wetlands (B1)
Important natural history sites (C1)
Principal characteristics of wetland classes (D1)
Principal characteristics of vegetation communities (D1)
Broader landscape values
Wilderness (A2, B1)
Old growth (A2, B1)
Natural landscapes (B1)
Undisturbed catchments (A2)

Source: PLUC 1997

Wetlands may be nominated for listing under the Ramsar Convention as Wetlands of International Significance (Ramsar 1999). Criteria for Ramsar listing are shown in Table 2.7. Ramsar listing encompasses criteria of diversity, richness, naturalness, and representativeness. Wetlands may be nominated if they meet at least one of the criteria.

Criteria for entry as a site of World Heritage Significance for natural values are shown in Table 2.8.

The concept of a representative suite of reserved natural ecosystems is also being pursued for marine environments in Australia. Australia's Oceans Policy 1998 has advocated implementation of a representative areas network. An ANZECC Task Force on Marine Protected Areas (MPAs) has been developing guidelines and a strategy for the implementation of a national representative system of marine protected areas (MPAs) (ANZEEC 1998, ANZEEC 1999). Criteria for the identification of MPAs are shown in Table 2.9. A similar set of criteria is recommended for MPA's at international level (Gubbay 1995).

Table 2.7 Criteria for listing a Wetland of International Significance (Ramsar site)

A wetland should be considered as being of international importance if it meets at least one of the criteria set out below:

1. Criteria for representative or unique wetlands

A wetland should be considered internationally important if:

(a) it is a particularly good representative example of a natural or near-natural wetland. Characteristics of the appropriate biogeographic region, or

(b) it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographic regions; or

(c) it is a particularly good representative example of a wetland which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a trans-border position; or

(d) it is an example of a specific of wetland, rare or unusual in the appropriate biogeographic region.

2. General criteria based on plants and animals

A wetland should be considered internationally important if:

(a) it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of those species;

(b) it is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna; or

(c) it is of special value as the habitat of plants or animals at a critical stage of their biological cycle; or

(d) it is of special value for one or more endemic plant or animal species or communities

3. Specific criteria based on waterfowl

A wetland should be considered internationally important if:

(a) it regularly supports 20 000 waterfowl; or

(b) it regularly supports substantial numbers of individuals from particular groups of waterfowl, indicative of wetlands values, productivity or diversity; or

(c) where data on populations are available, it regularly supports 1% of the individuals in a population of one species or subspecies of waterfowl.

4. Specific criteria based on fish

A wetland should be considered internationally important if:

(a) it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global diversity; or

(b) it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Source: Ramsar 1999

Table 2.8 Criteria for entry as a World Heritage site

'For a property to be included on the World Heritage List as natural heritage, the World Heritage Committee must find that it meets one or more of the following criteria:

(i) be outstanding examples representing the major stages of the earth's evolutionary history; or

(ii) be outstanding examples representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment; as distinct from the periods of the earth's development, this focuses upon ongoing processes in the development of communities of plants and animals, landforms and marine areas and freshwater bodies; or

(iii) contain superlative natural phenomena, formations or features, for instance outstanding examples of the most important ecosystems, areas of exceptional beauty or exceptional combinations of natural and cultural elements; or

(iv) contain the most important and significant natural habitats where threatened species of animals or plants of outstanding universal value, from the point of view of science or conservation, still survive.'

Source: World Heritage Unit, Canberra

Table 2.9 Criteria for Marine Protected Areas in Australia

Representativeness

Will the area:

- represent one or more ecosystems within an Interim Marine and Coastal Regionalisation of Australia
- add to the representativeness of the NRSMA, and to what degree

Comprehensiveness

Does the area:

- add to the coverage of the full range of ecosystems recognized at an appropriate scale within and across each bioregion
- add to the comprehensiveness of the NRSMA

Biogeographic importance

- Does the area capture biogeographic qualities

Naturalness

- How much has the area been protected from, or not been subjected to, human induced change

Ecological importance

Does the area

- contribute to the maintenance of essential ecological processes or life-support systems
- contain habitat for rare or endangered species
- preserve genetic diversity, that is, is diverse or abundant in species
- contain areas on which species or other systems are dependent, for example, contain nursery or juvenile areas or feeding, breeding or resting areas for migratory species
- contain one or more areas which are a biological functional, self-sustaining ecological unit

International or national importance

- Is the area rated, or have the potential to be listed, on the world or national heritage list or declared a Biosphere Reserve or subject to an international or national conservation agreement

Uniqueness

Does the area

- contain unique species, populations, communities or ecosystems
- contain unique or unusual geographic features

Productivity

- Do the species, populations or communities of the area have a high natural biological productivity

Vulnerability assessment

- Are the ecosystems and/or communities vulnerable to natural processes

Source: ANZECC 1998

The Great Barrier Reef Marine Park Authority has recently announced its intentions to provide specific protection to a suite of areas, which are representative of the range of ecosystem types within the Marine Park (GBRPMA 1999). The Representative Areas Program will maintain biodiversity and ecosystem processes across all ecosystem types within the Barrier Reef. Principles for representative areas within the area of the Marine Park are: selection within a regional framework, application of the precautionary principle, comprehensive inclusion of all habitats, adequate to sustain ecological integrity, and representativeness (GBRMPA 1999).

In order to discharge Australia's responsibilities under the Biodiversity Convention, a system of national reserves has been proposed (Environment Australia 1998). A five-year program, the National Reserves Program, has been funded under the Natural Heritage Trust to establish, in cooperation with states and territories, a comprehensive, adequate and representative National Reserve System.

Under this program, the objectives include the 'establishment and management of new ecologically significant protected areas which will be added to Australia's terrestrial National Reserve System' (EA 1998 p 43). Australia's Biodiversity Strategy (DEST 1996) identifies three components of Australia's biological diversity: 'terrestrial, marine, and other aquatic' (p7). Currently, a system of comprehensive, adequate and representative (CAR) reserves is being developed for terrestrial and for marine systems. At present 'other aquatic' environments are not specified under the National Reserve Program.

In summary, there is a good deal of knowledge and experience amongst Australia's land and water management agencies with core concepts of both criteria for conservation value and processes for assessment. There are common strands in criteria for what constitutes conservation value whether the criteria are to apply to forests, marine environments, other terrestrial habitats, World Heritage or wetlands of international significance. Agencies have the experience of ecosystem assessment either in the form of planning for representative reserve systems or in assessing riverine status and health.

The criteria applied by Boon in the SERCON approach to conservation assessments in riverine environments (Boon *et al* 1994, 1997) have elements in common with these criteria. The SERCON criteria were identified through survey of river specialists (Boon *et al* 1994). A similar exercise in Australia (Dunn 2000) also resulted in elements in common with both the general conservation discussed and with Boon's SERCON criteria, but also included additional attributes (Table 2.10). Notable differences include the recognition of hydro-geomorphic attributes as being of intrinsic conservation value (rather than a framework for site selection), as well as an emphasis on instream and catchment roles, processes and dynamics. Concurrently, work in the Queensland Environment Protection Agency (Phillips *et al* 2000) also produced checklists and thresholds for conservation values as part of the WAMP assessment process. Once again there was general consistency with both the SERCON and Dunn lists of the criteria and attributes.

Table 2.10 Criteria and attributes for conservation values of Australian rivers

Criterion	Attributes
1. Naturalness	1.1 undisturbed catchment 1.2 unregulated flow 1.3 unmodified flow 1.4 unmodified river/ channel features 1.5 natural water chemistry 1.6 absence of interbasin water transfer 1.7 intact and interconnected river elements 1.8 natural temperature regimes 1.9 natural processing of organic matter 1.10 natural nutrient cyt:1ing process 1.11 intact native riparian vegetation 1.12 absence of exotic flora or fauna 1.13 habitat corridor 1.14 natural instream faunal community composition 1.15 natural ecological processes, including energy base and energy flow through food webs
2. Representativeness	2.1 representative river system or section 2.2 representative river features 2.3 representative hydrological processes 2.4 representative aquatic macroinvertebrate communities 2.5 representativeinstream flora or riparian communities 2.6 representative fish communities or assemblages
3.Diversity or Richness	3.1 diversity of rock types or substrate size classes 3.2 diversity of instream habitats eg pools, riffles, meanders, rapids 3.3 diversity of channel, floodplain (including wetland) morphologies 3.4 diversity of native flora or fauna species 3.5 diversity of instream or riparian communities 3.6 diversity of floodplain and wetland communities 3.7 diversity of endemic flora or fauna species 3.8 important bird habitat
4. Rarity	4.1 rare or threatened geomorphologic features 4.2 rare or threatened ecological processes 4.3 rare or threatened geomorphological processes 4.4 rare or threatened hydrological regimes 4.5 rare or threatened invertebrate fauna 4.6 rare or threatened fish or other vertebrates 4.7 rare or threatened habitats 4.8 rare or threatened flora 4.9 rare or threatened communities or ecosystems 4.10 rivers with unusual natural water chemistry
5. Special features	5.1 karst, including surface features 5.2 significant ephemeral floodplain wetlands 5.3 dryland rivers with no opening to ocean 5.4 important for the maintenance of downstream or adjacent habitats such a floodplain/ estuary 5.5 important for the maintenance of karst system or features 5.6 important for migratory species or dispersal of terrestrial species 5.7 drought refuge for terrestrial or migratory species 5.8 habitat for important indicator or keystone taxa 5.9 habitat for flagship taxa 5.10 refuge for native species and communities in largely altered landscapes

Source: Dunn 2000

Despite these consistencies in operational and proposed criteria, 'conservation value' is an evolving construct. It does not remain static but evolves as scientists, managers, and community knowledge and perceptions change and develop. Examples might include conservation of genetic diversity, assessment of phylogenetic values using molecular techniques, and hydro-geomorphic analyses.

Table 2.10 (Dunn 2000) summarizes the most recent analysis of what river scientists and managers consider constitute criteria and attributes of ecological value of rivers in Australia. It has yet to be field-trialed. Only those selected attributes and criteria relevant to macroinvertebrates have been selected for the present study. These are defined in Chapter 3.

Chapter 3

Methodology and conceptual framework

A case study approach is determined as the most feasible way to gain a practical understanding of the processes of, and the issues inherent in, developing and implementing conservation assessment of riverine ecosystems. The elements of the study are then delineated in a conceptual framework built from current conservation theory and practice, river assessment strategies and evaluation practice. The framework establishes the information collection requirements for the case study and guides the subsequent evaluation of the assessment process.

3.1 Summary of project method

The goals of the study could have been accomplished by an essentially theoretical or desktop study, but a field study was considered to offer richer interpretation, more convincing arguments, and a sense of the practical issues of conservation assessment. Therefore I decided to undertake a field study of streams in areas of Tasmania without formal protection of riverine systems and to use the data and the experience of such an exercise as the central information source for my research.

Macroinvertebrates were selected as a focus for study for several reasons. A study of all aspects of river ecosystems would require expertise from a wide variety of disciplines and is beyond the capacity of a single individual. In addition, the time necessary for a study to define criteria (and their interpretation), collect and analyse data, and evaluate the assessment process for all aspects of riverine environments would be unrealistic for a study of this nature. Some selection was therefore necessary.

Much of the conceptual work on defining what constitutes conservation value has been directed to biota rather than to geomorphology, landscape, or ecosystem processes (IUCN website; EA 1996; WCMC 1996, 1998). Macroinvertebrates were chosen for the case study because they have been widely used as indicators of the nature and condition of aquatic environments, and are recognized as such by river managers (Walker & Reuter 1996; SDAC 1996; Davies 2000). Tasmania has a very restricted native freshwater fish and macrophyte fauna. There is basic information on the taxonomy and identification of macroinvertebrates, and some data are available on which to base comparisons. Finally, at this stage possible options for protection of high conservation values are generally restricted to biotic elements of ecosystems (Threatened Species Protection Act 1995; EA 1996; Environment Protection and Biodiversity Conservation Act 1999).

The project used an analysis of field data to establish conservation values for a suite of riverine sites in northern Tasmania. These data and assessment processes were then used to evaluate the application of generic conservation assessment criteria in riverine environments. The stages in the research may be defined in terms of a series of research questions.

Research questions

What macroinvertebrate taxa and communities occur in undisturbed streams and rivers in northern Tasmania?

- Can communities be defined?
- How do communities and species vary with environmental variables?
- Do streams vary in macroinvertebrate abundance and diversity?
- Do communities differ between the north-west and the north-east of the state?

What criteria and attributes could define conservation value of stream macroinvertebrates?

- What criteria are adopted for conservation value in other types of ecosystem?

- What conservation values are defined and protected by legislation?
- What conservation values are defined and protected by policy commitments?
- What other conservation values are considered of scientific significance?

What are the conservation values and status of the streams and rivers in the study areas?

- Can the conservation values be defined?
- What conservation values of the macroinvertebrates can be identified?
- Are some streams or rivers of higher conservation value than others?
- Can these rivers be protected?

What are the implications for the assessment of river conservation and management?

- Can stream macroinvertebrate values be encompassed within existing legislation?
- What are the constraints on stream macroinvertebrate conservation?
- What surrogate measures may be useful in defining river conservation values to protect macroinvertebrates?
- What framework might guide the assessment of conservation values for Australia's river systems?
- What proposals should be made to further recognition of the needs of stream macroinvertebrate conservation?

These issues were explored in the context of a conceptual framework built from the review of literature, current theory, and practice of river assessment, constructs of river ecology, and the research questions.

3.2 Developing a conceptual framework

The framework ensured that all aspects relevant to the research questions are covered by appropriate data collection. The framework also defined and delimited the study so that the scope was clear. While the inclusion of other related elements of river ecology and conservation management could be justified, the framework set down what was to be addressed in the study.

The framework was derived from analysis of key elements in the conservation assessment process discussed in Chapters 1 and 2, practical requirements for field collection, my research questions and hypotheses, anticipation of application of the research findings to the practice of river management and standards for quality evaluation.

The framework guided the data collection for and analysis of the field survey (Chapters 4 - 7). Information requirements for both biotic and environmental parameters were derived from the conservation value criteria and planning considerations. Information requirements are discussed in more detail under section 3.4.

The framework, Figure 3.1, consists of three core elements:

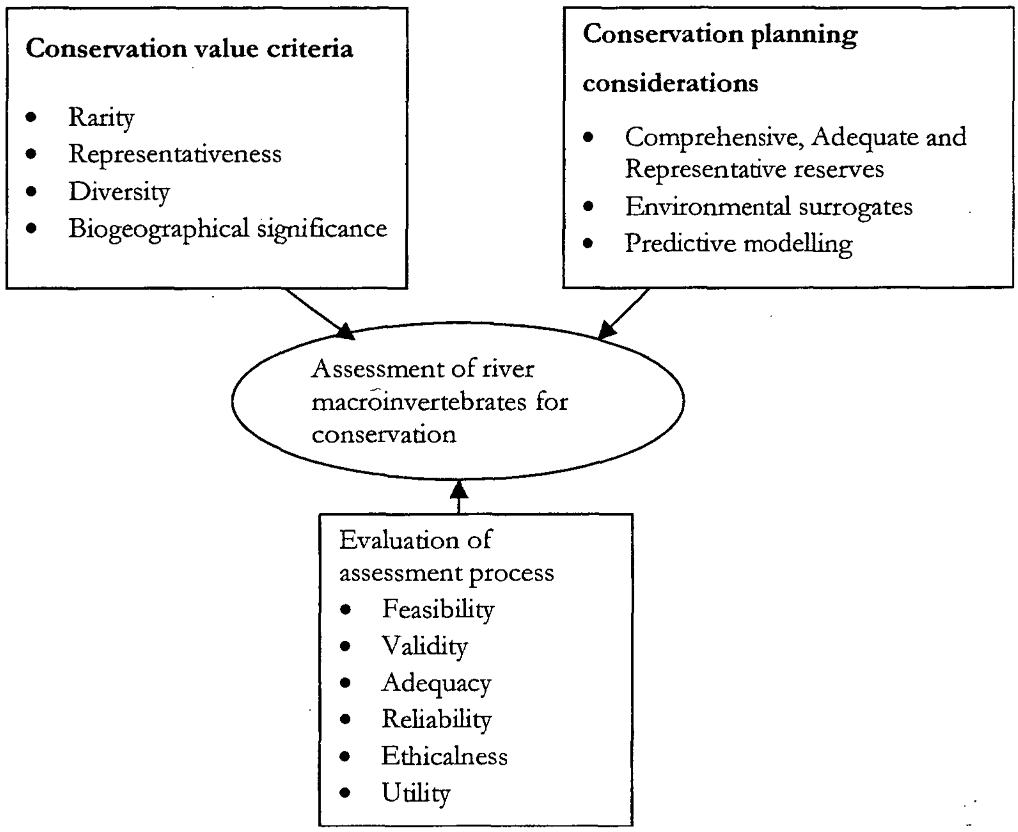
- the conservation values to be assessed in the river macroinvertebrate data
- conservation planning approaches which define additional conservation values
- evaluation criteria for a critique of conservation value assessment and planning approaches for river environments

3.3 Elements of the conceptual framework

3.3.1 Criteria for conservation value assessment

The review of the literature in Chapter 2 revealed a range of conservation values, which are more or less widely accepted as being of significance for natural systems. For the purposes of the study, four broad conservation criteria relevant to macroinvertebrates were selected. These were: rarity, richness, representativeness, and biogeographic significance.

Figure 3.1 A conceptual framework for the study



Rarity

Species, which are rare or threatened, have been a major focus of biodiversity conservation (IUCN; 1996, 1998; EPBC Act 1999). The IUCN has for many years been compiling the 'Red Data Book' listing rare and threatened species (IUCN 1990; http://www.iucn.org/redlist/2000/index.html). Rarity is perhaps the most tangible and measurable biodiversity quality or value. Public attention has been focused on the potential loss of species, especially if these are large, charismatic animals. Rarity may be defined in geographic terms where the area occupied by a species is very small, or in terms of population size where total numbers of individuals of that species is very low. Rare and threatened species lists have been constructed for most Australian states in association with legislation for protection of listed species.

Rarity is now being replaced by the concept of 'threatened species' (Threatened Species Protection Act 1995; Environment Protection and Biodiversity Conservation Act 1999). This concept is less easy to define quantitatively. Knowledge of a species ecosystem requirements and its capacity to maintain healthy populations under stress are necessary in order to make judgements about which species are threatened.

'Rare or uncommon species' remain a criterion for the Register of the National Estate (Australian Heritage Commission Act 1975 and Table 2.4) and listing on Commonwealth, State or IUCN lists is usually considered to be the benchmark for inclusion of a place in the Register. Listing or scheduling of a species under Commonwealth or State legislation is an important benchmark for intervention on land management issues (FPB 2000; MECP 1999).

Schedule 1 of the Commonwealth Endangered Species Protection Act[1] states that

> a species is endangered if it is likely to become extinct unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate, or its numbers have been reduced to such a critical level, or its habitats have been so drastically reduced that it is in immediate danger of extinction. A species is vulnerable at a particular time if within the next 25 years, the species is likely to become endangered unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate.

Schedule 2 of the ESP Act provides for the listing of endangered ecological communities. An ecological community is defined 'as an integrated assemblage of native species that inhabits a particular area in nature'.

> Such a community is endangered if it is likely to become extinct in nature unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate'.

The Tasmanian Threatened Species Act 1995 provides Schedules for listing at three levels of threat.

> **Endangered**: These are taxa, which are either:
>
> (a) in danger of extinction because long term survival is unlikely while the factors causing the species to be endangered continue to operate, or
>
> (b) are presumed extinct.
>
> **Vulnerable**: a species which is likely to become endangered while factors causing it to be vulnerable continue operating.
>
> **Rare**: a species which has a small population in Tasmania that is not endangered or vulnerable but is 'at risk'.

[1] The Commonwealth Threatened Species Act has now been subsumed within the Environment Protection and Biodiversity Conservation Act 1999 with the thresholds for listing remaining the same.

The Tasmanian legislation has no provision for threatened ecological communities.

Representativeness

Communities, which are good representative examples of that class of community are considered of conservation value because, not only are the species that make up that community intact, but also the processes and dynamics of the community are being sustained. Representative communities therefore provide a broader basis for conservation and do not rely on detailed knowledge of individual species requirements. Representative communities, if protected, also provide a reference for intervention at degraded sites and setting in which research to further understanding of the ecosystem can occur.

Representativeness is a key criterion for strategic planning of reserve systems (JANIS 1996, ANZEEC 1998, ANZEEC 1999, EA 1998). Representativeness is usually assessed by statistical analysis of community data to derive clusters of taxa, which together characterize a 'community'. The scale at which the community may be defined is dependent on level of detail of taxonomic information, analytical tools used, expert opinion on the scale at which environmental variables impact on ecosystems and the purpose for defining the communities.

Diversity or richness

Places of high species diversity, or 'hot spots' are considered of particular importance from a conservation management perspective since protection of such area is a cost-effective way to protect a larger number of species (WCMC 1996). In addition, the presence of a diversity of taxa may indicate some collateral value such as the biogeographic history of the ecosystem.

Diversity or richness are relative terms, so any assessment of diversity must be made by a comparison with similar places or environments. In addition, it is recognized that some places have naturally low diversity but are nevertheless important because this low diversity is characteristic of the particular ecosystem type.

Diversity may be further refined by assessment of the taxonomic level at which it is measured. Thus it has been argued that a site with a wide diversity of higher taxonomic groups (family or order) may be considered more diverse than a site at which the diversity is confined to a limited number of families (http://www.nhm.ac.uk/science/).

A number of studies have suggested that in aquatic environments, family level diversity is highly correlated with species level diversity (Marchant *et al* 1994; Growns & Growns 1997; Hewlett 2000). This has important implications for conservation assessment of Australian riverine systems, given the patchy knowledge of species level taxonomies.

Biogeographic values.

Recent assessments of conservation value such as the Regional Forest Assessments have included biotic values related to the biogeographic significance of the taxa (PLUC 1997; www.rfa.gov.au). This includes taxa, which are endemic to an area or display phylogenetic affinities with Gondwanic connections. It also includes species that may show evidence of geomorphic history by the present geographic distribution, and species that are at the limits of their range or are in outlying populations. The assessment for National Estate listing includes a criterion, which addresses biogeographic values (criterion A1, see Table 2.4). World Heritage criteria include 'an outstanding example representing the major stages of the earth's evolutionary history' and 'an outstanding example representing significant geological processes, biological evolution…' both of which may be interpreted as including biogeographic values.

Biogeographic attributes such as isolated, relictual or remnant populations and limits of natural range are of intrinsic conservation value in themselves. Such populations also contribute towards conservation of diversity at the genetic level (ANZEEC 1996).

3.3.2 Conservation planning considerations

Conservation planning addresses the questions of conservation value from a strategic perspective and a broader scale. Conservation planning may adopt different approaches to determining areas to be set aside for conservation purposes. In practice, the strategies may be used in combination or as a set of sieves to ensure representativeness. These approaches include Comprehensive, Adequate, and

Representative areas (CAR reserves), bioregional planning, use of environmental surrogates and predictive modelling. Each has particular data requirements.

CAR reserves

For a reserve system to be Comprehensive, Adequate and Representative means that it must incorporate all given values embodied in appropriately sized areas or combinations of area to provide for ecosystem sustainability. It means that all of ecosystem types, on whatever scale has been determined, are included within the system.

Information requirements are extensive, including the ability to identify and map species and their distribution, and knowledge of the environmental requirements of the species and ecosystems

Bioregional planning

Planning for reserves on a bioregional basis is an element of CAR reserve planning. It is also appropriate where the biota and ecosystem requirements are less well known. Provision of reserves of ecosystem types across a suite of geographically defined regions applies a precautionary approach to reserve planning where significant correlations with ecosystem variables are poorly known.

Bioregions are defined on the basis of a range of environmental parameters. Australia's bioregions have been identified in the IBRA (Interim Biogeographic Regions of Australia) regions (Thackway & Cresswell 1995a,b). This regionalisation was based in Tasmania upon regions with similar climate, landform, geology/lithology, vegetation, and floristics (Thackway & Cresswell 1995a p 26). It resulted in the identification of eight regions for Tasmania. An earlier Tasmanian study (Orchard 1988) also classified Tasmania into eight regions, largely based on vegetation. The Orchard classification was an input into the IBRA analysis. Riverine environmental or biotic data were not included in the analytical process for determining IBRA regions. Hughes (1987) identified four hydrological regions for Tasmania based on several stream-flow parameters.

Environmental surrogates

Representative areas for protection may use some type of environmental surrogate where data is limited. Commonly, and implicitly in Regional Forest Assessment, vegetation is used as a surrogate for faunal values (Oliver *et al* 1998; Lunney & Ponder 1999; Kitching 1999). This may be justified on the basis of habitat protection: a possible option for some vertebrates but not usually sustained for invertebrates (Oliver *et al* 1998).

Naturalness of habitat may also be considered as a possible surrogate in conservation planning and protection. The identification and protection of areas defined as 'wilderness' has a decades' long history in Australia supported by conservation lobby groups and reflected in both National Estate (Table 2.4) and World Heritage listings (Table 2.8). Values of such places lie not only in the perceived experiential values of wilderness (Hocking 1995a, b) but also in the value as an area in which ecosystem may continue under the influence of natural processes with limited influence of modern human activity (Lesslie & Maslen 1995). Rivers in natural condition are similarly considered important (US Wild and Scenic Rivers Act; Stein *et al* n.d.).

Predictive modelling

Predictive modelling is used as a tool for both assessment of the health or condition of a river and also for identification of potential sites of high conservation value. This may be based on detailed knowledge of the habitat requirements of a species, or on empirical relationships between environmental variables and the species or communities' occurrence or abundance. The British RIVPACS model is built from an extensive and long-term species-level data set, which enables predictions of stream macroinvertebrate communities at species level (Wright *et al* 1996). In Australia, the Monitoring River Health Initiative (Davies 2000) has enabled development of similar predictive models (AUSRIVAS) using family level analysis.

Estimates of hot spots or most favourable habitats for species of high conservation value may be approached by modelling of those variables that are known to be its habitat requirements, a strategy which was used for a variety of taxa in the Tasmanian regional Forest Agreement process (www.rfa.gov.au). Areas which seem highly favourable in terms of habitat requirements may be reserved on the assumption that the species is thereby protected.

Summary

Approaches to conservation planning suggest that various field data might enable decisions to be made about values of species, communities, and ecosystems. These data include: assessment of distributions by habitat type, bioregion, and level of naturalness of absence of disturbance and correlations with environmental variables including vegetation and habitat.

3.3.3 Evaluation criteria

Criteria need to be identified for evaluating the conservation assessment process. 'Meta-evaluation' or evaluation of an evaluation or assessment process is now well accepted as a strategy to ensure quality standards in a wide range of contexts (Worthen *et al* 1997). The development of this field has largely focused on program evaluation and a considerable number of 'quality standards' (Joint Committee 1981) have been generated. Standards that are relevant to this evaluation of the conservation assessment process are: feasibility, validity, reliability, ethicalness, adequacy, and utility (Worthen *et al* 1997).

Feasibility

This criterion for evaluation will be addressed by considering whether it is possible to apply the conservation criteria to river macroinvertebrates. The criterion will be applied at two levels: technical feasibility and practical feasibility.

Validity

This criterion addresses the question of whether the conservation criterion or strategic planning approaches are appropriate and valid for riverine ecosystems.

Reliability

This evaluation criterion will attempt to test whether these conservation criteria can be applied generally in riverine ecosystems, and whether such a river conservation assessment is capable of providing consistent outcomes with future replication.

Ethicalness

Any evaluation must address ethical standards that are relevant to the particular evaluation process. This evaluation criterion addresses scientific standards as well as standards of intellectual honesty and communication.

Adequacy

This criterion will explore the extent to which the conservation assessment criteria used adequately reflect the conservation values of macroinvertebrate species and communities, and the extent to which these may be used as a measure of river conservation values generally.

Utility

An evaluation must be useful for the purpose for which it is designed. The present study will be assessed against its purpose, i.e. to explore the issues of conservation assessment in riverine systems, not for the utility of the outcomes of that assessment.

3.4 Summary and application of the conceptual framework

I will apply the theoretical elements of the conceptual framework to the design of data collection and analysis, interpretation and conservation value assessment, and a critique of the assessment process. The criteria form the reference points for a case study of a conservation assessment process, using a field study of two areas of northern Tasmania. This analysis is then in turn applied to the concepts and approaches to conservation assessment and protection. Outcomes of all these stages will then be reviewed and evaluated. Implications and proposals for river conservation assessment are drawn from this discussion.

3.5 Data requirements

With the elements of the conceptual framework defined, it is now possible to identify the data requirements for the study. These are summarized in Table 3.1. Data for the study will be derived from two sources: primary data from a field study, and secondary data from existing data bases, data sets, species listings and other sources.

Table 3.1 Data requirements for conservation assessment of streams

Criterion/planning information	Information required	Basis for judgement	Source of data
Rare species	Taxon list	Occurrence, listing	Occurrence, listing
Threatened species	Species with specific habitat requirements	Correlation of distribution with environmental variables	Species lists
Threatened communities	Communities threatened as a consequence of ecological conditions	Correlation of distribution with environmental variables	Data analysis
High diversity	(a) Number of taxa per site (b) Level of taxon diversity	Comparisons between sites	Taxon lists MRHI database
Richness	Number of individuals per site	Comparisons between sites	Taxon lists
Biogeographical significance	Endemic species Spp at limits of range Outlying populations Gondwanan/Pangean species	Spatial level of endemism Phylogenetic level of endemism	Species lists Databases and references
Phylogenetic significance	Species of significant relationships or affinities Species of unusual morphology	Documentation - expert opinion	Species lists References
Representativeness	Classification and ordination of data	Statistical analysis	Classification and ordination of data MRHI database
Bioregional assessment	(a) IBRA region (b) Hydrological region (c) Rainfall profiles	Statistical analysis and interpretation	IBRA maps Hughes Weather bureau
Environmental surrogates	(a) Naturalness (b) Riparian vegetation (c) Stream profiles	Statistical analysis	WRI Vegetation survey at sites Habitat survey
Predictive models	Habitat requirements	Statistical analysis	Habitat survey Correlation with distribution

3.6 The field study

3.6.1 Survey sites

Survey sites were selected to include a range of types of stream habitat in two regions of northern Tasmania. None of the sites were in areas formally reserved for riverine values, although some sites were within Forest Reserves set aside for protection of forest values. In each area there were mountains or uplands with streams in reasonably natural condition. Representative areas of vegetation of different types - rainforest, sclerophyll forest and native grassland could be found with watercourses flowing through them. Both areas had been generally subject to logging operations, reaching back some decades at some locations. However, there remained areas that had been reserved as natural vegetation within the forestry areas, or were otherwise protected or not utilized for harvesting. A small number of sites had been subject to clearance around the turn of the century near mining areas and regenerated. A few sites were in areas of prior forest operations but had additional widths of stream buffer preserved as habitat corridors.

Sites in the north-west of the state all lay in the catchments of the Arthur or Pieman rivers. North-eastern sites fell in the upper catchments of the South Esk, Ringarooma and St Patricks river catchments in an area generally known as the north-east highlands, and the catchment of the Wyniford River further east on Blue Tier.

Restrictions imposed by the nature of the collecting equipment and storage of samples meant that all sites had to be within 300 metres of vehicle access. An extensive network of roads has provided access to logging operations over the last thirty or so years. A track providing service access to the pipeline carrying ore from the Savage River Mine to Port Latta allowed access to sites in the Tarkine rainforest area. Most of the roads are not open to the public, and rarely used. In 1996, a new road was opened to the public linking Balfour to Corinna. This road, the Western Explorer, gave access to two additional sites that were sampled in 1996.

Forestry and old mining activities also provided access routes in the north-east. The north-east highlands are less well-endowed with streams and rivers, and additional sites were included in the Blue Tier, lying further east. This area was also considered of potential interest because of its assumed biogeographic significance (Kirkpatrick & Fowler 1998). A total of 27 sites were selected in the north-west and 17 sites in the north-east.

For most sites four samples were collected over two years. Two spring samples (October/November) and two autumn samples (March - June) were collected. A few sites were not sampled in all four occasions. The collapse of the wooden bridge and subsequent roadworks and conversion to a ford destroyed Pineapple Creek (PC) on the Savage River Pipeline road. The backup pond and dumped fill changed the riverine environment completely and only the first three samples were completed. Two rivers in spate were too dangerous for sampling on one occasion (Hatfield at

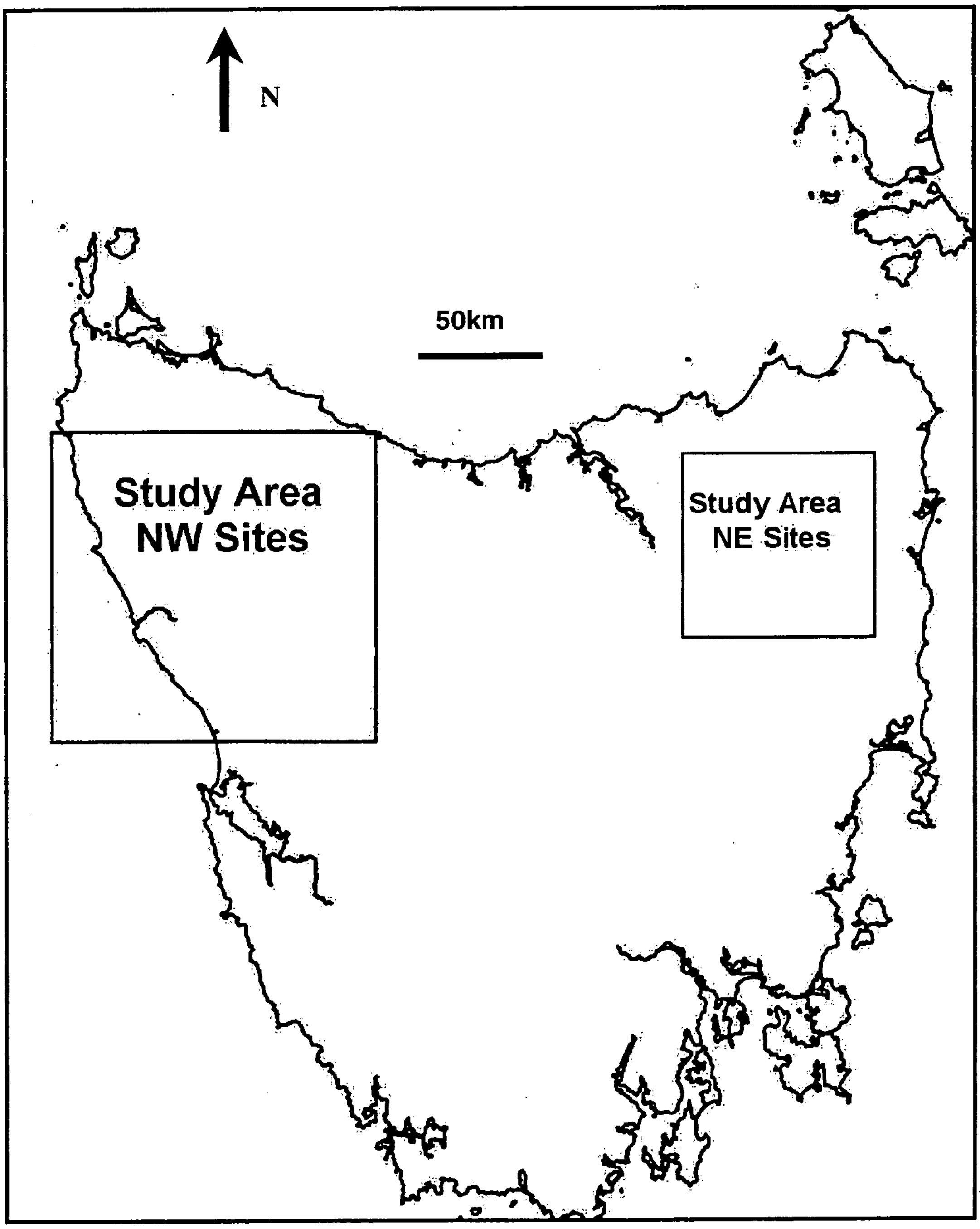
Huskisson HH, Sterling ST), and another (Ring River RR) was inaccessible due to heavy snowfall on the access road. The final analysis used forty-four sites, with data pooled and averaged by the number of sampling occasions to provide comparability. Any taxon occurring at any of the sampling events was included in the presence/absence data.

Locations of the sampling areas are shown in Figure 3.2. Details of these locations are given in Appendix 1.

All sites were considered to have suffered minimal disturbance at the outset of the project. At the time the project commenced, formal assessment of river naturalness through the Wild Rivers study was not available. However, a number of factors known to cause river disturbance or be the consequence of disturbance were taken into consideration and assessed from previous studies (Koehnken 1992), from district forest plans provided by Forestry Tasmania, and from observations at potential sites. The factors taken into consideration were: nature of the riparian vegetation; current condition of immediate catchment; control of flow, and impact of mine drainage or other chemical changes. The riparian vegetation essentially comprised native species, typical of the location and, with the exception of the immediate area of some bridge or road crossings, appeared in natural condition. In some cases, earlier disturbance had occurred as a result of anthropogenic fire events, or access for forest operations, but the forest appeared to have regenerated under natural conditions to mature forest. The river channels were also natural, without significant change to the profile or rock characteristics. None of the sample sites lay below dams, weirs or other controls on water flow, nor were any used for irrigation or mining operations. Sites which met the criteria of natural vegetation, absence of controls of flow regime, absence of evident or known acid mine drainage, and absence of other types of anthropogenic change to water quality such as fertilizer or pesticides could be included.

At each site, samples were collected upstream of any bridge or road crossing except in a few cases where upstream access was dangerous or impossible. These latter sites were all in places where roading was well overgrown and not currently in use, so were not subject to heavy road run-off or other impacts. In all cases samples were collected as far as feasible from the road crossing and within a river section which appeared to be generally representative of the river as a whole with regard to channel and substrate configuration and vegetative cover.

Figure 3.2 General location of the study sites



3.6.2 Collection methods

The study was delimited to collection of samples in riffle sections of the rivers, excluding large boulders or rockplates from the collecting area. Riffles are shallow broken water in a stream running over a stony bed. At each site, and on each sampling occasion, various environmental variables were recorded. Six Surber samples were taken at each site (Surber 1937; Elliott & Tullett 1983). A species accretion curve was undertaken to determine an appropriate number of samples. This exercise showed that six samples captured at least 98% of taxa. This figure was compared with sample sizes referred to in the literature where numbers of samples ranging from 2 to 15 (Bunn 1986; Richardson 1993; Quinn & Hickey 1990; Davies *et al* 1996) were collected at each site. The number varied according to the purpose of the assessment: large numbers of samples were required where statistical power was a critical factor in the analysis of the data. Six Surber samples per site, sampled twice over two years (total of 4 sampling events) was confirmed by Barmuta (1995 pers. comm.) as an appropriate number for a survey such as mine. For most sites, sampling took place on four occasions: very few taxa were found on only a single sampling occasion.

Samples were collected using a rule of thumb constraint that no separate substrate unit (cobble or boulder) could occupy more than 50% of the area of the sample. The Surber sampler has a mesh size of 500µ and samples material from a substrate area of 300 x 300mm, ie 300 mm squared.

Materials and fauna collected in the Surber were transferred to individual plastic containers and stored in a refrigerated box containing ice. At the end of each day, each sample was picked live and stored in 70% alcohol. Samples were kept cold until picking was completed, usually within 24 hours of collection. All visible living matter was picked from the samples and stored in 70% alcohol. All living material and any macro-invertebrates that had died during transport or storage were picked and stored.

The material was then sorted, identified to family level, and counted. All Plecoptera taxa were identified to species.

3.6.3 Site variables

Environmental variables recorded for each site are listed in Table 3.2. Water quality parameters were collected at each sampling visit and results averaged. Nitrate and phosphate were assessed using a HACH DR-2000 spectrophotometer. Water samples from selected sites showing high conductivity were analysed using a Varian

SpectrAA 800 to identify ions present.

Estimates of the bottom profile were made as follows. Categories of substrate size used follow those used in the Monitoring River Health Initiative (Davies 1994). Cobbles are between 64 and 256 mm, pebbles 16 and 64 mm, gravel 4 and 16 mm, sand between 1 and 4 mm. Particles less than 1 mm are classified as silt, while rocks exceeding 256 mm are classified as boulders. Two approximately 1 metre square areas of the stream bottom, which appeared representative of the whole bottom area, were identified. Two observers independently estimated percentage of substrate size for each plot and these were compared, discussed, averaged, and recorded as a single estimate for that river. The surface of the substrate was categorized as 'smooth', which were river stones worn to a rounded surface by river action, or 'rough' that is, river rocks which were not worn and had higher fractal dimensions.

Table 3.2 Site variables collected at each site

Variable	Unit
Latitude	AMG reference, checked by GPS
Longitude	AMG reference, checked by GPS
Altitude	metres
Bankful width	measured or estimated
Depth	at sample site
pH	
Conductivity	µS/cm
Temperature	°C
Phosphate	mg PO_4^{-3}/L
Nitrate	mg $N0_3^{-1}$/L
% boulder	estimated in category intervals to 5%
% cobble	estimated in category intervals to 5%
% pebble	estimated in category intervals to 5%
% gravel	estimated in category intervals to 5%
% sand	estimated in category intervals to 5%
% silt	estimated in category intervals to 5%
Substrate characteristics	smooth or rough
Riparian vegetation class	four categories - rainforest, eucalypt forest, grassland and alpine
% cover	estimated over sampling area
Slope	estimated from height/distance on 1:25 000 map

Riparian vegetation was classified into one of four broad categories. Rainforest was characterized by the presence of species including myrtle *Nothofagus cunninghamii*, sassafras *Atherosperma moschatum*, and celery top pine *Phyllocladus aspleniifolius*. Eucalypt forest was characterized by the presence of any species of the genus *Eucalyptus* in the immediate riparian zone, while grassland included a range of grassy and sedgey communities. Occasional small woody shrubs also occurred at these grassy sites but no trees. One site (Ring RR) had distinctive vegetation comprising alpine shrubbery and shrubby sub-alpine forest including deciduous beech *Nothofagus gunnii*, King Billy pine *Athrotaxis cupressoides* and the epacrid shrub *Richea scoparia*. Percentage of the stream or river reach that was shaded by vegetation was visually assessed by two independent observers and averaged. Any instream macrophytes, including epilithic mosses and lichens were recorded.

3.6.4 Data analysis

Data from the six subsamples were summed for each sampling occasion and recalculated for display as number of individuals per square metre. Comparison of all samples for each site showed no seasonal differences in taxa present so taxon numbers were averaged from the total of sampling occasion for each site.

Both ordination and classification techniques were applied to the data using the PATN software package (Belbin 1993). Flexible unweighted pair-group mean averaging (UPGMA) of the Bray-Curtis association measure was carried out using the ACO, FUSE, and DEND units of the PATN package. A dendrogram is produced from this procedure illustrating proximity of the sites in the agglomerative clustering procedure. Sites were also classified using TWINSPAN, which provides detail of the indicator species at each level in the hierarchy. Differences in mean environmental variables between TWINSPAN groups were tested using ANOVA in the Sigmastat package. Dendrograms in the report were drawn up from TWINSPAN analysis.

Ordination was undertaken using semi-strong hybrid multidimensional scaling (SSH) in PATN. The Bray-Curtis association measure was used and a three-dimensional solution reduced stress to a satisfactory level. Associations with variables were tested using principal axis correlation (PCC) in PATN. This procedure estimates the maximal linear correlation with each variable in the three-dimensional ordination space, and indicates the direction of the vector, which can then be plotted in the ordination space. Ordinations were displayed using the Harvardchart package and transformed to Word graphics files. Significance of the vectors was tested using a

Monte Carlo simulation procedure in which 100 simulations of the randomised data set were performed. Only significant ($p<0.05$) vectors were plotted.

Classification and ordination were used to provide any evidence of patterns or groupings within the data sets. For the purposes of assessing community structure the total set was modified in several ways. Analysis was undertaken using the whole data set, presence/absence transformed by $\log_{10}$, and a data set using a modified taxon/feeding group categorization. The overall patterns provided by the first three of these analyses were very similar. Only those analyses using the total untransformed data set and the taxon/feeding group analyses are reported in detail.

3.6.5 Identification

With the exception of a few groups, Tasmanian stream macroinvertebrates are not described to species level. The scale of the study and limited availability of appropriate taxonomic keys did not permit identification of all material to the lowest possible taxonomic resolution

Marchant *et al* (1995) suggest that presence/absence data are adequate to identify community structure, while Growns *et al* (1995) made use of family level data in the assessment of streams in the Blue Mountains. The AUSRIVAS models are built from data collected under the Monitoring River Health Initiative (MRHI) which used family-level data (Davies 1994; Davies 2000). Identification to order and family was considered adequate to describe the general community structure and functioning, and to identify any difference in assemblages occurring at the different site types. The Plecoptera were identified to species level using Hynes (1989) key for nymphs. These data were analysed separately and compared with and added the community data set for the purposes of assessment of conservation value.

Keys used are as follows:

Ephemeroptera: Dean & Cartwright (1991)

Plecoptera: Hynes (1989)

Trichoptera: Neboiss (1988), Dean & Suter (1996)

Crustacea: Williams (1988), Horwitz *et al* (1995)

Diptera, Coleoptera: Zoology Department of Tasmania workshop keys (R W White)

Other: Williams (1988)

Identification was verified using random checks between sorters. Species identification for the Plecoptera was checked by P. B. McQuillan.

3.7 Secondary data sources

Data was required from other sources in order to assess the sites and the field data from reserve planning perspectives and to assess the data within a broader context.

Two bioregionalisations of Tasmania were used: the Interim Biological Resources Assessment (IBRA) regions (Thackway & Creswell 1995a,b) and a Tasmanian bioregionalisation by Orchard (1988). The hydrological regions of Hughes (1987) and rainfall regimes (weather bureau sources) provide a broad characterisation of the hydrologies of the two areas. Although each has some drawbacks these are the only available hydrological data for the areas.

Environmental surrogacy may be used for reserves planning and this study explores three possible strategies: vegetation, river naturalness and environmental variables. Vegetation mapping drew on information about riparian vegetation collected at each survey site. A potentially powerful surrogate for stream conservation is river naturalness. The Wild Rivers Index (WRI) (Stein *et al* n.d.) was used to assess the utility of this parameter. The stream profile data from the field study was also assessed for its adequacy as a surrogate for reserve planning or predictive modelling.

Other non-field data include: Schedules of Commonwealth and Tasmanian Threatened Species Acts, published and non-published distribution maps and data bases, and research reports and scientific articles describing biogeography, taxonomic affinities and status.

3.8 Limitations and assumptions

3.8.1 Limitations

The study was delimited by selection of a single suite of conservation values of riverine systems. The field study covered only one sub-set of ecological values, that is macroinvertebrates from riffle sections of rivers, collected by Surber sampling. No attempt was made to generalize the values of these particular sites to other important river communities such as fish, macrophytes or microorganisms. Other aspects of river ecology, which may be considered a component of river conservation, such as geomorphology or floodplain systems, were not subject to analysis. However, a general discussion on river conservation concludes the thesis.

The macroinvertebrate data was further limited to a single collection method, undertaken at single point sites on a number of different rivers. Surber sampling was the most feasible option available at the time. No material was collected in a longitudinal fashion along a watercourse, although in several instances sites fell into the same sub-catchment. The sampling was constrained by the study period to four collections over two years, with only one of the years common to the two areas. However, in these study areas there are not substantial inter- or intra-annual variations in major environmental or climatic factors such as rainfall which might influence community structure or species distribution.

Most of the analysis is undertaken at a coarse taxonomic level, that is, mostly only to family level. The study was designed to provide a broad data set for scrutiny with reference to propositions for conservation assessment rather than a detailed description of the occurrences at individual sites. In addition, at the time the material was collected, few groups had adequate keys for larval stages, and at best the species level analysis would have been unequally distributed among different orders and families. Species level issues are addressed by the species level identification of a single Order, the Plecoptera. This group did have available an acceptable level of species level data, and in addition had prior information on expected distributions and habitat requirements.

Information on ecosystem requirements was limited to observations at each site of river characteristics, water quality parameters, and classification of substrate and riparian habitat type. No laboratory experiments were conducted to establish environmental requirements for individual taxa.

The study is essentially a comparative case study analysis, using two regions of northern Tasmania to test criteria for assessment of the conservation value of macroinvertebrates. The scale of these comparisons is appropriate in the Tasmanian context where it can be shown that there are differences in hydrology between the regions and an historic natural barrier between the regions. Nevertheless, caution must be applied in any transfer of conclusions from this study without assessment of the local context and scale of analysis.

3.8.2 Assumptions

The design of the study makes the assumption that a large number of point collections within a larger catchment area will provide a broad snapshot of the macroinvertebrate communities and distribution of taxa within a regional landscape. The mean of data from four collections at each site, was considered to provide a profile of the macroinvertebrates present.

It was assumed that the streams and rivers sampled were in essentially natural condition. That they were accessed by road, and in many cases occurred in areas of forest operations means that this is not strictly correct. However, none had any regulation or abstraction of flow, all watercourses had minimal riparian disturbance or at least more than minimal riparian reserve, and none was selected in areas of current forest operations.

3.8.3 The time-frame for the research and its implications

The doctoral project commenced in 1993 with initial exploration of available information on macroinvertebrate communities in Tasmania. Some initial sampling was undertaken in the north-west of the state in 1994 with a view to gaining an appreciation of the variability between sites and options for sampling. Systematic sampling of 25 sites in the north-west began in 1995: the following year a new road enabled access to two further sites. In addition, seven sites in the north-east were also sampled to provide data to compare sites with similar riparian vegetation in a different bioregion of Tasmania. Ten additional sites in the north-east were added in 1996 with a second sampling in 1997. Thus sampling stretched over a period of 3.5 years, with a common year for all sites in 1996.

The MRHI sampling program was launched in 1993 with the purpose of developing tools for assessing and monitoring river health in Australia. Sampling for development of the model and evaluation of the assessment protocol took place in Tasmania in the period Spring 1994 - Autumn 1996. Subsequently, additional sampling adopting the same protocol was incorporated into a biodiversity assessment, modelling, and classification of stream sites for the Tasmanian Regional Forest Agreement assessment process (Davies & McKenny 1997). Data from this project was available for the analysis phase of my doctoral project.

In the early years of the project, there had been little conceptual analysis of river conservation issues in Australia. Some earlier work (Blyth 1983; Macmillan 1984; Lake 1995; Lake & Marchant 1990) had identified the need to address stream conservation and some tentative methods. Assessment of macroinvertebrate values was undertaken in selected areas under the auspices of the National Estate Grants Program (Doeg 1995a,b) or for particular taxa (Horwitz 1990, 1996). Selection of criteria for what constituted conservation differed according to the researcher and were generally restricted to either/or rarity and taxon richness. The National Estate Grants Program (NEGP) perhaps encouraged a wider view because of its links with the Register of the National Estate (RNE), which has a broader set of criteria (Table 2.4). The same agency, which funded both the RNE and NEGP, the Australian Heritage Commission (AHC), also initiated the Wild Rivers program which generated and implemented the Wild Rivers assessment (Stein *et al* n.d.).

The NEGP provided funding for my study in the north-west and helped to shape the criteria used in assessment of conservation value. Concurrently, wider debates on invertebrate conservation in Australia were being encouraged, facilitated by biennial workshops on the topic sponsored by Australian museums. The study provided an opportunity to draw together some of the ideas on conservation value from all environmental domains.

A further strand in river conservation was emerging with the advent of a national water reform agenda (COAG 1994) and increased numbers of community-based catchment management initiatives. Both these triggered a more widespread concern for conservation of instream values. Thus the Land and Water Resources Research and Development Corporation (LWRRDC) identified a need to explore the identification and protection of streams of high ecological value and funded a project which I undertook during 1999 (Dunn 2000). The Environment Protection Agency in the state of Queensland also took up the issues (EPA 1999a, b; Phillips *et al* 2000).

Thus the project was undertaken in a period of rapid change from virtually no systematic approaches to river assessment to a high degree of involvement in river health assessment by all Australian states. Invertebrate specialists from all fields have demonstrated concern for wider recognition of invertebrate values in conservation debates (Lunney & Ponder 1999; Kitching 1999) and there is a concern amongst some river managers to develop theory and practice in riverine conservation in Australia (Dunn 2000).

This changing context has provided both challenges and opportunities. New resources such as the MRHI and Wild Rivers databases became available while an increasing number of river managers and some river scientists became involved in conservation issues. All this has shaped the project in an iterative fashion, although the initial purpose of evaluating criteria for macroinvertebrate conservation values remained intact.

The time-scale for the project has provoked more reflection on the dimensions and issues associated with river conservation management and protection. Inevitably, these issues, particularly questions of adoption and implementation in complex institutional settings, are only treated superficially. Many of these emerging issues will warrant a full study in themselves. The study takes a broad view and demonstrates how ecological studies need to articulate with management in matters of conservation assessment and protection. The increasing concern for river conservation amongst river scientists and managers, and a wider public interest in the issue provides a fertile context for application of the findings of my study.

Chapter 4

The field study sites and their fauna

Chapter 4 provides a description of all the sites: the habitats, the taxa present, the outcomes of statistical analysis to define macroinvertebrate communities and influences of environmental variables. These data form the basis for assessment of conservation values and implications for conservation planning.

The chapter begins with a summary of the various physico-chemical and substrate characteristics of the sites. Sites are classified into different riparian vegetation types, and identified by bioregion and level of disturbance using the Wild Rivers Index. Details of the site profiles are included in Appendix 1.

Occurrence of taxa by site is documented. Macroinvertebrate communities are defined using classification and ordination techniques. Raw data are analysed using PATN and Sigmastat packages. To provide a comparison with other riverine systems, communities are also defined using a feeding group classification (Quinn & Hickey 1990).

4.1 Overview of Tasmanian topography, geology and climate

Tasmania is a large continental island located between latitudes 40° and 43° South, separated from the south-east mainland of Australia by 300 k of Bass Strait. The island is roughly triangular in shape with an area of approximately 68 000 square kilometres. It is a mountainous island, with very little of its surface lying close to sea level. About half of the area of the state lies above the 300 metre (1000 foot) contour. Continuous lowland plains are limited in occurrence and extent (Davies 1965). Mountains rise close to the coast to altitudes up to 1600 m. These mountains are, very generally speaking, of two types. Those in the south and south-east are plateau-like, covered by Permian or Triassic sediments into which dolerite has been intruded. In the west and north-east the basement of folded pre-Carboniferous rocks is exposed through which the rivers have excavated valleys along the line of strike of the softer rocks. The harder rocks such as quartz metamorphics and conglomerates remain as ridges with the trend of the ridges clearly showing the axis of folding of the rocks.

Tasmania has a cool temperate maritime climate. The influence of the ocean moderates the effects of latitude on the climate, bringing mild winters, and cool summers. The size and mountainous character of the island leads to considerable regional and local differences in temperature regimes and rainfall (Langford 1965). Tasmania lies in the path of the general south-westerly air flows and the prevailing weather is dominated by the movement of these south-westerly winds across the open ocean. This brings high and frequent rainfall to the western parts of the state grading to low rainfall with peaks in winter in the eastern areas. The north-east, however, has higher rainfall around the mountain blocks of the Ben Lomond plateau and north-east highlands.

Tasmania had, until the time of white invasion, been home to numerous small Aboriginal tribes leading a semi-nomadic existence (Plomley 1996). There was no attempt to cultivate the land for crops although some management of the vegetation took place. The Aboriginals used fire to open routes through the sometimes dense forest and scrub, and to provide green pick from regrowth to attract grazing animals such as wallaby which they captured for food.

The first Europeans to live in Tasmania were convicts. These were soon followed by settlers keen to start a new and hopefully more prosperous life in the new colony. Alienation of the land began in the 1800s and by the 1820s development had occurred in a broad band linking Hobart to Launceston. Clearance, agricultural development and settlement continued to expand from this corridor and along the north, north-west and east coasts. Areas beyond were less suitable for farming activities, but were extensively explored, and in some cases opened up for mining and forestry activities. By the early 1960s agricultural activities covered most of the state except for the rugged south-west, parts of the central plateau and isolated mountainous ranges. Tasmania is left with a remarkable land area, which is in a natural condition sustaining entire ecosystems of native species. More than 20% of the land area is protected in National Parks or conservation reserves (SDAC 1996). However, even in these remote and otherwise undeveloped areas of the state, most major river systems have been modified.

The high rainfall and abundant river systems offered Tasmania the resources to develop a substantial hydro-electric power generating system. Urban and industrial development was encouraged by the construction of an extensive system of hydro-electric power developments. Tasmania was one of the first places in the southern hemisphere to develop such power with the opening of the city of Launceston's Duck Reach power station in 1895, and the state power scheme came under the Hydro-electric department of the state government in 1914 (Garvie 1965). Dams were built on many of the state's river systems, with massive development in the 1960s and 1970s. By 1990, few of Tasmania's larger river systems were not impacted by hydro-electric infrastructure.

Some 20% of the landmass of Tasmania is reserved in National Park, World Heritage Area or other reserve. However, these reserves were not designed to protect riverine ecosystems as such, and the largest area lies in the south-west. Even rivers within such 'protected' areas may be dammed for hydro-electric developments, most notably the Gordon, Huon, and Derwent rivers.

The location, climate and topography of Tasmania create distinctive hydrological and environmental regimes for its freshwater environments. Similar cool mountain streams exist in higher parts of the south-east mainland alpine areas, but these are subject to greater temperature extremes, winter snow and consistently warmer summers. Australia's forests are dominated by sclerophyllous species such as eucalypts and acacias. Unlike northern hemisphere forests, allochthonous litter inputs are slow in processing and have a peak in early summer (Lake *et al* 1985; Campbell *et al* 1992b). This type of carbon input affects the carbon cycling and overall ecosystem process of Australian streams (Boulton & Brock 1999). All these factors mean that Tasmanian stream environments and their faunas are not replicated elsewhere in the world.

4.2 Description of the survey areas

The field study focused on two areas of Tasmania (Figure 3.2) where there are few dedicated reserves that encompass the protection of riverine systems, and with little development other than forestry operations. Sampling in the two areas, called 'north-west' and 'north-east', was based on the selection of a wide range of site types. These areas each offered a range of sites with similar categories of native riparian vegetation. Rivers and streams of different width occurred in both regions, but the north-east sites were more limited in altitude range because of the extensive land clearance in that region. All accessible sites in both regions were sampled provided that they met the criteria for lack of disturbance discussed in Chapter 3. The range of site types enabled me to explore questions of possible differences in community structure with riparian vegetation, size or altitude.

The north-west area stretched from near Rosebery in the south to Guildford and across to the Kanunah Bridge on the Arthur River in the north. The most easterly stream was the Vale River, which drains into the upper reaches of the Mackintosh River and the Pieman dam. All rivers selected for study in the north west lie within the Arthur or Pieman river catchments. The north-east area comprised two areas separated by the Mt Victoria and Mt Albert range. Most sites were in the upper area of the plateau of the so-called north-east highlands, with some on the plateau edge. The second north-eastern area was Blue Tier, some 25 km to the north-east of the 'north-east highlands' massif. This area is of particular interest as an extreme limit of old *Nothofagus* forest recognized as a relictual rain forest and glacial refugium (Kirkpatrick & Fowler 1998). Its aquatic fauna might also exhibit relictual characteristics. Three sites were sampled in the Blue Tier area.

Locations of the sampling areas and sites are shown in Figure 4.1 and Figure 4.2. All detailed information on the location of the sites is provided in tables in Appendix A.

Both sampling areas lie within the fold structure geological province of Tasmania but they differ geologically (Davies 1965). The north-east sites all lie in an area of relatively uniform granitic bedrock, or quartzwacke or mudstone Mathinna sequences. The peaks are formed of dolerite, which is weathered to a talus fringe. The Blue Tier area is granite.

The north-west is, in contrast, more varied. The sampling area encompasses complex metalliferous rocks of the Mt Read volcanics, Tertiary basalt plains, quartzite of the Tyennan sequence, mudstones, calcite and magnesite limestone.

Figure 4.1 NW study area site locations

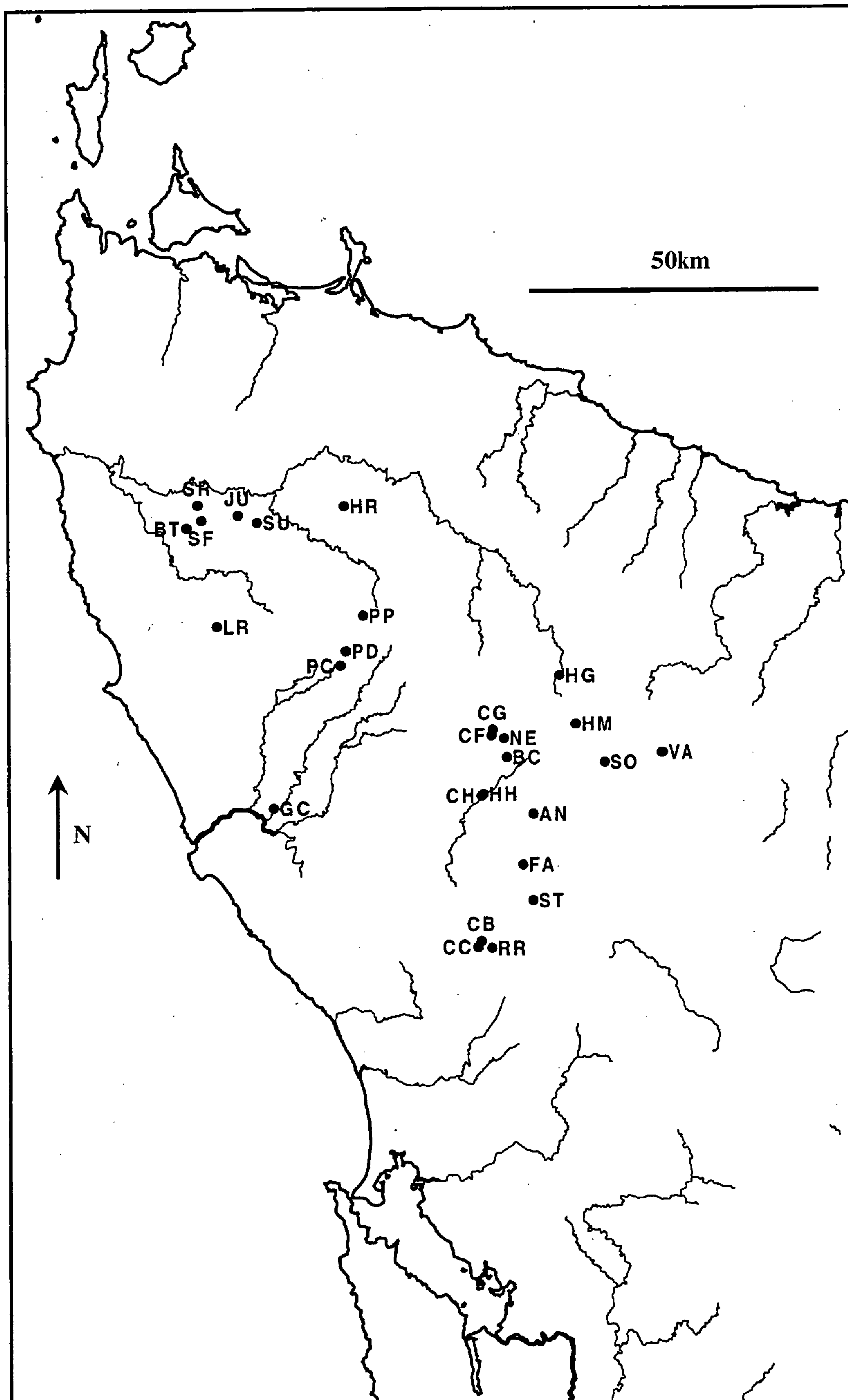
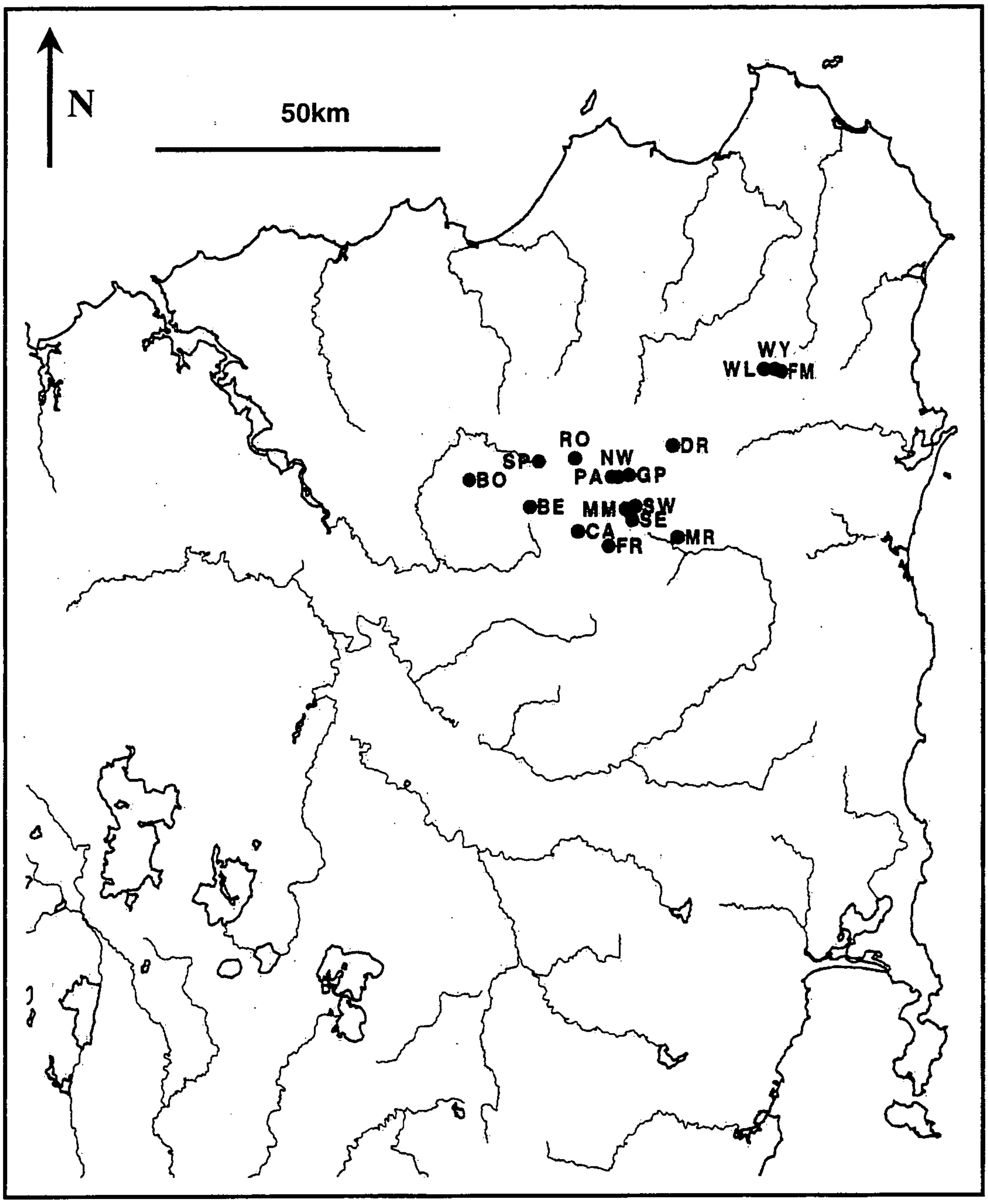


Figure 4.2 NE study area site locations



The differences in rock type, recent geological history and river geomorphology result in differences in river substrate characteristics and in water chemistry (Koehnken 1992; SDCA 1996). The waters of both study areas are generally just below neutral pH but the water flowing over or away from karstic rocks has a higher conductivity and more alkaline pH. No high conductivity rivers were found in the sites sampled in the north-east, but several showed such characteristics in the north-west. Rivers flowing over or carrying downstream granite particles had more gravel in or between rocks in the streambed.

Sites which were least impacted by human activity were selected. Nevertheless, it is acknowledged that both areas have had a past history of mineral exploration and logging. However, such activities were conducted in the past on a smaller scale with selective logging and individual mine workings, though with little effluent impact. River systems, which had had a substantial impact from old mine sites, such as the Ring downstream of the Hercules mine, were not included in the study survey. None of the sample sites were subject to hydro-electric developments. All the areas were in Crown Land areas, either as Unallocated Crown Land or State Forest.

4.3 The sites

Least disturbed sites were chosen across different altitudes and riparian vegetation communities. In the north-west, it was possible to find sites down to an altitude of 50 m which had relatively undisturbed catchments and intact native riparian vegetation. In contrast, rivers of the north-east were generally subject to land clearance and agricultural development at lower altitudes. Even at higher altitudes of the north-east highlands, increasing forest harvesting and plantation establishment are encroaching on the upper reaches of the river systems. Importantly, none of the sites were impacted by upstream river regulation either from impoundments or by direct abstraction.

Comparable sites in terms of width and riparian vegetation were selected in each area. Bank-full width ranged from 0.5 m to 20 m. Four broad classes of riparian vegetation were recognized: native grassland, sclerophyll forest, rainforest or mixed forest, and sub-alpine. Only a single site on Mt Read fell into the last category. Native grasslands occurred only at higher altitudes in both areas: four such sites were sampled in each area. Sites where typical rainforest species occurred such as myrtle *Nothofagus cunninghamii,* celery top pine *Phyllocladus aspleniifolius* or sassafras *Atherosperma moschatum,* were classed along with mixed forest as 'rainforest' even though the latter might also host occasional eucalypts. Eleven rainforest sites were sampled in the north-west and seven in the north-east. Riparian vegetation in which the dominant trees were eucalypts of any species were classed as sclerophyll forest: eleven such sites were sampled in the north-west and six in the north-east.

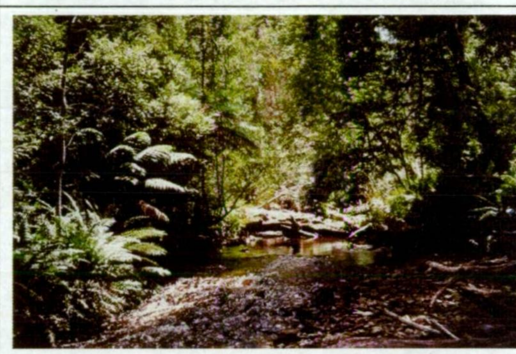
Key site characters are summarized in Table 4.1. Details of other variables documented for each site are provided in Appendix 1. These variables include conductivity, substrate size profiles, extent of cover, bioregions and wild river indices. Photographs of typical sites from each sampling area and for each vegetation class are displayed in Figure 4.3.

Table 4.1 Key site characteristics of the 44 study sites

River	code	altitude (metres)	riparian vegetation	width (metres)	pH meter	easting	northing
North-west sites							
Animal Creek	AN	400	m	4.0	5.7	384500	5389700
Biscuit Creek	BC	580	m	1.5	5.8	379900	5399600
Blackwater trib.	BT	100	m	2.0	6.7	325900	5439900
Cableway Creek	CB	400	m	1.0	6.0	375500	5367700
Conliffe Creek	CC	260	r	3.0	6.5	375600	5392900
Coldstream forest	CF	600	r	6.0	6.7	377300	5403400
Coldstream grassy	CG	600	g	6.0	6.9	377500	5404400
Coldstream @ Husk.	CH	180	r	13.0	6.8	374900	5366700
Farm Creek	FA	160	r	15.0	4.7	382700	5380900
Guthrie Creek	GU	50	r	3.0	7.3	340400	5390900
Hellyer @ Guildford	HG	560	r	20.0	7.0	375900	5393200
Hatfield @ Husk.	HH	180	m	17.0	6.8	389000	5413900
Hellyer @ Moorey	HM	650	g	3.5	6.8	391700	5405400
Holder Rivulet	HR	230	m	20.0	4.7	352400	5443600
Julius River	JU	130	m	6.0	7.5	334500	5442050
Lindsay River	LR	160	m	20.0	4.7	330900	5422700
Netherby Creek	NE	630	g	3.0	6.8	379400	5402900
Pineapple Creek	PC	300	r	4.0	6.7	351700	5415800
L Donaldson trib	PD	300	r	9.0	6.9	352600	5418300
Clearwater Creek	PP	480	r	3.5	6.1	355500	5424500
Ring @ Mt Read	RR	900	a	1.0	5.0	377300	5366500
Stephens @ forest	SF	150	r	4.0	6.9	396600	5398700
Southwell River	SO	690	r	2	6.7	328400	5441200
Stephens @ road	SR	50	m	5	7.0	327800	5443900
Sterling River	ST	170	m	15	6.1	384400	5374700
Sumac River	SU	120	m	3	7.53	337800	5440800
Vale River	VA	790	g	5	7.22	406500	5400400
Northeast sites							
Beckett Creek	BE	470	m	5	6.5	543300	5416500
Bonnies Creek	BO	890	r	1	6.5	533500	5421000
Cascade Creek	CA	810	m	3	6.67	551200	5412400
Dorset River	DR	350	m	4	5.72	566500	5426700
Full Moon Creek	FM	730	r	1	5.1	584400	5439000
Farrell's Creek	FR	720	m	5	6.04	556100	5418000
Gravel Pit Creek	GP	825	g	.5	5.7	559500	5421800
Memory Creek	MM	400	r	2	6.76	558900	5416100
Merry Creek	MR	330	m	4	6.6	567200	5411400
Newitts Creek	NW	790	g	1	6.18	557700	5421500
Paradise Creek	PA	810	g/heath	.5	6.0	556600	5421500
Ringarooma River	RG	870	r	3.5	5.8	550800	5424600
South Esk	SE	380	m	8	6.5	560000	5414300
St Patrick's River	SP	630	r	11	6.5	544800	5424100
Sweets Creek	SW	430	r	2.5	6.29	560500	5416600
Wellington Creek	WE	720	r	1	5.2	581600	5439400
Wyniford River	WY	710	g/heath	3	4.84	583400	5439400

Riparian vegetation classes are as follows: r= rainforest, m= mixed or sclerophyll forest, g= native grassland, g/heath= grassland with heathy elements, a= sub-alpine shrubbery

Figure 4.3 Typical sites in each sampling area

North-west	North-east
	
Native grassland: Vale River	Native grassland: Newitts Creek
	
Sclerophyll forest: Sterling River	Sclerophyll forest: Becketts Creek
	
Rainforest: Coldstream River at the Huskisson junction	Rainforest: St Patricks River
	
Sub-alpine: Ring at Mt Read	Grassland/heath: Wyniford River

Grassland sites only occurred between 600 and 825 m altitude. Rainforest sites occurred at all altitudes from 50 m to 890 m. However, at the higher altitudes, rainforest was likely to be confined to the gullies whereas at lower altitudes, rainforest might be dispersed more widely through the catchment. Eucalypt forest dominated at moderate altitudes but ranged between 50 m and 810 m. The only sub-alpine site was at 900 m.

The streambed of all sites was generally cobbles and pebbles. Site profiles (Appendix 1) indicate the nature of the bed at the sampling locations. The character of the streambed material was roughly classified by texture into either 'smooth' or 'rough' for those with pitted surfaces not worn by river flow. Long-term river action in the western study area resulted in smooth rocks in the larger rivers only.

In the north-eastern area, the dolerite boulders and cobbles were more often worn to a smooth surface in smaller streams. Riverbed gradients varied between 1 in 300 at the Coldstream sites on Knole Plain (CF and CG) to 1 in 10 at Bonnies Creek (BO) on the slopes of Mt Barrow in the north-east.

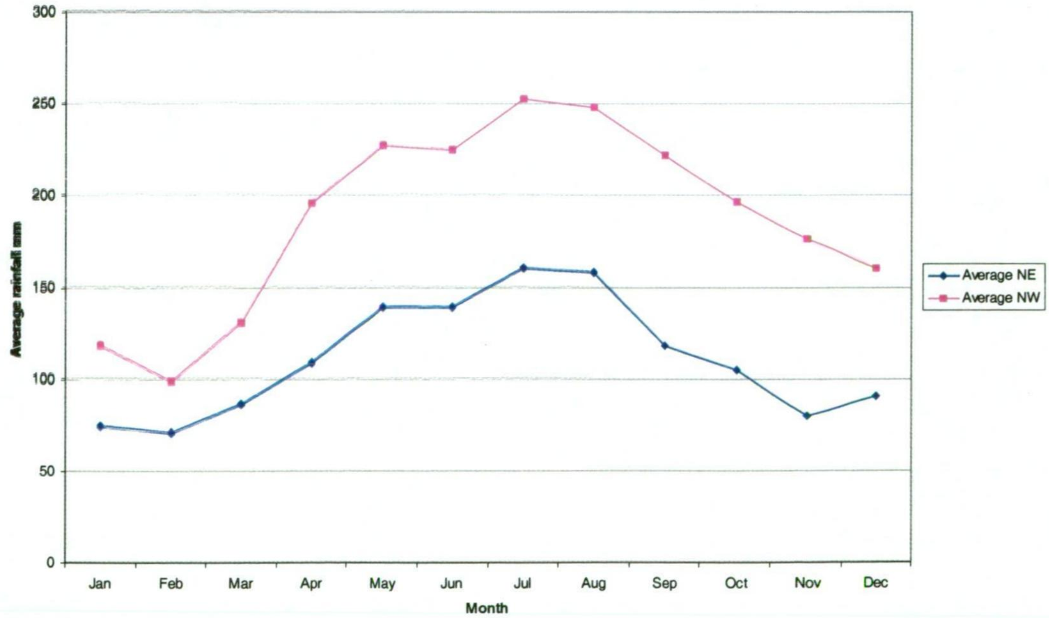
The aquatic chemical characteristics of the 44 sites at baseflow were, with a few exceptions, remarkably consistent. Dissolved nitrate and phosphate were measured at every site and on every sampling occasion. Values for all sites and all sampling occasions fell within the range of 0.00 to a maximum 0.95 mg of NO_3^{-1}/litre for dissolved nitrogen with a mean of 0.08 mg of NO_3^{-1}/litre from all records. For phosphates, the values fell in the range 0.00 to a maximum of 2.13 mg $P0_4^{-3}$/litre with a mean of 0.16 mg $P0_4^{-3}$/litre. Tasmania's waterways are typically low in nutrients and these values fall below a level that would have measurable impacts on the faunal composition so this parameter was not used in analysis.

The pH of the water varied in the north-west sites between 4.65 at Farm Creek to 7.5 at several sites. All north-east sites fell in the acidic range 4.84 at Wyniford River to 6.76 at Memory Creek. Conductivity usually ranged around 40 μS/cm for sites in the north-east, while values were generally a little higher in the north-west. Amongst sites sampled, the highest conductivity value, 280 μs, was recorded at the Vale River in the north-west.

All sites in the north-east lay within the Interim Bioregional Analysis for Australia (IBRA) region 'Ben Lomond'. Three IBRA regions were represented in the north-west sites: Woolnorth, West and South-west, and Central Plateau. The regions suggested by Orchard (1988) comply with the IBRA regions at these points. The rivers sampled fall into two of Hughes' (1988) categories of hydrological regimes for Tasmania. All of the north-east sites appear closest to Hughes' 'group 4' sites although the precise study area is poorly represented in her survey points. Seven of the sites in the north-west survey group also fall in the Hughes' 'group 4' hydrological category, while the remaining 20 sites in the north-west fall within the general westerly 'group 3' category. Thus all study rivers had moderate to low annual hydrological variability, but a more seasonal pattern of higher falls in the late-winter-early spring months in the north-east. In the north-west, discharge was high throughout the year, and flood flows could occur in any month. River data is reflected in the rainfall data shown in Figure 4.4.

Unfortunately, very limited data on river discharge in the two survey areas are available. Such records are principally kept for hydro-electric or river systems which are potential for development. Caution must be used in attempting to extrapolate from rainfall data, which is also biased in its collection with somewhat less representation of high altitude sites in the regions of the study. Nevertheless, indicative rainfall profiles can be assembled for the two areas, based on averages from several rainfall stations in each area (Figure 4.4).

Figure 4.4 Average monthly rainfall for north-west and north-east sampling areas



Indices of river disturbance for the study sites were drawn from the Wild Rivers Project database (Stein *et al* n.d.). These data present a summary of river naturalness as defined by the Wild River project parameters (Stein *et al* n.d.). An attempt will be made to establish any correlation of faunal data with the Wild River indices to explore the issues of potential surrogacy. Three measures were selected to depict the status of the rivers and streams sampled: the Land Use Factor (LUF), Catchment Disturbance Index (CDI) and River Disturbance Index (RDI). Flow Disturbance Regime Index (FRDI) was not used since all sites sampled scored '0', that is no rivers were subject to any impoundment or abstraction. The Land Use Factor incorporates seven classes of diffuse (area-based) impacts based on level of land clearance. The Catchment Disturbance Index is computed from contributing sub-catchment disturbance indices so that upstream effects of all forms of disturbance are captured. The River Disturbance Index is a sum of the CDI and Flow Disturbance Regime Index FRDI to provide an overall estimate of river disturbance. Results are reported in a range 0.0 to 1.0, with least disturbed sites having lower scores (Stein *et al* n.d.). Values at the study sites ranged from 0 - 0.75 for the LUF, 0 - 0.5 for the CDI and 0 - 0.45 for the RDI.

4.4 The macroinvertebrate fauna

4.4.1 Summary of methods and data analysis

The methodology for the study survey is reported in Chapter 3. The data reported here is drawn from Surber samples collected on four occasions (two spring, two autumn) in two areas of northern Tasmania. All material was live-picked and subsequently sorted, identified to family level and counted. The data from six Surber samples were amalgamated for each sampling occasion, and then averaged to represent assemblages at each site. If a taxon was collected on any sampling occasion, it was included as present at that site.

The data were then examined to assess distributions, explore community structure and patterns, analyze against environmental variables, and identify significant differences amongst the groups. The plecopteran fauna was also identified to species level and the findings of this analysis are reported in Chapter 6.

4.4.2 The taxa

Data from each seasonal sampling (usually four samples, two spring, two autumn) were averaged to provide a profile of the taxa present at each site. Sampling information is provided in Appendix 1. Total macroinvertebrate abundance at all sites varied according to season and between sampling occasions. Mean number of individuals per square metre of streambed as sampled with the Surber sampler ranged between 128 for a small creek in the north-east (FM) to nearly 2200 per m^2 at several sites in the north-west. Each site varied up to 6 or 7-fold in macroinvertebrate abundance between sampling occasions. However, there was no variation in the taxa present on a seasonal basis, only in the abundance, which could often be attributed to a single or very few taxa.

A summary of the taxa occurring at each site is provided in Table 4.2. Any taxon that occurred at that site was included, even if it was found in only a single sample.

The total number of sites at which each taxon occurred is summarized in Table 4.3.

Some taxa were widespread and occurred at all or most sites. These taxa include: Oligocheate worms, scirtid beetle larvae, elmid beetle adults and larvae, larvae of Diptera including tipulid, simuliid and chironomid larvae, leptophlebiid mayflies, gripopterygid stoneflies, hydrobiosid and philorheithrid caddis flies. Leptophlebiids were often the dominant taxon, occurring in large numbers regardless of season. Other frequently occurring taxa included mites (Hydracarina), psephenid beetle larvae, notonemourid stoneflies, and parameletid crustaceans. The taxa are typical of cool, well-oxygenated streams.

The table also shows that some taxa occurred infrequently or rarely. In some cases, this may be interpreted as collection in marginal habitat while in other cases, the habitat is suitable but the taxon is rare in its distribution. These issues will be further explored in Chapter 7. Frequency of occurrence by sites is shown in Table 4.3.

Table 4.2 Taxa ocurring at each site

	AN	BC	BT	CB	CC	CF	CG	CH	FA	GU	HG	HH	HM	HR	JU	LR	NE	PC	PD	PP	RR	SF	SO	SR	ST	SU	VA
Turbellaria		2		6		1	4	1	2		6	0	19		1		7			3	1	1	1			4	7
Gordiidae		1					1				1										0						0
Hydrobiidae		1	45			32	21	0		4	10		4		15		3	0				16				45	
Planorbidae							0			2	41		1		0					1		0				0	
Sphaeriidae							0				0				0		1										
Oligochaeta	7	19	22	43	47	14	20	68	49	10	60	13	36	28	17	38	5	74	54	27	42	12	2	5	55	13	10
Hydracarina	4	1	1	1		30	3	3	5	1	1	2	3	6	1		9	3	4	14	5	0	1	2	2	6	1
Eurisidae															8						1	1				3	
Parameletidae	1	33	42	25		49	94	2	25	12	36	5	53	4	98	2	37	13	7	29	1	8	4	1	1	38	14
Phreatoicidae		2				23	25			1			6		1		4										
Atyidae			0				0								1												
Dytiscidae Larvae				1			7																				
Hydrophilidae									2														1		1		
Scirtidae	16	12	13	1	8	55	4	17	9	3	11	3	2	2	2	5	3	1	5	5	9	7	2	6	2	21	8
Elmidae Adults	4	4	4		3	379	7	23	2	3	7	14	69	5	19	1	3	32	48	14		5	59	12	0	72	26
Elmidae Larvae	1		4		1	83	2	25	2	18	5	2	35	1	13		1	23	18	19		4	2	5	2	22	40
Psephenidae	3	5	5	7		5	6	5	7	2	3	7	14	4	6	1	8	3	31	13		7	6	3		13	28
Chrysomelidae larvae										1						1											
Tipulidae	6	1	1	3	1	2	3	3	3	1	4	3			1	1		1	2	1	4	0	7	3	1	4	2
Blephariceridae								2		6	1	14			2				0			0					
Ceratopogonidae	1	1				3	2	3	9	2	1	1	1	1	2	1			5	1				9		1	
Simuliidae	5	12	15	1	4	9	4	17	1	7	4	20	79	10	28	1	10	4	9	12	1	2	11	2	1	2	1
Thaumaleidae																								2			
Athericidae		2		0		3	5	2	1	1		1	2	1	2			1	0	0		1		3		3	
Stratiomyidae													0					1				0		1			
Empididae			0				2		1						1	1			1	1							
Chironomidae	23	39	10	36	6	72	95	33	22	24	23	76	47	21	23	7	69	23	62	62	4	2	168	2	40	29	29
Baetidae		1			4	47	46	127		1	119	146	173		20		2	8	45	1		35	6	3		29	159
Oniscigastridae		2				1	2		1								0			1							
Leptophlebiidae	93	116	62	173	55	164	113	128	68	156	114	133	21	98	15	85	36	13	116	111	17	73	122	65	66	157	419
Nannochoristidae		1													0				0		3					1	
Aeshnidae		4	0	0					1			0			0	1			1	1		0		0		0	
Eustheniidae	1	4	2	3	8	4	1	1	0	8	4	4	19	2	5	1	4	7	11	4		2				1	
Austroperlidae		4		2	5		1	1	1	14		2			3			5	3	3	115	3				1	
Gripopterygidae	3	35	25	8	16	18	81	9	9	48	7	19	237	28	6	2	28	33	48	78	10	32	89	7	5	62	13
Notonemouridae	1	2		17	3	34	7	3	13	5	1	1			1		1	2	1	5	7		5	7	2	1	2
Hydrobiosidae	11	6	7	4	2	8	9	14	7	6	9	15	8	7	11	2	9	1	23	3	13	4	13	8	9	2	29
Glossosomatidae		14	6		1	10		61	2	3	7	22	6		20			17	56	46		26		7		5	0
Hydroptilidae							0		0					1	1		0	2		8		1				0	3
Philopotamidae		0		9							0				1				1			0	1				
Hydropsychidae		1			1	3	1	3			1	3	52		2			1	2	1	1	1	1		1	12	1
Polycentropidae									1	1						1					0						0
Ecnomidae							1							2	2				0			1		1			
Limnephilidae				0		1	0		0												0						
Oeconesidae		1																			0						
Tasimiidae		1	0								0				1							3					
Conoesucidae	2	56	2	0		52	148	9	0	1	27	22	35	2	22		5	1	3	94	16	2	9			34	314
Helicopsychidae			29			4	1	2			4		1		2		0					15	3	1		5	
Calocidae		1	1	2		3	0	4		4	2	7	1	1	9		0	1	8	1	1	1	1	1		20	3
Helicophidae	0	4				5	3	3			0	5		1	1					11	13	1		0		3	18
Philorheithridae	5	1	1	2	3	30	3	12	3	1	4	6	1		8	1	1	6	5	4	2	5	2	7	2	4	3
Atriplectididae							2	1				1					1			0							
Leptoceridae	2	5	2			6	2	9	8		38	2	16	3	4	6		1	2	2		1	1	9	1	22	4

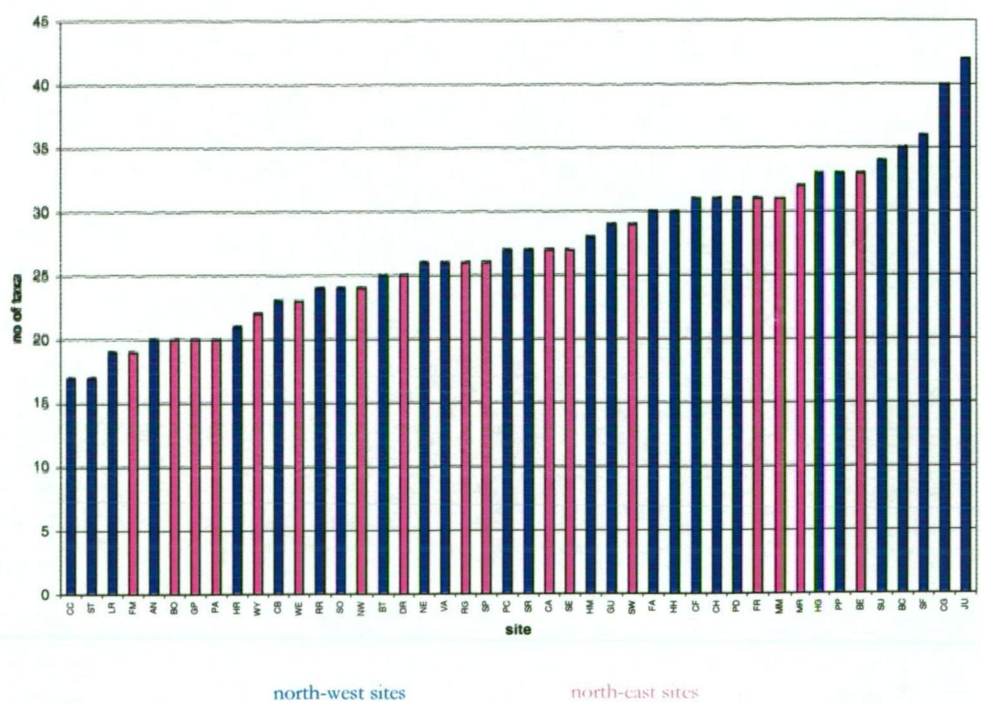
	BE	BO	CA	DR	FM	FR	GP	MM	MR	NW	PA	RG	SE	SP	SW	WE	WY
Turbellaria	1	3	5			5	1		1	1		2		4			
Gordiidae		1	1							1						5	
Hydrobiidae																	
Planorbidae																	
Sphaeriidae																	
Oligochaeta	9	3	17	26	6	17	28	2	18	2	2	36	35	43	11	8	15
Hydracarina	5			3		2	1	2	3	1		2	1	18	2	1	1
Eurisidae										1							
Parameletidae	2	1	58		30	18	1	4		2	27	34			6	62	46
Phreatoicidae	0	7	8		1	2	1				5	1	1	1	1	1	
Atyidae																	
Dytiscidae Larvae	1					1				7							
Hydrophilidae																	
Scirtidae	23	1	63	5	24	26	2	10	5	133	32	18	9	53	7	2	16
Elmidae Adults	96		10	3	2	36	1	20	1	23	19	7	18	2	3	15	28
Elmidae Larvae	9		4	1		27	2	15	2	34	58	3	7	7	1	3	8
Psephenidae	3	6	2	1		2	3	1	1	1		8		2	0	13	2
Chrysomelidae larvae									1								
Tipulidae	8	3	3	1	21	2	6	2	2	6	4		1	5	1	7	2
Blephariceridae	6				1			4					1		4	1	
Ceratopogonidae	4				1	1		1	2	1			11	3	1		
Simuliidae	48	1	6	2	3	11	4	28	3	3	3	1	10	12	6	2	15
Thaumaleidae																	
Athericidae	1		1	19	10	1	3	2	3	2		1	1	16	5	1	6
Stratiomyidae			1			1		1	1							1	
Empididae	4			1					1				1			1	
Chironomidae	32	85	24	1	17	67	2	19	33	21	16	14	28	4	23	3	8
Baetidae	150	1	0	6		69		84	3	4	1	2	77	39	6		
Oniscigastridae																	
Leptophlebiidae	19	2	133	62	6	213	27	40	39	51	13	135	69	128	62	44	116
Nannochoristidae	1	5	3	1		1		1			1	1		3			
Aeshnidae				0				1							1		
Eustheniidae	1	3		6		1		3	1			1	1		7		
Austroperlidae			1	9		1		1	1			3			6		
Gripopterygidae	20	8	15	8	1	54	189	66	9	238	120	9	14	45	33	5	149
Notonemouridae	1	28	29	7	2	9	15	1	5	1	1	24	2	2	2	3	2
Hydrobiosidae	16	6	4	4	6	26	2	12	7	6	8	8	15	12	18	3	12
Glossosomatidae	37		15	1		6	1	57	21		1	1	12	86	54		
Hydroptilidae				1			1	1	3				1		2		
Philopotamidae																	
Hydropsychidae	13	2						3	1				1	3	4		
Polycentropidae	2								1						1		1
Ecnomidae																	
Limnephilidae			1								1						1
Oeconesidae																	
Tasimiidae		1				1											
Conoesucidae	26				1	29	2	1	2	2	15	5	3	6	1		1
Helicopsychidae	1								5								
Calocidae	18	1	2	1		3		5	14			9	8	4	12	1	7
Helicophidae	4		2		1	43		1	1		6	6	1	5			123
Philorheithridae	6		0	1	1	2		1	1	1	1	1	1	1		1	9
Atriplectididae																	
Leptoceridae	19		1	32	1	1		4	118	1		1	45	8	2	1	1

Table 4.3 Number of sites at which each taxon occurred

Taxon	Sites	Taxon	Sites
Oligochaeta	44	Austroperlidae	22
Scirtidae	44	Phreatoicidea	19
Simuliidae	44	Hydroptilidae	16
Chironomidae	44	Aeshnidae	15
Leptophlebiidae	44	Nannochoristidae	14
Gripopterygidae	44	Helicopsychidae	14
Hydrobiosidae	44	Hydrobiidae	13
Elmidae Adults	41	Blephariceridae	13
Tipulidae	40	Empididae	12
Philorheithridae	40	Gordiidae	9
Paramelitidae	39	Stratiomyidae	9
Notonemouridae	39	Polycentropodidae	9
Hydracarina	38	Planorbidae	8
Elmidae Larvae	38	Limnephilidae	8
Psephenidae	38	Philopotamidae	7
Conoesucidae	36	Tasimiidae	7
Leptoceridae	36	Oniscigastridae	6
Calocidae	35	Ecnomidae	6
Athericidae	32	Eurisidae	5
Baetidae	32	Dytiscidae Larvae	5
Eusthenlidae	31	Atriplectididae	5
Glossosomatidae	30	Sphaeriidae	4
Turbellaria	26	Atyidae	3
Ceratopogonidae	26	Hydrophilidae	3
Helicophidae	26	Chrysomelidae Adult	3
Hydropsychidae	25	Oeconesidae	2
		Thaumaleidae	1

A range of taxon richness was evident amongst the sites. Taxon richness is shown in Figure 4.5.

Figure 4.5 Taxon richness at study sites



The richest sites were an order of magnitude richer in number of taxa than the poorest sites. Widespread taxa occurred at the poorer sites with equal frequency as at the richer sites (Table 4.2). Taxa which were relatively less well-represented at the poorer (less diverse) sites included most trichopteran families, turbellarians, Molluscs and baetid mayflies and austroperlid stoneflies. Both north-eastern and north-western sites were represented amongst the richer and poorer sites.

4.5 The faunal communities

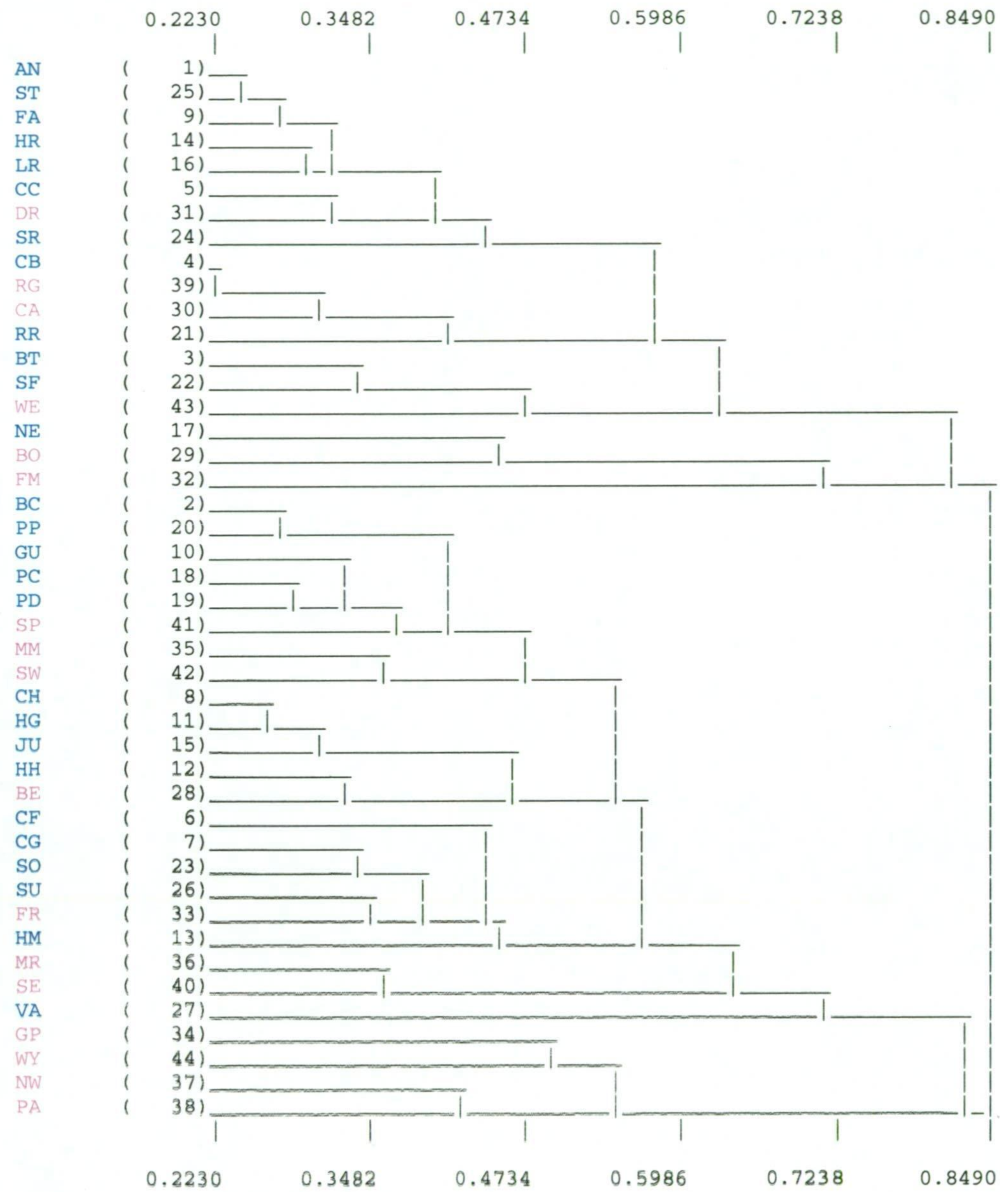
Analysis of the data using classification and ordination techniques explored the possible occurrence of community groupings among the study sites. The data were treated in two different ways: using all data in raw form, and with the taxon data amalgamated into taxonomic and functional feeding groups (Quinn & Hickey 1992). The taxonomic - feeding group analysis is discussed in more detail in section 4.5.2. Transformation of the data set by $\log_{10}(x+1)$ or to presence/absence (binary) data was explored but these were rejected as low Bray-Curtis dissimilarity measures (<0.45) indicated that there was little structural differentiation between sites.

4.5.1 Analysis using total frequencies

Site groups were identified using the PATN multivariate analysis software (Belbin 1993). Dissimilarity matrices were developed using the ASO subroutine in PATN. All site data were clustered by unweighted paired group mean averaging (UPGMA) with the FUSE sub-routine in PATN. The resulting dendrogram was plotted using the DEND routine, shown in Figure 4.6.

In Figure 4.6 greater distance along the horizontal axis of the figure indicates increasing dissimilarity. A small group of high altitude grassland sites in the north-east had the largest dissimilarity from other sites. Two other broad groupings may be identified: a chained group of undifferentiated sites and a large group with several subgroups. However, all groups were small with limited number of replicates, suggesting no clear delineation of site groups. This was further explored using a graphical examination of the MDS ordination (SSH in PATN).

Figure 4.6 Dendrogram of the UPGMA clustering of a Bray-Curtis matrix derived from all data at 44 study sites

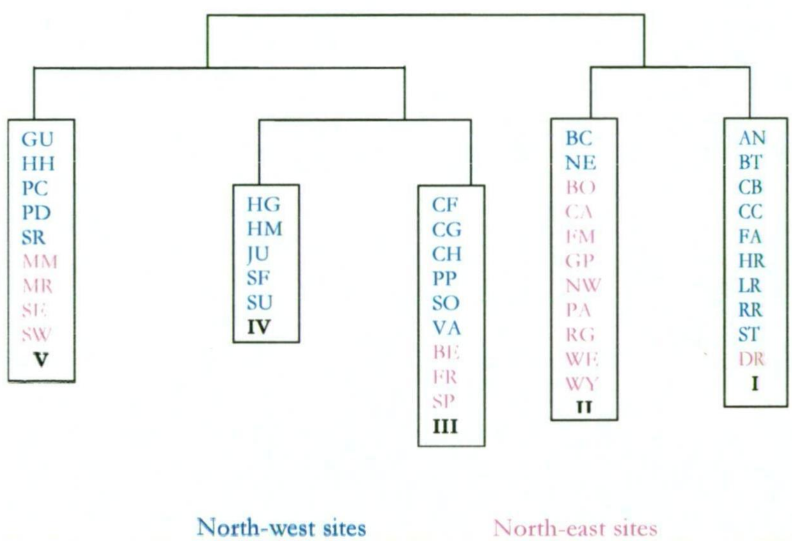


North-west sites North-east sites '(14)' indicates number in data set. 'HM' is the site.

The data were also classified using two-way indicator species analysis (TWINSPAN) in PATN. The resulting dendrogram displays the successive clustering of sites into groups based on the Bray-Curtis similarity matrix. Sites progressively fuse together with the most similar sites close together and differences between sites shown on the horizontal axis of the display. The most distinct differences in fauna are reflected in the first division, with each lower level division indicating lesser differences within the whole data set. The TWINSPAN classification of all data from the 44 study sites is shown in Figure 4.7.

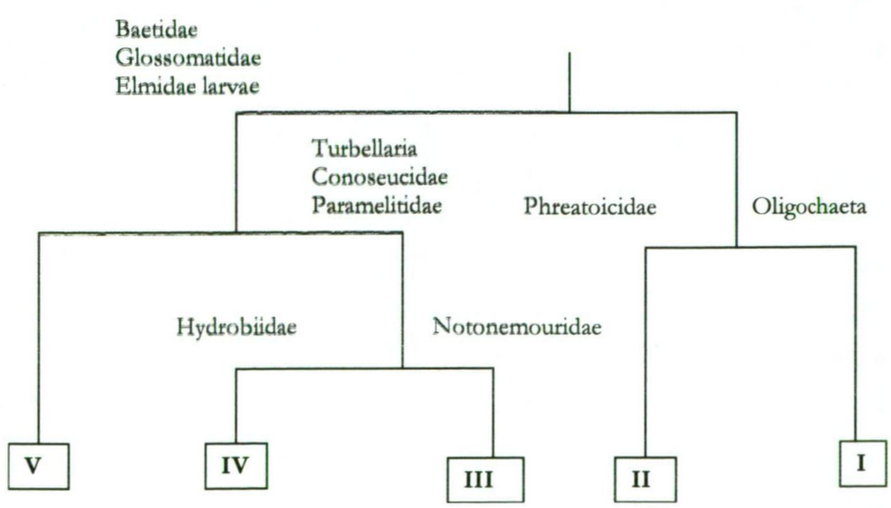
The TWINSPAN group **I** brings together several sites in the same area of the Pieman catchment, two sites from the far north-west and a single north-east site, Dorset River. Group **II** sites were principally high altitude, mainly grassland, north-eastern sites and two small creeks in the north-west. Groups **III**, **IV** and **V** included a range of mainly forested sites with both rainforest and eucalypt forest as riparian vegetation. Group **IV** sites were confined to the north-west survey area.

Figure 4.7 TWINSPAN classification of study sites Stress = .19



Indicator species for the divisions of the TWINSPAN were identified using the PCC subroutine in PATN. Significant taxa are shown in Figure 4.8.

Figure 4.8 Indicator taxa for the TWINSPAN groups



Analysis of variance using Sigmastat was undertaken to attempt to define any variables or characteristics of the sites which explained the group classifications. Variables in numerical form which were amenable to analysis were: northing, easting, altitude, bankfull width, bedslope, pH, conductivity, % vegetation cover, Land Use Factor (LUF), Catchment Disturbance Factor (CDI), River Disturbance Index (RDI), and % cover of each substrate class. In addition, significance of differences in taxon richness amongst the site groups was tested for using one-way analysis of variance.

ANOVAs for some of these variables proved to be not significant at the $p<0.05$ level. In the group of tables which follow, means followed by the same letter are not different at $p< 0.05$. The variables which were significantly different between the site groups were altitude, easting, pH, conductivity, and width. Taxon richness was also significantly different between the TWINSPAN groups. The data are summarized in Table 4.4 a-h.

The TWINSPAN groups differed significantly in their altitude (ANOVA $F_{4,39} = 13.3$, $p<0.0001$). Mean altitude of the sites ranged from 313 m to 760 m (Table 4.4 a) the site group with highest mean altitude, Group **II**, largely comprised of north-easterly sites. This is reflected in the significant difference of easting (ANOVA $F_{4,39} = 5.7$, $p<0 .0010$).

The analysis of variance for river width failed the normality test but the ANOVA on ranks was significant ($H_4 = 15.6$, $p=0.0035$). Group **II** sites had the lowest mean width, differing from all other groups (Table 4.4 c). Groups **I** and **II** were significantly different in mean pH compared with the other three groups (ANOVA $F_{4,39} = 11.0$, $p= <0.0001$) (Table 4.4 d). Group **II** was also different from all other groups in conductivity when analysed by rank (ANOVA $H_4 = 15.8$, $p=0.0033$) (Table 4.4 e).

ANOVAs on ranks of two classes of streambed substrate were significant for TWINSPAN groups using raw data: percentage of cobbles ($H = 11.8_4$ $p=0.0188$, Table 4.4 g) and of boulders ($H = 11.3_4$ $p= 0.00234$ Table 4.4 h). TWINSPAN Group II differed from other groups in the low percentage of cobble substrate while Group V had a slightly higher percentage of boulder bed.

Table 4.4 Variables significantly different among TWINSPAN groups (raw data)

(a) Altitude m

Group	Mean	S.D.	SEM	Contrast
I	313	232	73	a
II	760	97	29	b
III	573	181	180	c
IV	322	261	116	ac
V	269	144	144	ac

(b) Easting

Group	Mean	S.D.	SEM	Contrast
I	385500	67231	21260	b
II	528909	75439	22745	a
III	437022	84546	28182	b
IV	356280	31298	13997	bc
V	443889	112448	37482	b

(c) Width

Group	Median	25%	75%	Contrast
I	4	2	15.0	b
II	1	1	3.0	bc
III	5	5	7.3	b
IV	4	3	3.4	ab
V	4	3	2.9	ab

(d) pH

Group	Mean	S.D.	SEM	Contrast
I	5.58	0.78	0.246	a
II	5.87	0.64	0.194	a
III	6.62	0.37	0.123	b
IV	7.13	0.37	0.163	b
V	6.76	0.29	0.098	b

(e) Conductivity

Group	Median	25%	75%	Contrast
I	57	50	70	a
II	36	27	27	ab
III	49	43	57	a
IV	124	50	152	a
V	56	38	80	a

(f) Taxon richness

Group	Median	25%	75%	Contrast
I	22	19	25	a
II	23	20	26	ab
III	31	26	33	b
IV	34	32	38	b
V	29	27	31	b

(g) % cobble

Group	Median	25%	75%	Contrast
I	20	5	60.0	ac
II	0	0	41.3	bc
III	40	19	70.0	ac
IV	65	39	83.8	ac
V	70	50	81.3	a

(h) % boulders

Group	Median	25%	75%	Contrast
I	0	0	0.00	ac
II	0	0	0.00	bc
III	0	0	0.00	ac
IV	0	0	1.25	ac
V	5	0	10.00	a

Means followed by the same letter in the 'contrast' column are not different at P<0.05

Site taxon richness by rank was significantly different among the TWINSPAN groups (ANOVA H_4=24.6, p= <0.0001) (Table 4.4 f). Groups **I** and **II** had a lower taxon diversity than the other three site Groups.

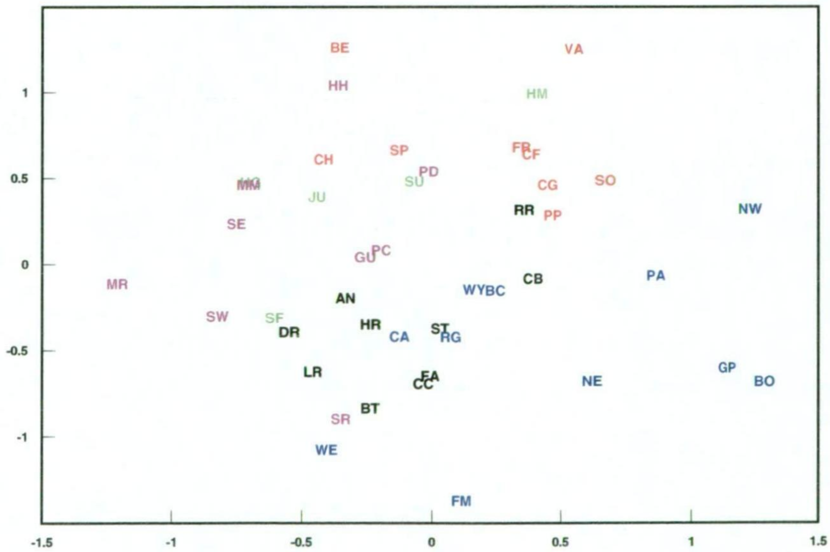
In summary, TWINSPAN groups **I** and **II** have lower taxon richness, and lower pH. Group **II** also has low conductivity. Groups **II** and **III** were the highest altitude groups of sites, while Group **II** was the group with significantly smaller rivers or streams and more easterly sites (Table 4.4 b, c). Mean values for variables identified as significant in Table 4.4 are now summarized by TWINSPAN group, Table 4.5.

Table 4.5 Mean values for variables identified as significant in the TWINSPAN classification

Parameter	Group I	Group II	Group III	Group IV	Group V
Easting	385500	528909	437022	356280	443889
Altitude m	313	760	573	322	269
Width m	4.0	1.0	5.0	4.0	4.0
pH	5.58	5.87	6.62	7.13	6.76
Conductivity μs	56.9	35.8	48.7	124.1	56.2
Cobbles	20	0	40	65	70
Boulders	0	0	0	0	5
Taxon richness	22	23	31	34	29
Sites	AN, BT, CB, CC, FA, HR, LR, RR, ST, DR	BC, NE, BO, CA, FM, GP, NW, PA, RG, WE, WY	CF, CG, CH, PP, SO, VA, BE, FR, SP	HG, HM, JU, SF, SU,	GU, HH, PC, PD, SR, MM, MR, SE, SW

The apparent differences among the TWINSPAN groups were explored by highlighting the groups on a graphical display of the MDS ordination (derived using the SSH routine in PATN). The output was represented in two dimensions using Harvardchart. Figure 4.9 highlights with colour-coding the locus of sites in each of the groups in the ordination space. Table 4.6 shows the relative importance of significant taxa in generating the MDS ordination.

Figure 4.9 Ordination of study sites using raw data.



TWINSPAN groups highlighted by colour coding

Table 4.6 Indicator taxa for MDS ordination of raw data, correlation values and their significance

Taxon	Correlation	Significance	Taxon	Correlation	Significance
Baetidae	0.807	**	Glossosomatidae	0.557	**
Gripopterygidae	0.766	**	Leptoceridae	0.534	**
Elmidae Larvae	0.752	**	Conoesucidae	0.524	**
Leptophlebiidae	0.685	**	Scirtidae	0.504	**
Hydrobiosidae	0.657	**	Chironomidae	0.543	*
Elmidae Adults	0.640	**	Limnephilidae	0.491	*
Calocidae	0.620	**	Blephariceridae	0.464	*
Oligochaeta	0.597	**	Philorheithridae	0.460	*
Simuliidae	0.577	**	Phreatoicidea	0.447	*
Paramelitidae	0.566	**	Dytiscidae Larvae	0.426	*
			Hydrospsychidae	0.407	*

** indicates p<.01, * indicates p< .05

The MDS ordination supports the TWINSPAN classification. TWINSPAN groups **I** and **II** sites (shown in colour as 'CB' and 'NE' respectively) also separating from the rather undifferentiated group of 22 sites (BC to VA) shown in the dendrogram. The UPGMA analysis yielded groups at a Bray-Curtis value of >0.5.

In summary, the five TWINSPAN groups may be characterized in the following way.

Group **I**: low altitude (mean around 300 m), moderate size rivers and streams with low pH and low taxon richness, baetid mayflies, glossosomatid caddis, elmid beetle larvae and phreatoicid crustaceans are few or absent. All forested streams except a single sub-alpine site and only one site is in the north-east study area. Most of the north-west sites lie in the Pieman area near Rosebery, the remaining three sites being at the westerly side of the Sumac area. The north-east site is on the northern side of the north-east highlands and the lowest altitude site for this study area.

Group **II**: highest altitude sites (mean around 760 m), mostly in the north-east, small streams with mean width only 1 m, low pH and conductivity, and low taxon richness. Baetid mayflies, glossomatid caddis, elmid beetle larvae few or absent but phreatoicid crustaceans present. Five of the 11 sites are in grassland areas while the remainder are forested. All except two sites are in the north-east.

Group **III**: a range of medium altitude (mean around 560 m) moderate size rivers or large streams with a mean width around 5 m, pH near neutral at 6.62, high taxon richness (mean 31 taxa) including Turbellaria, conoesucid caddis and paramelitid amphipods. This group is distinguished from group **IV** by numbers of notonemourid stoneflies. The sites are, with one exception, in forested areas. The six north-west sites generally lie in the easterly part of the sampling area.

Group IV: lower altitude (mean 320 m) moderate size rivers or large streams (mean width 4 m), pH 7.13 and conductivity also higher than other groups. Highest taxon richness, including Turbellaria, conoseucid caddis and paramelitid amphipods and distinguished from group II by presence or abundance of hydrobiid molluscs. These five sites are all in the north-west, two in the Hellyer river near Guildford, and the other three in the region of karstic rocks south of the Arthur river. One is in grassland, the others are all forested sites.

Group V: low altitude sites (mean 300 m), moderate rivers or streams (mean width4 m), mean pH 6.8 and moderate taxon richness (mean of 29 taxa per site). Baetid mayflies, glossosomatid caddis and elmid larvae present as indicator taxa but otherwise the fauna is not so diverse as groups **IV** and **V**. All sites are in forested areas with north-east and north-west sites almost equally represented.

4.5.2 Analysis by functional feeding groups

A study of New Zealand rivers (Quinn & Hickey 1990) demonstrated that New Zealand rivers could be classified into 10 broad groups by analysis of the macroinvertebrate data according to feeding behaviours. Their work used a mix of taxonomic and functional feeding groups to classify all taxa at 88 sites. The resulting classification was based on macroinvertebrate biomass using ash-free dry weight of each of the taxonomic feeding group classes.

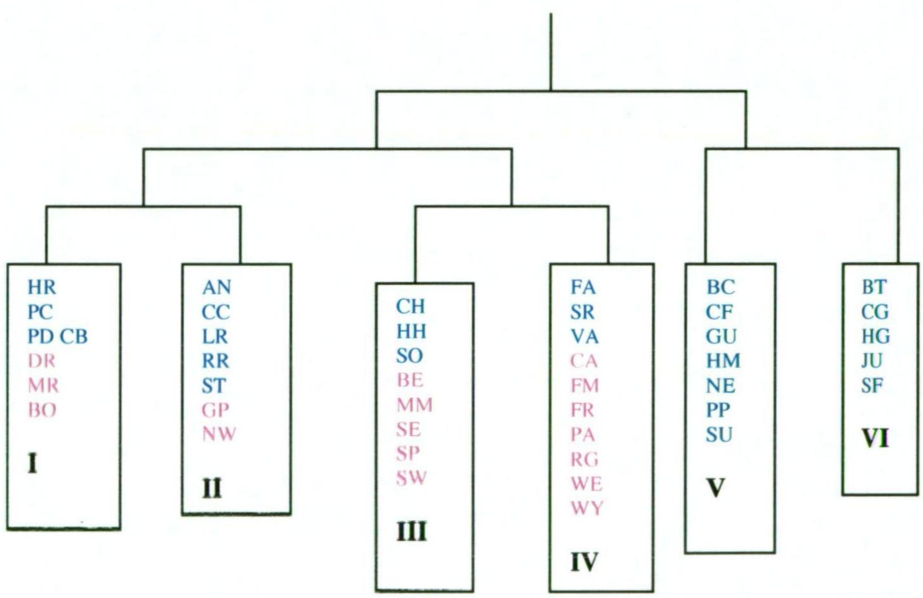
Resolving the information to biomass by ash-free dry-weight procedure was considered to be beyond the resources, scope, and primary purposes of the present study. The purpose of analysis by functional feeding group was two-fold: firstly as an alternative means of identifying and characterizing the 44 study sites, and secondly to make some general comparisons with the New Zealand faunal communities.

Some modification of the Quinn & Hickey technique was necessary in my study.

Analysis of biomass was not used and use of taxon numbers was considered to be an appropriate and adequate measure for comparative and descriptive purposes. Some changes were made in the categories to reflect the different elements of the respective faunas. For example, Megaloptera form a significant taxonomic group in New Zealand but are rarely present in Tasmanian streams. Conversely, simuliid and chironomid Diptera are important in Tasmania's lotic habitats but in the New Zealand analysis are included with other Diptera.

All taxa present were categorized into one of thirteen taxonomic or broad functional feeding groups. The list of assignment of all taxa is provided in Appendix 1. Then this data set was subjected to classification using TWINSPAN in PATN, the procedure used by Quinn and Hickey (1990). This process resulted in identification of six site groups as shown in Figure 4.10.

Figure 4.10 TWINSPAN classification of sites by functional feeding group analysis



Indicator taxa for the divisions are shown in Figure 4.11.

The TWINSPAN classification clusters sites with similar faunal community profiles. The taxon frequencies for site in each group were summed, then these data were expressed as a percentage of the total number of individuals. This provided a broad picture of the functional feeding group profiles of each site group. The data were plotted graphically in Excel and the result is shown in Figure 4.12.

Figure 4.11 Indicator taxa for TWINSPAN analysis of functional feeding groups

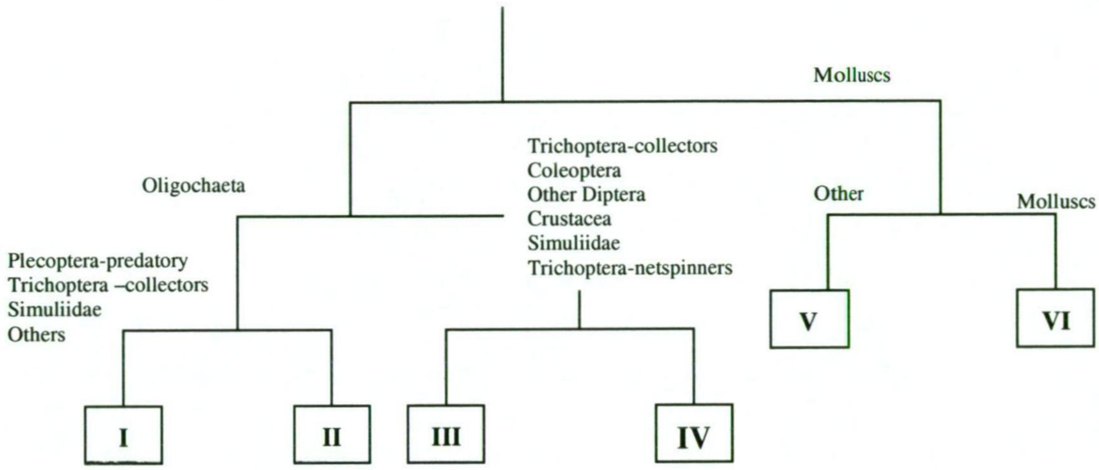
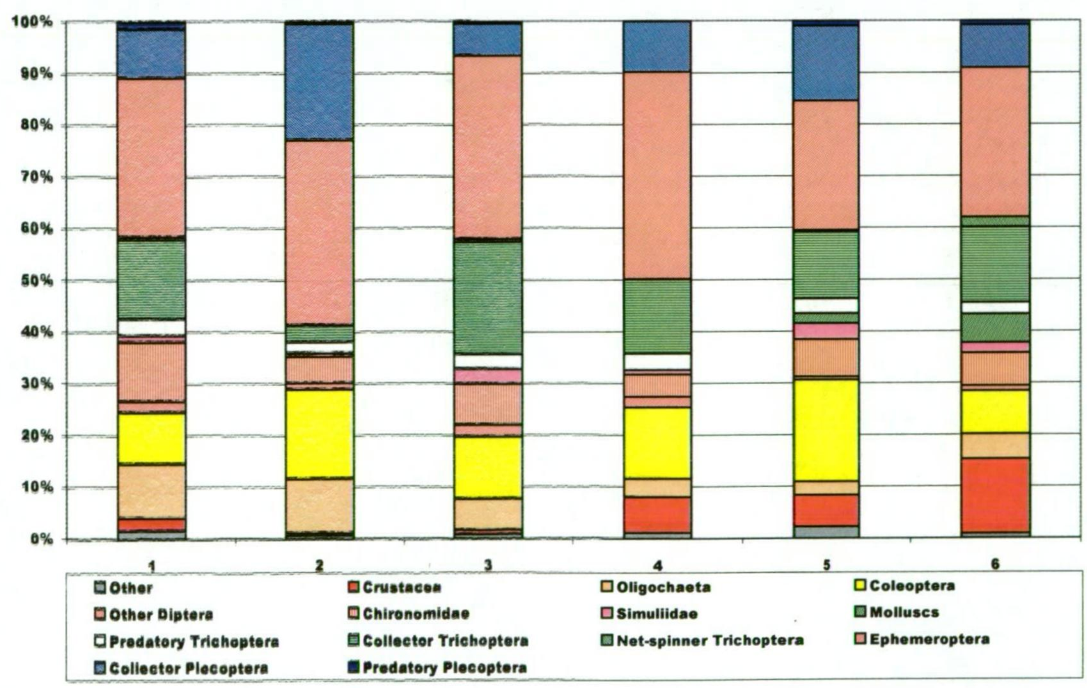


Figure 4.12 Community composition for the six TWINSPAN groups



The overall pattern of community structure is similar for all sites. This has much in common with those of river classes 1-4 (Quinn & Hickey 1990) in New Zealand. The New Zealand sites were also from cool upland cobble-bedded sites. In contrast, the New Zealand classes 5-10 were generally from more lowland sites and subject to various types of disturbance, including moderate to severe flooding.

The Tasmanian site groups did have some inter-group differences in feeding group composition. Groups **V** and **VI** were the only groups to have significant numbers of Molluscs. Group **VI** was the only group to have significant numbers of net-spinning caddis. Group **II** was dominated numerically by Ephemeroptera and non-predatory Plecoptera.

Analysis of variance, using SIGMASTAT was undertaken to attempt to define any significant variables or characteristics of the site groups. The same variables were used as to those for the raw taxon data: northing, easting, altitude, bankful width, bedslope, pH, conductivity, % vegetation cover, Land Use Factor (LUF), Catchment Disturbance Factor (CDI), River Disturbance Index (RDI), and substrate size. In addition, taxon richness at the sites was tested for significance amongst the site groups.

ANOVAs for most of these variables proved to be not significant at the $p<0.05$ level. The variables to reveal significant differences between the site groups were easting, pH, and species richness Table 4.7 a-c.

Table 4.7 ANOVAs for functional feeding group analysis which demonstrated significant differences between TWINSPAN groups

(a) Easting

Group	Mean	S.D.	SEM	Contrast
I	442771	106568	40279	ab
II	424171	93651	35397	ac
III	489450	88873	31421	a
IV	508110	96487	305012	a
V	366000	21299	8050	bc
VI	351060	29830	13340	bc

(b) pH

Group	Median	25%	75%	Contrast
I	6.50	5.800	6.71	b
II	5.70	5.170	6.16	a
III	6.62	6.500	6.77	b
IV	5.90	5.100	6.67	b
V	6.75	6.280	7.17	b
VI	6.92	6.860	7.09	b

(c) Taxon richness

Group	Mean	S.D.	SEM	Contrast
I	25.6	4.70	1.77	a
II	20.1	2.90	1.10	b
III	28.9	3.00	1.06	a
IV	25.1	4.00	1.27	ca
V	30.9	3.30	1.26	a
VI	35.2	6.70	2.99	ad

There were few variables that were significantly different amongst the TWINSPAN groups for the functional feeding group analysis. The functional feeding group analysis separates out more easterly sites (ANOVA $F_{5,38}$ =4.16, p=< 0.01, Table 4.7 a). Groups **II** was significantly different in mean pH compared with the other groups based on ANOVA on ranks (ANOVA H_5 =16.8 p=0.005) (Table 4.7 b). This site group had the lowest mean pH and also had the lowest mean species richness ($F_{5,38}$ =10.1 p<0.0001, Table 4.7 c) based on ANOVA of the ranks.

Significant variables for the functional feeding group TWINSPAN groups are shown in Table 4.8. There were no significant differences by substrate nor by any of the Wild Rivers Indices.

Table 4.8 Significant variables and sites for classification by functional feeding groups

Parameter	Group I	Group II	Group III	Group IV	Group V	Group VI
Easting	442771	424171	489450	508110	366000	351060
pH	6.50	5.70	6.62	5.90	6.75	6.92
Taxon richness	25.6	20.1	28.9	25.1	30.9	35.2
Sites	HR PC PD DR MR (CB) (BO)	AN CC LR RR ST GP NW	CH HH SO BE MM SE SP SW	FA SR VA CA FM FR PA RG WE WY	BC CF GU HM NE PP SU	BT CG HG JU SF

Although there is considerable commonality between the taxonomic and feeding group composition of the sites, some distinctions may be made amongst some of the groups. Groups **V** and **VI** are the only groups to have a significant proportion of Molluscs. These sites are only westerly sites (confirmed by the ANOVA on the easting). Group **VI** sites are also the taxonomically richest sites. The mean conductivity (124 μS) is also higher, though not demonstrably significantly different from other sites.

Group **II** sites are significantly more acidic (mean pH = 5.7) and have significantly lower taxon richness than the remaining site groups. In the TWINSPAN analysis, Group **II** separated from other sites by absence of indicator taxa, suggesting a paucity of a range of taxa.

4.6 Summary

The study sites show a range in taxon diversity and, to a degree, some nuances in the type of community structure. However, there is little amongst the measured variables to account for these differences, especially as the diversity varies by a factor of up to 100%. Some taxa appear to have somewhat different site preferences: baetid mayflies, phreatocoid Crustacea and conoesucid caddis being absent from sites of low pH, for example. It seems possible that some taxa respond to environmental variables that are not readily measurable such as changing river dynamics, or to subtle differences in microhabitat such as certain forms or sizes of woody debris. High diversity sites may be the result of the particular mix of substrate size, rather than to a particular substrate characteristic.

Before evidence of conservation values at these sites is considered, two other perspectives will be explored. Firstly, the relationship between the study sites and other sites across Tasmania, to assess the degree to which these study sites are typical of other sites. This is presented in Chapter 5 using the Monitoring River Health Initiative database for comparison. Then in Chapter 6, one order of macroinvertebrates, the Plecoptera, is identified to species level and sites described with reference to a species level data set.

Chapter 5

The survey data in a Tasmanian context

In order to attempt to locate the thesis survey data within the larger statewide context, several analyses were undertaken with reference to the Monitoring River Health initiative data set which became available during the course of the study. The Monitoring River Health Initiative provides a broad overview of Tasmania's riverine environments. Data from the reference sites is used as a basis for comparison of the survey sites to explore conservation assessment issues such as: How 'rare' are the rarer taxa? Are the survey sites unusually diverse compared with other areas? And, are the survey sites typical of undisturbed rivers and streams in Tasmania?

Caveats must be placed on the use of data which was collected for a different purpose and using different methodologies. Nevertheless, in addition to some justification of claims for the survey sites, this analysis demonstrates some important principles and limitations of conservation assessment.

5.1 Introduction

The data from the survey of 44 sites, described in Chapter 4, provides a detailed picture of the macroinvertebrate fauna of two geographical areas of the state. In determining a case for conservation value, it is useful to place these data in a Tasmanian context. A Tasmanian context provides a wider geographic perspective on the conservation values of the taxa shown to be present at the survey sites. Thus a comparison with sites from across the island will allow judgements to be made on whether the sites are particularly rich in taxa, or whether the sites are indeed representative of the whole state or simply of the region. Species that are found to be uncommon in the survey area may be quite abundant in other areas of the state. Conversely, taxa may be particularly frequent in the survey areas or sites compared with other places in the state. Such issues are important to examine in making judgements about whether sites are significant at only a local level, or whether a site is particularly significant on a wider geographic scale.

The primary purpose of analysing all the data sets together was not so much to identify site groupings but to see whether (a) the study sites appeared to be spread amongst the state-wide MRHI-based samples within the cluster analysis and (b) the study sites were located geographically and biologically close to the MRHI sites. In addition, if the survey sites did form a distinct group or groups, is it possible to distinguish environmental correlates for these groups?

Analysis of any conservation survey will make use of all available sources. For the present study, these sources include: species records and mapping of particular taxa (Hynes 1989; Neboiss 1981), listing under threatened species legislation, mapping of river disturbance and data from the Monitoring River Health Initiative (Oldmeadow *et al* 1998). Most of the information that will be used is available in a form that is amenable to direct comparison. However, further analysis of the Monitoring River Health Initiative data is required in order to use this as a basis for analysis and judgement. This chapter reports the strategy adopted to make comparisons between the study data and the MRHI-based data and the results of this analysis.

5.2 The Monitoring River Health Initiative

The Monitoring River Health Initiative (MRHI) is a national project, which is designed to provide predictive bioassessment models against which the quality of the riverine environment can be monitored and assessed (Davies 1994). Using a standard sampling and sorting protocol, a range of sites considered to be more or less unimpacted by human activity was sampled. These form the 'reference' sites for the project. Other sites deemed to be affected by various forms of human activity were also sampled as 'test' sites to track observable change in the biota over time and hence changes in habitat quality. Data from the reference sites were used to develop predictive models against which biotic change (using macroinvertebrate data) could be measured at the test sites.

In addition to collections made for the MRHI itself, macroinvertebrate collections were made under the Regional Forests Assessment (RFA) program in 1996, using the same MRHI sampling protocol (Davies & McInney 1997). These additional collections were made in other areas of the state, primarily the south-west, where no collections had been made for the MRHI program, in order to provide a more complete statewide coverage for the purposes of a biodiversity assessment of Tasmanian stream macroinvertebrates. (The RFA in Tasmania adopted a broad approach to the scope of data relevant to forest values.) A report was prepared for the Regional Forest Assessment based on analysis of the two (MRHI and RFA) data sets (Davies & McInney 1997). This analysis addressed some basic conservation values of stream macroinvertebrate communities with a focus on taxon richness. Attempts were also made to define communities and to analyse the influence of environmental variables.

The two MRHI-based data sets (the actual MRHI project and the subsequent RFA sampling project) together comprise the largest current set of aquatic macroinvertebrate data in the state with some 150 reference stream sites sampled between one and four occasions. These data provide a perspective on macroinvertebrate communities statewide. Therefore evaluation of status of the 44 survey sites in a broader state context was undertaken using the MHRI data.

5.3 Procedures for comparing the data sets

The MRHI was undertaken for the particular purpose of developing predictive models for the bioassessment of 'river health' in Australia. In order to have national consistency and efficiency of data collection effort, specific rapid assessment protocols were devised (Davies 1994). The sampling and analysis were not designed with conservation assessment as a primary purpose and are at best semi-quantitative. In addition, any comparison of data from two different data collection methods must be treated with caution. In order to minimize data incompatability, several procedures were adopted.

Only data from MRHI reference sites were included on the grounds that the survey sites had been selected for lowest possible levels of disturbance. The 44 survey sites in the present study were only sampled in riffle sections of the rivers. In the MRHI procedure, various habitat types are sampled separately. For the purposes of the comparisons in the present study, only the riffle data were used. Both the MRHI and the survey site identification procedures used a similar level of taxonomic resolution, with only minor adjustments necessary to provide compatible taxon lists.

However, there were also a number of important differences between the two data sets. Sampling techniques were quite different and the subsequent picking protocol had different requirements and constraints. MRHI protocol uses a kick-sample method while the study data were collected by Surber sampling. The latter method may be inclined to collect more of the animals inhabiting the immediate river substratum layers. Kick-sampling may result in collection of more active or mobile taxa. The two methods in effect collect from different areas of river substrate, so that the final counts of macroinvertebrates have no common standard area.

In both survey strategies (MRHI and the Surber sampling) each sample was live-picked, but the MRHI protocol requires only up to 30 minutes or up to 100 individual animals, with an effort to collect the range of taxa present. The Surber samples from the study survey were live-picked until no further animals could be found. Picking of the MRHI was undertaken in field conditions that could have adverse light or temperature conditions affecting both efficient of the collectors and activity levels of the fauna. Smaller, more cryptic or more sluggish species may be over-looked. The study samples were also live-picked. This task was undertaken following holding of the samples in a cooler box until the end of the day's field sampling. Picking was done indoors with good lighting, magnification, and usually higher ambient temperatures. Under the latter conditions and with efforts to collect all living (or formerly living) animals, smaller, slower, rarer or more cryptic species would be more likely to be collected.

Thus there is a possibility of some difference in the number and type of taxa within the two data sets. In addition, the MRHI picking protocol was set to a time or taxon numbers limit, so in comparison the survey data from this study has much larger numbers of organisms recorded.

Two survey design features also undermined the parallels in the data sets. The MRHI survey focussed more on river types which could provide comparisons with impacted sites. Such sites are more often in middle to lower river reaches so the MRHI had fewer smaller and headwater streams than the survey data. The average width of all sites in the study was 6 metres compared with the average of all sites in the RFA analysis of MRHI sites (n=212) at 10.7 metres. The study sampling for the majority of sites occurred over two years, with spring and autumn collections for each year, resulting in four sampling events. It was noted that occasional or rare taxa might only be collected once in the four visits to a site. For MRHI sites, the chance of finding such taxa were limited to the two sampling occasions used in the model development phase of the project. The RFA sites were visited only once. In the final analysis of the MRHI sites, taxa which occurred at less than ten per cent of sites were removed to reduce 'noise' from the rare taxa for model development.

Several strategies were adopted to reduce these differences. Raw MRHI data sets were used which included all taxa and sites considered outliers. Only riffle habitat data from reference sites were used. The differences in numbers of individuals were redressed by the use of presence/absence data in analysis of the combined data sets. A second approach was to modify the survey data set to approximate to the numbers that were collected under the MRHI procedure using statistical techniques.

5.4 Assembling the combined data set

Data were made available from the MRHI program in the form of spreadsheets from samplings in spring 1995 and autumn 1994. These data were averaged to provide taxon information for some 192 sites from all areas of the state except the south-west. The 'RFA' data came from two sampling series in spring and autumn of 1996 with different sites sampled on each occasion. Therefore all sites were included. This yielded a further 162 sites.

Taxa from the MRHI data set were tagged with code numbers allocated by the Victorian Environmental Protection Agency (Dean pers. comm. 2000). All taxa data were arranged in the same sequence according to the Victorian EPA taxon codes, and the 44 sites from the present study were added in the same arrangement.

This provided a combined spreadsheet of all taxa collected by the three sampling programs. Analysis of this full set of data was undertaken using presence/absence procedures in Excel and association matrices in PATN. Analysis of the taxonomic-functional feeding groups (Quinn & Hickey 1990) was undertaken only on the MRHI data since taxon abundance is necessary for the analysis and a combined analysis would have been biased by the larger numbers in the Surber sampled data.

5.5 Statistical manipulation of the survey data

In order to adjust for the difference in sample size, a procedure was undertaken to subsample the Surber sample data to a level equivalent to the average total abundance in the MRHI samples. This provides an approximate estimate of the taxa that would have occurred under the MRHI protocol, attempting to equalize the number of taxa recovered within similar size samples. In addition, specific taxa were excluded as they had been found to be under-represented in the MRHI samples as a result of the field-based live-picking technique (Humphrey 1997). The procedure was as follows. The average sample size for all MRHI samples was determined (160 individuals). Then each survey sample was processed with the Virtual Marchant Sub-Sampler VMSS (Marchant 1989; Walsh 1997) to bring the numbers of individuals as close as possible to this average number. Once this had been completed for all sites, the data was reassembled with the MRHI data set.

The next step was to remove those taxa that have been identified as most likely to be missed by the MRHI picking protocol. Humphrey and Thurtell (1997) have demonstrated statistically that certain taxa were under-represented, that is significantly less frequent in the MRHI live-pick protocol than in the whole sample from which the picking was done. Humphrey & Thurtell (1997) list 14 such taxa. Of these, 2 were not relevant in this study and 6 were considered to be sufficiently common and important to be unlikely to be overlooked in Tasmanian samples. These were Gripopterygidae, Elmidae adults and larvae, Scirtidae, Chironomidae and Simuliidae. Those remaining taxa, which might be overlooked from the rescaled survey data set, were excluded. Those excluded were: Caenidae, Ceratopogonidae, Empididae, Sphaeridae, Hydroptilidae. The statistical probability of missing each taxon is summarized in Table 5.1. Details of these determinations are provided in Appendix 2.

Table 5.1 Probability of missing taxa in MRHI live-pick protocol

Taxon code	Taxon	Probability of missing taxon	Taxon code	Taxon	Probability of missing taxon
CHIRZZZP	Chironomidae pup.	.765564	UACAZZZX	Unid. Acarina	.234452
SPHAZZZX	Sphaeridae	.689028	CAENZZZN	Caenidae nymphs	.195907
EMPIZZZL	Empididae	.677438	SIMUZZZL	Simuliidae larvae	.150567
HPTIZZZL	Hydroptilidae	.616631	SCIRZZZL	Scirtidae larvae	.134601
CERAZZZL	Ceratopogonidae	.513792	GRIPZZZN	Gripopterygidae larvae	.08024
ELMIZZZL	Elmidae larvae	.505619	ELMIZZZA	Elmidae Adults	.078056
UOLIZZZX	Unid. Oligochaeta	.35081	CHIRZZZL	Chironimidae larvae	.055795

Source: Humphrey & Thurtell (1997)

5.6 Analysis of the total data set

5.6.1 Taxon occurrence

Table 5.2 shows the number of sites at which each taxon recorded in any of the MRHI survey, RFA survey or the study data set occurs. Several taxa were widespread across most sites occurring at 90% or more sites. These include: Chironomidae, Leptophlebiidae, Gripopterygidae, Oligochaeta, Simuliidae and Hydrobiosidae. These taxa are common in sites with cool, free-flowing well-oxygenated streams and rivers.

The occurrence of specific taxa will be discussed in Chapter 7. Taxa which occur infrequently may be uncommon for several reasons. They may be accidentally collected by a sampling procedure, which does not usually capture such taxa, such as Parastacidae and Hymenosomatidae. The preferred habitat of other taxa occurring infrequently may be somewhat different from the riffles where the samples were collected, for example, species that prefer lower gradient backwaters or amongst macrophytes. Thus Calamoceratidae are more usually associated with brackish waters and Gerridae and Dixidae with lentic habitats. Some taxa appear to be restricted to some areas of the state, such as the Sialidae. Some taxa are likely to be clearly rare or uncommon in Tasmania. Selected species, which might thus constitute species of conservation value, are considered in Chapter 7.

Table 5.2 Number of sites at which each taxon occurred in the combined MRHI and study data n =398

Taxon	Sites	Taxon	Sites	Taxon	Sites
Chironomidae	390	Helicopsychidae	102	Stratiomyidae	10
Leptophlebiidae	389	Philopotamidae	93	Dixidae	9
Hydrobiosidae	389	Helicophidae	92	Atriplectididae	7
Gripopterygidae	381	Turbellaria	88	Physidae	6
Simuliidae	377	Ceratopogonidae	87	Chrysomelidae larvae	5
Oligochaeata	357	Empididae	85	Hydrophilidae	4
Elmidae Adults	321	Hydroptilidae	72	Corixidae	4
Leptoceridae	305	Phreatoicidae	50	Sialidae	4
Scirtidae	298	Polycentropidae	49	Osmylidae	4
Conoesucidae	285	Sphaeriidae	43	Oeconesidae	4
Eustheniidae	273	Ecnomidae	41	Thaumaleidae	3
Baetidae	269	Tasimiidae	29	Gerridae	3
Tipulidae	259	Gordiidae	27	Lymnaeidae	2
Elmidae Larvae	254	Dytiscidae Adults	22	Noteridae	2
Hydropsychidae	247	Ceinidae	21	Gyrinidae Larvae	2
Philorheithridae	246	Dytiscidae Larvae	21	Staphylinidae	2
Hydracarina	229	Nannochoristidae	20	Curculionidae	2
Parameletidae	222	Ancylidae	19	Siphlonuridae	2
Calocidae	220	Planorbidae	19	Gomphidae	2
Psephenidae	191	Eurisidae	19	Odontoceridae	2
Glossosomatidae	150	Caenidae	15	Calamoceratidae	2
Austroperlidae	139	Veliidae	15	Anaspididae	1
Aeshnidae	124	Hirudinea	14	Corophidae	1
Blephariceridae	121	Oniscigastridae	14	Janiridae	1
Athericidae	118	Atyidae	12	Hymenosomatidae	1
Hydrobiidae	112	Parastacidae	11	Gyrinidae Adults	1
Notonemouridae	104	Limnephilidae	11	Culicidae	1
				Lestidae	1

5.6.2 Taxon richness

Comparison of the survey sites with the statewide data using raw presence/absence scores, suggest that the study sites were particularly rich in taxa. Given the caveats concerning differences in collecting and picking the samples, this is not surprising. When modified by the virtual sub-sampling (VMSS) process, the study sites remained on average higher than sites assessed using the MRHI protocol, that is, both the original MRHI data set and the additional sites sampled under the RFA project. Table 5.3, shows the comparison in site taxon richness for the raw and modified data sets arranged in size classes. The mean values for taxon richness at the study samples when used in the raw form (mean taxon richness = 27) were greater than that for the

MRHI-based samples (mean taxon richness = 19). However, when modified by the VMMS procedure, the study sites were of the same order as the MRHI sites (mean taxon richness = 20). A similar pattern was evident in the size classes with the greatest numbers of sites falling in the range 25 - 29 class for unmodified study site data but both MRHI and the VMMS-modified study sites had the greatest numbers of sites in the range of 20-24 taxa (Figure 5.1).

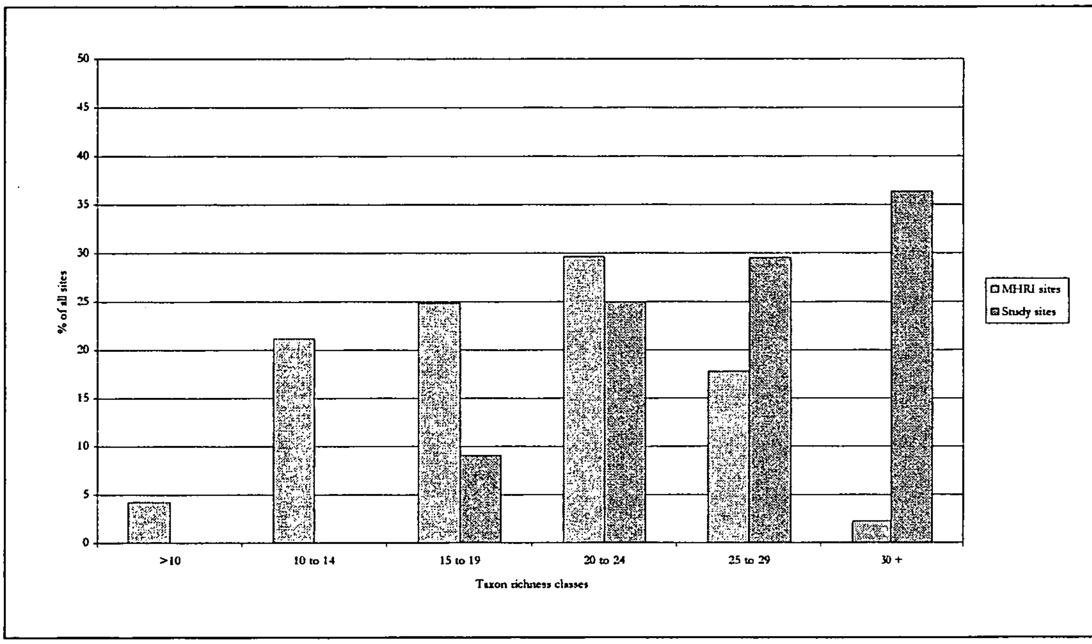
Table 5.3 Comparison of the percentage frequency of occurrence of taxa in the two different collections, MRHI-based and study collections

Taxon	MRHI	Thesis study	Taxon	MRHI	Thesis study
	n=354	n=44		n=354	n=44
Chironomidae	97	100	Tasimiidae	6	5
Leptophlebiidae	97	100	Ceinidae	6	0
Hydrobiosidae	97	94	Ancylidae	5	0
Gripopterygidae	94	99	Gordiidae	5	7
Simuliidae	93	90	Dytiscidae Larvae	4	0
Oligochaeta	88	97	Veliidae	4	0
Elmidae Adults	78	90	Hirudinea	4	0
Leptoceridae	75	53	Eurisidae	4	2
Scirtidae	71	90	Planorbidae	3	5
Conoesucidae	70	64	Parastacidae	3	0
Eustheniidae	68	48	Atyidae	3	0
Baetidae	66	64	Dixidae	3	0
Hydropsychidae	62	25	Oniscigastridae	2	2
Tipulidae	61	62	Physidae	2	0
Elmidae Larvae	60	78	Nannochoristidae	2	14
Philorheithridae	58	60	Corixidae	1	0
Hydracarina	53	55	Sialidae	1	0
Calocidae	52	51	Osmylidae	1	0
Parameletidae	51	81	Gerridae	1	0
Psephenidae	43	67	Limnephilidae	1	2
Glossosomatidae	34	64	Limneaidae	1	0
Austroperlidae	33	37	Noteridae	1	0
Aeshnidae	31	7	Gyrinidae Larvae	1	0
Hydrobiidae	28	21	Staphylinidae	1	0
Blephariceridae	25	16	Chrysomelidae Adult	1	0
Helicopsychidae	25	14	Curculionidae	1	0
Athericidae	24	44	Thaumaleidae	1	2
Philopotamidae	24	5	Siphlonuridae	1	0
Helicophidae	18	39	Gomphidae	1	0
Notonemouridae	18	62	Oeconesidae	1	0
Turbellaria	17	32	Odontoceridae	1	0
Polycentropodidae	11	7	Atriplectididae	1	7
Ecnomidae	10	7	Calamoceratidae	1	0
Phreatoicidea	9	30	Hydrophilidae	0	2
Dytiscidae Adults	6	5	Stratiomyidae	0	9

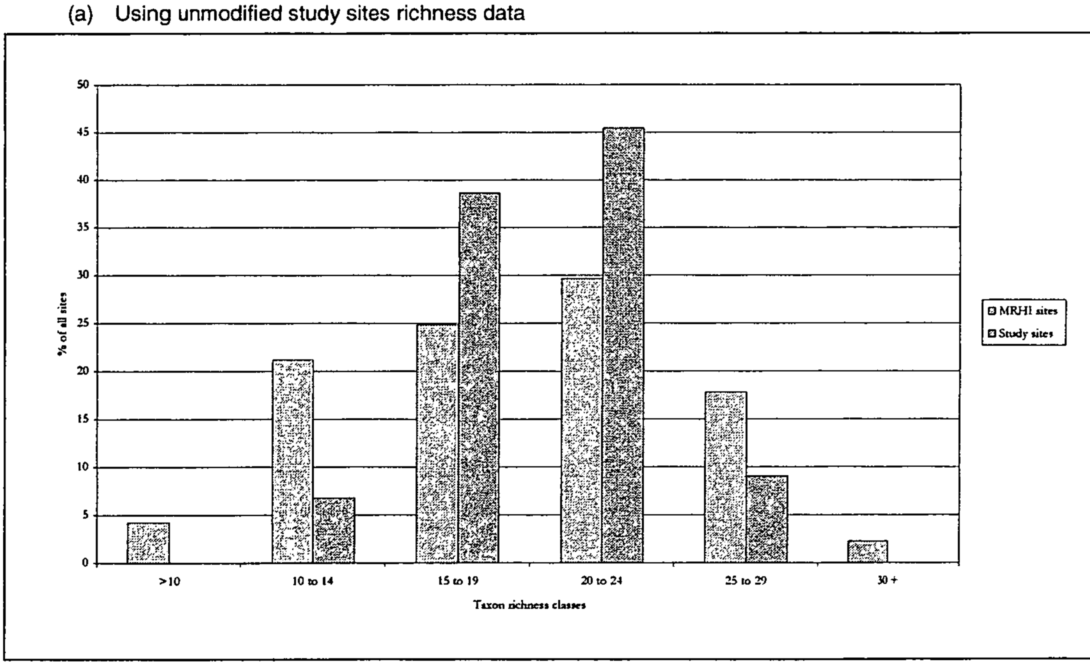
Comparison of the percentage occurrence of the taxa within the MRHI-based data collections and those of the study are shown in Table 5.3.

Taxa which were demonstrated by Humphrey (1998) to be missed in the MRHI picking protocol have been excluded from Table 5.3. These include Ceratopogonidae, Caenidae and Hydroptilidae. Between the two data sets there is a good concordance in the levels of occurrence following VMMS modification with a few exceptions.

Figure 5.1 Comparison of taxon richness for MRHI-based and study data sets by size class



(a) Using unmodified study sites richness data



(b) Using study site richness after VMMS modification

The data were sorted by site taxon richness and then the number of sites occurring in each richness category or class was calculated. Figure 5.1 shows the distribution of sites by taxon richness as a percentage of all sites falling within each richness class.

Figure 5.1(a) shows the distribution of sites of different richness comparing between the MRHI-based data sets and the unmodified data from the study area. Figure 5.1(b) shows the comparison between MRHI data and the study site richness distribution after modification by the VMMS technique. The unmodified study data, Figure 5.1(a), shows that % of all MRHI sites fell below the lowest values of the study sites, while % of the study sites exceeded the 90th percentile of all MRHI sites. After reduction to a common sample size using the VMMS sub-sampling protocol, the distribution of sites by species richness is quite similar between the two data sets (Figure 5.1(b). The study sites showed a more limited range of richness distribution than the MRHI based data sets.

As a further check on differences in taxon richness, sites common to both data sets were sought. Seven such sites were identified. Taxon richness was compared for the two approaches to sampling (Table 5.4).

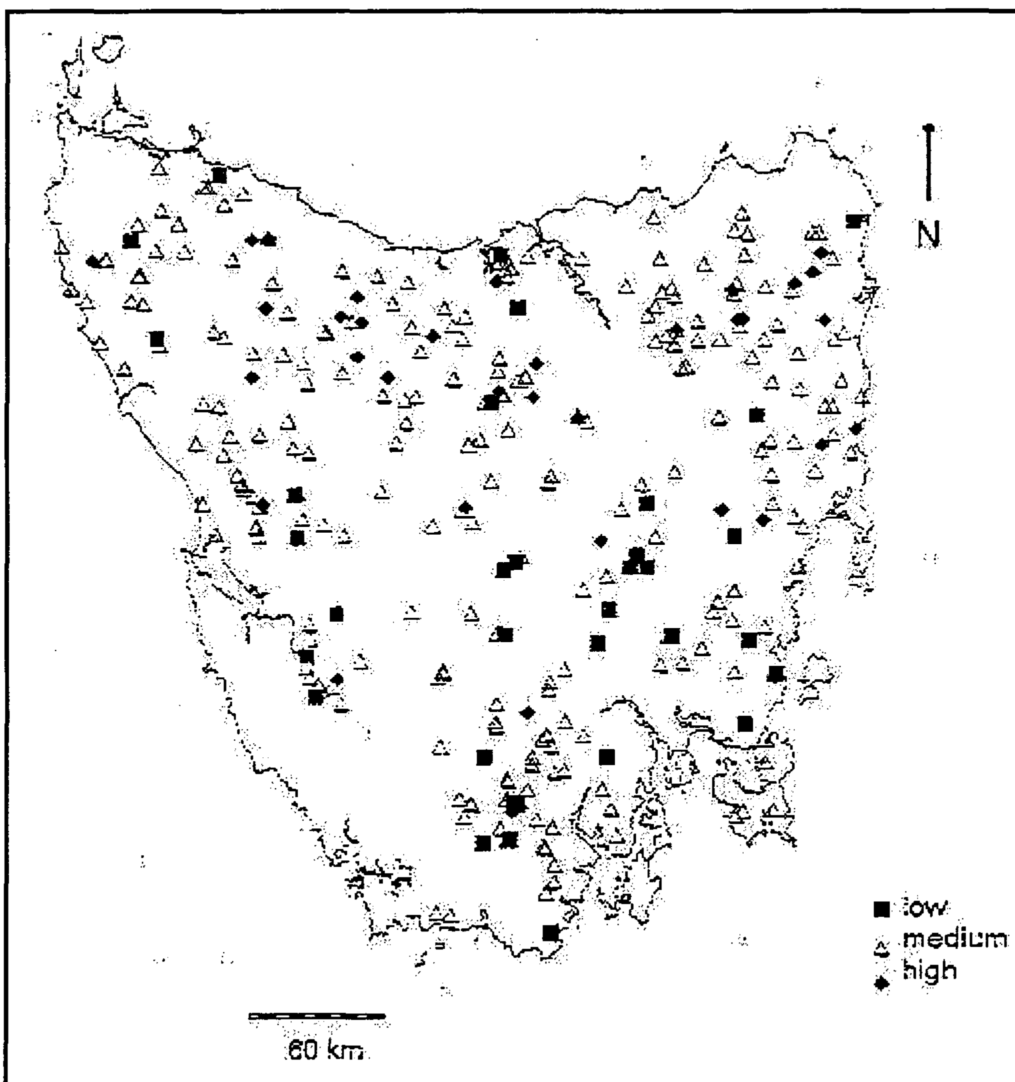
This showed that the samples taken using the Surber sampler were generally higher in taxon richness, although adjusting the sample data to equivalent total abundance made them approximately equivalent. Analysis of 'missed' taxa however, indicated that while greater numbers of a taxon (21) were picked from the survey data and not collected at these sites by the MRHI program, seven taxa were missed at different sites by both methods while five taxa were only collected in the MRHI sampling. When modified by the VMSS procedure, taxon richness at five of these seven sites fell below that of the MRHI sample. However, a paired t-test on this data set showed that the difference is not significant. The data manipulation may have overcompensated by deleting an excessive number of taxa but the magnitude of the difference is small. Since the MRHI sampling protocol sets taxon diversity as a prime search strategy in picking the sample, there remains a possibility of some bias.

Davies and McKenny (1997) conclude that '[s]ites of high diversity were not distributed in a regional fashion but were located in all areas of the state'. Davies and McKenny's map of the distribution of sites according to three classes of diversity, low, medium, and high (<12, 12-21, >22 taxa) is shown in Figure 5.2. These data have been modified to remove taxa that were uncommon. No clear trend is evident of a regional pattern of sites of higher (or lower) diversity amongst the sites nominated as reference sites, i.e. those that were in relatively good condition. In Tasmania, the sites of high diversity do not appear to be correlated with hydro-geomorphic or any distinctive chemical conditions of the waterways.

Table 5.4 Comparison of taxon richness at seven sites common between study data and MRHI data set

Study data code/MRHI code	CH/A25	HH/A24	SO/F147	HG/BO4	MM/F104	SE/DO7	RG/F135
MRHI	23	26	18	22	13	21	20
Survey raw	31	30	26	22	21	27	31
Survey VMSS	21	21	14	22	21	19	18

Figure 5.2 Distribution of stream sites in Tasmania according to macroinvertebrate taxon diversity at family level (Davies & McKenny 1997)



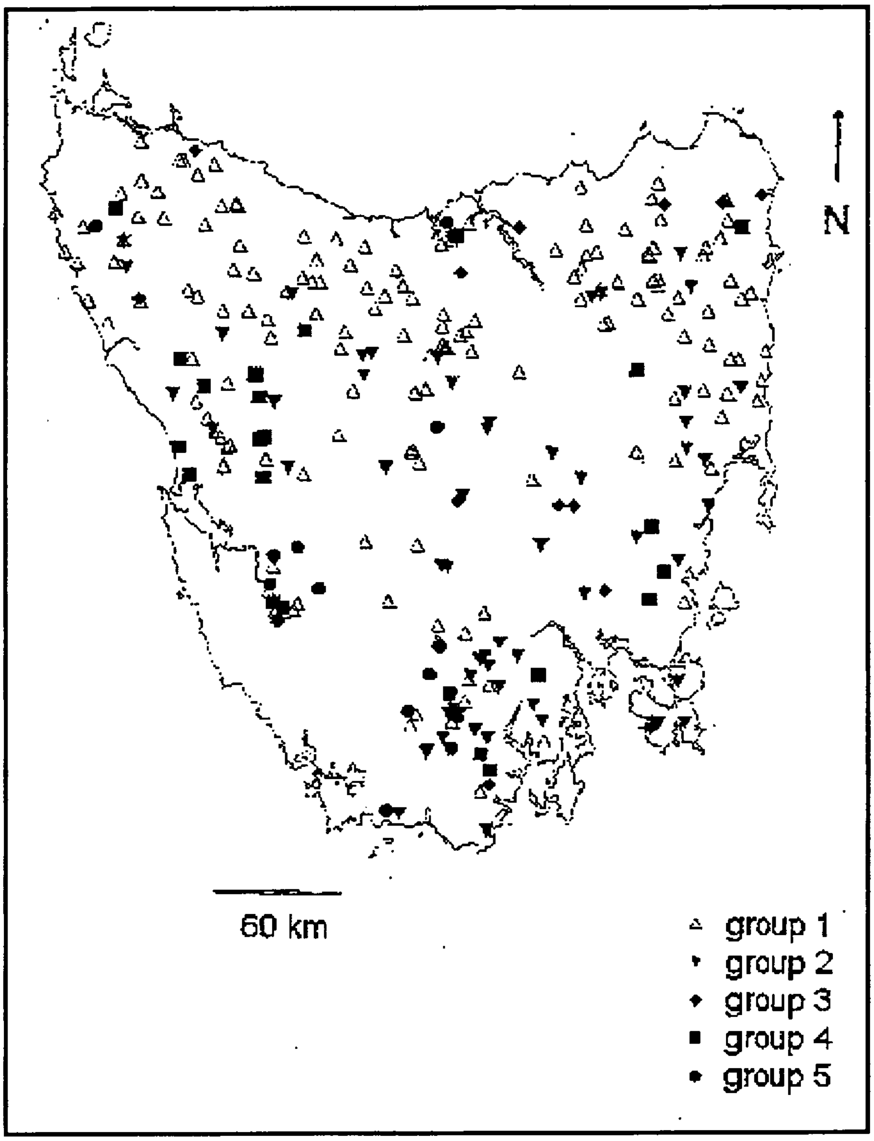
Survey areas for the present study are indicated in the maps in Chapters 3 and 4 (Figure 3.2, Figure 4.1, and Figure 4.2). Study areas do appear to reflect areas where there are greater numbers of high diversity sites, given the limitations of the MRHI site sampling.

5.6.3 Multivariate analysis

The MRHI and RFA reports detail the classification and ordination of sites conducted using these databases (Oldmeadow 1998; Davies & McKenny 1997). Although site groups were identified, both reports suggest considerable chaining within the UPGMA analyses. Oldmeadow (1998 section 3.4) commented that 'macroinvertbrate communities across the north of the state are remarkably similar in their composition'. In addition, he states that the 'communities are also relatively similar from upper catchment area to low land sites, although some taxa such as the Blephariciidae, are restricted mostly to headwaters'. For this MRHI data set, this 'typically led to the development of dendrograms with no clear clustering of sites and groupings at low Bray-Curtis values' (Oldmeadow 1998, section 3.4).

Similarly, Davies and McKenny (1997) found that the '[r]esults of the cluster and classification analysis revealed a relatively weak structure in the data' (p 31). In addition, the map of the five stream site groups identified by classification procedures showed 'little or no bioregionalisation at the state level' (p 31). Examination of their map, Figure 5.3, showing site groups together with inspection of Table 4 listing discriminating environmental variables (Davies & McKenny 1997 p 32) suggest that the groupings may in fact reflect geomorphic rather than regional factors. Thus the site group 5 may not be so much a 'western-south western faunal type' as suggested by Davies and McKenny but a result of the river class, geology and geomorphic style of the rivers sampled in this region.

Figure 5.3 Distribution of five UPGMA site groups Davies & McKenny (1997)

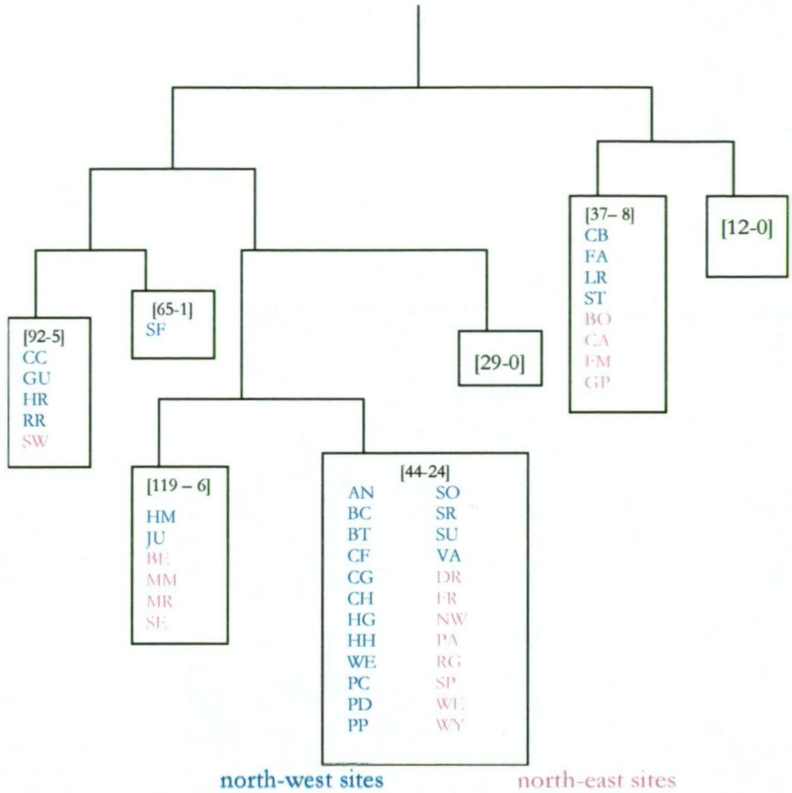


5.7 Analysis of the whole data set using VMSS modified study data

The combined data set of MRHI, RFA and VMSS modified study data was analysed using PATN. The dendrogram derived from UPGMA clustering was excessively long and displayed a high degree of chaining (Beta 0.1, stress .27). A summary picture of the location of the study sites within the total data set is more readily evident in the TWINSPAN classification, as shown in Figure 5.4.

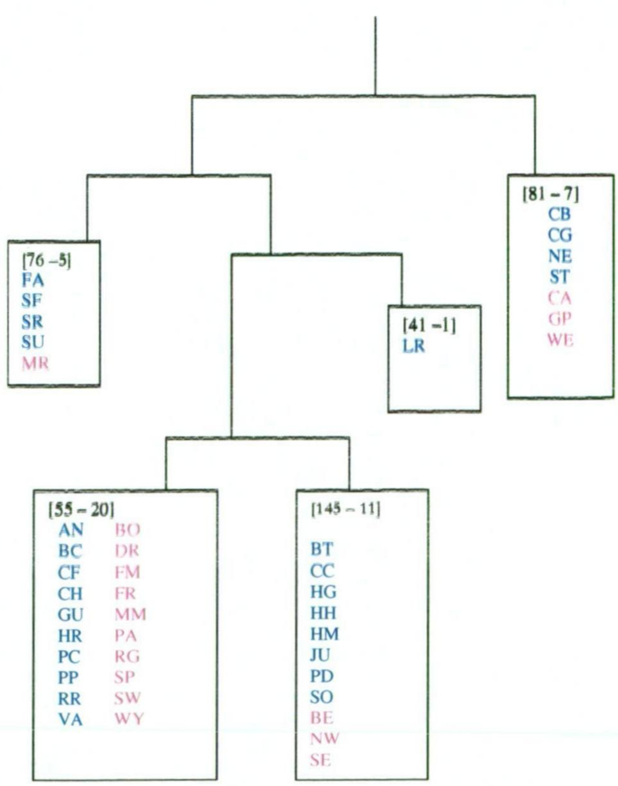
The site groups indicate the total number of sites within each group and the number these sites which are from the survey data, displayed thus: '[44 - 24]'. Codes for the survey sites which fall within each group are listed showing eastern or western distribution.

Figure 5.4 Location of study sites within the classification of raw data



The analysis was also performed using the same data set converted to presence/absence format, and the TWINSPAN array displayed in a similar way (Figure 5.5).

Figure 5.5 Study sites within classification of presence/absence data

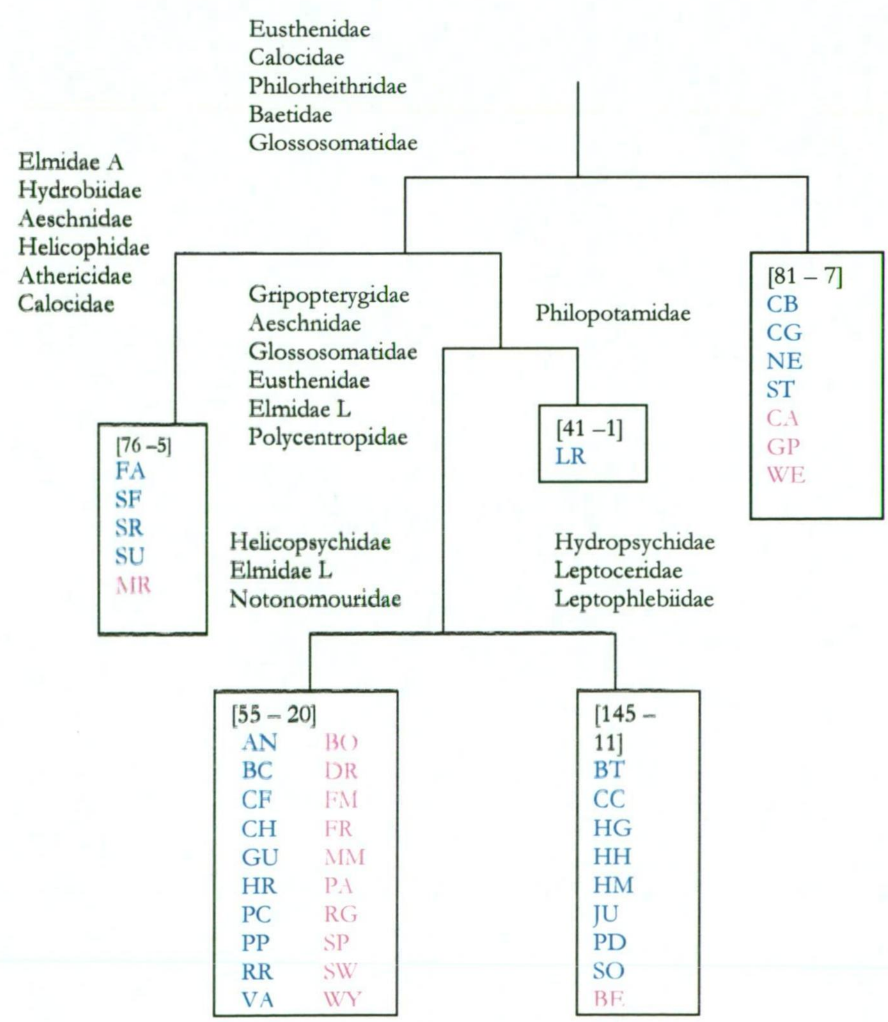


The allocation within site groups is demonstrated in a similar way to the previous figure (Figure 5.4).

It may be concluded that while the study sites tend towards particular groups, there are also sites dispersed across groups. The sites from the MRHI-based data sets in the same groups as the study sites occurred widely across the state, suggesting a parallel with the distribution of MHRI sites (Davies & McKenny 1997) shown in Figure 5.3.

Inspection of the indicator taxa for the TWINSPAN divisions of the raw data from the study sites alone (Figure 4.6) are reflected in the taxon profiles for the study sites Table 4.2. Some taxa are more frequently found in the study sites compared with the MRHI survey sites (Table 5.3). Indicator taxa for the TWINSPAN division of presence/absence data are shown in Figure 5.6.

Figure 5.6 Indicator taxa for TWINSPAN classification of sites using VMSS modified presence/absence data set.



Notonemouridae and Athericidae occur more frequently in the study sites perhaps because they utilize deeper substratum. Philopotamidae, Leptoceridae and Hydropsychidae occurred more frequently in the MRHI-based data sets, possibly indicating a preference for larger rivers by at least some genera or species within these families. The average width of all sites in the survey was 6 metres compared with the average of all sites in the RFA analysis of MRHI sites (n=212) at 10.7 metres, though without more detailed knowledge of taxon requirements and occurrence within the various data sets, any conclusions on stream width must be treated with caution. There is apparent consistency between the site groups to which the survey data sites adhere, as well as in the indicator taxa and the observed taxon occurrences.

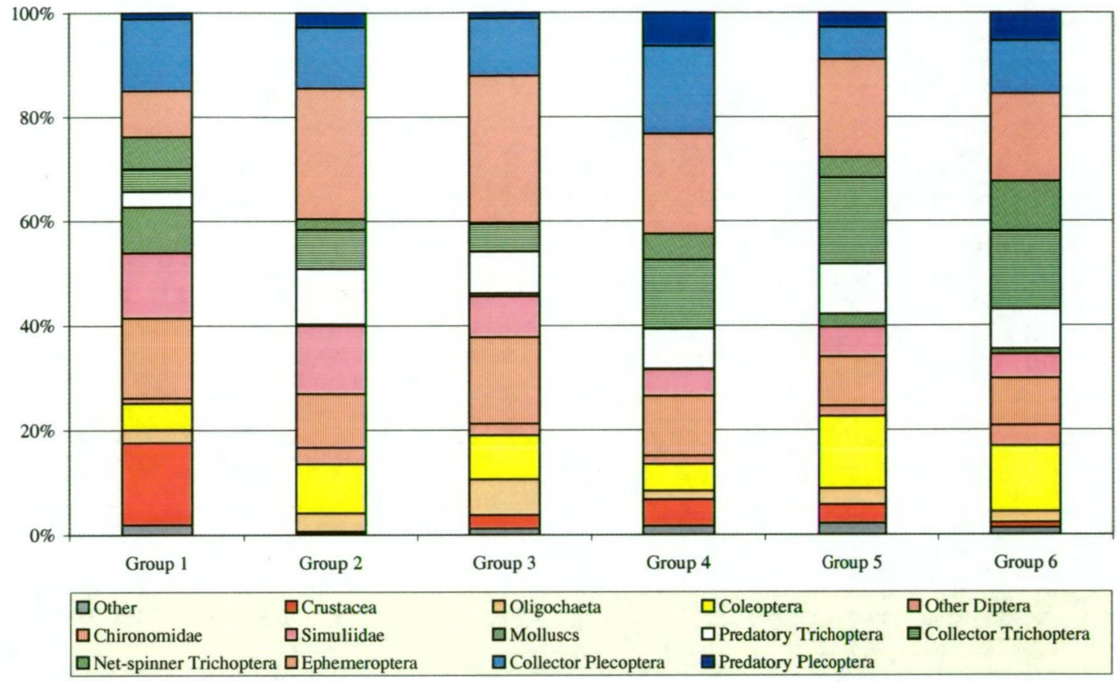
5.8 Community structure of the MRHI data set

In Chapter 4, a procedure was described which enables broad feeding group profiles to be constructed for stream macroinvertebrates (Quinn & Hickey 1990). If the survey sites and the MRHI site community compositions are similar, it may be concluded that the survey sites are reasonably representative of the types of stream macroinvertebrate communities occurring in Tasmania. Conversely, if the community structures differ grossly between the two data sets, then either the sites are distinctive, or the differences may be attributed to the different sampling methods.

Analysis of the MRHI data set was undertaken in a similar way to that described for the survey data. The same taxon code assignment was adopted and the data set analysed using TWINSPAN to generate site groupings. Then the allocated taxon/feeding group data from each group of sites was averaged, and site profiles displayed using Excel. Only the MRHI data were used in the analysis, since it is necessary to use raw data rather than presence/absence data for this analysis. The much larger numbers, especially of the more abundant taxa which were recorded in the study data set, would have created a bias in a combined analysis. The community profiles for MRHI sites are shown in Figure 5.7.

The overall patterns in community structure are very similar to those of the TWINSPAN groups generated from the study data (Figure 4.9).

Figure 5.7 Community composition for the six TWINSPAN groups using MRHI data

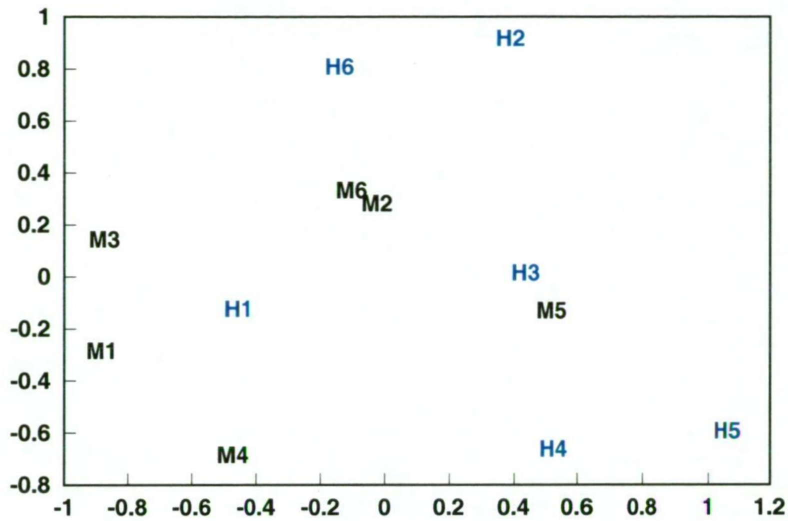


Abundant taxa, especially Ephemeroptera but also Elmidae, Gripopterygidae, Chironomidae, may be underrepresented in the MRHI profiles due to the picking protocol which sets a time or numerical limit to collection. Some taxon groups occur more frequently in the MRHI data set, such as net-spinning Trichoptera in Groups 1 and 3, and predatory taxa including both Plecoptera and Trichoptera in several of the TWINSPAN groups.

In order to further clarify whether the study sites were representative of the sites throughout Tasmania used in the MRHI-based data sets, the functional feeding group analysis was subjected to some limited analysis. A Pearson Product-moment correlation was applied to the distribution of the taxonomic/functional feeding group data totalled across all sites in each data set. The results suggested that there was not a significant difference. The pair(s) of variables with positive correlation coefficients and P values below 0.05 tended to increase together. For the pairs with negative correlation coefficients and P values below 0.05, one variable tended to decrease while the other increases. For pairs with P values greater than 0.05, no significant relationship existed between the two variables.

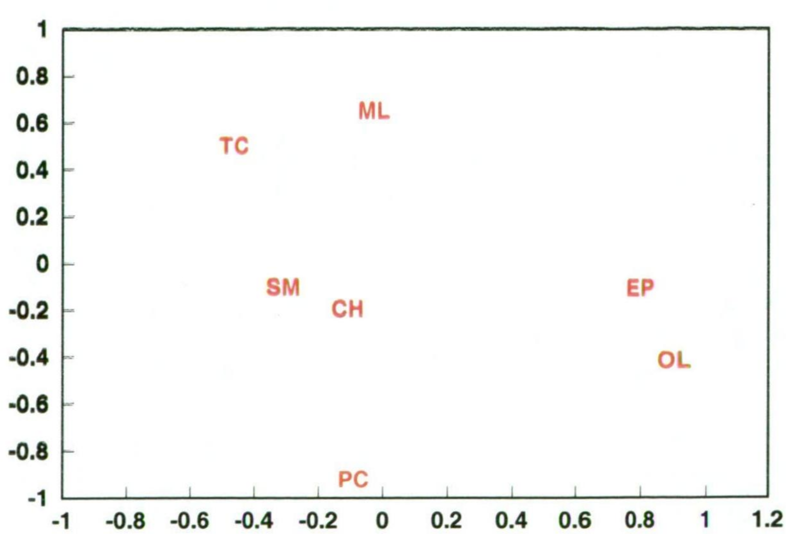
Another way to test the similarities between the two data sets was to conduct an ordination of the groups. The results are shown in Figure 5.8 and the significant feeding groups are shown in Figure 5.9.

Figure 5.8 Ordination of functional feeding group analysis for two data sets



Data points M1 - M6 are the MRHI site groups
Data points H1 - H6 are the site groups from study data set VMSS modified site groups

Figure 5.9 Feeding groups of significance in ordination of MRHI and study data sets



Taxa with significant correlations are: TC=Collector Trichoptera, EP=Ephemeroptera, OL = Oligochaeta, PC = Collector Plecoptera, ML=Molluscs, SM=Simuliids, Ch=Chironomids

The functional feeding group analysis tends to confirm the results of the multivariate analysis of the combined data set. That is that Tasmania's rivers and streams have a broadly similar faunal structure, of which the survey data is representative.

5.9 Conclusions

Examination of other data sets of Tasmania's stream macroinvertebrate fauna suggests that the study sites were typical of the riffle fauna of Tasmanian streams and rivers. Limitations resulting from low levels of taxonomic resolution and differences in sampling methods aside, there appears to be commonality in both the taxon occurrences and in the community structures identified in both study data and the MRHI-based data sets. Perhaps the most problematic interpretation lies in regard to taxon richness, since this is affected by several elements of the sampling. However, the evidence suggests that the study data is a more comprehensive assessment of diversity, for several reasons. The sampling method appears to collect taxa which were not collected so often by the MRHI method. Even though picking the MRHI samples set a priority on collecting a broad range of taxa, several taxa are occasionally or consistently missed (Humphrey & Thurtell 1997; Oldmeadow 1998), including some taxa that actually occurred in very large numbers (Oldmeadow 1998). The additional numbers of sampling occasions in the study, not surprisingly, yielded greater numbers of taxa.

The large data set derived from MRHI and RFA surveys also provides distributional information, which can complement the existing data sources, especially filling gaps where previously little such information existed. These data will be scrutinized in the assessment of conservation values at the survey sites in Chapter 7.

5.10 Summary

Detailed comparison of the study data with a large data set providing statewide data was undertaken. The statewide data set provided some limited comparative information on less common taxa. Comparison of the communities was managed by a statistical procedure, which enabled the study data to be compared with the MRHI data. Once this modification had been applied to the study data set, it was possible to analyse the two data sets to assess whether the study sites were representative of sites elsewhere in Tasmania.

This procedure enabled data from a limited area to be set within a wider context, despite different methodologies. This enabled some comparisons to be made, such as sites of high diversity, sites that are representative and some tentative assessments of overall community structure of Tasmania's macroinvertebrate faunas.

The MRHI data set represents a significant resource of macroinvertebrate information. While it was designed for a specific purpose other than conservation assessment, this chapter has shown that the MRHI data not only provides opportunity for indicative assessments and an archive of material which could be further analysed, it also has the capacity to provide a context for analysis for smaller targeted data collections.

Chapter 6

The Plecoptera of the survey sites

The Plecoptera data from the field survey are used to test the application of the conservation criteria at species level. Chapter 6 provides the descriptions and other data on which this assessment will be based. The occurrence and distribution of the Plecoptera at the 44 sites is summarized. Possible factors influencing the distribution of species are discussed. Multivariate analysis and analysis of variance of the data suggest some species groupings and possible regional and environmental preferences.

The implications of the evidence from the Plecoptera species analyses will be considered in Chapter 7.

6.1 Introduction

Conservation assessment approaches and protection measures that have legislative support are largely based on species rather than on communities or habitats (discussed in Chapters 1, 2 and 9). Identification of conservation values based on species is, therefore, a critical perspective. This chapter considers the evidence of conservation values of the sites using species level analysis of the Plecoptera found at the sites, and tests the possibility of distinct stone-fly communities or assemblages within the two study areas. Conservation protection options are then applied to the evidence, and the data is assessed for application in a theoretical exercise of conservation planning for aquatic macroinvertebrate values, based on this group.

The Plecoptera were chosen as the target taxonomic group largely because they are one of the few groups of macroinvertebrates which have more or less adequate taxonomic keys to identify to species level. The Plecoptera are also widespread in Tasmania over a range of different habitat types (Hynes 1988; Theisinger 1991).

Members of the Plecoptera are a common component of aquatic assemblages, along with the Ephemeroptera and Trichoptera, and typical of most clear, flowing water sites. In addition, they are a group of considerable biogeographic significance (Illies 1965; DEST 1997; Zwick 2000).

All sample sets from sites in the study yielded at least two families of Plecoptera. Specimens were identified using the Hynes (1988) key, where possible to species level, and counted. In a few cases, distribution information was used to separate similar species, in accordance with the Hynes (1988) information.

6.2 The Tasmanian Plecoptera fauna

The Plecoptera are a group of hemimetabolous insects with aquatic larval stages. They are commonly found in most Tasmanian freshwater habitats. The number of instars appears to be variable and life history in Australian forms ranges from 1 to 3 years (Hynes 1975, 1989). Adults are weak flyers that are seldom found far from their aquatic habitats. The stonefly nymphs favour cool, well-oxygenated habitats and in Australia few species (and no notonemourids) are found in tropical regions (Zwick 2000). Highest species diversity in Australia occurs in cooler, mountainous south-east mainland Australia and in Tasmania (Bureau of Flora and Fauna 1988; Theisinger 1991).

The Plecoptera are an ancient group of rather primitive insects that may have originated in the southern hemisphere (Hynes 1988). The classification is based on a cladistic classification by Zwick (1973, 1980). Three of the four Australian families are members of the more ancient sub-order Antarctoperlaria (Zwick 1973, 1980, 2000; Theischinger 1991). The distributions of these three ancient families, the Eustheniidae, Gripopterygidae and Austroperlidae, show typical connections with South America and New Zealand usually referred to as having Gondwanic affinities. Thus their distribution was controlled by the split-up of the landmass of Gondwana beginning at the close of the Jurassic period some 180 million years ago.

The Notonemouridae is a member of the sub-order Arctoperlaria that includes the dominant stonefly families of the northern hemisphere (Zwick 2000). The family Notonemouridae is exclusively found in the southern hemisphere, although there are conflicting views of its origins. Theischinger (1991) suggests that the sub-order originated in the south before migrating northwards, and the Notonemouridae subsequently returned to the south. Zwick (2000) dismisses this proposition, arguing for a relictual status for the notonemourids from an early southern stem-group.

All four Australian families are represented in the Tasmanian plecopteran fauna. The Eustheniidae (four known species in the state) are large, conspicuous and widespread predators occurring in small numbers at most sites. The Austroperlidae comprise four described species in the state, all of which are endemic to Tasmania. Two genera, *Tasmanoperla* and an undescribed species of *Austropentura*, are typically found in heavily shaded forest streams while *Crypturoperla paradoxa* is considered a species of alpine and sub-alpine areas.

The dominant family is the Gripopterygidae with some 27 described species, of which 23 are endemic to the state. Ten gripopterygids belong to the Tasmanian endemic genus *Cardioperla.* The fourth plecopteran family is the Notonemouridae with 11 species, nine of which are endemic.

Table 6.1 summarizes endemism of Plecoptera of Australia, including Tasmania, at generic level. A summary of the genera and species occurring in Australia and Tasmania and their level of endemism is shown in Table 6.2.

Table 6.1 Plecoptera genera occurrence and endemism in Australia and Tasmania

Total Plecoptera genera found in Australia	No. of genera **endemic** to Australia	No. of genera occurring in Tasmania	No. of genera **endemic** to Tasmania
26	23	18	4

The taxonomy of Tasmania Plecoptera has been summarized by Hynes (1988). The majority of nymphal forms can be identified to species level. Theischinger (1991) provides a key to the families and partial taxonomic keys to species have been developed for the Plecopteran fauna on a state-by-state basis (Hynes & Bunn 1984; Hynes 1998; Suter & Bishop 1990; Yule 1997). There is, however, no Australia-wide integrated taxonomic key below family level (Hawking, pers. comm.). Theischinger (1991) provides a brief examination of taxonomic relationships within the families, largely based on work undertaken in the 1980's (Zwick 1973; 1980).

Hynes (1989) provides brief information about the distribution and habitat preferences of the Tasmanian Plecoptera, based on collections of both adults and nymphs. Associated unpublished maps indicate the occurrence of the species by 10 kilometre resolution.

Table 6.2 Summary of occurrence of Plecoptera species and endemicity

Family/Genus	Occurrence	No. of species in Australia	No. of species in Tasmania	No. of species endemic to Tasmania
Eustheniidae	Aus, NZ, S. Am.			
Eusthenia	Aus.	11	4	4
Thaumatoperla	Aus.	4	0	0
Stenoperla	Aus., NZ,	5	0	0
Austroperlidae	Aus, NZ, S. Am			
Acruroperla	Aus.	1	0	0
Austroheptura	Aus.	3	0	0
Austropentura	Aus.	3	1	1
Crypturoperla	Aus.	1	1	1
Tasmanoperla	Aus.	2	2	2
Gripopterygidae	Aus., NZ, S. Am.			
Cardioperla	Aus.	9	9	9
Dinotoperla	Aus.	30	4	3
Dundundra	Aus.	1	0	0
Eunotoperla	Aus.	1	0	0
Illiesoperla	Aus.	11	1	0
Kirrima	Aus.	1	0	0
Leptoperla	Aus.	24	3	2
Neboissoperla	Aus.	3	1	1
Nescioperla	Aus.	1	0	0
Newmanoperla	Aus.	4	1	1
Riekoperla	Aus.	26	2	1
Trinotoperla	Aus.	16	5	5
Notonemouridae	Australia., NZ, S.America, southern Africa, Malagasy			
Austrocerca	Aus.	2	2	1
Austrocercella	Aus.	15	1	1
Austrocercoides	Aus.	3	2	2
Kimminsoperla	Aus.	6	3	3
Notonemoura	Aus.NZ	2	1	0
Tasmanocerca	Aus.	1	1	1
Total species		**186**	**44**	**38**

Sources: Theisinger 1991; Hynes 1989; Bureau of Flora and Fauna 1988

Table 6.3 provides a summary of the rarity, endemism, and biogeographic significance based on the information provided by Theischinger (1991) and Hynes (1989) with associated distribution maps.

Table 6.3 Status of Tasmanian Plecoptera

		Rarity			Biogeographic/ phylogenetic significance				
		Listed species/meeting threshold r1	Listed species/meeting threshold r2	Uncommon species r3	Endemic speces: Tasmania	Endemic speces: regional or local	Tasmanian endemic genus	Gondwanan/Pangean species	species of unusual morphology/life-history
Austroperlidae	Austropentura sp*.	+			+	+			
	Crypturoperla paradoxa*				+		+		+
	Tasmanoperla thalia*				+	+	+		
Eusthenidae	Eusthenia spectabilis*				+				
	Eusthenia costalis*				+				
Gripopterygidae	Leptoperla varia*				+				
	Leptoperla Sp A*				+				
	Cardioperla flindersii*				+				
	Cardioperla diversa*				+		+		
	Cardioperla nigrifrons*				+		+		
	Cardioperla lobata*				+		+		
	Cardioperla incerta*				+	+	+		
	Cardioperla spinosa*				+		+		
	Cardioperla edita*				+		+		
	Cardioperla Sp B*				+		+		
	Dinotoperla marmorata*		+		+	+			
	Dinotoperla serricauda								
	Dinotoperla opposita*			+	+				
	Trinotoperla tasmanica*				+				
	Trinotoperla inopinata*				+				
	Trinotoperla zwicki*				+				
	Trinotoperla comprimata				+	+			
	Reikoperla triloba								
	Reikoperla pulchra*		+		+	+			
	Newmanoperla prona*			+	+				
Notonemouridae	Austrocercoides zwicki*				+				
	Tasmanocerca bifasciata*				+	+	+		
	Austrocerca tasmanica								
	Kimminsoperla albomaculata*				+				
	Notonemoura lynchii								
	Austrocercella cristinae*				+				

* endemic species to Tasmania.

The high degree of endemism and phylogenetic affinities of the four plecopteran families found in Tasmania suggest a group of particular biogeographic interest in a world context (Zwick 2000). Zwick's recent (2000) analysis of the phylogenetic relationships and zoogeography of the Plecoptera endorses, based on cladistic analyses, the grouping together of the three families Eustheniidae, Gripopterygidae and Austroperlidae in the sub-order Antarctoperlaria. Zwick (2000) regards the Antarctoperlaria as 'a textbook example of a hierarchy of disjunct sister-groups whose distribution is most parsimoniously explained by assuming evolution on a common landmass that subsequently broke up' (p 734). The localized distributions of several subfamilies of Gripopterygidae and Eustheniidae can be readily explained by accidental regional extinctions or relatively recent local radiation (Zwick 2000 p 734). Such explanations are certainly consistent with recorded distributions (Hynes 1988) of the members of the Antarctoperlaria in Tasmania.

Zwick (2000 p 725) considers the Notonemouridae to be a gradotaxon remnant of an ancient nemouromorph lineage, a heterogenous 'paraphyletic assembly of early nemourid lines surviving on fragments of Gondwanaland [sic] where Nemouridae do not occur'. Zwick (2000) rejects the proposal of Illies (1965) for a southern origin and a northward migration of early notonemourids across the equator with a subsequent return of some elements of that fauna to the southern hemisphere. Rather, Zwick regards the present day notonemourids as 'an independent surviving nemourid stem-group lines probably coming from the northern hemisphere at different times and along different routes' (p 737).

Such work highlights the contribution of the Plecoptera to an understanding or interpretation of evolution of insect groups and of earth history. The present distribution and endemism of this group may also provide evidence of geological history and climate change (Zwick 2000; Huntsman *et al* 1999).

6.3 Plecoptera at the survey sites

Plecopteran species occurred at every site surveyed. Distribution of species by site is shown in Table 6.4. Species that are endemic to Tasmania are highlighted. Only five of the species recorded are also found on the Australian mainland: *Dinotoperla serricauda*, *Trinotoperla comprimata*, *Reikoperla triloba*, *Austrocerca tasmanica* and *Notonemoura lynchii*.

Some species were widespread. *Eusthenia spectabilis* and *Leptoperla varia* occurred at around 70% of sites but only in small numbers at each site. *Austrocercoides zwicki* exhibited a similar pattern at slightly fewer sites. *Reikoperla triloba* occurred at two thirds of all sites in variable numbers, including one site, Hellyer at Moorey Road (HM), with very large numbers of individuals. *Tasmanoperla thalia* occurred at 16 of the 27 westerly sites. *Cardioperla diversa* and *C. spinosa* occurred at most of the eastern sites but few of the western sites.

Table 6.4 Occurrence of Plecoptera species by sites

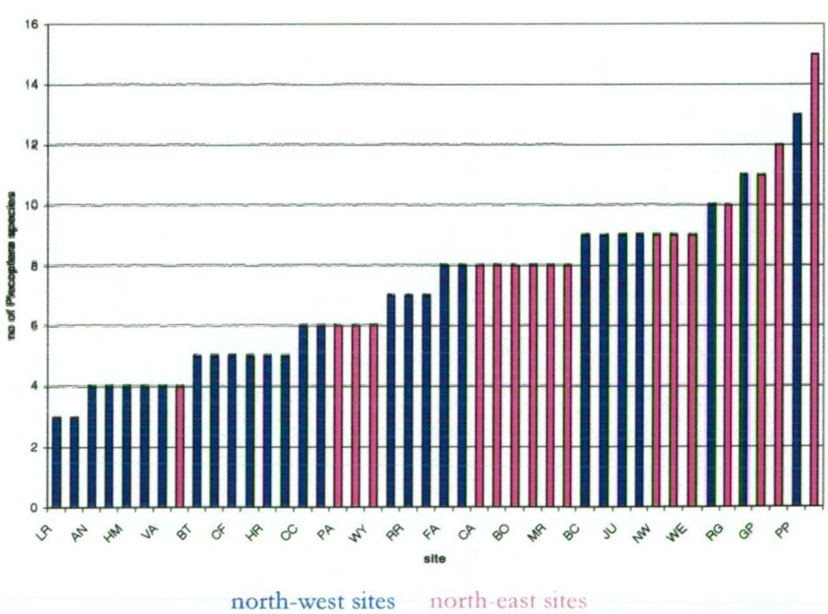
	Austropentura sp*.	Crypturoperla paradoxa*	Tasmanoperla thalia*	Eusthenia spectabilis*	Eusthenia costalis*	Leptoperla varia*	Leptoperla Sp A*	Leptoperla aff bifida*	Cardioperla flindersi*	Cardioperla diversa*	Cardioperla nigrifrons*	Cardioperla lobata*	Cardioperla incerta*	Cardioperla spinosa*	Cardioperla 'Newitts Creek'*	Cardioperla edita*	Cardioperla Sp B*	Dinotoperla marmorata*	Dinotoperla serricauda	Dinotoperla opposita*	Trinotoperla tasmanica*	Trinotoperla inopinata*	Trinotoperla zwicki*	Trinotoperla comprimata	Trinotoperla/Nebiossoperla?	Reikoperla triloba	Reikoperla pulchra*	Newmanoperla prona*	Austrocercoides zwicki*	Tasmanocerca bifasciata*	Austrocerca tasmanica	Kimminsoperla albomaculata*	Notonemoura lynchii	Austrocercella cristinae*	Total taxa
AN				+		+															+		+												4
BC		+	+	+		+								+							+					+			+	+					9
BT				+		+						+									+		+												5
CB			+	+													+		+				+			+	+			+	+				9
CH			+	+																		+				+			+						5
CF				+		+						+														+			+						5
CG			+	+		+	+		+			+						+	+										+				+		10
CC			+	+							+												+	+						+					6
FA			+	+		+					+										+		+							+				+	8
GU			+	+		+																								+					4
HH				+										+								+				+			+	+					6
HG				+		+													+							+			+						5
HM				+	+	+																				+									4
HR			+	+		+							+													+									5
JU			+	+	+	+				+			+									+				+			+						9
LR				+									+														+								3
NE				+		+					+	+							+							+			+						7
PC			+	+	+	+						+									+		+			+			+						9
PD			+	+	+	+			+		+	+							+		+		+						+						11
PP		+	+	+	+	+	+					+	+						+		+		+			+			+						13
RR		+	+							+						+	+				+													+	7
SO						+							+													+									3
SF			+	+	+	+						+		+							+		+												8
SR			+			+						+									+								+						5
ST			+			+							+																	+					4
SU				+		+				+				+									+			+			+						7
VA																	+	+								+			+						4
CA	+									+				+					+		+								+	+					7
FR	+			+		+				+				+					+							+			+						8
GP						+			+	+				+							+					+	+		+		+				9
NW									+	+				+							+											+			6
PA						+				+				+							+					+									5
RG	+	+		+						+				+							+					+			+						8
SP						+				+				+					+							+			+						6
BE				+		+				+		+		+					+							+			+						8
BO				+						+										+	+								+						5
DR	+			+	+	+				+								+	+										+						8
FM						+								+																	+				3
MM	+	+		+		+				+				+					+		+	+				+						+			11
MR	+					+		+						+					+							+			+						7
SE				+		+				+				+												+			+						6
SW	+	+		+	+	+				+				+								+	+		+	+			+			+			14
WE						+				+		+		+					+		+								+	+		+			9
WY						+				+				+									+			+			+						6
Total sites	7	6	16	30	8	32	2	1	4	18	4	11	6	19	1	1	3	3	14	1	18	5	12	1	1	26	3	1	27	9	3	4	1	2	

* Tasmanian endemic species

Eight species occurred at only a single survey site. *Cardioperla edita* was recorded only at the Ring River (RR) the highest altitude site in the study and *Trinotoperla comprimata* occurred at nearby Conliffe Creek (CC). *Newmanoperla prona* was only recorded from Sweets Creek (SW), a forested site in the north-east. *Notonemoura lynchii* was recorded only at Coldstream 'grassy' (CG) in the upper Coldstream River as it flows on the boundary of rainforest and grassland at Knole Plain, near Waratah. A further four species which defied conclusive identification were found at particular sites: *Cardioperla* 'Newitts Creek' at NW in the north-east grasslands, *Cardioperla* 'Dorset River' at the most north-easterly forest site, a specimen from Sweets Creek in the north-east forest which keyed out between *Neboissoperla* and *Trinotoperla* and at Merry Creek (MR) in the same area, a *Leptoperla* apparently close to the mainland species *L. bifida.*

Species richness by site is shown in Figure 6.1. Some sites proved to have a rich and diverse plecopteran fauna. Five sites had ten or more species of Plecoptera. In the north-east, the two sites with highest diversity were in the Upper South Esk catchment, Sweets Creek (SW) with 14 species and Memory Creek (MM) with 11 species. In the north-west the highest diversity sites were two sites in catchment of the Little Donaldson River (PP and PD with 13 and 11 species respectively), and Coldstream 'grassy' (CG, 10 species). These sites also had high diversity of Tasmanian endemic Plecoptera species, since none of these sites had more than two non-endemic taxa present.

Figure 6.1 Number of Plecoptera species by site



A Mann-Whitney test showed that there was a significant difference (p=0.0165) between the Plecoptera species richness of eastern and western sites (Table 6.5). There is a wider range of species richness in western sites, with the generally depauperate acidic brown-water sites having the lowest number of Plecoptera taxa).

Table 6.5 Comparison of Plecoptera species richness in eastern and western sites

	Mean	25%	75%
North-east sites n=17	8.00	7.50	9.25
North-west sites n =27	6.00	4.25	8.75

The Plecoptera varied considerably in abundance both between species and in some cases, between sites for the same species. Several *Cardioperla* species occurred in moderate to large numbers at a few sites: these include *C. flindersii* at two grassland sites in the North-east, Newitts Creek and Gravel Pit Creek (NW and GP), *C. diversa* at the same two sites and also several other sites in both the north-west and north-east. *C. lobata* was very numerous at two sites in the upper Coldstream (CG and CF), while *C. spinosa* was dominant in the north-eastern grassy sites at Wyniford River (WY) and Paradise Creek (PA). *C. spinosa* was more widespread in north-east sites, and site types in the north-east, than in the north-west. The *Dinotoperla* and *Trinotoperla* species generally occurred in small numbers at any site with the exception of *Trinoperla zwicki*, which was quite numerous at Farm Creek (FA). Notonemourids were never as abundant as the gripopterygids. At many sites, notonemourids were more numerous in autumn samples than spring samples. Among the notonemourids, the most commonly occurring species was *Austrocercoides zwicki* found at 27 of the 44 sites.

6.4 Habitat preferences

Table 6.6 shows the abundance of each species at each site. The sites are arranged according to catchment and/or geographic proximity.

Table 6.6 Plecoptera species by site and catchment/area

	Austropentura sp.*	Crypturoperla paradoxa*	Tasmanoperla thalia*	Eusthenia spectabilis*	Eusthenia costalis*	Leptoperla varia*	Leptoperla Sp A	Leptoperla aff bifida	Cardioperla flindersii*	Cardioperla diversa*	Cardioperla nigrifrons*	Cardioperla lobata*	Cardioperla incerta*	Cardioperlaspinosa*	Cardioperla 'Newitts Creek	Cardioperla edita*	Cardioperla Sp B	Dinotoperla marmorata*	Dinotoperla serricauda	Dinotoperla opposita*	Trinotoperla tasmanica*	Trinotoperla inopinata*	Trinotoperla zwicki*	Trinotoperla comprimata	Trinotoperla/Nebiossoperla?	Reikoperla triloba	Reikoperla pulchra*	Newmanoperla prona*	Austrocercoides zwicki*	Tasmanocerca bifasciata*	Austrocerca tasmanica	Kimminsoperla albomaculata*	Notonemoura lynchii	
Western area																																		
Lower Pieman/Rosebery																																		
AN				1		1															1		1											
CB			2	3													1		4				4			3	1			1	18			
CC			3	7							1												12	2						1				
FA			1	1		8					1										1		42							1				2
ST			1			1							3																	2				
RR		113	2							51						1	1				1													15
Coldstream																																		
BC		1	3	3		6								5							6					1			9	11				
CF				3		9						76														4			23					
CG			1	1		16	1		2			52						2	1										7				1	
NE				4		16					3	6							1							1			11					
CH			1	1																		1				3			2					
HH				4										1								1				16			1	2				
Surrey Hills																																		
HG				4		2													1							3			1					
HM				25	2	5																				319								
SO						1							1													33								
VA																	4	1								2			1					
Sumac road																																		
BT				2		1						1									14		1											
JU			2	4	1	3				17			1									4				4			1					
HR			1	1		6							2													1								
SF			2	4	6	1						23		1							1		4											
SR			2			1						4									2								6					
SU				1		1				48				1									1			1			1					
Western Explorer Road																																		
LR				1									1														1							
GU			14	1		8																								1				
Donaldson catchment																																		
PC			5	6	1	2						13									1		9			1			4					
PD			3	6	3	5			1		2	13							1		1		23						1					
PP		2	2	2	1	12	8					22	13						1		4		2			1			4					
Eastern area																																		
Mt Maurice/Ben Nevis area																																		
CA	1									1				2					1		3								6	13				
FR	1			1		1				12				12					8							20			9					
RG	2	1		1						1				5							2					1			22	1				
SP						2				41				1					1							1			2					
BE				1		1				2		1		3					4							9			1					
Paradise Plains																																		
GP						3			37	112				9							1					14	2		2		1			
NW									34	81				17	15						1					1			0			1		
PA						7				6				54							1					4			0					
Mt Barrow																																		
BO				1						1										3	1								27	0				
Dorest valley																																		
DR	8			2	3	8				1								1	1										7					
Upper South Esk																																		
MM	1	1		3		2				38				2					5		2	3				14						1		
MR	1			1		1		1						1					1							5			4					
SE				1		1				1				1					1							9			2					
SW	6	1		7	1	1				12				1							1	5	1		1	14		1	1			1		
Blue Tier																																		
WE						2				1		1		1					1		1								1	1		1		
WY						8				2				134									1			3			3					
FM						1								1															0		2			

* Endemic species to Tasmania

There is some apparent clustering of particular species within a particular catchment or area. *C. lobata* is more frequently captured in the Coldstream and Donaldson catchments, while *R. triloba* is most abundant in the area of the Surrey Hills: close geographically though in headwaters of separate catchments. *A. zwicki* is most commonly found in the Coldstream catchment in the west and in the Mt Maurice/Ben Nevis area of the north-east. The sites in the latter group are in geographic proximity but three different catchments are represented. There are insufficient data to make statistically based judgements on the significance of these distributions, but there is no *prima facie* evidence of environmental variables which account for them. Distributional information of this kind warrants further investigation and is relevant to conservation planning and protection for aquatic invertebrate biodiversity.

A few species are confined to either the west or east of the state. An undescribed species of *Austropentura* occurs only in the east, and was more widespread than suggested by Hynes (1989). *Tasmanoperla thalia* occurs only in the west of the state (Hynes 1989). Both these austroperlids are confined to shaded forest sites and their geographic distribution was supported by my evidence. The austroperlid *Crypturoperla paradoxa* is reported by Hynes to be confined to the west of the state. The field survey extended its known distribution in the west with records in the upper Coldstream catchment at Biscuit Creek (BC) and the Little Donaldson catchment at Pineapple Creek (PP). Both these sites were at lower altitude than Hynes' suggested habitat preference for 'steep streams at high altitudes' (1998, p 73). Nevertheless, its highest abundance was recorded at the highest altitude site in the survey, the Ring River at Mount Read (RR). However, specimens, which keyed to *Crypturoperla* (a very distinctive Plecopteran), were also found at three sites in the north-east: the Ringarooma River at Mount Maurice (RG), Memory Creek (MM) and Sweets Creek (SW), both in the upper South Esk catchment. Sites other than the sub-alpine Ring site were all forested sites with fast-flowing streams and rocky beds.

Three other species, which Hynes records only from the west of the state, were also found in a few eastern sites. *Cardioperla lobata* was found at two forested sites in the east, Becketts Creek (BE) and Wellington Creek (WE). However, the distinction between *C. lobata* and *Reikotriloba pulchra* is problematic and adult specimens would be needed to confirm these records. *Trinotoperla zwicki*, another 'western' species was also found at two eastern sites, Sweets Creek (SW) and Wyniford River (WY). *Tasmanocerca bifasciata* was found at three eastern sites, Cascade Creek (CA), Ringarooma River at Mount Maurice (RG) and Wellington Creek (WE) on Blue Tier.

The four species of the genus *Trinotoperla* all occurred principally in forested sites, with the exception of *T. tasmanica*. This species also occurred at the three grassland sites on Paradise Plain in the north-east. *Dinotoperla serricauda*, a species also found in NSW and Victoria, was most common in the north-east. The other two *Dinotoperla* species recorded in the survey had quite restricted distributions. *D. opposita* was only found at Bonnies Creek, a very small mountain creek in the north-east on the slopes of Mt Barrow. Hynes (1998 p 75) suggests that the nymphs of these species are 'rarely found' though records are scattered across the state. *Dinotoperla marmorata* was only found at two high altitude grassland sites in the north-west, at Coldstream 'grassy' (CG) and the Vale River (VA). These records confirm Hynes' assessment of the species as 'uncommon' and his distribution map shows records in only three 10 km grid squares in the state, two of which are in the same area as CG and VA.

Among the gripopterygids, clear habitat preferences were hard to distinguish. Some sites had as many as eight species from this family. The genus *Cardioperla* is endemic to Tasmania and has nine described species. In addition, Hynes also lists 'species A', and the present study revealed two further species which appeared to be undescribed species of *Cardioperla*: 'species B' from two sites in the Ring catchment near Rosebery in the west (RR and CB), and 'Newitts Creek' from a small creek in the Paradise Plains area of the north-east (NW).

Seven other described species of *Cardioperla* were collected in the study survey. There was considerable overlap in habitat requirements or preferences, based on observable parameters such as riparian vegetation, altitude, stream width and substrate. There was also considerable geographic overlap in distribution of some species. The limited numbers of sites at which many species occurred precluded statistical analysis of habitat preferences, so the conclusions can only be indicative. Further collecting, longitudinal data from key sites, data from earlier collections and experimental testing would inform hypotheses on preferred habitat.

Hynes (1998 p 74) suggests that only three of the nine described *Cardioperla* species are confined to western regions, the remainder being widespread across the state. In this study *Cardioperla incerta* was only found in fast-flowing medium to larger rivers in the north-west, agreeing with Hynes' assessment of its distribution. Although his species summary indicates that *C. lobata* is a western species, his distribution map indicates specimens have been recorded from four 10 km grid squares in the north-east. The present study also found *C. lobata* in the north-east at two sites which may correspond with Hynes' records, at Becketts Creek (BE) and Wyniford River (WY).

Cardioperla diversa was found predominantly in the eastern sites with only three of a total of 18 sites where it was recorded in the survey being in the west. Similarly, *C. spinosa* was more common in the east, and was very numerous at the Wyniford River site on Blue Tier. Four of the records for this species out of a total of 19 were in the west of the state. In the west *C spinosa* tended to be confined to forested sites whereas it occurred at all site types in the east. *C spinosa* appears to favour the higher altitude sites, where it was most numerous. *C. spinosa* was recorded at 15 sites in the north-east suggesting it is more widespread in this region than indicated by Hynes' data.

C. edita occupies the highest altitude sites among the *Cardioperla* genus. It was only found at one site in this study, the Ring River at Mount Read (RR). Hynes (1989) indicates a preference by this species for treeless sites and most records occur on the Central Plateau. The Ring River record represents a significant westerly extension to the range of this species.

The notonemourids tended to be more abundant in autumn samples possibly suggesting a different emergence and breeding pattern (Hynes & Hynes 1975; Theischinger 1991). The present study was too limited to provide such information, which requires systematic, sequential, and purposeful sampling to ascertain. Notoneumourids were never present in large numbers.

Table 6.7 provides a revised version of Table 6.3, incorporating the information gained from the survey sites.

Taxa highlighted in red are specimens that did not key out to recognisable taxa in the Hynes (1989) key. Their status is uncertain since they may occur more widely across the state. Additional values introduced to include survey data include 'species with habitat under threat', 'species at the limit of their range' and 'outlying populations'. The latter two criteria fall under the criterion of biogeographic significance, while the species with habitat under threat reflects the shift from extent of distribution to environmentally threatening processes. Although difficult to establish threats in a categorical fashion, one example may be the potential threat to preferred habitat of *Dinotoperla marmorata*. This species appears to favour open grassland sites at high altitude. These sites are characterized by lack of woody debris, absence of shading and hence wide diurnal variations in temperature during the sunnier months. Conversion of grassy sites into plantation forest, or simply natural progression to a shrubbier and hence more shaded stream habitat may prove detrimental to this species.

Table 6.7 Status of Tasmanian Plecoptera species incorporating study site information

		Rarity				**Biogeographic/ phylogenetic significance**						
		Listed species/meeting threshold r1	Listed species/meeting threshold r21	Uncommon species r3	Species with habitat under threat	Endemic species: Tasmania	Endemic species: regional or local	Tasmanian endemic genus	Gondwanan/Pangean species	species of unusual morphology/life-history	Spp at the limits of range	Outlying populations
Austroperlidae	Austropentura sp*.	+				+	+					
	Crypturoperla paradoxa*					+		+		+	+	+
	Tasmanoperla thalia*					+	+	+				
Eusthenidae	Eusthenia spectabilis*					+						
	Eusthenia costalis*					+						
Gripopterygidae	Leptoperla varia*					+						
	Leptoperla Sp A*					+						
	Leptoperla aff bifida*	?		?		+	?					
	Cardioperla flindersii*					+						
	Cardioperla diversa*					+		+				
	Cardioperla nigrifrons*					+		+				
	Cardioperla lobata*					+		+				+
	Cardioperla incerta*					+	+	+			+	
	Cardioperla spinosa*					+		+				
	Cardioperla 'Newitts Creek*	?			+	+	+	+				
	Cardioperla edita*					+		+				
	Cardioperla Sp B*	?				+		+				
	Dinotoperla marmorata*		+		+	+	+					
	Dinotoperla serricauda											
	Dinotoperla opposita*			+		+						
	Trinotoperla tasmanica*					+						
	Trinotoperla inopinata*					+					+	
	Trinotoperla zwicki*					+						+
	Trinotoperla comprimata					+	+					
	Trinotoperla/Nebiossoperla?	?				?						
	Reikoperla triloba											
	Reikoperla pulchra*		+			+	+					
	Newmanoperla prona*			+		+						
Notonemouridae	Austrocercoides zwicki*					+						
	Tasmanocerca bifasciata*					+	+	+				+
	Austrocerca tasmanica											
	Kimminsoperla albomaculata*					+						
	Notonemoura lynchii											
	Austrocercella cristinae*					+						

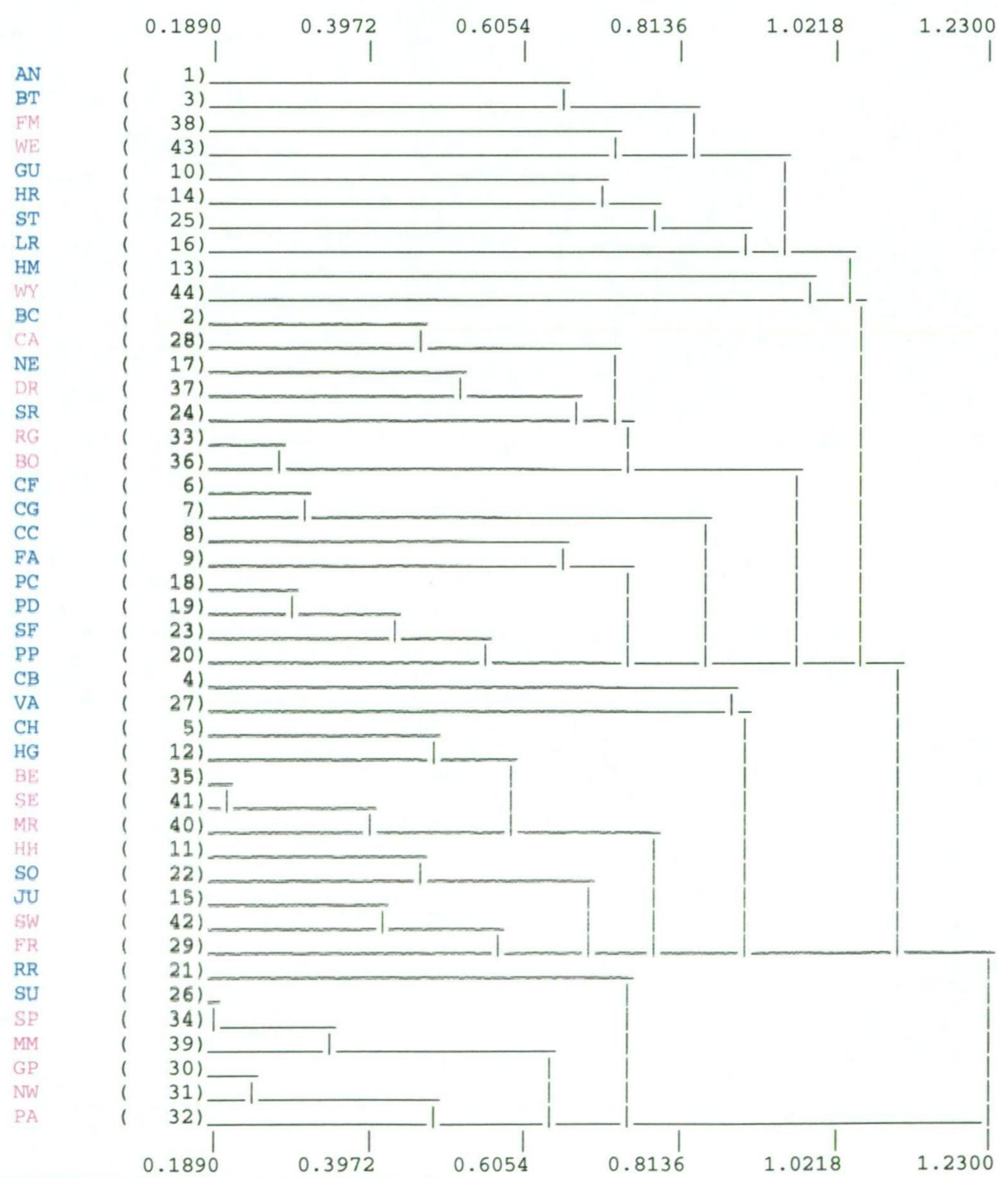
Extensions in known limits of range of some species and location of some outlying populations are of particular biogeographic interest. Four species, *C. paradoxa*, *T. zwicki*, *T. bifasciata* and *C. lobata* previously known only from the west were recorded in the north-east highlands or Blue Tier areas.

The present study broadly supports Hynes' assessment of regional and habitat occurrence for most species. Since the surveys were not exhaustive and confined to two regions, conclusions about habitat requirements or preferences must be made with caution.

6.5 Plecoptera communities

The Plecoptera data were analyzed using PATN (Belbin 1993). The dendrogram resulting from Bray-Curtis association is shown in Figure 6.2 (β = .1 Stress = .19).

Figure 6.2 Dendrogram of UPGMA analysis of Plecoptera at survey sites

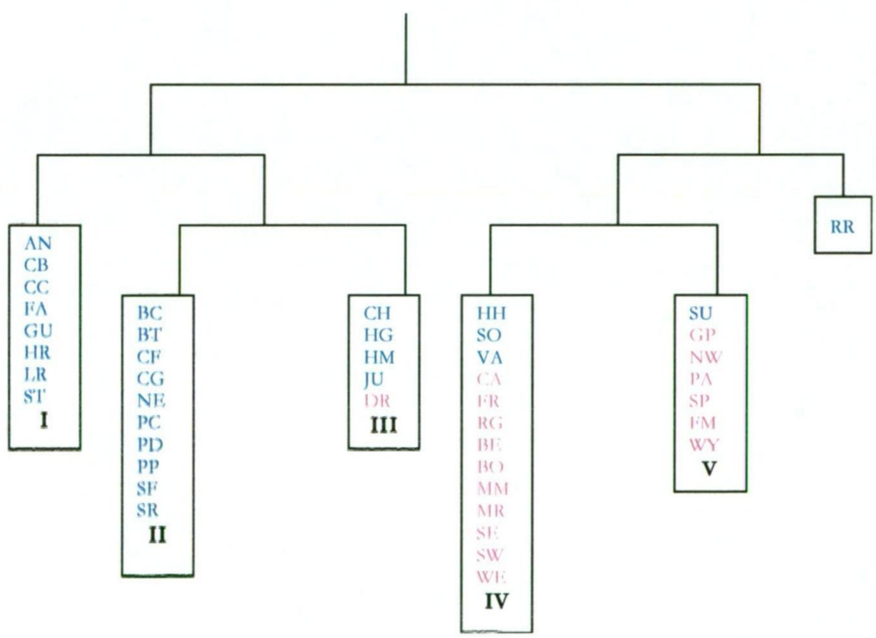


North-west sites North-east sites 'SU' is the site code '(32)' is the site number

Classification of the sites using TWINSPAN in PATN resulted in five site groups and an outlier (Figure 6.3).

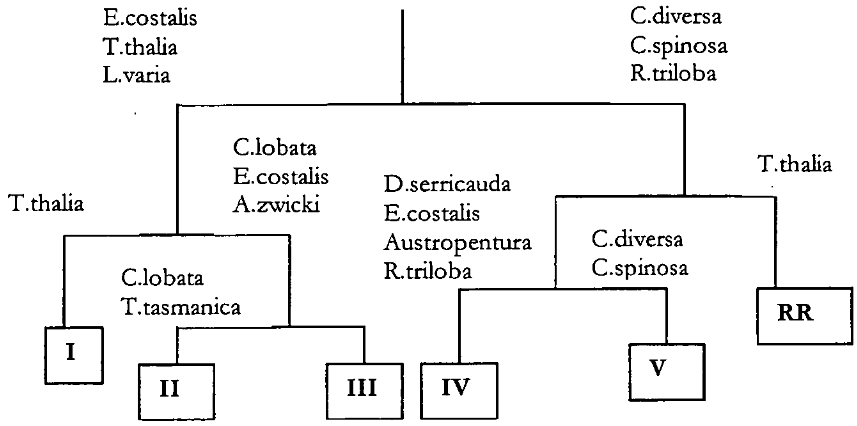
Analysis of variance, using Sigmastat was undertaken to attempt to define any variables or characteristics of the sites which explained the group classifications. Variables in numerical form which were amenable to analysis were: northing, easting, altitude, bankfull width, bedslope, pH, conductivity, % vegetation cover, % of each class of streambed substrate size, Land Use Factor (LUF), Catchment Disturbance Factor (CDI), River Disturbance Index (RDI), In addition, total taxon richness and richness of Plecoptera species at the sites was tested for significance amongst the site groups.

Figure 6.3 TWINSPAN classification of site by occurrence of Plecoptera



The classification shows a distinct regionalisation of sites. Indicator species for the TWINSPAN divisions are shown in Figure 6.4.

Figure 6.4 Indicator species for TWINSPAN classification of sites by Plecoptera



Variables that were not significant were bedslope and pH, all categories of substrate size, River Disturbance and Catchment Disturbance indices. Details of significant variables are shown in Table 6.8 a - f.

Table 6.8 Variables demonstrated to be significant in TWINSPAN analysis of Plecoptera species data

(a) Easting

Group	Median	25%	75%	Contrast
I	375200	346400	383550	ac
II	354050	328400	377500	ac
III	389000	365325	435400	bc
IV	551200	501750	560125	b
V	557700	547750	557425	b

(b) Northing

Group	Mean	S.D.	SEM	Contrast
I	5392113	27424	9696	bc
II	5419390	17260	5458	a
III	5416190	19000	8495	ac
IV	5413431	11891	3298	ac
V	5429729	9417	3559	a

(c) Altitude

Group	Mean	S.D	SEM	Contrast
I	228.8	122	43.2	a
II	379	227	71.7	bc
III	341.7	228	102.1	b
IV	590.8	234	64.9	b
V	659.3	247	93.4	b

(d) Conductivity

Group	Median	25%	75%	Contrast
I	60.2	53.3	73.6	a
II	56.3	47.2	124.1	a
III	53.2	40.5	82	ac
IV	39.8	36.7	48.9	ac
V	33.7	26.6	35.8	bc

(e) Taxon richness - all taxa

Group	Mean	S.D	SEM	Contrast
I	22	5.04	1.78	a
II	31.1	4.93	1.56	a
III	31.8	6.46	2.89	ac
IV	27.6	3.84	1.07	ac
V	23.6	5.22	1.97	bc

(f) Land Use Factor

Group	Median	25%	75%	Contrast
I	0.28	0.18	0.4	a
II	0	0	0.11	ad
III	0	0	0.58	ac
IV	0	0	0	bcd
V	0.11	0	0.35	ac

The TWINSPAN groups differed significantly in geographic location both by northing (ANOVA $F=4.81_{38,4}$, $p=0.0031$) and by easting (ANOVA on the ranks $H=23.3_{4}$, $p= 0.0001$), Tables 6.8 a and b. Group I included the most southerly sites, all located in the Pieman catchment and also of lowest mean altitude (Table 6.8c). The more easterly site groups, groups IV and V, separate from the western groups I, II and III by the absence of the western species *Tasmanoperla thalia* and presence of *C diversa* and *C spinosa* (Figure 6.4). Group I was also distinguished from other groups by a lower mean altitude ($F\ 5.44_{4\ 38}$, $p=0.0014$).

Conductivity was significantly different among the groups based on the ANOVA on ranks ($H=15.3_{4}$, $p= 0.0041$). The two eastern sampling areas at Blue Tier and Paradise Plains represented six of the seven sites in Group V. These have significantly lower conductivity and both lie at around 700m on granite bedrock.

Smaller streams appeared to have high Plecoptera species richness and some taxa were only found in smaller streams. However, although bankful width was significantly different on the ANOVA on ranks ($H =9.57_{4}$, $p= 0.0484$), the All Pairwise Multiple Comparison Procedure failed to discriminate among the site groups. Similarly, differences in pH could not discriminate between site groups (ANOVA on ranks $H=11.1_{4}$ $p=00251$).

Total taxon richness was significantly different amongst the groups based on Plecoptera data, but not richness of the Plecoptera species themselves. The difference among groups for total taxon richness was significant at <.001 ($F=5.97_{38,4}$, $p=.0008$). River disturbance was assessed using three elements of the Wild Rivers database. No significant differences were found amongst the TWINSPAN groups on River Disturbance (RDI) or Catchment Disturbance Index (CDI) but the land use (LUF) was significant on the ANOVA on ranks ($H=9.92_{4}$, $p = 0.0418$). These data must be treated with caution, not only for the methodological reasons outlined in Chapter 3 but also because land use will have changed since the index was calculated. Increased forest operations, especially harvesting and clearfelling, have occurred in the Upper Esk valleys in the last five years.

Attributes of site groups which were significantly different are summarized in Table 6.9.

Table 6.9 Summary of mean values for variables identified as significant in TWINSPAN classification

Parameter	Group I	Group II	Group III	Group IV	Group V
Easting	375200	354050	389000	551200	557700
Northing	53921130	5419390	5416190	5413431	5429728
Altitude (m)	229	379	374	591	659
Conductivity (μs)	61	56	53	40	34
Total Taxon richness	22	31	32	28	24
Land Use Factor (LUF)	27	0.0	0.0	11	0.0
Sites	AN CB CC FA GU HR LR ST	BC BT CF CG NE PC PD PP SF SR	CH HG HM JU DR	HH SO VA CA FR RG BE BO MM MR SE SW WE	SU GP NW PA SP FM WY

Group I is a group of lower altitude, forested, generally medium-sized rivers in the north-west, with lower total taxon richness and the highest Land Use Factor value. All lie within the Arthur-Pieman catchment although not all within close geographic proximity. Five of the eight sites are near Rosebery, two on the Western Explorer road in the far west while the remaining site is the northernmost sites of the western sites (see Figure 4.1).

Group II sites are smaller rivers and streams confined to the north-west, all forested with the exception of CG and NE. They are generally at moderate altitude and notably grouped in close geographical proximity: BT, SF and SR near the Kunana Bridge over the Arthur River; BC, CF, CG and NE in the upper Coldstream catchment; and PC, PD and PP in the Donaldson catchment at the Savage River Pipeline road. These sites had a high taxon richness. The Land Use Factor analysis showed a significant difference from the other groups and had a mean value of zero, that is, no impact of Land Use as assessed under the Wild River project (Stein *et al* n.d.).

Group III includes four moderate-sized rivers of the north-west and a single north-east site, the Dorset River, which is also of moderate size. These sites share a high taxon richness.

Groups IV and V comprise higher altitude sites. Group IV has a high plecopteran species richness but comparatively lesser taxon richness for the entire macroinvertebrate fauna. The sites are smaller rivers and streams, except for HH, the Hatfield River at the Huskisson junction. With the exception of the Vale River, VA, all sites lie in forested valleys. Group V is a mixed group, which includes a single western site, SU, the others comprising three grassland sites on Paradise Plains, two sites on Blue Tier and the St Patricks River. The Ring River was an outlier and is not included amongst the site groups. The Ring River site is located close to the source of the river at 900 m and is the only site with true sub-alpine riparian vegetation. It was distinctive from all other sites sampled by the abundance of an in-stream Bryophyte, the Hepatophyte *Chiloscyphus okaritinus ssp austrogenus.* This provided habitat and possibly food source for the large numbers of *Crypturoperla paradoxa* which inhabited that site.

The multivariate analysis of the Plecoptera data suggest some assemblages which have some habitat preferences, as yet poorly defined. Greater species richness of the Plecopteran fauna was evident in smaller streams, and at moderate to higher altitudes. Other habitat preferences were less readily apparent. However, it may be claimed that forested streams offer food sources and/or microhabitats that are favoured by this macroinvertebrate group.

6.6 Summary

The data presented in this chapter not only provided information about the Plecoptera of these sites to be incorporated into an assessment of conservation values at these sites, it also illustrates some of the issues associated with data collection, analysis and interpretation for aquatic conservation assessment.

The species level data supported the general contention that there is a correlation between species richness and family level taxon richness. It may be claimed, therefore, that family level assessment is an adequate surrogate for biodiversity assessment and for determining community structure (Marchant *et al* 1994, Growns & Growns 1997). Davies & McKenny (1997) found that analysis of MRHI-based data, which uses family level analysis, had limited value in determining either site groups of high taxon richness, nor of providing any indications of a regional distribution of sites of high diversity. I conclude from my study that while these two indices (family and species) may be correlated, at least for the Plecoptera:

- species level analysis provided an enhanced capacity to statistically define communities, and

- there was not a linear relationship between family and species diversity at every sites and therefore some sites important for Plecoptera may be neglected, and

- Plecoptera of conservation value did not always occur at sites that were high in either Plecoptera species or richness of all taxa.

The Plecoptera are one of the best-known groups of aquatic invertebrates in terms of their taxonomy and distribution in Tasmania. Yet the study was somewhat hindered by taxonomic inadequacies because of using nymphal forms some of which cannot be distinguished except by implied geographic distributions. Three apparently undescribed species were found in what was a fairly limited survey, indicating that there remain large gaps in the knowledge of this group in the state. The distributional information was also a constraint on assessing rarity according to the thresholds set under threatened species legislation. There are a number of issues here: whether the available distributional information is exhaustive or adequate (which it clearly was not); whether taxa which are limited to a single catchment but exceed the area thresholds should be assessed as rare for aquatic ecosystems; whether the taxonomy is current (there has been no update on the Plecoptera taxonomy since Hynes' work in 1988, and no Australia-wide work on this group); whether the distributional information is current (similar comments to previous, with the added concern that there has been no integrated analysis of Tasmanian and Victorian taxonomies and distributions), and the current lack of a specialist working on the Australian Plecoptera to whom such queries could be addressed.

In addition to assessment of conservation values based on rarity, most biogeographic conservation values refer to species level data. Many of the comments about rarity can equally apply to assessment of biogeographic values since these depend on similar data. Information on distribution of Plecoptera species according to environmental variables such as altitude, streambed substrates, riparian vegetation, stream size and flow (not reported in detail) showed very few clear habitat preferences. Many species were widespread, even though they might be more abundant in particular catchments or areas. It would, therefore, be difficult to use environmental variables as surrogates or to predict distributions of rare taxa as the basis for protection. The one exception, not confirmed statistically, was the possible indication that smaller streams were important both for richness of Plecoptera and also as the habitat for species of conservation value. Such streams included class 4 streams as defined under the Forest Practices Code, which are not protected by a streamside reserve.

The Plecoptera data illustrates that many aspects of conservation assessment for aquatic invertebrates require species level data.

Chapter 7

An assessment of the conservation values of macroinvertebrates at the study sites

The evidence of the previous descriptive chapters is considered with reference to the conservation criteria identified in the conceptual framework. There are four criteria - rarity, richness, representativeness and biogeographic significance - each with indicative values or attributes. Appropriate thresholds or decision rules are proposed to define levels of significance for these values. The criteria and thresholds are used to assess conservation values of the macroinvertebrate taxa, communities and Plecoptera species present at the study sites. These identified conservation values are then assembled for all sites to evaluate which sites appear to have high conservation values.

7.1 Requirements for conservation assessment

Four key elements are required for conservation assessment:

- **criteria** to answer the question 'What constitutes a conservation value?'
- **thresholds, standards or decision rules** to provide benchmarks for what is considered significant
- **bases for comparison** to make judgements in the context of other sites, regions or wider area, and
- **data** to provide evidence for claims for particular taxa and sites of conservation value.

The data from the study is now subjected to an assessment of conservation values and sites of high conservation value identified. Key elements of the assessment framework - criteria, thresholds and the bases for comparison - are first reviewed. The study was undertaken in Australia so elements of the assessment process are framed to a degree in the Australian legislative, administrative and policy contexts outlined in Chapter 2.

7.2 Criteria for conservation value

Four general criteria were outlined in the conceptual framework (Chapter 3). These criteria are widely accepted in conservation assessment, planning and protection for other types of ecosystem such as forests (JANIS 1996), Marine Protected Areas (ANZEEC 1998, 1999;GBRMPA 1999), wetlands (RAMSAR 1999) and grasslands (Environment Australia 1998). The criteria are also central components to the assessment of sites for entry in the Register of the National Estate (Australian Heritage Commission Act 1975; PLUC 1997). The criteria are also generally consistent with the criteria adopted for the SERCON assessment of conservation of river systems in the UK (Boon *et al* 1994; Boon *et al* 1997; Boon *et al* 1998). Recent work has explored from a theoretical perspective the application of conservation criteria to riverine systems in Australia (Dunn 2000; EPA 1999a, b). For the purposes of the present study, those criteria and attributes appropriate for macroinvertebrates have been selected.

The specific attributes proposed under the four criteria - rarity, richness, representativeness and biogeographic significance - are summarized in Table 7.1.

Table 7.1 Criteria and attributes for assessment of conservation value of stream macroinvertebrates

Criterion	Attributes
Rarity	Rare
	Uncommon
	Species with threatened habitat
	Threatened communities
Richness	High taxon richness at family level
	High taxon richness at species level
Representativeness	Representative macroinvertebrate community
	Representative Plecoptera community
Biogeographic or phylogenetic importance	Endemic - Tasmania
	Endemic - regional or local
	Endemic - genus or above
	Monotypic genus
	Gondwanan affinities
	Taxon at its limit of range
	Outlying population
	Unusual morphology or life-history

Criterion 1: Rarity

Rare species have been long recognized as of high conservation value, requiring special management intervention to limit extinctions (IUCN 2000). Rarity has variously been defined by geographical extent of distribution, size of breeding population, species decline and population fragmentation (Ramsar 1999; IUCN 2000). Degrees of rarity may be defined for legislative and descriptive purposes (Tasmanian Threatened Species Protection Act 1995, EPBC Act 1999). More recent threatened species legislation in Australia has turned towards protection of species which can be demonstrably threatened by ongoing human-induced threatening processes, and the concept of 'threatened species' has become an attribute of, or surrogate for, rarity.

It is now further acknowledged that whole ecosystems may become extinct or be irreversibly altered as a consequence of human induced change. Evidence from the more obvious and visible types of ecosystem such as native grasslands (Kirkpatrick *et al* 1995) and ecosystems with highly specialized requirements such as mound springs (EA 1997) has led to the protection under law of threatened communities (EPBC Act 1999). This attribute is not focussed on rare taxa but on an entire ecological community, individual species within which may not achieve the status of rarity.

Criterion 2: Richness

Richness or α diversity is usually measured as the number of species occurring within an area of given size (Huston 1994). Protection of places with high biotic richness or diversity is a fundamental mechanism of capturing many species within a protected area. In addition, high diversity may indicate a 'hot spot' or place where speciation has occurred (Simmons & Cowling 1996; Flather *et al* 1997; Daniels 1997). Places of high taxonomic richness are seen as a priority for conservation and protection (EA 1998; Ramsar 1999).

It has been shown that for stream macroinvertebrates there is a close correlation between family and species richness (Marchant *et al* 1999; Growns & Growns 1997; Wright *et al* 1998; Hewlett 2000). Two attributes defining richness are adopted for the present analysis: taxonomic richness at family level and richness of the Plecoptera species.

Criterion 3: Representativeness

Some authors (Phillips *et al* 2000) regard representativeness not as a criterion for conservation value but as a tool for conservation planning. Representativeness is a cornerstone of templates for river management and for the study of river functioning. Inclusion of representative communities also allows for recognition of communities which are characteristic of riverine systems rather than only those communities which are selected because of species richness (Criterion 2), or because they are threatened (Criterion 1). Further, communities that are naturally of low diversity as a consequence of water chemistry or extreme hydrological conditions may escape recognition for their natural value as a representative type of ecosystem. Therefore representative communities are included as attributes of the criteria for reserve planning for forests (JANIS 1996), marine areas (ANZEEC 1998 1999; GBRMPA 1999) and the national reserve system generally (EA 1998).

Criterion 4: Biogeographic or phylogenetic significance

The flora and fauna of Tasmania is particularly significant from a biogeographic perspective. One of the most southerly temperate elements of the ancient Gondwana landmass, subjected to more extensive periods of glaciation and less severe aridity since the Mid-Tertiary than the rest of Australia and undergoing episodes of separation from mainland Australia, the island state has an array of taxa of biogeographic interest. Its flora and fauna are important in informing geological and climate history in a world context as well as at an Australian scale. The story of the state's own ecological history is also revealed by consideration of present distributions and affinities.

Several attributes are identified which capture the essence of this criterion. They have previously been applied internationally in World Heritage listing (UNESCO 1999), nationally in Regional Forest Agreements and the Register of the National Estate and locally in the Tasmania Regional Forest Agreement (PLUC 1997). These attributes have been discussed in Chapter 2 and shown in Tables 2.4, 2.6, 2.8.

Various invertebrate taxa from aquatic environments have been identified as being of special biogeographic interest. These include the Anaspidae (Tasmania) (Environment Australia 1997; Horwitz 1990), Phreaticoidea (Australia and Tasmania)

(Wilson & Johnson 1999), Macrocrustacea (Australia and Tasmania) (Horwitz 1988, 1990, 1996) and Plecoptera (Australia and Tasmania) (Hynes & Hynes 1980; Zwick 2000).

Much of the Tasmanian stream macroinvertebrate fauna is highly endemic at species level. For example, some 75% of all Trichoptera species (Neboiss 1981, 1988, 1991) and 80% of all Plecoptera species are endemic to the state (Hynes 1989; Theischinger 1991). Other groups as yet inadequately described are likely to be similar. Notably many of these are of ancient lineage (Wilson & Johnson 1999; Zwick 2000). Some taxa may have special biogeographic significance because of the present-day patterns of distribution on a world scale.

Attributes that are used to capture the dimensions of the biogeographic criterion focus on geographic levels of endemism (Australia, state of Tasmania, regional or local) and endemism at different taxonomic levels (family, genus and monotypic genera). Aspects of significance that reflect past ecological processes are based on present distribution. These are species at their limits of range and occurrence of a species as an outlying or relictual population.

A final attribute clustered under biogeographic significance focuses on phylogenetic significance. Taxa which have some distinctive phylogenetic relationship, or a morphology which is unique or in some way aberrant from other members of that group, are included under this general attribute. More detailed analyses of the nature of such phylogenetic relationships and the interactions with biogeographic factors is beyond the scope of this study.

7.3 Thresholds and decision rules

The determination of what constitutes 'significant' is, in the final analysis, a subjective decision. Nevertheless, it is necessary and desirable for standards to be made as explicit as possible. This encourages comparability in judgement and greater transparency of the assessment process. For a systematic conservation assessment process, agreement on these thresholds and decision rules should be established from the outset (Dunn 2000; Phillips *et al* 2000). Expert opinion, established precedents and a consultative process usually contribute to this process, for example for the Regional Forest Agreement and Marine Protected Areas programs (PLUC 1997;

ANZEEC 1999).

The different conservation criteria call for different approaches to setting thresholds.

Criterion 1: Rarity

Rarity has been defined both on a geographic distribution scale (Tasmania Threatened Species Protection Act 1995; IUCN 2000) and on the basis of size of extant populations (Ramsar 1999, IUCN 2000.). Population size is not a feasible or appropriate threshold to use for most invertebrates for several reasons. There is insufficient understanding of population dynamics of many taxa and populations may be flexible and responsive to environmental conditions. Critical factors in maintenance of population levels are complex especially for species with both aquatic and terrestrial stages.

Thresholds for rarity applied in the present assessment reflect the standards adopted in the Tasmanian Threatened Species Act, as follows:

r1 indicative distributional range extends less than 100 x 100 km

r2 indicative distributional range occupies 20 or less 10 x 10 km AMG squares

r3 taxa that are not r1 or r2, but have very small or localised populations wherever they occur

Threatened species under both Commonwealth and state legislation are defined according to scales of threat from rare to vulnerable, to endangered, to extinct. The latter category is not used in the analysis. The distinction between 'endangered' and 'vulnerable' species is problematic for stream ecosystems where ecological requirements and species dynamics are poorly known. Therefore the threshold adopted for the present study is that applied to the category 'vulnerable', as follows:

> 'a species which is likely to become endangered while the factors causing it to be vulnerable continue operating'.

Vulnerable is the first step in decline towards extinction which is presumed to be imminent if the species becomes endangered (TTSP Act 1995).

Threatened community is used as an attribute for rarity because of the critical importance of integrated ecosystem functioning in maintenance of the conservation values of rivers (Moss 2000). This is not a criterion for listing under the Tasmanian Threatened Species Act, but it is under the Commonwealth legislation (EPBC Act 1999)[2] and in some other Australian states. The definition and threshold is expressed in the following way:

> An ecological community is defined as an integrated assemblage of native species that inhabits a particular area in nature. Such a community is endangered if it is likely to become extinct unless the circumstances and factors threatening its abundance, survival or evolutionary development cease to operate.
>
> Source: Endangered Species Protection Act Schedule 2.

Criterion 2: Richness

Species richness has been defined as the number of taxa at a site. There are not clear thresholds for what constitutes 'high species richness' since this is a relative issue in different biomes and among different taxonomic groups and ecosystems. It may therefore be constructed as a comparative index of similar sites, with a threshold set in an arbitrary fashion. The Tasmanian Regional Forest Agreement for example, used available faunal data sets to compile cumulative tallies on 10 km grid squares (PLUC 1997 p 65). Total species numbers for each grid square were ranked on the basis of coincident species distributions and reviewed by an expert panel. Places were considered to meet the threshold if they were also of 'good landscape integrity'. Thus the process of establishing the thresholds for this criterion in the RFA used several decision rules rather than numerical threshold.

The study sites represent a localized site on a watercourse. The data provides an opportunity to compare taxon richness at similar sites in similar microhabitats within a geographic area, and to deduce which of these sites sustains greater taxon richness. It was therefore decided to use an arbitrary cut-off of the highest 10% of sampled sites in taxon richness as the threshold for this criterion.

Criterion 3: Representativeness

Two general decision rules were adopted for nominating sites which were important as representative communities or assemblages. The first rule required selection of

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[2] New Commonwealth legislation, the Environment Protection and Biodiversity Conservation Act 1999, enacted in July 2000, supercedes the Endangered Species Protection Act but *pro tem* uses the same definitions as its precedent.

sites by statistical methods using the centroids of TWINSPAN groups plotted in ordination space. The site closest to the centroid for the group may be considered the best representative of that group. The second rule was applied to identification of TWINSPAN groups, which might be justified as representative of a particular macroinvertebrate community. This was less clear-cut since there was considerable overlap amongst the groups as shown in the ordinations and classifications (Figure 5.3, Figure 5.4, Figure 5.6, and Figure 5.7 and in Chapters 4 and 6). Factors including the distinctiveness and cohesion within the taxon group analyses and distinguishing environmental variables were taken into account. Thus the assemblages identified as 'representative' could be seen to be typical of particular habitats.

Criterion 4: Biogeographic significance

Setting thresholds for biogeographic significance might be regarded as a form of expert panel approach. The threshold for endemism at geographic, phylogenetic or taxonomic level draws on the published work of experts on those fields and from distributional data.

Four attributes related to endemism are recognized for the assessment. Two relate to distribution: endemic to Tasmania and endemic to a region or locality. Two reflect the importance of taxonomic level for endemism, that is, endemic at genus level or above, and monotypic species.

The criterion also provides for taxa that are not necessarily endemic but have a particular significance in the context of Gondwanan history or world-scale phylogeny of the group.

Two attributes of biogeographic significance relate to present distributions, which may reflect refugial or relictual conditions as outlying populations or at limits of known range. These attributes are also important components in protection of genetic diversity and hence robustness to threatening processes.

The final attribute under this criterion, unusual morphology or life history, is only loosely considered as of biogeographic or phylogenetic significance. It may mean an aberrant condition, which does not conform to other members of the group but may be the result of evolutionary traits or response to the local environment.

The threshold for each of these attributes is essentially a presence-absence assessment based on expert knowledge of the taxa. Thresholds for each of the attributes and criteria are summarized in Table 7.2.

Table 7.2 Attribute thresholds for conservation assessment

Criterion	Attributes	Threshold
Rarity	Rare	r1, r2 or r3, as defined by Tas Threatened Species Act
	Uncommon	Found infrequently (<5% of sites) at scattered sites
	Species with threatened habitat	Listed species with evidence of threatening processes affecting habitat
	Threatened communities	Communities which are subject to threatening processes
Richness	High taxon richness at family level	Sites of highest 10% of richness
	High taxon richness at species level	Sites of highest 10% of richness
Representative-ness	Representative macroinvertebrate community	Site from identified community in good condition, not threatened
	Representative Plecoptera community	Site from identified community in good condition, not threatened
Biogeographic or phylogenetic importance	Endemic - Tasmania	E1 - Tasmanian endemic
	Endemic - regional or local	E2 - Endemic to particular region of the State
	Endemic - genus or above	E3 - Tasmanian endemic genus level or above
	Monotypic genus	E4 - Tasmanian endemic genus single species
	Gondwanan affinities	Taxa which have special significance in world phylogeny related to Gondwana or other
	Taxon at its limit of range	Taxon at edge of range
	Outlying population	Occurrence of population separated by substantial geographic distance from other populations
	Unusual morphology or life-history	Taxon which exhibits morphology or life-history that is atypical for the group

7.4 The bases for comparison

All available collated sources of information are used as a basis for comparison of the study data. These include: published summaries of the phylogeny and taxonomy of key groups (Hynes & Hynes 1980; Hynes 1989; Theischinger 1991; Neboiss 1981, 1991; Wilson & Johnson 1999; Zwick 2000), distribution maps (Neboiss 1981; Hynes unpublished data), Schedules for Threatened Species Act, and published studies of the Tasmanian stream macroinvertebrate fauna (Richardson & Swain 1978; Swain *et al* 1984; Chilcott 1987; Richardson & Serov 1992; Davies & McKenny 1997; Oldmeadow *et al* 1998).

The Monitoring River Health Initiative database was an important source of information. These data provide a family level overview of the macroinvertebrate fauna of Tasmanian streams and rivers, and therefore may be useful to validate the comparisons with the study sites. Analysis and mapping of site groups (Davies & McKenny 1997; Oldmeadow 1998) provide a comparative context for the data from the study sites. In Chapter 5, data from the study sites were integrated and analysed with all available state data collected using the MRHI protocol. It was concluded that the faunal communities of the study sites are similar to those of stream macroinvertebrate communities around Tasmania. Thus a statewide basis for assessment has been established. The MRHI data also provides further evidence on occurrence and distribution of the taxa.

Some taxonomic groups can be identified and mapped for Tasmania to a level at which conservation value can be attributed at family level. Evidence of thresholds for these selected groups is summarized in Table 7.3 - Table 7.6. Table 7.4 has already been shown in Chapter 6 in the discussion on the Plecoptera as Table 6.3 and is reproduced here.

These summary tables, based on the work of taxonomic experts, can be used in making conservation value assessments at site level.

Table 7.3 Tasmanian Plecoptera in the Australian context

Family	Australia genera	Australia species	Tasmania genera	Tasmania species	Tasmania endemic genera	Tasmania endemic species
Eustheniidae	3	20	1	4	0	4
Austroperlidae	5	8	3	4	2	4
Gripopterygidae	12	127	8	26	1	22
Notonemouridae	6	29	6	9	1	8

Table 7.4 Plecoptera species indicative conservation values

		Rarity			**Biogeographic/ phylogenetic significance**				
		Listed species/meeting threshold r1	Listed species/meeting threshold r21	Uncommon species r3	Endemic species: Tasmania	Endemic species: regional or local	Tasmanian endemic genus	Gondwanan/Pangean species	species of unusual morphology/life-history
Austroperlidae	Austropentura sp*.	+			+	+			
	Crypturoperla paradoxa*				+		+		+
	Tasmanoperla thalia*				+	+	+		
Eustheniidae	Eusthenia spectabilis*				+				
	Eusthenia costalis*				+				
Gripopterygidae	Leptoperla varia*				+				
	Leptoperla Sp A*				+				
	Cardioperla flindersii*				+				
	Cardioperla diversa*				+		+		
	Cardioperla nigrifrons*				+		+		
	Cardioperla lobata*				+		+		
	Cardioperla incerta*				+	+	+		
	Cardioperla spinosa*				+		+		
	Cardioperla edita*				+		+		
	Cardioperla Sp B*				+		+		
	Dinotoperla marmorata*		+		+	+			
	Dinotoperla serricauda								
	Dinotoperla opposita*			+	+				
	Trinotoperla tasmanica*				+				
	Trinotoperla inopinata*				+				
	Trinotoperla zwicki*				+				
	Trinotoperla comprimata				+	+			
	Reikoperla triloba								
	Reikoperla pulchra*		+		+	+			
	Newmanoperla prona*			+	+				
Notonemouridae	Austrocercoides zwicki*				+				
	Tasmanocerca bifasciata*				+	+	+		
	Austrocerca tasmanica								
	Kimminsoperla albomaculata*				+				
	Notonemoura lynchii								
	Austrocercella cristinae*				+				

* denotes endemic species

Table 7.5 Trichoptera families indicative conservation values

Family	Status	Genera / species in Australia	Tas genera	Tas species	Number / % endemic to Tasmania	Possible conservation value
Atriplectidae	Restricted to Aus & Seychelles	1/1	1	1	0 species 0%	1 species only in Aus
Conoesucidae	Restricted to the Australian region	6/21	5	17	14 species 82%	Tasmania is the Australian stronghold for this family. Also abundant in New Zealand
Ecnomidae	Occurs in most faunal regions	2/22	2	6	5 species, 80%	
Glossomatidae	Occurs in all faunal regions	1/10	1	3	3 species 100%	The genus *Agapetus* also occurs in northern hemisphere
Helicophidae/ Calocidae*	Restricted to Australia and New Zealand	7/24	5	10	6 species 60%	
Helicopsychidae	Occurs in all faunal regions	1/6	1	2	1 species 50%	
Hydrobiosidae	Mostly Australian and Neotropical regions	14/57	10	29	20 species 66%	Related to northern hemisphere family Rhyacophilidae
Hydropsychidae	Occurs in all faunal regions	8/27	4	8	6 species 75%	
Hydroptilidae	Occurs in all faunal regions	12/101	6	15	5 species 33%	
Leptoceridae	Occurs in all faunal regions	14/80	10	28	7 species 25%	
Limnephilidae	Palearctic, Nearctic, Australia	1/3	1	2	1 species 50%	Largely neo-arctic family poorly represented in southern hemisphere
Odontoceridae	Scattered in most faunal regions	2/4	1	1	0 species 0%	Not recorded by Neboiss - 'thought to occur' in Tas
Oeconescidae	Australia & New Zealand.	1/1	1	1	1 species 100%	Only Australian species is endemic to Tasmania
Philorheithridae	Australia & Neotropical regions	5/13	5	9	7 species 78%	Half of the Australian species are endemic to Tasmania
Philopotamidae	All faunal regions	2/18	1	9	8 species 89%	
Plectrotarsidae	Australia	3/5	3	4	3 species 75%	2 genera endemic to Tasmania
Polycentropidae	All faunal regions	7/13	2	6	6 species 100%	1 genus endemic to Tasmania
Tasimiidae	Australia and Neotropical regions	2/6	2	4	3 species 75%	

* Some specimens are difficult to separate to family level (Jackson 1997) so included together.

7.5 Conservation values of taxa of the study sites

Criterion 1: Rarity

No taxa scheduled under either Commonwealth or state Endangered Species Acts were found at the study sites. The Commonwealth list includes a total of only four invertebrates, one of which is found in Tasmania, the giant freshwater crayfish *Astacopsis gouldii*. The sampling strategy did not target this species. Species listed under the Tasmanian legislation are heavily biased to certain taxonomic groups advocated by interested individuals rather than on any systematic or priority assessment. Several freshwater groups are represented including hydrobiid molluscs, caddis flies and taxa associated with karstic habitats or the Great Lake ecosystem (Bryant & Jackson 1999).

Table 7.6 Trichoptera families in Tasmania Conservation significance assessment

Family	Rating	Assessment of conservation significance
Atriplectidae	***	Only representative in Australia, uncommon
Conoesucidae	****	Highly endemic, numerous species, abundant, Australian stronghold for the family. Biogeographic significance
Ecnomidae	**	Highly endemic
Glossomatidae	**	All endemic species of a genus occuring in N and S hemispheres
Helicophidae/ Calocidae#	**	Moderate endemism
Helicopsychidae	*	Only species recorded in the study areas is endemic
Hydrobiosidae	**	Moderate endemism, southern hemisphere analogue
Hydropsychidae	**	Moderate endemism
Hydroptilidae	*	Some endemism
Leptoceridae	*	Some endemism
Limnephilidae	**	Biogeographic significance, family poorly respresented in southern hemisphere, moderate endemism
Odontoceridae	**	Confirm occurence, possible limit of range
Oeconescidae	****	High biogeographic significance as only Australian representative of this southern hemisphere family
Philorheithridae	***	Highly endemic, half of Australian species endemic to Tasmania, biogeographic significance
Philopotamidae	**	Highly endemic
Plectrotarsidae	**	Highly endemic, restricted to Australia
Polycentropidae	**	Highly endemic, restricted to Australia
Tasimiidae	**	Highly endemic, restricted to Australia

Some specimens are difficult to separate to family level (Jackson 1997) so included together.

Criteria and thresholds for the Commonwealth legislation rely entirely on impacts, or expected impacts, of threatening processes on the status of the species (EPBC Act 1999). Habitat requirements, distributions, and critical population sizes are poorly known for many stream invertebrates in Australia, and none of the taxa recorded in the study met this threshold. Since no species at the study sites are scheduled under the Threatened Species Act, none can qualify as 'vulnerable'. The plecopteran assemblage associated with high altitude streams of grassland areas of the north-east may be considered threatened since much of this vegetation community has been lost to plantation forestry and agriculture. The remnants may be subject to natural succession to scrub then forest. However, no formal assessment or comparisons with similar habitats has been undertaken.

Using data from the survey undertaken in this study (Chapters 4 and 6) together with evidence from the MRHI survey (Davies and McKenny 1997; Oldmeadow *et al* 1998 and Chapter 5), and documented records (Hynes 1989; Neboiss 1981), several taxa from the study sites meet the criteria for listing as rare under the Tasmanian Threatened Species Act. Several others appear to be uncommon and therefore may be considered candidates for protection. However, listing on the Tasmanian Threatened Species Protection Act 1995 is a requirement for critical habitat definition and thus the basis for species protection. Hynes (1988) identified some plecopteran species as at least 'uncommon' and such species in the study samples reflected this assessment of their status.

Of those Plecoptera species recorded in the study, one, the sole Tasmanian representative of the genus *Austropentura* has a range of less than 100 by 100 km (r1), two, *Reikoperla pulchra* and *Dinotoperla marmorata* occur in 20 or less 10 km by 10 km AMG squares (r2) and two, *Newmanoperla prona* and *Dinotoperla opposita* are taxa which have very small and localized populations (r3). A further four species are new or apparently new records for Tasmania and may also fall into one of these categories.

Only Plecoptera were identified to species level but other taxa may be included if a family is represented by single species in the state. The trichopteran *Tascuna ignota* (Oeconescidae) is such a taxon. Taxa which are considered of conservation value on the criterion of rarity, together with the sites at which they occur, are summarized in Table 7.7.

Criterion 2: Richness

Two estimates of richness have been selected, taxon richness at family level and species richness for the Plecoptera (Figure 4.4 and Figure 6.1).

A comparison of the taxonomic richness of the study sites with those of the MRHI survey (Table 5.2 and Table 5.3) suggest that the study sites are among the more taxonomically rich river sites in Tasmania. Figure 5.2, a map showing the distribution of sites of high, medium, and low taxon richness using the MRHI-based data, shows that in the north-east there are few sites in the higher richness category. This suggests that the study sites in this region are particularly significant. It should be noted that the analysis of MRHI based samples in the RFA report (Davies & McKenny 1997) used only the most frequently occurring taxa with uncommonly occurring taxa deleted from the analysis, thus reducing the potential taxon richness.

Table 7.7 Taxa and sites of conservation value for rarity

Thresholds and attributes	Taxon	Site (s)
Endangered		
Vulnerable	*Cardioperla* Newitts Creek	NW
Rare r1	*Tascuna ignota* (Oeconesidae)	BC
Rare r2	Austropentura sp nov	CA FR RG DR MM MR SW
	Dinotoperla marmorata	CG VA DR
	Reikoperla pulchra	CB LR GP
Rare r3	*Cardioperla* 'Newitts Creek'	NW
	Leptoperla aff. bifida	MR
	Trinotoperla/Nebiossoperla	SW
Uncommon	*Dinotoperla opposita*	BO
	Newmanoperla prona	SW
Threatened community	High altitude native grassland stream communities	PA GP NW CG NE HM VA

Some sites in the study exhibited high species diversity of Plecoptera. Five sites had ten or more species representing all four families. Plecoptera species richness (ten or more species at some sites) may be compared with the total figure of 17 species for all rivers and streams of the Tasmanian Wilderness World Heritage Area (Chilcott 1987). The Tasmanian plecopteran fauna as a whole is more diverse than that of Victoria, which has a total of 42 described species compared with 47 in Tasmania (Hynes & Hynes 1980). The mainland sites close to Tasmania in the Otway ranges and South Gippsland, each have 15 recorded species (Hynes & Hynes 1980) while sites in the mountainous areas of the Upper Snowy and Upper Bemm Rivers catchments have total Plecoptera taxon richness of 11 and 16 species respectively from all sites (Doeg 1995b; Doeg 1997). Doeg's data is based on only a single sampling occasion for 25 (Upper Snowy) and 17 (Upper Bemm) sites. The highest plecopteran taxon richness at any single site was 7 species. The highest number of Plecoptera species found at any individual site in the Grampians area of Victoria was also seven (Doeg 1995a).

It is notable that there were no north-eastern sites among the richest sites by all taxa, but three of the five highest sites for Plecoptera were located in the north-east. With the exception of Gravel Pit Creek GP, all sites with high diversity had a moderate forest canopy or in the case of Coldstream grassy, CG, substantial woody debris. Gravel Pit creek flowed from a wooded area with the sampling site approximately 50 m downstream of the forest.

Applying the threshold of the top ten percent of sites, the following sites fall above the nominated threshold (Table 7.8).

Table 7.8 Sites important for high taxon richness

Thresholds and attributes	Sites
High taxon richness at family level	JU CG SF BC SU
High Plecoptera species richness	PD GP MM PP SW

Criterion 3: Representativeness

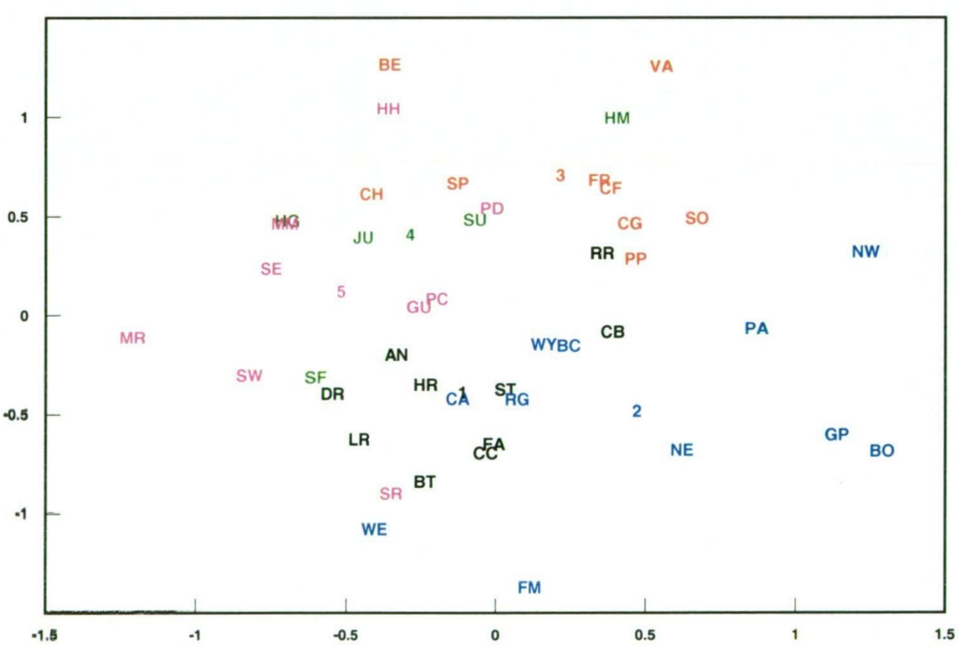
The macroinvertebrate communities among the sites surveyed were quite similar in broad taxon composition. This is in agreement with the data from the MRHI survey and the RFA survey which also found low level of discrimination of community groups in the classification and ordination of the data (Oldmeadow *et al* 1998; Davies & McKenny 1997). Analysis of the Plecoptera species data also suggested broadly similar community structure by this group.

Analysis of the family level study data by taxonomic functional feeding group did reveal some differences among community structure (Figure 4.9). This analysis confirmed a community typical of acidic streams, with lower taxon diversity and abundance, increased proportions of Plecoptera, lower proportions of trichopteran taxa, and an absence of Molluscs.

Sites that may be considered representative of macroinvertebrate assemblages were selected by statistical methods from the study data. Centroids were calculated from the TWINSPAN classifications of site groups and then plotted on MDS ordinations of the data. The closest site to the point of the centroid may be regarded as the 'best' representative of that group of sites.

Each of the classifications of the study data was subjected to this analysis. The location of the centroid was determined by taking the mean of all sites within each TWINSPAN group and plotting this spot on the MDS. In each case the closest site to this centroid spot was selected as the representative site for that TWINSPAN group. One example is shown in Figure 7.1. TWINSPAN sites are colour-coded with the centroids for that group shown as a number in corresponding colour.

Figure 7.1 Ordination of study sites (raw data) showing centroids for each site group



north west sites north east sites

The closest sites to the centroid of each site group for the three analyses are shown in Table 7.9.

Table 7.9 Site closest to the centroid of each TWINSPAN group

Raw data, all taxa		Functional feeding group analysis		Plecoptera	
TWINSPAN Group	Site	TWINSPAN Group	Site	TWINSPAN Group	Site
I	ST/AN	I	PC	I	CC
II	NE/CA	II	ST	II	PC
III	FR	III	CH	III	DR
IV	JU	IV	RG/CA	IV	VA
V	SW/PC	V	PP/SU	V	SP
		VI	JU		

north west sites   north east sites

For the purposes of proposing sites of conservation value, it is suggested that particular site types be nominated as a sub-set of the possible sites identified in Table 7.9. Applying the second decision rule for this criterion, the sites should represent communities or assemblage that can be associated with environmental variables or descriptions. In some cases there was a clear overlap in characterisation of the community according to more than one analysis and these were combined. Selected communities and assemblages and representative sites are shown in Table 7.10.

Table 7.10 Sites of high conservation value for representativeness

Representative communities	TWINSPAN group	Sites
Community typical of low altitude acid streams of NW, naturally low taxon richness	All taxa I FFG II	AN or ST
Community typical of small, high altitude headwater streams of NE and NW, in both forest and grassland	All taxa II	CA, NE
Community typical of rivers and large streams of forested areas at moderate altitude	All taxa III	FR
Community typical of moderate rivers and large streams of high conductivity with high taxon diversity (TWINSPAN groups taxonomic/feeding group analysis V and VI, raw data analysis group)	All data IV FFG V and VI	JU PP
Community dominated by diversity of EPT taxa in forested streams	All taxa V FFG IV	CA
Plecopteran assemblage of low altitude western sites only	Plecoptera I	CC
Plecopteran assemblage typical of westerly sites with high taxon diversity	Plecoptera II and III	PC
Plecopteran assemblage typical of forest streams more easterly	Plecoptera IV	SW
Plecopteran assemblage of high altitude easterly streams	Plecoptera V	SP

north west sites   north east sites

Criterion 4: Biogeographic and phylogenetic significance

The fauna of Tasmania's freshwater environments is widely recognized for its high degree of endemism, Gondwanan affinities, importance for interpretation of geological history and climates of Australia and of the interpretation of phylogeny of several key groups (Environment Australia 1998; WCMC 1998; Wilson & Johnson 1999; Zwick 2000). Table 7.5 and Table 7.6 illustrate such values for one group, the Trichoptera families. Plecoptera species values are shown in Table 7.4.

The Plecoptera are highly endemic in Tasmania. Some species are widespread within the state. Of those recorded in the present survey, six were confined to one or other region - west or east of the state. *Austropentura* sp., and *Cardioperla* 'Newitts Creek', and were confined to the eastern region, while *Tasmanoperla thalia*, *Cardioperla incerta*, *Dinotoperla marmorata* and *Trinotoperla comprimata* were only found in the west. New records of *Crypturoperla paradoxa*, *C. lobata*, *Trinotoperla zwicki* and *Tasmanocerca bifasciata* indicated outlying populations in the eastern regions of these species previously described as being from the west only. Three genera are endemic to Tasmania: *Tasmanoperla* with three described species, *Crypturoperla*, a monotypic genus and *Cardioperla* with nine described species and a further three undescribed species.

The families Austroperlidae, Gripopterygidae and Eustheniidae are all ancient families with Gondwanic distributions. Thus the endemic species of these families are of special biogeographic interest. The non-endemic species of these families, of which the only three recorded in the present study, were the gripopterygids *Dinotoperla serricauda* and *Reikoperla triloba* and *Trinotoperla comprimata* also occur in Victoria and New South Wales.

The phylogenetic significance of the Plecoptera lies at family level. All the four Australian families are considered of interest (Campbell *et al* 1986; Hynes & Hynes 1980). Campbell *et al* (1986) map the distributions of the three families and some sub-families of Antarctoperlaria and suggest that while Tasmania has the Gripopterygidae and Austroperlidae in common with New Zealand, mainland Australia and South America, the sub-family Eustheniinae is not found in New Zealand. Despite common families, at species and in three cases (*Crypturoperla* and *Austropentura*: Austroperlidae and *Cardioperla*: Gripopterygidae) genus level, there is considerable endemism. This raises questions of how, or at what stage, the speciation occurred. Hynes & Hynes (1980) claim that 'clearly, because it is the southernmost, coldest wettest part of the continent, some Tasmanian endemism is ecological' (p 86). This argument is supported by the number of mainland species that are restricted to high mountain stream habitats (Campbell *et al* 1986). Tasmanian endemic taxa that are restricted to high altitudes may be considered relictual species.

The Plecoptera are considered as a whole to have importance in phylogenetic and biogeographic studies of freshwater groups (Zwick 2000). Tasmania has particular significance for the Australian fauna because of its high endemism, the glacial history of the landmass (Colhoun & Hannan 1990), and the probable retention of moist climates and hence cool well-oxygenated streams since the Tertiary (Ollier 1986; Kirkpatrick 1997). Paleobotanical evidence suggests that during the late Pleistocene, the eastern part of the state was drier than it is today (Ellis 1985) although rainforest species such as myrtle *Nothofagus cunninghamii* and celery-top pine *Phyllocladus aspleniifolius* retained a presence in the eastern highlands, which is the core eastern study area.

Several of the plecopteran taxa have distinctive morphologies, which are very different from the streamlined and mobile body form typified by genera such as *Leptoperla*, *Trinotoperla* or *Austrocerca*. All the austroperlids have sturdier body shapes and are very slow-moving, their antennae and cerci are shorter and more robust. *Crypturoperla* has stout posterolateral spines on each side of the abdomen. The function of these spines is unclear but interestingly, some species of *Cardioperla* have similar though less well-developed structures, and paired abdominal protuberances also occur in some species of elmid beetle larvae which occur in similar forest stream habitats (Glaister 1999).

Particular taxa can be demonstrated as of high conservation value on the basis of their biogeographic values. The thresholds to be applied are defined in Table 7.2. The occurrence of a taxon, which reaches the threshold of biogeographic significance, is recorded together with the study site(s) at which it is present. The results of this analysis are provided in Table 7.11.

Table 7.11 Biogeographic significance of species and sites

Attributes	Taxa	Site(s)
Endemic (Tasmania)	Numerous taxa, various orders and families	All sites
Endemic - regional or local	*Austropentura*	CA FR RG DR MM MR SW
	Tasmanoperla thalia	BC CB CH CG CC FA GU HR JU PC PD PP RR SF SR ST
	Cardioperla incerta	HR JU PP SO ST
	Cardioperla Newitts Creek	NW
	Dinotoperla marmorata	CG VA
	Trinotoperla comprimata	CC
	Reikoperla pulchra	CB LR
	Tasmanocerca bifasciata	BC CB CC FA GU HH ST
	Tasmanophlebia lacustris (Ephemeroptera: Oniscigastridae)	BC CF CG FA PP
	Tascuna ignota (Trichoptera: Oeconescidae)	BC
Endemic - genus or above	*Cardioperla*	All *except* AN CH GU HG HM
	Crypturoperla	BC PP RR RG MM SW
	Tasmanoperla	BC CB CH CG CC FA GU HR JU PC PD PP RR SF SR ST
	Tasmanocerca	BC CB CC FA GU HH ST CA WE
Monotypic genus	*Crypturoperla paradoxa*	PP RR RG MM SW
	Tasmanocerca bifasciata	BC CB CC FA GU HH ST CA WE
Gondwanan affinities	All Plecoptera	All sites
	Oniscigastridae	BC CF CG FA PP
	Oeconescidae	BC
	Atriplectidae	CG CH HH NE
	Conoesucidae	Widespread, most sites
	Philorheithridae	Widespread, most sites
	Phreatoicidea	BC CF CG GU HH JU NE RG SE SP BO CA FM FR GP PA SW WE
Taxon at the limit of range	*Crypturoperla paradoxa*	BC PP RG MM SW
	Cardioperla incerta	LR
	Trinotoperla inopinata	SW MM
	Archaeophylax ochreus (Trichoptera: Limnephilidae)	WY
Outlying population	*Crypturoperla paradoxa*	RG MM SW
	Cardioperla lobata	BE WE
	Trinotoperla zwicki	SW WY
	Tasmanocerca bifasciata	CA WE
	Archaeophylax ochreus	CA PA WY
Unusual morphology or life-history	*Crypturoperla paradoxa*	BC PP RR RG MM SW
	Nannochoristidae	BC RR SU BE BO CA FR MM PA RG SP

north west sites   north east sites

In addition to data on Plecoptera species, several other taxa are included in the table. These include taxa that are the single species representatives of a family recorded for Tasmania. *Tasmanophlebia lacustris* is the sole species of the family Oniscigastridae (Ephemeroptera) and regionally endemic to western Tasmania. The family has only three genera, one each in Australia, New Zealand, and South America (Campbell 1988). This taxon is therefore of significance as a regional endemic and for its Gondwanan affinities. It occurred uncommonly in riverine habitats but is also found in lentic habitats so may not be considered rare.

Tascuna ignota is the sole Australian member of the Oeconescidae (Trichoptera) and is only found in Tasmania. The remaining five genera of this family occur in New Zealand (Neboiss 1988). It was found at only one study site, Biscuit Creek in the upper Coldstream catchment, and at only two of the 354 sites in the MRHI based surveys. Thus *Tascuna ignota* is of importance for biogeographic reasons as well as being an uncommon species.

Two species of limnephilid caddis are recorded for Tasmania (Neboiss 1981), one of which is restricted to the area close to the original Lake Pedder in the southwest. The Limnephilidae is widely distributed in the Palearctic and Nearctic regions but is represented in Australia by only a single genus with three species (Neboiss 1988; Environment Australia 1998). *A. orcheus* is generally a western species with a disjunct population in the north-east. The species was found at two sites in the north-east highlands area, Cascade Creek CA and Paradise Creek PA. The record at Wyniford River WY in the Blue Tier area represents an easterly limit of range on the boundary of this eastern population.

Other families, which are of particular interest for their Gondwanan affinities, include the Atriplectidae, Conoesucidae and Philorheithridae (Trichoptera) and the crustacean group Phreatoicidea. The Atriplectidae is small with only two monotypic genera, one in each of Australia and the Seychelles. The Australian species *Atriplectides dubia* occurred at a few sites in both the study survey and the MRHI samples.

Tasmania appears to be a centre of speciation for the Conoesucidae in Australia: of the total of 20 Australian species, 14 are endemic to Tasmania and only two are not recorded in the state (Neboiss 1988). The Philorheithridae is restricted to Australian and Neotropical regions, and is a highly endemic group in Tasmania at species level.

However, since these families were not identified to species level, no detailed assessment of conservation value could be undertaken. They occurred widely through both areas surveyed in the study.

The Phreatoicidea are of considerable biogeographic interest and highly endemic in Tasmania (Wilson & Johnson 1999). Several species are listed under the Tasmanian Threatened Species Act 1995, but these are distributed within the Great Lake catchment area. Sites at which these taxa occurred are noted but no further assessment of specific conservation values was undertaken.

7.6 Identifying stream sites of particular conservation value

Table 7.7 to Table 7.11 summarize evidence of taxa of conservation value and the sites at which these taxa occur. Table 7.12 summarizes this information on a site basis, with each taxon record appearing as '1' in the table. A crude 'conservation score' may be compiled for each site by addition of these records. These conservation scores are shown in rank order in Table 7.13. These scores must be treated with caution since no weighting has been given to different items, the occurrence of some taxa provide a score under different attributes (and therefore may be considered double-counting) and some low-scoring sites may be highly significant for one or a few attributes only. Notably sites that have been identified as representative of a particular community or assemblage (Table 7.10) could fall into lower indicative score categories. Conversely, sites with high indicative scores might not be captured by a reservation system based only on assessment of representative riverine macroinvertebrate communities.

Table 7.12 Occurrence of attributes of conservation value at each site in western and eastern study sites

Criteria and attributes	AN	BC	BT	CB	CC	CF	CG	CH	FA	GU	HG	HH	HM	HR	JU	LR	NE	PC	PD	PP	RR	SF	SO	SR	ST	SU	VA	BE	BO	CA	DR	FM	FR	GP	MM	MR	NW	PA	RG	SE	SP	SW	WE	WY
Criterion 1: Rarity																																												
Vulnerable																																					1							
Rare r1		1																																										
Rare r2				1			1									1											1			1	1		1	1	1	1			1			1		
Rare r3																																				1	1					1		
Uncommon																													1													1		
Threatened community							1						1				1										1							1			1	1						
Criterion 2: Richness																																												
High taxon richness at family level		1					1								1							1				1								1	1							1		
High Plecoptera species richness																			1	1														1	1							1		
Criterion 3: Representativeness																																												
Macroinvertebrate communities or assemblages of:																																												
low altitude acid streams of NW	1																								1																			
small, high altitude headwater streams																	1													1														
large streams of forested areas at moderate altitude																																	1											
large streams of high conductivity															1					1																								
forested sites with high diversity of EPT taxa																														1														
Plecoptera of low altitude western sites					1																																							
Plecoptera of moderate altitude western sites																		1																										
Plecoptera of easterly forest streams																																										1		
Plecoptera of high altitude easterly grassland streams																																									1			
Criterion 4: Biogeographic significance																																												
Endemic - regional or local		1		1	1	1	1	1	1	1		1		1	1	1		1	1	1			1	1	1		1			1	1		1		1	1	1		1			1		
		1		1	1		1		1	1				1						1					1																			
		1		1	1		1		1											1					1																			
		1																																										
Endemic - genus		1	1	1	1	1	1		1			1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1
		1																		1	1														1				1			1		
		1		1	1		1	1	1					1	1			1	1	1	1	1		1	1					1														
		1		1	1				1	1															1																			
		1		1	1					1		1																															1	
Monotypic genus		1		1	1				1	1		1								1	1				1					1					1				1			1	1	
Gondwana affinities		1				1	1		1											1									1					1										
		1					1	1				1					1																											
		1				1	1			1		1			1		1													1		1	1					1	1	1	1	1	1	
Taxon at limit of range		1														1				1															1				1			1		
																																			1							1		1
Outlying population																												1		1					1			1	1			1	1	1
																														1												1	1	1
Unusual morphology or life-history		1																		1	1					1		1	1	1			1		1			1	1		1	1		
		1																			1														1				1					
Total	1	18	1	9	9	4	11	3	8	6	0	6	1	4	6	4	5	4	4	12	6	3	2	3	8	3	4	3	4	11	3	2	5	6	12	4	5	5	10	2	4	16	6	4

Table 7.13 Indicative conservation scores

site	score	site	score
BC	18	HR	4
SW	16	PD	4
PP	12	SR	4
MM	12	VA	4
CG	11	BO	4
CA	10	DR	4
RG	10	FR	4
CB	8	MR	4
FA	8	SP	4
CC	7	WE	4
JU	7	WY	4
RR	7	CH	3
ST	7	SU	3
NW	6	BE	3
CF	5	LR	2
GU	5	FM	2
HH	5	SE	2
NE	5	BT	1
PC	5	HM	1
SF	5	SO	1
GP	5	AN	0
PA	5	HG	0

north west north east

The site with the highest indicative score was Biscuit Creek BC, a very small class 4 (headwater) stream in the upper Coldstream catchment in the northwest. Taxa of conservation value found at the site include all the four endemic Plecoptera genera and three regionally endemic Plecoptera. It was the only site where *Tascuna ignota* (Trichoptera: Oeconescidae) was found. Other taxa of biogeographic significance included Nannochoristidae, Oniscigastridae, Phreatoicoidea and several trichopteran families. Notably, the Tasmanian endemic plecopteran *Crypturoperla paradoxa* was found there, a northerly extension to its range. Other sites in the western study area with high scores are Coldstream 'grassy' in the upper reaches of the Coldstream River on Knole Plain, and Clearwater Creek, a tributary of the Little Donaldson River.

The first easterly records of *Crypturoperla paradoxa* contributed to the high conservation values of the sites Memory Creek MM, Sweets Creek SW and Ringarooma River at the upper Maurice Road RG. The presence of this taxon suggests a relictual population in the north-east highlands area. Other taxa of conservation value include the regional endemic *Austropentura* sp. nov. (Plecoptera: Austroperlidae), Nannochoristidae, and Phreatoicidea. The two sites in the upper South Esk catchment, Memory Creek MM and Sweets Creek SW were the limit of range of *Trinotoperla inopinata,* and an outlying population of *Trinotoperla zwicki* was identified at Sweets Creek.

With the exception of site CG, all sites with a 'score' of 10 or more occurred in forested sites four of which were rainforest and the remaining two in mixed sclerophyll forest. All were above 400 m altitude.

Other sites with lower scores may however exhibit values not represented amongst the highest scoring sites. For example, Newitts Creek NW is the only habitat of an undescribed species of *Cardioperla*, and a threatened Plecopteran assemblage. *Dinotoperla opposita* is an uncommon plecopteran which only occurred at Bonnies Creek. The Sterling River was identified as a representative of a macroinvertebrate community of acid streams of the west coast and the Julius River representative of the high taxonomic diversity, high conductivity streams of the north-west. Neither of these types is captured amongst the highest scoring sites. Clearly if all macroinvertebrate values are to be recognized and protected, a simple scoring system is an inadequate basis for assessment. Nevertheless it has provided a method for mapping values, and the basis for further analysis should systematic protection of rivers be considered.

7.7 Summarizing conservation value assessment

Table 7.13 illustrates one approach to summary of the values assessment: a simple addition of each occurrence of any attribute. Problems are associated with this approach. These include 'double dipping' where the presence of a taxon may rate under different attributes such as endemic genus and species at the limit of range. If the purpose of the assessment is to gain an appreciation of biogeographic values this inherent weighting may be immaterial, but it may create a bias that is unacceptable for other comparative purposes. If the primary purpose of the assessment is to identify hot spots for rare species or high taxon richness, then these values will require greater weighting than other values. Similarly, if the purpose of the assessment is to select sites for a system of riverine reserves, 'representativeness' may be the essential criterion. A further problem with any system of combining different attributes is that some may be auto-correlated, for example with the rather uniform nature of aquatic macroinvertebrate communities in Tasmania, sites with several rare taxa are also likely to have higher species richness.

In practice, river scientists and managers regard some values as more important than others (Boon 1997). SERCON (Boon *et al* 1997) uses a system of weighting for each element of the SERCON analysis. To arrive at a 'score' for each attribute, the outcomes of the SERCON assessment are mapped on a usually five-point scale or 'quality band', and then multiplied by the weighting for that factor. These weighted scores can then be summed to provide a SERCON criterion weighted index in the form of a numerical score and a rating by quality band (Boon 1997). The system proposed by the Queensland Environment Protection Agency (Phillips *et al* 2000) follows a similar strategy. Both SERCON and the QEPA assessment process reject a final overall score such as that proposed by O'Keeffe *et al* (1987) in the earliest attempts to develop such an approach to river conservation assessment. Use of the criterion indices will vary according to the aim of the assessment process. For example, if the aim is to select important river sections for rare species, then the rarity criterion would be paramount, while plans for a CAR system of riverine reserves would place high value on representativeness.

Weightings and quality bands must be developed and endorsed collaboratively between river scientists and managers with reference to the aims of the conservation assessment. The SERCON weighting was determined by survey of a project specialist group comprising 161 individuals with a broad spectrum of expertise relevant to conservation. Assigning a rating or quality band can have several uses. It may form the basis of site selection where the specific aim has been made explicit. A rating provides a mechanism for monitoring change over time or setting priorities for management intervention, rehabilitation, or restoration. It can also act as an incentive for improvement.

Categories of quality band or scale should be derived by reference to an expert panel within a particular assessment context or process. Similarly, weightings need to be agreed amongst stakeholders. This step was beyond the scope of the present study which also lacked a management context for any application of the outcomes of the conservation assessment.

7.8 Conservation values in landscape and catchment contexts

Although the criteria and attributes for analysis were drawn from commonly agreed or accepted criteria for terrestrial systems, the particular characteristics of riverine environments suggest that other additional criteria may be important.

A further dimension of the conservation values of some sites lies in the value of the macroinvertebrate community in a landscape context. A macroinvertebrate community of a riverine sample site located at low altitude, yet in an undisturbed catchment and landscape context, is unusual on a world scale. Such sites are not only of interest in themselves but important as reference and research situations for gaining a better understanding of natural river processes and models. Winterbourn (1981) and Lake *et al* (1985) have discussed the relevance of the River Continuum Concept (Vannote *et al* 1980) to southern hemisphere riverine systems, suggesting that the processes, dynamics and communities of Australian and New Zealand rivers generally do not follow its precepts. Sites or river sections which provide evidence of river dynamics in the southern hemisphere may be considered of significance from a landscape perspective.

The Arthur River, of which several sampling sites in the north-west are tributaries (Hellyer, Sumac, Holder, Julius, Stephens and Lindsay), is the last remaining major river in Tasmania without significant hydro-electric development from headwaters to mouth. It lies generally in the northern hydrological region of Hughes (1987) and present a rare example of representative, unregulated, temperate southern hemisphere river system and thus the entire catchment is of high conservation value.

Groups of stream sites which together form the headwater streams of a subcatchment with particular characteristics or conservation significance may also be considered of special interest. Such groups of sites include the Coldstream catchment sites (Coldstream grassy and Coldstream forest, Netherby Creek, Biscuit Creek and Coldstream at Huskisson), Upper South Esk sites (Paradise Creek, Newitts Creek, Gravel Pit Creek, Memory Creek, Sweets Creek and Farrells Creek), and the creeks draining into the Ring River at Rosebery (Ring, Conliffe and Cableway Creek). Some of these site clusters appeared to have distinctive taxa while there were also many common elements between the component streams.

The sites Coldstream grassy CG and streams in grassland areas of Paradise Plains in the north-east (PA, NW, GP) under some analyses fell into TWINSPAN groups with sites from forested areas. Each of these sites was in an area of grassland which had evidence of prior forest elements. These sites are of interest for research into the hypothesis of influence of prior land use on stream macroinvertebrate communities (Harding *et al* 1998).

Smaller streams and class 4 headwater streams appeared to be often of particular value. Such sites often had high indicative (raw) scores for conservation value (Table 7.13) and some taxa were only recorded at such sites. Ten of the twelve sites with highest indicative conservation scores were rivers or streams of less than 5 m width. A Spearman correlation failed to demonstrate a significant relationship between indicative score and stream width though, of course, the indicative scores were arbitrary measures. Other approaches such as weighting of values, might have given a different result. The presence of some uncommon taxa, restrictions of other taxa to smaller streams and the presence of taxa beyond usual range suggests that the value of smaller streams warrants further investigation. Further research needs to be done to establish the significance of these sites: one explanation lies in the shallow water column precluding the invasion of exotic trout species which are aggressive predators of macroinvertebrates.

Attempts were made to explore correlations between sites with high conservation values and measures of river disturbance using the Wild Rivers Index and its components. However, since all sites were in relatively undisturbed condition, it was difficult to discriminate whether there were clearly special macroinvertebrate values at sites in more natural condition. Nevertheless, naturalness of the macroinvertebrate communities may be considered an important criterion of conservation value, as changes to community composition are well-established as a consequence of a range of types of disturbance at both point-source and catchment scales (Campbell & Doeg 1989; Lake & Marchant 1990; Barmuta *et al* 1992; Collier 1993 a,b; Frissell & Bayles 1996; Gore 1996; Harding *et al* 1998; Pringle 2000; Schofield *et al* 2000). Streams presently in natural condition may be of particular significance given the argument that present-day riverine communities reflect earlier land use patterns of decades ago (Harding *et al* 1998). If this is the case, riverine habitats and ecosystems, which appear to be in 'good' condition even where some river disturbance has occurred, may simply be continuing on borrowed time.

Chapter 8

Principles and issues in the conservation assessment process

General principles and issues in assessment and evaluation procedures will first be discussed, and then the actual strategies adopted for the study will be examined. Limitations, constraints, and issues emerging from the field study are discussed. Implications for river conservation assessment in Australia are identified.

8.1 Assessment principles

8.1.1 Assessment purposes

Usher (1995) identifies five key elements that must be addressed in planning for a monitoring program[1]: purpose, method, analysis, interpretation, and fulfilment. The first four of these elements are relevant to planning an assessment. Usher (1995) points out that these need to be dealt with in sequence because each step is reliant on decisions made at the previous one.

The purpose for the assessment needs to be defined at the outset. The purpose defines both the nature and the parameters of the process. The purpose indicates required standards and scope of the criteria for assessment. Thus assessment of riverine health usually is made relative to sets of accepted parameters of water quality and macroinvertebrate community composition (Boulton 1999; Ladson *et al* 1999; Karr 1999; Norris & Thoms 1999; Hart *et al* 1999) or using a reference framework, is

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[1] Monitoring, assessment and evaluation are distinct processes but they have some elements in common.

made relative to a spatial or temporal set of reference site data or conditions (Reynoldson *et al* 1997; Linke *et al* 1999). Protocols, standards, and scale of analysis may be already defined (Davies 1994; Wright *et al* 1989; Walker & Reuter 1996).

The standards used in an assessment include not only standards for technical aspects of the process but also for the process itself (Australian Heritage Commission 1996). Thus establishing the purpose of the assessment defines not only its parameters and data requirements, but also often also the standards for procedure and for interpretations of the outcomes.

The establishment of the purpose of the assessment is critical in natural resource and natural area management in order to:

- avoid conflict amongst interested parties,
- place the assessment in context, and
- foreshadow consequent management actions resulting from the assessment outcomes.

In the context of conservation assessment, the outcomes may include the identification of places to be reserved, priorities for conservation within a broader management context, implications for restoration or rehabilitation, or legal consequences from the identification of threatened species.

Much of the previous work on river assessment is directed to assessment of river health rather than of conservation values (Barmuta *et al* 1992; Fairweather 1999; Karr 1999; Norris & Thoms 1999). There is a long history of assessment of riverine health, starting with a utilitarian concept of health from a human health perspective to determine water quality standards for drinking water, through monitoring of various environmental parameters to including biological (e.g. macroinvertebrate) assessment as an indicator of system 'health'. This has now progressed to the setting of ecosystem protection standards including environmental flow requirements (ANZEEC & ARMCANZ 1996; Hart *et al* 1999). Present day assessments of health based on prediction of expected macroinvertebrate assemblages through the Monitoring River Health Initiative and AUSRIVAS (Davies 1994; Oldmeadow *et al*

1998; Davies 2000) brings the assessment of river health close to the assessment of conservation values. The MRHI differs from a conservation assessment in its purpose and hence has somewhat different criteria and thresholds, as well as different approaches to design of data collection, analysis, and reporting.

Defining the purpose is an important first step in conservation assessment (Dunn 2000). Conservation assessment may be conducted in order to identify a suite of 'representative' rivers for protection. Conservation assessment may have a focus on comparing rivers to set priorities for management, or simply to determine the conservation values of a particular river within a general catchment management context (Dunn 2000). Outside the river management context, conservation assessment may be undertaken for research purposes or to assess the conservation status.

Because definition of the assessment's purpose results in definitions of parameters for data requirements, scale, criteria, analytical procedures and reporting, it is often not possible to use data collected for one purpose for use in a different setting or for another purpose.

8.1.2 Criteria and thresholds

Criteria for assessment are identified as a result of defining the assessment purpose. In essence, these criteria are 'indicators' of the state of the system. River health indicators include: levels of coliform bacteria, pH, presence (or absence) of certain taxon groups, levels of dissolved oxygen and so on. More recently, Rutherfurd *et al* (1998) have suggested that river health is defined by five interacting elements: physical structure, riparian zones, water quantity, water quality, and organisms. This also illustrates that even if the purpose of an assessment such as river health is defined, the interpretation of the criteria which define 'health' may change over time.

In the case of conservation assessment, defining generally accepted criteria for 'conservation value' is a crucial starting point. These criteria may be defined by: criteria for legal protection (EPBC 1999); criteria identified in formal policy or strategy documents (EA 1998); criteria adopted for formal (i.e. legislated) conservation assessments (Tasmanian RFA 1997); consideration of external criteria for conservation value by for example international organizations or under international priorities or protocols (Ramsar Convention Bureau 1996; IUCN 1996; European Commission 1992), and emerging research-based criteria seen as important by the scientific community (www.nhm.ac.uk/science; WCMC 1998).

Thresholds are less readily defined, except where legislated thresholds have been identified, as in the case of threatened species or communities (EPBC 1999).

8.1.3 Data collection

Data collection methods should be designed to provide information that is relevant to the purpose of the assessment. Therefore consideration needs to be given as to how conservation values will be assessed (i.e. on what basis for comparison or by what standard), the scale of the assessment and comparison, feasibility of data collection and the quality standards that will apply. In reality, an ideal assessment process will be moderated by the practicalities of available resources including time, funds, expertise, and level of existing knowledge. In Australia, scarcity of ecological knowledge of stream biota is considered a major barrier to river restoration (Barmuta *et al* 1992), a situation that equally applies to conservation assessment. In Tasmania, river forms have not been documented or classified, thereby limiting the options for choice of scale for a conservation assessment.

Any conservation assessment will require a basis for comparison of the attributes shown at the particular site with those at other sites. Basic principles for making comparisons in any assessment include using evidence collected at places or sites on a similar scale and in a similar manner. Comparisons can only be made by comparing like with like, both in scale and in broad character. The more physically similar are the sites, the more readily a comparison can be drawn. Thus establishing a scale for analysis and comparison is a primary issue for resolution in design of an assessment.

There are a number of different approaches to classification of rivers and riverine habitats (Naiman *et al* 1992). These may be based on physical features of the river at a variety of scales or based on biological attributes, or a combination of the two (Naiman *et al* 1992). Evidence from the conservation assessment should be compared with similar data, collected at similar scales. The same authors provide detailed analysis of the advantages and disadvantages of using the various scales. The smaller the scale, the more feasible it is to collect comparable data, but important features of riverine processes are lost and the task of assessment becomes even more complex (Naiman *et al* 1995, Table 7.4).

8.1.4 Data analysis

A key principle of data analysis is that the methods adopted should be those generally agreed as meeting accepted standards for the particular discipline area. It is often the case that a range of different approaches to statistical analysis are available based on somewhat different assumptions and with different constraints on interpretation. Appropriate data analysis techniques should be selected according to the primary purposes of the assessment and applied with necessary caveats to interpretation.

8.1.5 Interpretation, summarizing and reporting

If the outcomes of the conservation assessment are to lead to management decisions, then both interpretation and presentation of results must be comprehensible to river managers who may not share the same levels of understanding as, for instance, a river scientist. Conversely, the reduction of data and its presentation should not obscure important information.

8.2 Addressing and managing these principles in the study

8.2.1 The purposes of the assessment

The primary purpose of the assessment conducted in this project was to provide a case study of a conservation assessment process in the riverine environment. The exercise of undertaking the assessment would enable an evaluation of the conservation assessment process that drew on a practical and real world problem. While a theoretical analysis of the process would have been feasible, it was felt that a practical exercise would highlight the realities not only of the technical aspects of the assessment but implications of the management framework.

As part of the primary purpose for the conservation assessment, a practical exercise using the field data was designed to enable analysis of the validity of particular conservation criteria for riverine systems.

The conservation assessment process also yielded some indicative Tasmanian sites of conservation value and this provided data with which to explore the protection options for these sites, and the issues that are inherent in establishing protection of riverine systems. This stage follows in Chapter 9.

8.2.2 Criteria and thresholds, interpretation and application

The four key criteria for conservation assessment - rarity, richness, representativeness and biogeographic value - are in common with conservation criteria for other types of ecosystem which have been subject to systematic efforts at conservation planning in Australia (see Chapters 2 and 3). There is value in such consistency as a basis for arguing a case for riverine conservation and gaining support from a wider field of ecologists, scientists, natural resource managers, and conservation interest groups. Consistency of accepted conservation criteria facilitates a shared basis for the argument for river conservation, for developing frameworks for assessment and for developing management agreements.

Criteria were selected which were *a priori* relevant to accepted conservation values (EA 1996; EPBC Act 1999; Tasmanian RFA 1997; www.nhm.ac.uk/science). Criteria, which might be used for assessment of river health, such as condition, disturbance, presence of exotic species, or 'naturalness', were not included, although measures of river wildness were considered as variables in the analysis. There is some debate as to whether condition and naturalness should be included as conservation criteria (QEPA 1999; Boon *et al* 1994; Dunn 2000). The arguments for each criterion are provided in Chapters 3 and 7.

Thresholds for the assessment of sites of conservation value were based on external standards where available or on clearly stated and argued decision rules (Table 7.2, Chapter 7). External standards were selected from the thresholds for threatened species listing under the Commonwealth and state Acts. Decision rules were largely modelled on decision rules adopted for the Tasmanian RFA (1997).

8.2.3 Data collection and the bases for comparison

Details of the survey procedure and sampling methods are given in Chapter 3. The chosen strategy was consistent with other surveys for conservation value assessment (see for example Doeg 1995a b; Quinn & Hickey 1990; Richardson & Serov 1992), namely, site collections covering the best possible range of types of site and numbers of sites within the specified area. The Surber sampling method was adopted to provide quantitative sampling over a standard area of streambed in a specified habitat type. Samples were taken over two years and two seasons to control for any gross seasonal or inter-annual effects. Checks on procedure for each step of sampling, picking and identification were conducted to minimize any possible inter-operator differences. None were found, although this was not done with a rigorous quality assurance/quality control methodology, it was done with replication of sample counts and identifications. A reference set of each plecopteran species was re-checked by an experienced entomologist.

Taxonomic resolution was limited by the absence of keys below family level for most groups at the time the study was undertaken. Thus the data are constrained to the family taxonomic level of analysis. A key to the Plecoptera was available but some taxa were impossible to separate on morphological features and some species remain undescribed. Taxonomic keys for more groups are now available but few of these resolve to species level for immature stages. Time resources were an additional limiting factor and it was decided that assessing more sites would achieve more project goals rather than studying fewer sites in greater detail.

Surber samples provide consistent collections of the fauna within a given area, and to a similar average depth. Using these Surber samples and picking and identifying every specimen maximized the likelihood of all taxa from the site being collected. The use of six samples and four sampling occasions at each site increased the likelihood of collecting taxa which are less common at that site. In contrast, the Monitoring River Health Initiative sampling protocol is designed for a different purpose, as a rapid assessment of the general state of the health of the river indicated by the macroinvertebrate fauna gathered over a 10 metre area of the river bed. Thus the use of MRHI data is somewhat problematic as a basis for comparison and to provide a state-wide context. In addition to the differences in sampling procedure and picking protocol, the published Tasmanian data analyses (Davies & McKenny 1997; Oldmeadow *et al* 1998) used data reduction techniques which eliminated uncommon taxa prior to site classification, though not for analyses of raw data.

The analysis using plecopteran species data might have been enhanced if all MRHI archived material was to have been identified to species level. However, this would have been a very large task and it would have been also confounded by the disproportionate absence of notonemourids from the MRHI data. There was also the possibility of a bias as a result of a difference between the two data sets in average stream size. It was decided to use the report and maps provided by Hynes (1988). Hynes drew on secondary sources for the Plecoptera database but the evidence was not systematic across the state nor over time. This source is, therefore, liable to have some gaps or inaccuracies. Absence of a systematic reference data set is a common problem in conservation analysis. The use of existing reports and references must be resorted to, a strategy adopted in the Tasmanian Regional Forest Agreement assessment process (Mesibov 1996; PLUC 1997).

As indicated, the Tasmanian MRHI data set in, as in other states, could provide a broad overview of potential sites of value but there are difficulties in using this material as a basis for comparison with data from a more detailed survey using different sampling techniques.

Modification of this study's data set by using the virtual subsampler (VMSS) (Marchant 1989; Walsh 1997) described in Chapter 5 to bring the study data closer to the MRHI data set, resulted in severe data reduction. Caveats concerning this procedure have been identified in Chapter 5. It may be concluded that the comparison of the survey data or the Marchant reduction against the MRHI data set is less than ideal. This is certainly the case: an extensive comparative data set containing data derived using the same sampling techniques would be preferable, but such is not the reality of much conservation analysis. Nevertheless, the VMSS procedure provided a consistent and statistically valid approach to providing a statewide context for the study data. In fact it could be argued that the MRHI data set provides a better basis for comparison than presently exists for many terrestrial invertebrate groups.

8.2.4 Data reduction, summarizing and reporting

There is general agreement (Boon 2000; QEPA 1999; Dunn 2000) that the original values must not be lost sight of if numerical scores or ratings are used to summarize the outcome. The detailed information provides essential information for conservation and management decisions. In addition, individually important values may be obscured when a river section achieves a low total score. If only high scoring rivers are considered to be of high conservation value, then some values, especially those associated with naturally low diversity streams, will not achieve recognition and protection.

Table 7.13 summarizes the total scores of values used to demonstrate *indicative* sites of high value in this study. These data should be considered in conjunction with the full data on conservation value (Table 7.12). If the assessment was undertaken with a specific management purpose, say the selection of a suite of rivers representative of macroinvertebrate communities or protection of rivers with uncommon or biogeographically significant taxa, then the choice of sites could be made according to the detailed information.

8.3 Limitations of the survey methodology and criteria

8.3.1 The conservation criteria

Rarity is the only criterion which gains the force of legislation to support moves for protection of a site since it is a well-established as a basis for conservation (IUCN 1996; Environmental Protection and Biodiversity Conservation Act 1999; Threatened Species Act Tasmania 1995). Even today, many scientists perceive rarity as the only, or major, characteristic which defines a species' conservation status (see for example, Hawking 1999; Horwitz 1990; Hutchings & Ponder 1999). The thresholds for listing or scheduling under the state or Commonwealth legislation generally present great problems when applied to invertebrate taxa generally (Hutchings & Ponder 1999), and are likely to pose particular problems in riverine systems. For example, a taxon may be confined to a single catchment but nevertheless occur in more than the number of 10 km grid squares prescribed as a threshold by the Threatened Species legislation because of the longitudinal nature of riverine systems. Such a taxon may have its distribution confined to a single catchment but cannot be considered threatened if it exceeds the threshold. At present, taxonomic constraints limit the possible listing of species in many orders of largely aquatic invertebrate groups. The current level of knowledge of the biology and ecology of most aquatic groups is an inadequate basis for assessment of threatening processes. In any case, scheduling of threatening processes can only be applied under Tasmanian legislation to species that are already listed.

In the present study, sites could be selected which were rich at a regional level, but in order to assess richness on a wider scale, comparison with MRHI data was attempted. A judgement was made based on manipulation of the survey data but because of the differences in sampling methodology, the outcome was not completely clear. This illustrates the difficulty of making such judgements, exacerbated by the use of family (or higher) level taxonomic data. Informal observation during sorting suggested, for example, that several different genera of some trichopteran families appeared to be present at some sites, while that family might be represented a single taxon at others.

Assessing sites as being taxon rich must always be a subjective process and should be referenced to comparisons with similar sites. There is no absolute standard or reference condition for what constitutes a site of special richness. Various authors (Marchant *et al* 1995; Growns & Growns 1997; Wright *et al* 1998; Hewlett 2000) have suggested that a general assessment of 'richness' in aquatic systems can be reliant upon family level but family level analysis is inadequate for the purpose of conservation assessment.

While to date most biodiversity assessments (i.e. assessment of taxon or species richness) have used a simple sum of the total number of taxa present, there are now proposals that this should be fine-tuned (www.nhm.ac.uk/science) to take account of different taxonomic levels and endemism. Thus, if two sites have a similar taxon richness, the site with more families represented in the biota is considered to be more diverse and of higher conservation value. Similarly, sites with higher numbers or proportions of taxa endemic to a place would be considered of higher value than a site with species which are widespread. Neither of these aspects of diversity were addressed in the present study, although the sites with endemic species did rate higher in the indicative conservation scores.

A Spearman rank order correlation showed that plecopteran species richness varied with the taxon richness for all taxa at family level. The pair(s) of variables with positive correlation coefficients and P values below 0.05 tended to increase together. However, both data are required in order to make a comprehensive assessment of conservation values for the sites. The emphasis on the utility of family level taxon richness values (Marchant *et al* 1994; Growns & Growns 1997), while it has utility for programs such as the Monitoring River Health Initiative could confound the debate on what constitutes conservation value of rivers for some stakeholders in river management.

Some aquatic systems are characterized by low taxon richness and are nevertheless natural in condition and representative of that river type (Bunn & Davies 2000). It is not clear from the Tasmanian data (both the study data and the MRHI data) acidic streams with low diversity are habitat for a distinctive suite of species or are simply characterized by the absence of certain taxon groups.

Some environmental parameters did correlate with the groupings derived using family level macroinvertebrate data (Table 7.12 and Table 7.13). However, there was an absence of clearly defined community structures and an overlap in environmental parameters. A preferred approach may be to define riverine habitats as the starting point for conservation assessment for riverine environments (Boon 1997) rather than on community composition. In the UK, the initial classification of riverine habitat was based on macrophytes (Holmes 1983) and now incorporates geomorphology (Holmes *et al* 1999). Two Australian states have adopted quite different systems, based at different scales. In Western Australia, broad groupings of rivers by drainage division and river morphology have been identified (WAWRC 1992; WRCWA 1997). In Queensland, a process of defining Baseline Aquatic Sections (BAS) is proposed to form the basis for assessment of riverine habitats (EPA 1999a). Neither of these systems in fully tested and implemented as a framework for determining conservation values, nor has there been detailed work on combining macroinvertebrate community data with river classification. A geomorphic classification of Tasmanian rivers is in preparation (K. Jerie pers. comm.) but it is yet to be seen how appropriate this will be as a basis for an integrated conservation assessment.

The difficulty of characterizing representative riverine faunal communities was evident in the study. It was apparent from both the survey data and from the MRHI data that, in Tasmania, where riverine habitats are in relatively undisturbed condition and river flows are more or less constant, macroinvertebrate communities are quite similar at family and functional level. Nor are there clearly evident community structures associated with different types of river habitats such as headwaters or larger watercourses. A finer analysis of community structure might be apparent if taxonomic resolution to species was possible.

Biogeographic values are becoming recognized in the scientific community as an important component of biodiversity conservation, both as intrinsic values and for the value in providing for protection of biodiversity at a genetic level (www.nhm.ac.uk/science; Tasmanian RFA 1998; EA 1997). Despite this, there is no formal recognition of biogeographic values in legislation or even in most approaches to planning of reserves for conservation. As a criterion, it is comprised of several often inter-correlated elements: endemic species, species at the limit of range or species in relictual or refugial populations. The 'taxonomic impediment' limits the ability to conduct a full assessment of the biogeographic significance of macroinvertebrates in Tasmanian streams since, in most cases, evidence of these biogeographic values must be presented at genus level, at least. While the aquatic fauna as a whole in Tasmania is highly regionally and locally endemic, this presents something of a dilemma in setting thresholds of significance for such a conservation value.

8.3.2 Conservation values in a landscape context

A particular perspective on site value is conferred by consideration of the site in a landscape context. Streams and rivers with undisturbed catchments at low altitude are uncommon in temperate regions on a world scale (Frissell & Bayles 1996). Thus the macroinvertebrate communities of such rivers may be considered to have special value. Groups of sites with important values within the same catchment may be considered to have added value as elements of a landscape or catchment sequence compared with single sites with similar values. Zwick (1991) and Frissell & Bayles (1996) highlight the problem of habitat fragmentation in riverine conservation resulting in small isolated sites that are effectively refuges in a sea of disturbance. Protection of a suite of sites within a catchment could be an important strategy to avoid this progressive erosion of sites of high value. Sites which have taxa not found in surrounding areas as a consequence of disturbance may also be considered high value at the landscape level because they provide a refuge from currently occurring threatening processes.

8.3.3 Naturalness as a potential conservation criterion

Naturalness was not included as a criterion in the present study for several reasons. Firstly, there was no readily definable reference condition for naturalness of faunal communities at the level of resolution required. Study sites were selected as far as possible to be in an undisturbed condition in order to explore natural variation among sites. Thus, the range of naturalness values was limited and not amenable to analysis. The study focused on exploring only macroinvertebrate values rather than all possible ecological values, although naturalness of macroinvertebrate communities could be a legitimate criterion in itself. Within the Australian context, protocols for assessing conservation values such as the Register of the National Estate or Regional Forest Agreements have generally used naturalness or condition as a parameter for selecting the most appropriate sites rather than as a selection criterion. Extensive areas of the landscape have been considered to be in a relatively undisturbed condition, although naturalness of the vegetation is now acknowledged to have been subject to modification over millennia by Aboriginal land management practices (Plomley 1996). Such modification would generally not apply to Australian rivers.

'Naturalness' is a criterion which is frequently adopted in systems for assessing conservation values (Boon 1997; Dunn 2000). Others consider naturalness to be an aspect of condition of a river rather than a value *per se* (EPA 1999b). The concept of naturalness has been a difficult one for assessment in most developed landscapes where distinctions between 'natural', 'semi-natural', and 'artificial' cannot be rigidly defined (Boon 1997).

Boon (2000) discusses the difficulties inherent in defining naturalness for riverine systems. In the Australian context, wilderness is an accepted conservation value for terrestrial habitats. Wilderness was used as a criterion for the Register of the National Estate and subsequently in Regional Forest Agreements (see Table 2.4 and Table 2.6, Chapter 2). It is also recognized as a World Heritage value (www.unesco.org/whc/nwhc/). Therefore it seems that river naturalness or wildness might legitimately be included as a conservation criterion or value in Australia, in addition to being an important parameter for selection of places for conservation[3].

In Australia, naturalness in the landscape has often been defined in terms of 'wilderness' which has been assessed using a number of quite specific measures of 'remoteness' and 'naturalness' to provide scales against which areas of the landscape can be mapped (Lesslie & Maslen 1995). The Tasmanian Wilderness World Heritage

[3] The extensive mapping of river wildness values might be seen as a potential source of electronically stored data for this purpose but it was found in Tasmania that there were difficulties with combining

Area Management Plan (1999) drawing on a discussion by Robertson *et al* (1992) defines a wilderness area as an area that is:

> of sufficient size to enable the long-term protection of its natural systems and biological diversity;
>
> substantially undisturbed by colonial and modern technological society, and
>
> remote at its core from points of mechanized access and other evidence of colonial and modern technical society. (TWWHA Management Plan 1999 p92).

'Wilderness' is a key element in protection of terrestrial landscapes in Australia, partly as an intrinsic value, and partly because it is used to delineate large-scale areas where ecological processes can operate generally independently of many human-induced changes. In a similar way, a project was undertaken to identify 'wild rivers' in Australia (Stein & Stein n.d.) with the aim of defining 'pristine' or 'near-pristine' systems for management. A number of parameters of naturalness were defined and combined into measures of river disturbance and catchment disturbance. The River Disturbance Index (RDI) is a measure of the extent of modification to flow regime and in-stream impacts, while the Catchment Disturbance Index (CDI) is a measure of change in the catchment. These were weighted equally to provide the Wild River Index (WRI), a summary of the 'naturalness' of the river or river section.

Efforts to determine any correlation between invertebrate communities or particular taxa with site values for Wild Rivers Index (WRI), River Disturbance Index (RDI), Catchment Disturbance Index (CDI) or Land Use Factor (LUF) in the study areas proved unsuccessful for this study. This may be partly accounted for by technical difficulties inherent in accessing the data for each site[4] which meant that some compromises had to be made and some values drawn by extrapolation from the river disturbance maps (PLUC 1997). This factor, coupled with the scale of the study site assessment being much smaller than the catchment units used for deriving the WRIs and the limited range of values for the key wild river parameters at the study sites, meant that the results have to be treated with caution.

All 44 sites in the study had relatively low values of the Wild Rivers Index (i.e. were less disturbed). All scored a zero classification for River Disturbance, that is, no

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the data for a number of technical reasons.

[4] A project officer from the GIS section of the Department of Primary Industry Water and Environment found that the projection used was not compatible with state databases, and that data were missing from some sites while data for other sites appeared to be incongruent with values shown on the wild rivers Excel database.

impacts on the instream flows or water quality were recorded in the Wild Rivers data. One possible impact on the 'wildness' of macroinvertebrate communities observed in the field study was the presence/absence of brown trout, possibly mediated by stream depth. Data on trout distribution was not available and not included in the WRI database. Further work needs to be undertaken to explore this issue.

Despite the inconclusive evidence from the present study, the potential value of the Wild Rivers database as an indicator of sites likely to be of high conservation value, and for identifying rivers with low disturbance levels, should not be discounted.

8.3.4 The scope of the study

The survey conducted in this study used a single sampling method targeting cobble substrates in riffles streambed sections. Thus assessment of the conservation values of the rivers undertaken was effectively limited to an assessment of values associated with this microhabitat. If a full analysis of all macroinvertebrate values were to be undertaken, other microhabitats would need to be sampled. Further sampling using different methods would be required to reflect all biological values of the sites. Other elements of the biotic value of the riverine habitats might include, for example:

- fish and larger crustacea;
- biota associated with macrophytes, pools, snags, edges or bedrock;
- lower plants and algae, and
- communities of riparian zones.

For example, an aquatic moss collected at Hellyer River at Moorey Road (HM), has been identified (A. Moscal pers. comm.) as *Andreaea australis* which is recorded as rare This is only its seventh record in Tasmania and it is a Gondwanan species found in the Australian Alps and New Zealand. Additional surveys would also be required to assess values for hydro-geomorphic values and ecosystem dynamics.

Analyses using broader scale assessments are now being developed and evaluated (Allan & Johnson 1997; Johnson 1997; Davies *et al* 2000) and could complement the Wild Rivers data and pending geomorphic classifications of Tasmanian rivers.

The scope of potential conservation values for Australian rivers has been identified (Dunn 2000). These values reflect many commonalities with conservation assessment undertaken in UK under the SERCON program (Boon *et al*.1997, 1998). Boon argues that conservation assessment should be 'integrated', by which he means wide in scope and bringing together a range of aspects of riverine features, habitats, and biota. The established experience in the UK, as well as proposals made in other countries for a similar range of values (Collier & McColl 1992; 1993; O'Keeffe *et al* 1987), reflects a general consensus on values similar to the directions emerging in Australia (EPA 1999b; Dunn 2000).

8.3.5 The use of point data

The survey site data, and also the MRHI data, provide only point information within a river section. How far can such data be extrapolated to represent a reach or section? With terrestrial habitats, sampling may be considered representative where the habitat is generally similar but riverine habitats are typically patchy at this scale (Cooper *et al* 1997). The longitudinal nature of the habitat and generally unidirectional flow of resources and stressor impacts create special problems for identification of a 'representative' sampling strategy.

There are two issues in this study – the potential for extrapolation of the data from point to reach and the extrapolation of macroinvertebrate point data to ecosystem/habitat assessment. These pose the questions: are the data from the site representative of the entire reach? And, are the macroinvertebrate data indicative of the conservation values of the ecosystem or habitat as a whole? Both these questions are important for assessment of the extent for the values of the river, and in determining strategies for protection.

8.3.6 Data reduction, summarizing and reporting

Summarizing value and making comparisons between sites using such data is fraught with technical and perceptual problems. Early attempts to assess conservation values of rivers (O'Keeffe *et al* 1987) focussed on reducing multi-value assessments to a single score. The work of Boon *et al* (1997, 1998) to develop the SERCON approach recognized that aggregating scores based on different criteria was problematic and also unhelpful in determining management requirements. A number of issues underlie these concerns:

- attribution of a numerical score to essentially subjective or arbitrary categories, quality bands or scales;
- whether or not different elements of the assessment should be weighted and if so, on what basis;
- validity and usefulness of summing scores, even within the same broad categories of criteria;
- utility of comparing rivers using a scoring system, and
- interpretation and perceptions of scores by river managers and the wider community.

There are a number of approaches which may be used to derive a numerical value or rating for each conservation attribute. These include simple presence/absence, a score ('1 - 5') or a rating ('A - E'). Categories are usually determined prior to the assessment. Some examples of the alternatives for classification of ratings are shown in Table 8.1 drawn from the QEPA methodology for the Water Resources Environmental Planning (WREP) for Water Infrastructure Planning, Implementation and Development Project (WIPDIP).

It should be noted that each attribute has a specific range, although in several cases these are arbitrary and subjective descriptive categories.

Table 8.1 also illustrates an approach to weighting with each attribute given a value according to the considered importance of that criterion. In the Queensland Environment Protection Agency WREP for WIPDIP process, scores are arrived at by multiplying the score of each river section (BAS) by its weighting and providing summary scores for each broad criterion. At each stage of summary, data is reduced and interpretation becomes more remote from the actual values. Figure 8.1 illustrates the steps involved in arriving at a single value score for a river through a stepwise assessment process. At Step 3 the real conservation values are masked as a classification, which then progressively is reduced by arithmetic means to a summary score. At each step, information is progressively lost about specific values which may be important for river management.

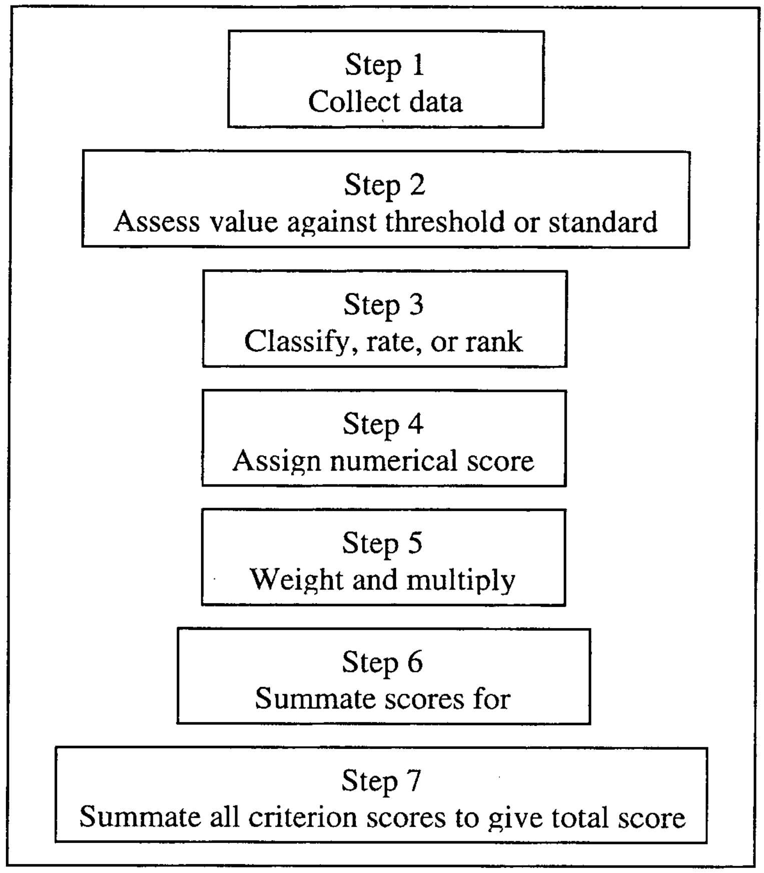
Table 8.1 Examples of scaling of indices, WREP for WIPDIP

Indicator measure	Scale	Rating (R) 1	2	3	4	5	Weighting (W)	Max. Score (R x W)
Uniqueness								
Geomorphology (eg. gorges, rock features, waterfalls, wetlands, substratum, longitudinal channel shape, channel cross-section)	c,s	Frequent examples			No other examples (unique)		4	20
Biology (eg. riparian, floodplain and instream communities, level of endemism	c,s	Frequent examples			No other examples		5	25
Naturalness								
Hydrology – • median annual (% of median natural flow)	c,s	‹50%			100%		1	5
• annual interbasin transfers (% of median natural flow)	c	100%			Nil		1	5
• floodplain inundation frequency (% of natural)	c,s	‹60%			100%		1	5
• bank full flow frequency (% of natural)	s	‹60%			100%		1	5
• depth of baseflow (variation from natural)	s	›50% (higher or lower)			Nil		1	5
Macroinvertebrates: • composition of flow preference groups (variation from natural)	c,s	High			Low		5	25
Condition								
Macro-invertebrates, variation from reference condition for: • expected/observed ratio	c,s	High			Low		1.7	8.5
• signal expected/observed ratio	c,s	High			Low		1.7	8.5
• composition of functional feeding groups	c,s	High			Low		1.7	8.5
Fish, variation from reference condition for: • species richness	c,s	High			Low		1.3	6.5
• composition of trophic status groups	s	High			Low		1.3	6.5
• composition of movement categories	s	High			Low		1.3	6.5
• age distribution	s	High			Low		1.3	6.5
Rarity								
Taxa, ecosystems or habitats identified as endangered, of concern or other conservation significance, but not listed under legislation.	c,s	None		Of concern		Endangered	5	25

c = catchment scale; s = subcatchment or project scale

Source: EPA 1999b

Figure 8.1 Steps in preparing a summary conservation assessment



The difficulties associated with summing these scores has been recognized by developers of the EPA program (EPA 1999b) and by Boon (2000). These authors each suggest that the preferred option for the assessment process is to provide a 'profile' of scores which offers river managers more detail of what the individual values are. Importantly, as noted by Boon (2000), this allows a conservation assessment profile to be applied to different management purposes or used for different conservation planning processes[5].

There is general agreement (Boon 2000; EPA 1999b; Dunn 2000) that the original values must not be lost sight of if aggregated numerical scores or ratings are used, for this provides essential information for conservation and management decisions. In addition, individually important values may be obscured by a river section achieving a low total score. If only high scoring rivers are considered to be of high conservation value, then some values, especially those associated with naturally low diversity

[5] In an analogous fashion the Victorian Index of Stream Condition, outlined in Chapter 2, provides a

streams, will not achieve recognition and protection. Another clear example is a stream which is known habitat for a significant threatened species but has no other high conservation attributes. A weighting system in a wide-ranging conservation assessment process would not necessarily reflect the importance of such a river unless specific decision rules were also to be applied.

A range of mathematical options (Boon 1994, 1997, 1998; EPA 1999b) is available for managers to weight scores: these will not be described here as the weighting should be part of a collaborative process designed and used for a particular assessment purpose. However, it is important to reiterate that in most instances a 'score', which is subsequently weighted, is not an absolute or even a relative mathematical value but a scale of arbitrary numerical values. Any scoring system, especially if weighting is adopted to provide summary information, needs to have such caveats applied to interpretation.

There are a number of options to providing a single score. These include: a profile of scores across all values, or groups of similar values for example SERCON; using the scoring as a series of 'sieves' to sort data for particular values such as representativeness; classification or grouping of rivers which meet descriptive criteria such as the NSW Stressed Rivers (Table 2.1) or US Wild and Scenic Rivers (Table 2.3), and defining decision rules to interpret weighted and/or aggregated scores for the purpose of comparing a number of different rivers. The purpose of the assessment should delimit how scoring, classifying and aggregating data should be applied to the data, and the options explored and defined at the outset of the assessment process.

8.4 Summary

Analysis of how the principles and issues underlying conservation assessment could be transferred into the practical exercise of an assessment in a riverine environment has demonstrated the range of problems, which need to be explored if such conservation assessment of Australian rivers is to proceed. While there is value in using commonly agreed criteria, these have limitations to the way in which these can be applied in riverine ecosystems. Many assumptions underlying definition of conservation values, thresholds and implications for protection are inadequate, or

profile of impacts on river environments.

even simply not appropriate, for aquatic biota. Conversely, there are aspects of riverine habitats which have particular values which are not usually prominent in terrestrial conservation value assessments. These include ecosystems processes and landscale scale values. A further impediment associated with such riverine values lies in the difficulty in defining suitable indicators or measures of such values.

A number of technical issues also need further exploration before acceptable and appropriate assessment processes can be agreed upon. These technical aspects include: alternatives for summarizing and aggregating data, scale and resolving point source data collections, and the utility of surrogate measures, especially the values of natural river systems.

Chapter 9

Options for protection of streams of high conservation value in Tasmania

The scope of available measures for river protection in Tasmania is discussed, and possible options canvassed for the protection of the sites identified in the survey as of conservation value. The evidence from the macroinvertebrate survey is also used to assess the implications for possible implementation of system of reserves for freshwater habitats in accordance with the parameters of the national reserve system. While the data and analyses apply specifically to the situation in Tasmania, the threats, issues, and constraints are examples of the problems and issues faced across Australia and, to varying degrees and forms, elsewhere in the world.

9.1 Options for the protection of riverine sites of conservation value in Tasmania

A range of types of protection tools have been identified which could potentially be used for riverine habitats in Australia (Dunn 2000; Phillips *et al* 2000). Those currently applicable in Tasmania may be broadly grouped as:

- Legislation
- Policies, strategies, agreements
- Planning tools
- Codes of Practice
- Voluntary agreements or covenants

9.1.1 Legislative measures

Legislation that can provide some form of protection for rivers or river habitats in Tasmania is summarized in Table 9.1.

Table 9.1 Legislation which may be relevant to protection of fauna values of rivers

Act	Jurisdiction	Scope
Inland Fisheries Act 1995	Tasmania	Controls taking and disturbance of 'fish', including macroinvertebrates.
Water Act 1999	Tasmania	Addresses ownership and distribution of water in rivers and provides for the development of Water Management Plans and assessment of environmental flows.
Environmental Management and Pollution Control Act 1994	Tasmania	Sets framework for controls of discharge and environmental impacts.
National Parks and Wildlife Act 1970	Tasmania	Protects threatened wildlife.
		Controls what activities are permissible in designated reserves.
		Provides for the scheduling of National Parks.
Forestry Act 1920	Tasmania	Provides for preparation of Forest Practices Plans in accordance with Forest Practices Code.
Mineral Resources Development Act 1995	Tasmania	Administers permits for mineral exploration which must address environmental issues.
Regional Forest Agreement (Land Classification) Act 1998	Tasmania	Provides for reservation of various areas for forest values as defined under the RFA
Forest Practices Act 1985	Tasmania	Deals with environmental regulation of forest operations, including affects on streams.
Threatened Species Protection Act 1995	Tasmania	Provides for the scheduling of rare and threatened species and declaration of critical habitats.
		Requires species recovery and threat abatement plans.
Environment Protection and Biodiversity Conservation Act 1999	Commonwealth	Provides for the scheduling of threatened species and communities.
World Heritage Properties Conservation Act 1983	Commonwealth	Provides for the listing of WH properties in Australia.

Table 9.1 indicates that in general, legislative protection of the state's rivers is not directed primarily to conservation of ecological values, though some contribution to in-stream conservation may indirectly result from maintenance of water quality, environmental flow regimes and riparian forest management. The only legislation which directly refers to the protection of environmental values is the Water Management Act 1999 (EDO 1999). Any protection is, however, made in general terms within the context of sustainable use of water resources, rather than from a particular conservation perspective. The Water Management Act has only recently been proclaimed and slow progress is being made on both Water Management Plans

and the assessment of environmental flows.

Protecting water quantity or quality is addressed primarily in the Water Management Act 1999 and the Environmental Management and Pollution Control Act 1994. The Water Management Act 1999 has, as its stated aim, 'to further the objectives of the resource management and planning system of Tasmania and in particular to provide for the use and management of the freshwater resources of Tasmania' (Water Management Act 1999). Under the Act, the Minister can direct that a Water Management Plan be developed which 'must include:

> (a) an assessment of the water required by the ecosystems that depend on the water resource and the times at which, or the periods during which, those ecosystems will need that water, and
>
> (b) an assessment of likely detrimental effects, arising from the taking or use of water from the resource, on the quantity of water that is available to meet the needs of the ecosystems that depend on the resource, and
>
> (c) an assessment of likely detrimental effects of the plan on the quality of water'
>
> Source: Water Management Act 1999, part 4.

The provisions of the new Act have over-ridden the moves towards a state policy on Integrated Catchment Management (ICM) planning (D. Wright, Catchment Management Officer DPIWE, pers. comm.16/10/00). With a legislated requirement for a Water Management Plan, this has taken precedence. Where an existing community-based ICM group is already involved, this broader perspective is incorporated. The Water Management Plan requirement to address environmental flows provides an opportunity for protection of macroinvertebrate conservation values. The reality is that knowledge of ecosystem requirements is inadequate for this purpose and flow provision is, at best, an estimate (Arthrington & Zalucki 1998; Arthrington *et al* 1998; Fuller & Read 1997). The situation is exacerbated by the limited human resources available to support the water management plans initiative (D. Wright pers. comm.). In 2000, some seven or eight Water Management Plans are under development in river systems considered to be of high priority. It appears unlikely that further Plans will be developed in the near future (Roberts, pers. comm.). In fact, the urgent community pressures for approval of new dams is pre-empting the evaluation of environmental flows as required under the Act itself. New dams require an Environmental Impact Statement which includes an environmental flow assessment and recommendations but it appears that the development time-frame in some cases does not allow for an adequate flow assessment process (M.

Temple-Smith pers. comm 28/10/00,). Development of Water Management Plans for a catchment have no parameters relating to protection of any river sections or sub-catchments which might provide for both biodiversity conservation and as a template for management or monitoring of the catchment as a whole (M. Temple-Smith pers. comm 28 October 2000). The earlier proposals for a state Water Plan flagged in the draft Bill were dropped from the final legislation. There is therefore, no integrated policy for water management across the state.

The ministerial duties under the Water Management Act are

(a) to manage the water resources of Tasmania in accordance with the objectives of this Act; and

(b) to develop and coordinate policies relating to the sustainable use and development of those water resources; and

(c) to allocate the water available from watercourses, lakes, wells and surface water in a manner consistent with the objectives of the Act; and

(d) to compile, maintain and update information in respect of the water resources of Tasmania; and

(e) to promote public awareness of the importance of Tasmania's water resources and to encourage the conservation of those resources; and

(f) to encourage community involvement in water resource management.

Source: Water Management Act 1999, part 3.

With the Act's focus on distribution of water resources and community pressures for increased water use, there is little formal scope for applying the Act to principles of conservation of riverine values, even on a sub-catchment scale.

The Environmental Management and Pollution Control Act 1994 has indirect effects on maintenance of water quality and hence may contribute to protection of in-stream values. It prescribes waste management with respect to waterways from both point sources and diffuse sources. Where contamination of water is found, the Act will be triggered to maintain water quality.

The Inland Fisheries Act 1995 is primarily concerned with management of the freshwater recreational fishery, which largely comprises non-native salmonids. The Inland Fisheries Act makes illegal the taking of any 'fish' ('acclimatized' or 'indigenous') without a license. 'Fish' is defined by the Act as including '(a) any animal that throughout its ordinary life lives in water, and (b) the spawn, fry or young of such an animal'. Thus, technically, any macroinvertebrate or vertebrate which lives its entire life in freshwater may not be taken or 'disturbed'.

The Threatened Species Protection Act 1995 may contribute to conservation of riverine systems if a species is listed. Numerous hydrobiid snails, several caddis and some crustacean species are scheduled. The most prominent of these is the giant freshwater crayfish *Astacopsis gouldii* which is considered threatened. The scheduling of this taxon under the Commonwealth Endangered Species Protection Act has lead to a conservation focus in a number of stream and rivers of northern Tasmania draining into Bass Strait (Lynch & Bluhdorn 1997; IFC 1999). The Forest Practices Act may be triggered by a listed taxon, requiring special provisions for a forest practices plan or special management zone.

The only Acts which directly affect conservation of river systems are the Threatened Species Protection Act, or the Parks and Wildlife Act if places have been scheduled for riverine values. There is no legislation which directly provides protection for wild rivers in Tasmania. As yet, there is no apparent integration of the Water Management Act with any possible provisions for conservation of riverine biodiversity under the draft state Nature Conservation Strategy, nor for river-based reserves under the national reserve program.

9.1.2 Policies, strategies and agreements

Non-legislative measures which direct government activities potentially of relevance to river management or conservation are shown in Table 9.2. International conventions to which the Commonwealth government is a signatory set the framework for various bilateral agreements between the Commonwealth and states. The Commonwealth sets out its own strategy for implementation and enacts appropriate legislation, but this can only be brought into effect in relation to the Commonwealth's legislative powers and responsibilities. Individual states have responsibility for land and water management so interpretation and implementation of agreements may vary from state to state. The Commonwealth may provide financial or other incentives to encourage or set priorities for implementation of its declared strategies.

Table 9.2 Agreements and strategies of relevance to riverine ecosystems

Instrument	Jurisdiction	Scope
Convention on Wetlands of International Importance (Ramsar)	All (Commonwealth and all states)	Listing of wetlands of International Significance.
World Heritage Convention	All	Assessment and listing of sites of World Heritage value.
International Convention on Biological Diversity	All	Provides a framework for global biodiversity conservation and sustainable use of biological resources.
National Strategy for Ecologically sustainable Development	All	A core objective is protection of biodiversity and maintenance of ecological processes. Management of biological diversity at regional level is a key element.
National Biodiversity Conservation Strategy	All	Aims to improve identification, conservation and management of Australia's biodiversity
National Water Quality Management Strategy	All	Provides a national framework within which each state will develop action plans for water management. Provides water quality standards.
National Reserves Program	All	Aims to achieve a national representative system of protected areas, including developing methods for identification, incentives for protection, consistent management principles and funding for purchase of sites.
National Wetlands Program	All	Promotes conservation of Australia's wetlands through a range of programs
World Heritage Convention	All	Provides for the identification and protection of places of outstanding international significance for natural and/or cultural values
National Land and Water Audit	All	A 4-year program to assess the status of Australia's natural resources.
Regional Forest Agreement	All	Establish ecologically sustainable management of the whole forest estate, including security of forest resources and a system of reserves
Wetlands Policy (Draft)	Tasmania	Provides direction to ensure wetlands are protected and properly managed
Draft Nature Conservation Strategy	Tasmania	Provides a state action plan within the framework of the national Strategy to ensure best practice management for the maintenance of healthy ecosystems and conserve genetic, species and ecosystem diversity. Incorporates physical environment and natural processes as well as biota.

Each state is required to develop its own strategy for implementation of nationally agreed policies, and Tasmania is presently preparing a Wetlands Policy and a Biodiversity Strategy. Both of these measures may offer opportunity for protection of some riverine environments or sites. At the present time in Tasmania, river biodiversity is not addressed.

The Regional Forest Agreement (RFA) is a special case of a Commonwealth-State agreement. It has a lifespan of 20 years (Tasmanian Regional Forest Agreement

1997). The Tasmanian RFA was reached after several years of data compilation, mapping, community consultation and expert analysis to determine which forested areas should be available for harvesting and which areas should be reserved either as National Parks, forest reserves or other category (Public Land Use Commission 1997 Regional Forest Agreement Land Classification Act 1997; Tasmanian Regional Forest Agreement 1997). Following the RFA, land classifications and uses have been determined and scheduled under the Regional Forest Agreement (Land Classification) Act 1998. The RFA also recognized and sustained the provision of Mining Prospectivity Zones (MPZs). Thus the provisions of this agreement are enshrined in legislation and large tracts of land are both open for mineral exploration and for forest operations.

In Tasmania, the RFA incorporated the entire state and the scope extended incorporated a wide range of values even in non-forested areas. Two data sets of potential interest to river conservation were assembled under the RFA process: the Wild Rivers project (Stein & Stein n.d.) and the analysis of MRHI and additional data to attempt to identify riverine sites of high diversity (Davies & McKenny 1997).

'Wild rivers' were a focus of a national Australian Heritage Commission project on wilderness values in Australia. The output was included for consideration as a sub-set of wilderness assessment for the Tasmanian RFA. River sections were mapped using algorithms compiled from a range of indices of disturbance to arrive at a final 'score category' for disturbance. Lower scores indicated less disturbed sites. When data from the Wild Rivers project was mapped against land tenure, it was found that over 95% of wild rivers occurred within existing reserves. Since this met the RFA threshold for wilderness protection, no further action was seen to be necessary under the RFA to protect the least disturbed rivers on any regional basis (P. Wells, pers. comm.).

The analysis of macroinvertebrate communities (Davies & McKenny 1997) did not demonstrate 'hot-spots' for aquatic fauna, nor any indicative patterns of distribution of riverine communities (Figure 5.3). Nor were there any strong correlations with environmental variables which might be amenable to use as the basis of predictive modelling of riverine communities or taxa.

The Regional Forest Agreement determined reserve requirements directed towards forest (vegetation) communities and ignored establishment of riverine reserves in forested areas based on specific river or aquatic ecosystem values.

9.1.3 Planning provisions

Tasmania has an over-arching Resource Management and Planning System (RPMS) to promote sustainable development of resources of air, water, and land. This integrated planning and environmental management system began in 1994, and relevant state acts from that time are linked to its objectives providing consistent environmental goals and establishing 'a whole of government, industry and community approach' to planning (EDO 1999). The Resource Management and Planning System has five objectives, the first of which is 'to promote the sustainable development of natural and physical resources and the maintenance of ecological processes and genetic diversity'. Under the RMPS state and local government bodies are required to incorporate ecologically sustainable development in their planning. Land use and development is regulated under the Land Use Planning and Approvals Act 1993, and the State Policies and Projects Act 1993 deals with the creation of Tasmanian Sustainable Development Policies. These state policies are approved by parliament and have the force of law, as a consequence of which state and local governments are obliged to comply. The only such policy of relevance to rivers is the Policy on Water Quality Management referred to under section 8.2. A draft Policy on Integrated Catchment Management did not reach the approval stage and has been superseded by the provisions of the Water Act 1999.

Local government plans have to comply with the provisions and objectives of the RMPS. The only objective which refers to environmental values *per se* is 'to promote sustainable development and to maintain genetic diversity'.

The Water Act 1999 makes provision for local water plans. It is not clear how Water Management Plans prescribed under the Water Act 1999 will relate to local government plans, particularly given that many river systems and catchments are not confined within a single municipality.

9.1.4 Codes of Practice

Tasmania has two codes of practice which include provisions designed to protect watercourses (Table 9.3). There is currently no Code of Practice, or other relevant environmental management tool, for the agricultural sector despite the large area of lands affected by agricultural practices and land clearance.

Table 9.3 Agreements and strategies of relevance to riverine invertebrate ecosystems

Code	Jurisdiction	Scope in relation to river protection
Forest Practices Code	All forest operations on private and Crown land	Provides for buffer strips according to stream class.
Mineral Exploration Code of Practice	All mineral exploration activity	Minimize environmental impacts of mineral exploration activities.

Mineral exploration is permitted in prospectivity zones which cover much of Tasmania and mining is permissible in all reserve categories *except* National Park, Nature Reserve and State Reserve. Thus any area designated Conservation Area, Regional Reserve, Nature Recreation Area or Forest Reserve may be subject to mining activities. Under the Mineral Exploration Code of Practice (Mineral Resources Tasmania 1999) site-specific conditions may be set on an exploration license if rare or endangered species are known to be near the site. The Code provides general advice on appropriate ways to minimize impacts of tracks, road crossings and drilling sites on watercourses, streams, drainage lines, and wetlands. The Code recommends that watercourses should be protected in a manner consistent with the guidelines provided in the Forest Practices Code (Mineral Resources Tasmania 1999, p 48).

The Forest Practices Code (Forestry Commission 1993) is applied to the proposed Timber Harvesting Plans or Forest Practices Plans which must be prepared under the Forest Practices Act 1985 for every commercial forest operation in Tasmania. The Forest Practices Code prescribes the manner in which forest operations are to be planned and conducted so as to provide reasonable protection to the environment. Investigation is required (p 57) for the presence of any scheduled species under the Threatened Species Act 1995 or poorly reserved vegetation types and, if present, a strategy is negotiated with specialists and the Chief Forest Practices Officer. Water quality and stream protection are addressed specifically, the former by endeavouring to reduce soil and some riparian disturbance. The Code and planning provisions purport to limit annual levels of activity in the vicinity of town or domestic water supplies, the latter by the provision of buffer strips or 'streamside reserves' but this does not always happen in practice (P.E. Davies pers. comm. 2000). Minimum streamside reserve widths are set according to the watercourse type for all streams over 50 ha catchment area (Table 9.4). Streams smaller than 50 ha catchment area are not provided with reserves, and receive protection only in the form of a machinery exclusion zone. All riparian reserves may be burnt as part of normal clearfell and burning forest operations.

Table 9.4 Minimum streamside reserve widths

Watercourse type	Minimum horizontal width from stream-bank to corresponding outer edge of Reserve	Total stream reserve protection
Class 1. Rivers and lakes – waters which are important for town water supplies or recreational uses	40 m	80 m
Class 2 Creeks, streams and other watercourses from the point where their catchment exceeds 1000 ha	30 m	60 m
Class 3. Watercourses carrying running water most of the year between the points where their catchment is between 50 and 100 ha	20 m	40 m
Class 4. All other watercourses carrying water for part or all of the year for most years.	No logging machinery within 10 m of the streambank except at defined crossing points	

9.1.5 Incentives, programs and voluntary agreements

The Commonwealth National Heritage Trust (NHT) program (and formerly the Landcare program) has provided community groups with funds for a wide variety of environmental projects, including projects related to waterways. These can support protection of riverine values, for example by facilitating stream rehabilitation and developing catchment management plans. The initiative comes usually from local groups and is more likely to focus on restoration or 'improving' rivers in poorer condition rather than conservation.

Other programs under the NHT umbrella include Rivercare which is 'aimed at ensuring progress towards the sustainable management, rehabilitation and conservation of rivers' (www.affa.gov.au/docs/1_nrm/nht_landcare/nht/nrp) and the National Wetlands Program which aims 'to promote the conservation, repair and wise use of wetlands across Australia.' The Endangered Species Program is another program funded under the NHT which might be applied to riverine systems. It has been established with 'the goal of protection and conservation of Australia's native species and ecological communities in the wild. A feature of the program is that it focuses on the need for addressing key threatening processes... as well as action on individual species and ecological communities' (www.affa.gov.au/docs/1_nrm/nht_landcare/nht/nrp-). Access to much of the funding under these programs is targeted at community-based groups, the funding is not focused on systematic conservation, nor are research-based projects encouraged or supported.

A Fish Habitat Improvement Fund is a recent initiative of the Freshwater Anglers Association in Tasmania in conjunction with the Inland Fisheries Commission. Although the priority lies in improving the wild fishery (which is largely non-native salmonids) some possibility exists for incorporating more general river conservation measures into the projects.

Landowners can enter voluntary agreements under the Parks and Wildlife Act 1970 Section 37. A conservation covenant is entered on land titles and places legal restrictions on the area. It prohibits the owner or occupier of the land from destructive activities. Such a covenant may be appropriate for riverine habitats such as riparian zones, backwaters, or swamps, though it would be hard to protect the actual river channel and flow unless located in headwaters.

9.2 Options for protection by reserve planning: the implications of the survey data.

9.2.1 A Comprehensive, Adequate and Representative reserve system

Comprehensive, Adequate and Representative or CAR reserves are a cornerstone of the biodiversity strategy and sustainable resource use planning. Such reserves may be considered to capture and protect biodiversity at ecosystem scales. CAR reserves have been implemented for forest systems in Tasmania and some other Australian states based on regional analyses of ecosystems and communities, and having regard to principles of terrestrial reserve design and ecological requirements. Marine reserves have been instituted on a similar basis in New Zealand waters (DoC NZ 1995) and elsewhere and are proposed for Australian waters (ANZEEC 1998; ANZEEC 1999). The Ramsar convention on Wetlands of International Significance also advocates a CAR-based approach to wetlands conservation. The National

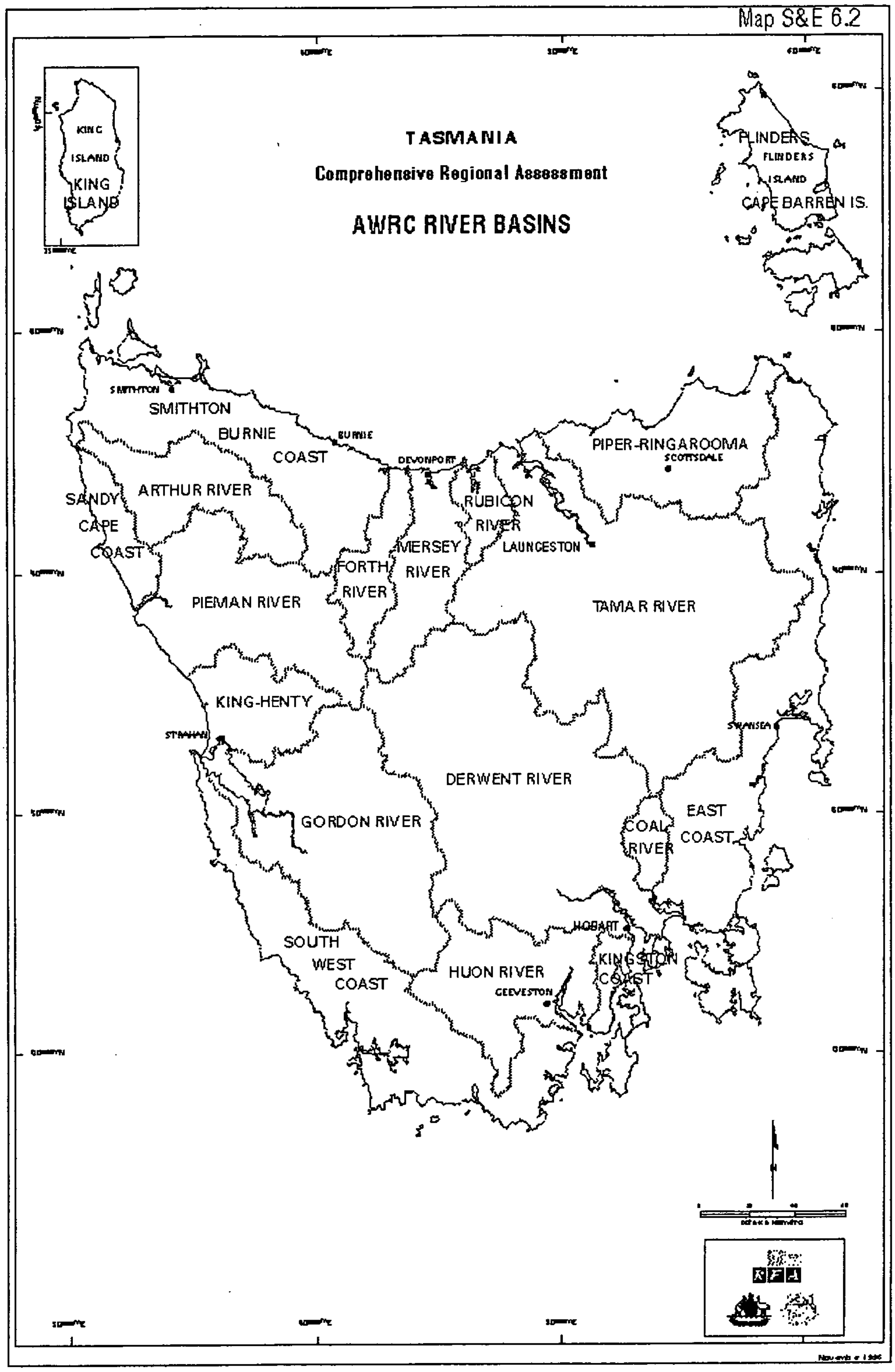
Biodiversity Strategy objective 1.4 is to 'establish and manage a comprehensive, adequate and representative system of protected areas covering Australia's biological diversity' (DEST 1996 p.9). The Tasmanian response to this strategy is the Nature Conservation Strategy, still (November 2000) in progress. A CAR reserve system is likely to be a plank of this Action Plan (S. Bryant pers. comm.).

A starting point for setting a framework for a CAR reserve system is bioregionalisation. Attempts to develop bioregionalisation for Tasmania date back to the early 1980s (Wells *et al* 1992) and were usually for botanical mapping and analysis. Orchard's (1988) map of Tasmanian bioregions was solely based on botanical analysis. A widely accepted approach to bioregionalisation in Australia has been designed by Thackway & Cresswell (1995a, b). This regionalisation was based in Tasmania upon regions with similar climate, landform, geology/lithology, vegetation, and floristics (Thackway & Cresswell 1995a, p 26).

A separate, hydrological classification of Tasmania's rivers was explored by Hughes (1987) based on past discharge records. Classification of data from 77 sites yielded four distinctive and spatially significant categories: a south-eastern group of sites with hydrological regimes similar to the southeast mainland of Australia, a south-western group with high mean annual runoff, and two somewhat overlapping groups stretching in an arc across the northern coast of the state. The latter two groups are typical of temperate regions. The south-west hydrological category has no analogue elsewhere in Australia (Hughes 1987). In the Australian Water Resources Council (ARWC) delineation of drainage divisions for Australia, the whole of Tasmania is classed as one drainage division.

No classification of rivers such as proposed for Western Australia (WARWC 1992; WRC WA 1997) has been attempted for Tasmania. The Australian Water Resources Council (ARWC) river basins (Figure 9.1) capture the larger Tasmanian rivers as single catchment entities and groups the smaller streams draining to the coastal areas. The state encompasses seven major catchments, two minor catchments and eight coastal drainage regions, each with numerous, usually short, rivers (RFA 1997).

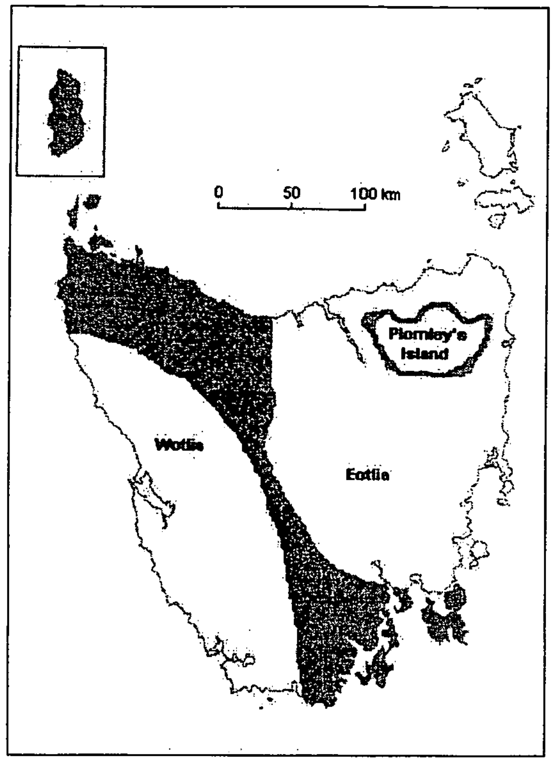
Figure 9.1 ARWC River basins for Tasmania



The two areas surveyed in this study fell into the same sets of bioregions of both Orchard and Thackway and Creswell. In the north-west, three bioregions were represented and all the north-east sites fell in the same bioregion (see Appendix 1). There was no significant correlation between the bioregions and the various TWINSPAN groups in the multivariate analysis. All the sites lie within the approximate areas of the northern hydrological categories of Hughes. Plecoptera species and family level analyses could not be correlated with hydrological regimes. The RFA analysis of macroinvertebrate communities (Davies & McKenny 1997) suggested that there might be a distinct south-west community group, but rivers sampled in this area using the MRHI protocol also had significantly higher mean bank-full width, suggesting that other variables may also be influencing the TWINSPAN analysis. Clearly bioregional analysis of species and community distributions needs further research, especially as it applies to aquatic values. The lack of coherence between terrestrially based bioregions and aquatic system types has been noted for NSW while attempting to identify river macroinvertebrate community types under the MRHI (E.Turak pers. comm.) This is not surprising, due to the differences in spatial patterns and impacts of different environmental controls between terrestrial and quasi-linear riverine systems.

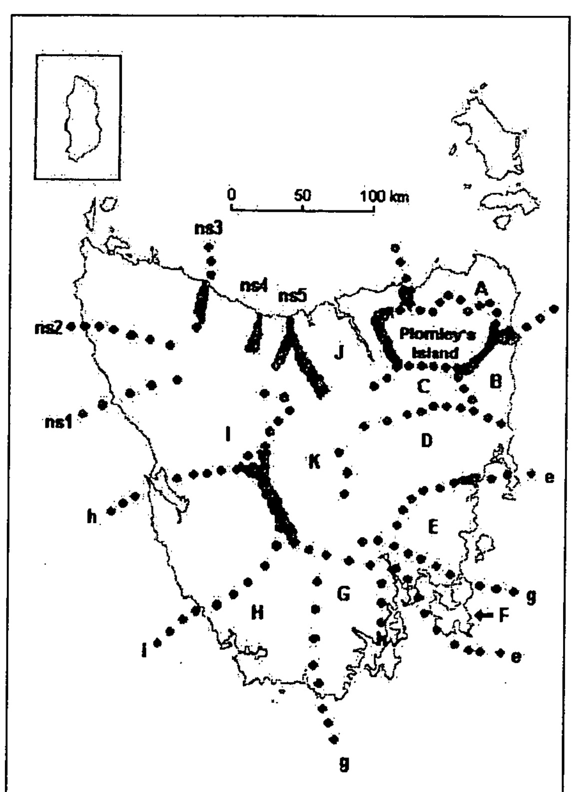
Mesibov (1996) suggests alternative bioregions for invertebrates in Tasmania, shown in Figure 9.2 and Figure 9.3, but his boundaries are poorly defined and based on interpretation of phylogenies rather than observable characteristics, distributions and communities. Mesibov used a range of taxon groups, most of which were terrestrial, as the basis of his bioregional analysis. The division of the state into 'Weotlia' and 'Eotlia' separated along 'Tyler's Line' (Figure 9.2) is generally valid for several aquatic groups including Plecoptera, Trichoptera, some crustacea, Rotifera (Mesibov 1996; Tyler 1992; Hynes 1989; Shiel *et al* 1986; Neboiss 1981). The names were proposed by Mesibov (1996) to reflect areas 'west of Tyler's line' (Weotlia) and 'east of Tyler's line' (Eotlia). The division of the state in this manner reflects both differing geomorphic origins of the regions and a present habitat divide created by the drier and largely cleared Tasmanian Midlands (Tyler 1992). The data from the survey described in this thesis supports this division as a control on the distribution of some taxa. In addition, the survey data supports Mesibov's 'Plomley's Island' region in the north-east. This 'region' supports a number of terrestrial taxa unique to the area and of biogeographic importance. Similarly, the limited information available from the survey and from previous records (Hynes 1989; Neboiss 1981; Ponder 1996) suggests that such a pattern may also exist for some aquatic taxa. The area of the north-east highlands is an 'island' surrounded by considerable altered down-stream catchments so it could well be an important relictual habitat for some taxa. The further analyses of 'faunal breaks' and implied bioregions shown in Figure 9.1 have not been analysed in this study. It does however, provide hypotheses which could be tested for aquatic taxa.

Figure 9.2 Some invertebrate regionalisation showing 'Tyler's Line' (Mesibov 1996)



The approximate position of 'Tylers' line is shown as the broad band of shading.

Figure 9.3 Proposed invertebrate bioregions for Tasmania Mesibov (1996)



The RFA in Tasmania included a mapping of the near pristine and pristine 'wild rivers' as defined by an index compiled from several measures of catchment disturbance (Stein & Stein n.d.). A map was generated showing all river systems in Tasmania categorized on a scale of river disturbance. These data were not applied to design protection for riverine habitats (P. Wells pers. comm.).

Rivers of high wilderness quality (low disturbance index) were mapped according to reservation status and over 90% of rivers of high wilderness quality were found to occur in existing reserves. Consequently it was determined that there were no additional reservation requirements under the terms and decision rules of the RFA. Thus most of the wild rivers occur in reserves in the west of the state (RPDC 1997) and not founded on CAR principles.

In conclusion, present bioregional analyses based largely on terrestrial parameters appear to be unsatisfactory as a basis for predicting riverine macroinvertebrate communities. Hence they are unlikely to be useful as a measure for bioregional reserve planning for such ecosystems. As yet, no more appropriate basis for bioregionalisation has been attempted. The AWRC river basin analysis could provide such a framework as an interim measure. The river basins also have some consistency with the hydrological categories of Hughes (1987).

As yet, there have been only limited attempts to start to conceptualise a framework for protection of river values in Australia in terms of a representative system of reservation (WRCWA 1999, Dunn 2000; Phillips 1999).

9.2.2 Environmental surrogates

Surrogacy as a strategy

A practical approach to overcoming the limitations of knowledge of the ecology of many, perhaps most, invertebrate species and the taxonomic impediment while providing for adequate invertebrate conservation is to use some form of surrogate. This strategy assumes that the surrogate accurately reflects distribution of the taxa or communities of interest. Such habitat level approaches to conservation (New 1995) are an alternative to the species level focus, which has driven much conservation effort, particularly for charismatic vertebrate species.

Three possible surrogate strategies are discussed: vegetation, naturalness, and predictive modelling.

Vegetation

As an alternative approach to bioregional analysis, vegetation or habitat is sometimes proposed as a surrogate for planning for invertebrate conservation (New 1995). However, increasing evidence suggest that even for terrestrial habitats, this is inadequate with poor correlations between vegetation and invertebrate fauna (Oliver *et al* 1997). Hutchings and Ponder (1999) conclude that 'there is no good evidence to support the idea that vegetation is a useful surrogate for most invertebrates or invertebrate communities' (p 306). Given that the scale of vegetation mapping rarely accommodates riparian vegetation and does not include aquatic macrophytes, a vegetation mapping surrogate is even less likely to be useful for aquatic invertebrates.

The evidence of the survey also suggests little relationship between different riparian vegetation types and broad macroinvertebrate community structure for the types of habitats surveyed. Apart from a suggestion of distinctive Plecoptera communities in higher altitude grassland sites, there was no consistency of riparian vegetation amongst the various groups derived from TWINSPAN analyses of raw data on all taxa at family level, functional feeding group or the Plecoptera species (see Table 4.5, Table 4.8, and Table 6.6, and Appendix 1). This was somewhat surprising since the nature and timing of allochthonous carbon sources differs between rainforest, sclerophyll forest, and grassland, as does the balance between allochthonous and autochthonous carbon sources under the different light conditions created by overhanging vegetation.

The study evidence indicates that reservation of a range of vegetation types, as implied by the Regional Forest Agreement for example, will not provide systematic protection for conservation values of stream macroinvertebrates. The provisions for protection of forest types (and also other vegetation types such as native grasslands on forest land) may afford some *ad hoc* protection. However, the signing of the RFA has effectively determined 'conservation values' for Tasmania. New proposals for reserves or other protection are unlikely to be considered for the twenty-year life of the Agreement.

River naturalness

The protection of sites that are in near-natural condition may be considered as an alternative environmental surrogate. River systems in Tasmania were assessed on a scale of disturbance in the Wild Rivers project (Stein & Stein n.d.) and the status of rivers with low levels of disturbance or high river wildness quality was considered in the RFA process (P. Wells pers. comm.). While preservation of rivers of such value is important, it is not a sufficient condition for the protection of a representative system of rivers. Few of the rivers in the survey area achieved the highest levels of wildness yet displayed substantial biological conservation values. In addition, no clear correlation was demonstrated between the various indices that comprise the Wild Rivers project and key conservation criteria such as species richness. Elements of the indices may not clearly correlate with in-stream faunal values. Nevertheless at the extreme, there is ample evidence that the habitat, ecosystem and communities of rivers change dramatically and is a basic assumption of the MRHI and other river health assessment programs (Wright *et al* 1984; Wright *et al* 1989; Norris & Thoms 1999; Karr 1999; Davies 2000).

Rivers which are considered 'wild' are nevertheless important as ecosystems which retain natural ecosystem processes. Just as 'wilderness' is considered of high ecological value for terrestrial systems for this reason, so too river naturalness is an attribute of ecological value (Dunn 2000). Maps of river disturbance for Tasmania accompanied documentation for the Regional Forest Agreement (www.rfa.gov.au).

Predictive models

A third option for surrogacy lies with the assessment of likely habitats for species or communities of conservation interest based on correlations with environmental variables This has been widely accepted for terrestrial taxa in Tasmania (for example Bell *et al* 1997; Jones & Rose 1996; Brereton *et al* 1997) and is also a basis for some conservation assessment in aquatic ecosystems (Wright *et al* 1996). Where the specific ecosystem and habitat requirements are known, the presence of a taxon may be inferred for similar habitats. Protection of such habitats may be effected if the species is listed under threatened species legislation.

The survey data did not reveal clear ecosystem requirements for any rare or threatened taxon, with the possible exception of Plecoptera in the Paradise Plains area. The claim for this area is based only upon the study's evidence of distinctive taxa and communities and the very limited examples of such high altitude native grassland habitat in north-east Tasmania.

The Monitoring River Health Initiative and its main bioassessment framework AUSRIVAS is based on a predictive model, but is only operable at a family level, and therefore of limited value in identifying and predicting sites of high conservation value. AUSRIVAS could scope high priority sites for taxon richness, given the correlation between family and species richness (P. Davies pers. comm.). Other important conservation value criteria based upon species level identification could not be captured. These criteria include rarity which provides a tool for protection and biogeographic values such as locally endemic taxa which enhance diversity values (IUCN 1998). Even for forest types for which environmental requirements are, by comparison with river fauna relatively well-known, a sole dependence on environmental predictions proved inadequate to capture all conservation values (Kirkpatrick & Brown 1993). At least for terrestrial invertebrates, there is 'a strong link between vegetation cover and maintaining invertebrate diversity but conserving vegetation alone is neither a sufficient nor a reliable means of conserving our invertebrate fauna intact' (Lunney & Ponder 1999 p 450). The report of the conference on biodiversity conservation concludes that 'there is evidence that plants or plant communities are not effective substitutes for many invertebrates' (Lunney & Ponder 1999 p 450). The efficacy of using vegetation as a surrogate for aquatic taxa is even more remote.

The only surrogate strategy, which shows promise for identifying sites for conservation in riverine systems is river wildness or naturalness. Even so, measures for protection cannot simply be addressed at river site level for maintenance of those wild characteristics also requires protection of catchment and water flow.

9.3 Protection options for high conservation value study sites

The sites identified in the survey provide data for assessment of possible options for protection at specific sites. Implications for protection in Tasmania can then be explored through real case examples. Two over-arching considerations must first be discussed: issues of land tenure, and addressing threats to the sites.

9.3.1 Land tenure issues

Protection proposals are constrained within current land tenure at the sites. The areas surveyed were generally in Crown Land classed as State Forest and small areas of private land. Some of the Crown Land is leased on a long-term basis to particular companies to manage the forest planning, harvesting operations and plantation development. Areas are scheduled under the Regional Forest Agreement either for a forest resource, Forest Reserve, State Reserve or other (RFA 1997). Some sampled sites lie in areas declared as Forest Reserves, which means they are reserved from timber harvesting. Where the sites are located within areas scheduled for harvesting, the area is subject to the provisions of the Forest Practices Code.

9.3.2 Addressing the threats to conservation values

Protection must address the actual or potential threats to conservation values. Threats to riverine systems have been classified (Allan & Flecker 1993) into six groups, of which three are immediately relevant to streams in the areas under review: habitat loss and degradation, spread of exotic species and chemical and organic pollution. Habitat loss and degradation takes a number of forms, including river engineering, deforestation, land transformation and in-stream habitat modification.

Exotic species introductions, notably in Tasmania of salmonid fish, have an impact on macroinvertebrate taxa (Flecker & Townsend 1994; Townsend 1996; Cadwallader 1996). A number of streams in the survey areas are known to support populations of trout, a few are trout-free because of natural obstacles to upstream migration while the very smallest streams would be too shallow for salmonid habitat. The introduced hydrobiid snails *Potamopyrgus antipodarum* may be a threat to native freshwater snails due to its dispersive abilities and apparently more flexible habitat requirements (Ponder 1996) and possibly could also displace other taxa of similar feeding behaviour.

Chemical discharge is controlled under the Environmental Management and Pollution Control Act 1994 but some streams remain impacted by old mine workings in various parts of the state (SDAC 1996; Davies *et al* 1996; Davies 1999). Streams known to have such acid mine drainage in the sampling area were not included in the study though some streams of (probably natural) high concentrations of heavy metals were included (Koehnken 1992). Tolerance levels of aquatic macroinvertebrates to the run-off of fertilizers or pesticides from forest management is poorly understood (Campbell & Doeg 1989; Davies et al 1994 a; Davies *et al* 1994 b). Even in low concentrations, phosphate fertilizer discharge into streams of low ionic properties can cause flushes of algal matter (Dunn, pers observation) which alter the natural substrates and stream processes. Diffuse organic pollution such as animal waste is not controlled under legislation except at focal points such as dairies.

Forest operations and associated activities appear to hold the greater risk for the sites in the survey area (Gilfedder & Dunn 1997). The impacts may be direct in the form of disturbance to the forest canopy and siltation from road crossings. Risdon (1998) found that the physical characteristics of road crossings in Tasmanian eucalypt forests in areas of logging operations past and present significantly influenced sediment input, which in turn was correlated with changes in macroinvertebrate fauna, notably an increase in the densities of Oligochaete worms and a decrease in density of austroperlid and eustheniid stoneflies. Canopy loss changes the temperature and light regimes in forested streams with consequences for autochthonous carbon cycles and life-histories of invertebrates, especially insects (Davies & Nelson 1994). Indirect impacts on streams in logged areas or downstream from forest operations result from changes in run-off, discharge rates and patterns and siltation (Davies & Nelson 1993). Risdon (1998) found a lower density of austroperlid stoneflies in logged compared with unlogged catchments, although no causal relationship was evident. Trombulak and Frissell (2000) argue there are multiple effects of roading on both terrestrial and aquatic habitats.

Growns and Davis (1993) demonstrated that even with a 100 m buffer strip, streams of a clearfelled catchment were different from streams in an undisturbed catchment, although they concluded that streams in the buffered area were more similar to undisturbed streams and therefore the zone was effective in ameliorating any disturbance attributable to the clearfelling. Davies and Nelson (1994) found that all impacts of logging were significant only at buffer widths less than 30 m. Noting that under the Tasmania Forest Practices Code, only streams or rivers with a catchment in excess of 1000 ha or more are protected by a buffer strip of 30 m (Table 8.3) it is clear that smaller streams in forested areas are subject to threatening processes (Davies & Nelson 1993; Davies & Nelson 1994) and that recovery is likely to be slow (Growns & Davis 1991).

The dangers of incremental threats to riverine systems are also recognized. Zwick (1992) highlights the issue of habitat fragmentation as it affects riverine environments, especially of headwater streams. Loss of connectivity is a critical issue particularly in the lower catchment (Frissel & Bayles 1996). Pringle (2000) raises the issue of cumulative hydrologic alterations and management consequences arising from actions of other jurisdictions.

Non-anthropogenic threats to aquatic systems arise from the possible effects of climate change and natural vegetation succession patterns. Climate change expectations are for a warming and drying of the Tasmanian climate which will threaten alpine habitats and headwater streams (SDAC 1996). A more immediate and evident threat comes from vegetation succession where grassland ecosystems are gradually taken over by shrubby, then forested communities. Since grassland themselves are considered under threat, management of such areas is now proposed to incorporate maintenance of the grassy species (B. Ellis pers. comm.).

Even though the study areas were not candidates for major hydro-electric dams, some dam proposals have been made in their vicinity. A proposal to dam the grassland of Knole and Netherby Plain to create an artificial trout fishery was rejected by Forestry Tasmania because of the conservation values of the grassland. It is possible that irrigation dams could be proposed for rivers of the north-east highlands and that water supply dams or other alteration to the hydrology and flow of some streams of the north-west could be required to support mineral exploration or mining.

A further threat to the conservation values of some riverine systems lies simply in neglect or ignorance of the values. This might apply for example to the naturally low pH sites which are of low biodiversity and hence may be considered by the general community as of low conservation value.

The maps in Figure 9.4 and Figure 9.5 show that all sampling areas lie within crown land allocated under the Forestry Act, although some sites fall within areas protected as forest reserves. All sites lie within mineral prospectivity zones, indicating the availability of these areas for mineral exploration and possible mining.

Figure 9.4 Land tenure and mineral prospectivity zones, north-east Tasmania

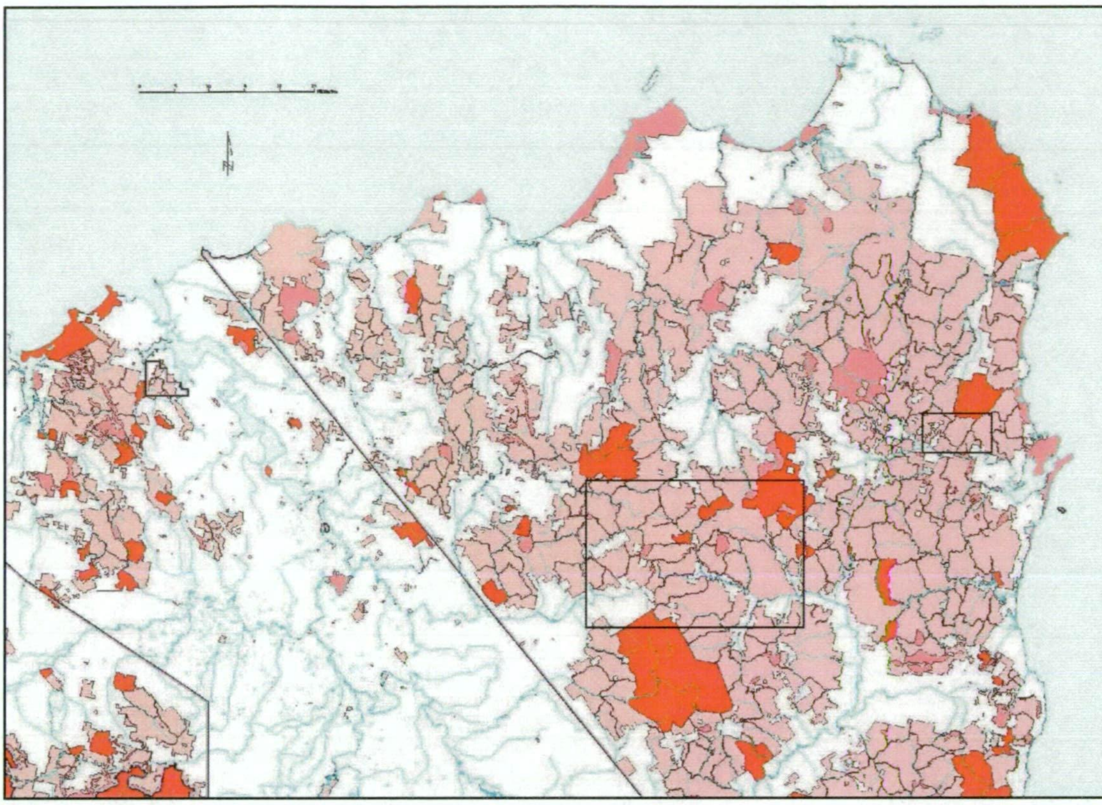
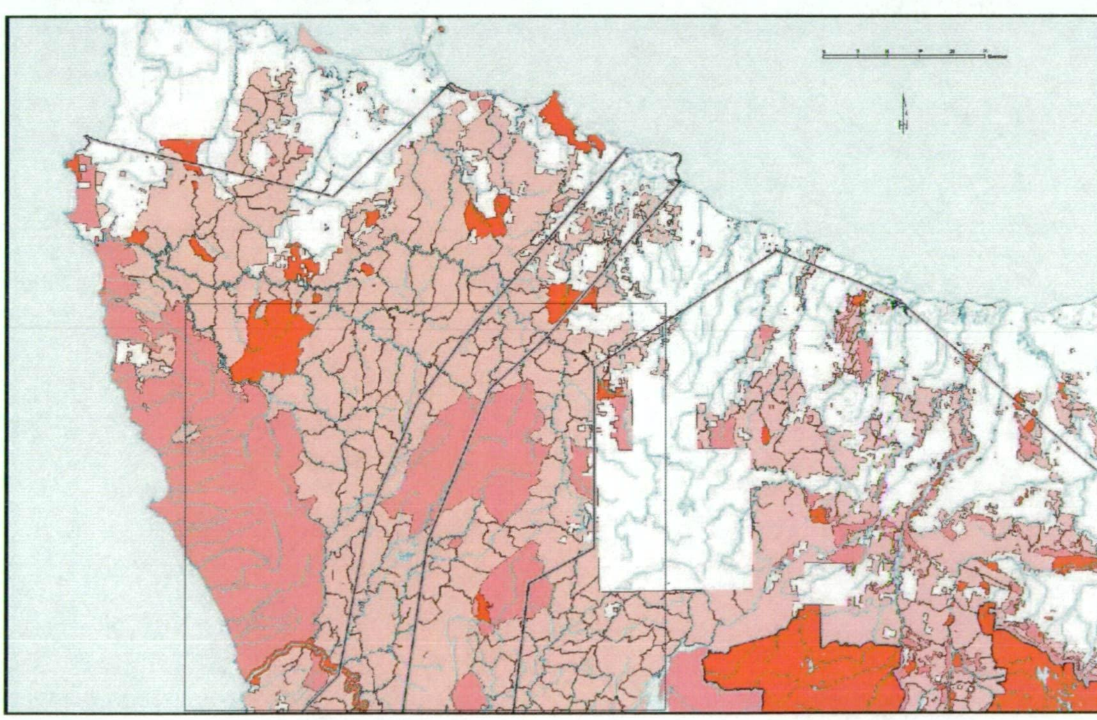


Figure 9.5 Land tenure and mineral prospectivity zones, north-west Tasmania



Dedicated Conservation Reserves | Informal Reserves | Other Public Land | Private Land

Special Prospectivity Zone boundaries (Zone is on shaded side)

Source: www.rfa.gov.au (Sampling sites lie within the areas shown by black boxes)

9.4 Protection for those sites of high value identified in this study

The survey sites of high conservation value all lie within public land. As a consequence of the Regional Forest Agreement, no further consideration of the status of those lands will be undertaken until the 20-year life of the Agreement has elapsed, with one exception. The one exception is the sites located on the Savage River Pipeline Road, which lies within an area acknowledged for its conservation values, but also potentially important as a source for Myrtle *Nothofagus cunninghamii* harvesting. The Regional Forest Agreement notes that there is agreement to postpone harvesting and any associated roading in this area pending a review of red myrtle resources to be conducted in the first five years of the Agreement. Pending the outcome of this review, the area will either continue to be deferred forest or will be considered to ensure availability of this resource (RFA 1997 Sections 54 & 55). Thus this area has uncertain status and remains subject to risks from the present road access. Three sites of high conservation value lie along the course of the Pipeline Road: Pineapple Creek PC, a tributary of the Little Donaldson PD and Clearwater Creek PP.

Most other sites within the survey area lie in State Forest, Forest Reserve, State Reserve, Nature Recreation Area, Regional Reserve or Conservation Area. All of these categories allow for mineral exploration and mining (RPDC 1999). The Final Recommendations for CAR Reserves Report (RPDC 1999) advocates a Reserves Code of Practice to reflect and underpin the Forest Practices Code, and to incorporate the Mineral Exploration Code of Practice. Nevertheless, such areas are still available for exploration and mining. Sites such as Biscuit Creek BC (Figure 9.6) which lie within State Forest, are subject to the Forest Practices Code when roaded or harvested, but in that particular case, the stream would receive no protection because of classification as 'Class 4' which does not even allow for a streamside reserve (see Table 9.4).

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Figure 9.6 Biscuit Creek: high conservation but no streamside reserve

Because of the accessibility of the survey sites, all would be at risk of introduction of exotic species, and only the very small could avoid invasion by trout. Netherby Creek NE is believed to be currently trout-free because a substantial waterfall prevents upstream colonization, but the site is highly accessible and therefore vulnerable to deliberate introduction of salmonids.

Roading already exists at most of the study sites, but additional risks occur in road maintenance and widening. Additional siltation arises from this disturbance and has occurred at three sites during the period of the study. At one site on the Pipeline Road Pineapple Creek PC, the wooden bridge collapsed, a bulldozer had to be retrieved from the streambed and a new crossing was subsequently constructed as a crude ford. In addition, an upstream pond was created and thereby the stream was altered in form for some 40 m. Pineapple Creek now receives direct wash from the unsealed road pavement and risks chemical or oil contamination from vehicles passing through the continuously flowing stream at the ford. Other site in the same locality such as Clearwater Creek (Figure 9.7) are at risk from similar road grading actions.

Figure 9.7 Clearwater Creek: at risk from road upgrading

Forest operations occur upstream of areas which may be designated as Forest Reserves. Thus a site within such a forest reserve may appear to be protected but may be still subjected to impact from the down-stream effects of logging operations (Davies & Nelson 1993; Grown & Davis 1994). Sweets Creek SW (Figure 9.8), a high conservation value site in the north-east, was subject to such logging upstream after study sampling was completed (Figure 9.9 and Figure 9.10).

Figure 9.8 Sweets Creek: threatened by upstream clear-felling

The felling was undertaken using cable logging on the steep slope and the slash was subsequently burned. The impact on the stream fauna of this high conservation value stream site has not been assessed, but clearly this site has no protection against such events.

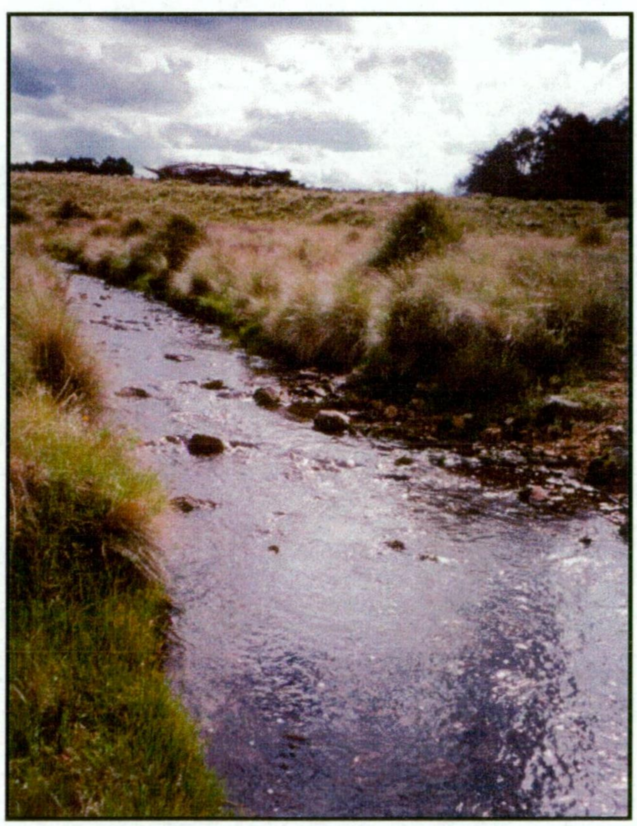
Figure 9.9 Clearfelling on Ding Dong Hill: the catchment of Sweets Creek

Figure 9.10 Clearfelling on Ding Dong Hill: the catchment of Sweets Creek

Although the study sites are not currently at risk of major reduction in flow as a consequence of regulation or abstraction, they are at risk of the cumulative effects of forest operations, siltation, roading, and long-term changes in catchment. Change in water chemistry and temperature regimes are possible as a consequence of nutrient impacts, particularly in plantation areas, and loss of cover.

Much of the north-west grassland area lies in private hands as part of the Surrey Hills block. Large tracts of the North Forest Products land are being converted from old-growth forest upstream of the Hellyer River. The grasslands of Westwing Plain are made available on grazing leases and stream-banks are trampled by cattle during the summer months. Where the Hellyer River flows through the Plain at site HM (Figure 9.11) the rare aquatic moss *Andreaea australis* is now subject to the threatening impacts of both increased siltation and increased nutrient load as a consequence of conversion to plantations in addition to the grazing impacts.

Figure 9.11 Hellyer River at Westwing Plain: threatened by plantation development upstream



Although the present owners of the Surrey Hills area are amenable to maintaining the grassland for its intrinsic conservation values, a change of ownership could see much of this grassland converted to plantation. In addition, maintenance of grassland values does not necessarily offer protection to the aquatic habitats of the streams flowing across the plains.

The Forest Practices Code is intended to protect water quality and regional forest plans are expected to respect catchments which supply town and rural domestic water supply. The Code prescribes limits on the extent of logging which can occur within a time period for town water supply catchments. This is not used in practice owing to a lack of integrated controls on vegetation clearing and forestry (Davies pers. comm.2000). There is no such protection for other headwater streams or other catchments which may be subject to extensive logging and possibly plantation development in a short period. Requirements for the protection of instream ecosystem health and conservation under such conditions are unknown. Although the Forest Practice Code sets out guidelines for streamside protection, forest practice legislation does not set required environmental outcomes from forest practices legislation. Thus a stream in an area prone to wind-throw or highly erodable soil may be 'protected' by the appropriate buffer strip width but the outcome may be that the stream is subjected to impacts of the forest operations. In addition, monitoring of compliance with the Code is limited by resources and the lack of regulatory requirements to do so. In addition, the Forest Practices Act has no jurisdiction in relation to roading or forest management which pre-dated the Code.

In summary, the study sites could only achieve better protection for their in-stream conservation values if (a) guidelines for roading and maintenance were established and enforced, (b) class 3 and4 streams were protected by adequate buffer strips and (c) logging operations were minimized upstream of significant sites or subject to special conditions.

9.5 Protection options for Tasmanian rivers and streams

Protection options for the conservation of Tasmania's waterways are very limited. Overriding the usual constraints of legislative provisions, Tasmania has the additional constraint of a Regional Forest Agreement, which has virtually precluded any further formal or informal reserves to be declared on public lands for the next twenty years. In addition, current strategies for implementation of a new Water Act sees no provision for systematic protection of representative suites of rivers which could be important templates for management of the State's rivers.

The proposed Nature Conservation Strategy may offer some avenues to begin to pursue the concept of a Comprehensive, Adequate and Representative system of river reserves, in compliance with the National Biodiversity Strategy. Even were this to proceed, a range of different approaches to protection would need to be implemented. Only the western part of the state has a significant representation of rivers and their catchments within existing reserves, or indeed in pristine or near-pristine states. Other areas with rivers that have had at this stage minimal regulation are now under threat from proposals for large irrigation developments.

Current interest by community groups in Rivercare and similar programs may be another useful avenue to pursue the protection of riverine conservation values. The disadvantage of this approach lies in the *ad hoc* nature of the exercise and the priority for many groups on restoring already degraded river systems.

The problems, issues, and constraints in providing river protection are not unique to Tasmania or Australia generally. Boon (1992b) has discussed the common obstacles to river management resulting from the nature of river systems. He highlights the range of legislation that might be appropriate to protection of rare species in UK (Boon 1992c) while Moss (1999) tracks the changes in approaches to, and strategies for, river conservation in UK over recent decades. Gardiner and Cole (1992) advocate catchment planning as the way forward for river protection in the UK. Constraints of different jurisdictions, multiple legislative tools and inherent conflicts of use are common worldwide (Ormerod 1999).

Moyle and Yoshiyama (1994) propose a five-tiered approach to the protection of aquatic biodiversity for California. This tackles conservation on five fronts: listing of species likely to become extinct within 20 years; implementation of restoration management strategies for clusters of declining species in common habitats; creation of a system of Aquatic Diversity Management Areas to provide state-wide systematic biodiversity protection; designation of a system of key watersheds, and development of schemes for bioregional landscape management. They emphasize that this strategy is developed within the context of California's particular climatic and biogeographic characteristics, and with regard to the rapid decline in aquatic biodiversity. However, Moyle and Yoshiyama suggest that such an hierarchical approach with the emphasis on watersheds has widespread application.

One country, Norway, has developed a national plan for protecting river systems (Halvorsen *et al* 1998). The trigger for this plan was the increase in hydro-electric developments in the 1950s and 60s which 'made it necessary to take environmental impacts more into consideration' (p 2417). The plan has been enacted in stages between 1973 and 1993 under four simply presented government guidelines:

- The selected river systems with adjacent areas should provide a variety of uses and riverscapes. Some of the areas should be very extensive in size.
- The protection plan should ensure a fair distribution throughout the country
- The plan must be not so comprehensive that it puts too heavy a burden on Norway's electricity supply
- Other inroads in protected areas that may impair their value for nature conservation, sports recreation and science should be avoided.

Halvorsen *et al* (1998) p 2417.

Such an approach has particular relevance for Tasmania, which has similar reliance on hydro-electricity and common agricultural and forestry activities.

A common theme in advocating protection of river conservation values is the need to use scientific information and to encourage commitment and involvement of the scientific community (Doppelt 1993; Pringle 1993; Boon 1992).

My proposed model for assessment (Figure 10.1) indicates that 'protection options' form one dimension of the five-dimensional model. A commitment to protect rivers may be the significant driver for assessment of conservation value, and is likely to set at least some of the parameters for that assessment, including scope, scale, criteria (or their relative significance) and the process itself. Conversely, without a context or a vision for protection of rivers, the assessment will lack focus and probably resources. Thus I argue that options for protection is a necessary dimension of any model for river assessment.

9.6 Requirements for river protection in Tasmania

Several important elements of a strategy for protection of the biodiversity of Tasmania's waterways emerge from the study. In order to proceed with protection of a representative, adequate and comprehensive suite of rivers, the following needs have been identified.

- an agreement on what constitutes conservation value for river systems
- support and advocacy from both community and scientists
- integration with current state and Commonwealth government initiatives
- a complementary approach to the concept of 'protection'
- creative and inclusive strategies for protection across different land tenures and within different river management regimes
- a river protection plan which adopts a multi-tiered approach

Chapter 10

Evaluation of the conservation assessment process

The conservation assessment process is subject to evaluation using a set of commonly applied quality standards. Evidence is drawn from previous chapters, brought together, and tested against the quality standards. This analytical process highlights the potentials and problems for assessment of conservation values in riverine systems in Australia.

10.1 The purpose of evaluating the assessment process

In this chapter, the assessment process is itself subject to evaluation. The term 'assessment' is used for the conservation assessment of the field study of macroinvertebrates conducted in northern Tasmania, while the term 'evaluation' is used for the examination of the process itself. In broad meaning the two terms are very similar but are used for different processes in this chapter to assist the reader.

If a conservation assessment process is to be applied in river management, the quality of the process needs to be ensured, the steps in the assessment must be clear, and limitations of the assessment need to be evident. Fundamentally, both those undertaking the assessment and those using its results need to be aware of all elements that constitute the process.

Assessment of macroinvertebrates is used as an example of how a wider assessment of riverine conservation values might be applied. The field study represents only one strand in the conservation values of riverine systems. Other issues of importance may emerge from a similar systematic evaluation of conservation assessment of other strands such as geomorphic analysis, riparian zones, and landscape scale values.

10.2 Quality standards

Six commonly agreed quality standards for evaluation processes were identified in the conceptual framework. A conservation assessment process is an evaluative process, and if it is to be appropriate and useful, then it needs to be scrutinized according to these standards. The study data has been used as a case study to explore river conservation assessment and its application in an Australian setting. I will now use this case study to evaluate the conservation assessment process.

The general standards for evaluation are feasible, valid, reliable[6], ethical, adequate and useful. The meanings of these terms in an evaluation context are provided in Table 10.1 together with the specific issues that will be addressed.

Table 10.1 Evaluation standards, definitions and issues for the evaluation of the case study of conservation assessment

Standards	Definition – an evaluation which:	Evaluation issues
Feasible	is capable of being undertaken within given resources, with relevant expertise and technically possible	Was it possible to develop and apply a systematic framework for river conservation assessment using commonly applied criteria?
Valid	is a true measure of what it is intended to measure	Was the assessment a true reflection of the conservation value of these rivers?
Reliable	will provide the same results if repeated, or can be applied to other assessments	Could the assessment procedure be replicated elsewhere?
Ethical	meets standards of ethical practice,	Was the assessment conducted and the results presented in an ethical manner?
Adequate	is sufficient to provide information necessary for decision-making	Does the assessment adequately reflect the conservation values of the rivers studied?
Useful	serves its intended purpose.	Was the assessment process useful for exploring river conservation assessment issues and processes?

10.2.1 Standard 1: feasible

Was it possible to develop and apply a systematic framework for river conservation assessment using commonly applied criteria?

A framework comprising criteria and thresholds was devised and tested using survey data for macroinvertebrates from two regions of Tasmania. The assessment of some conservation values using family level data and plecopteran species data proved to be feasible with certain caveats.

[6] In evaluation terminology reliable is a generic term, which includes the scientific concept of

The assessment criteria were based on other types of ecosystem and on experiences in riverine environments overseas. For the limited range of habitat sampled, the framework proved to be feasible. However, the comparisons made to establish significance were limited to the two areas, north-west and north-east Tasmania. The comparisons made in the statewide setting using the MRHI data has to be treated with some caution because of differences in sampling and other protocols.

The thresholds for listing under threatened species legislation are problematic for fauna of riverine habitats, and this was confirmed by the study data. The thresholds for all four nominated conservation criteria proved feasible to apply although conclusions could not be drawn with certainty.

It is clearly possible to develop a system for assessing conservation value of rivers based on macroinvertebrate analysis, which would be recognized by the wider conservation community. Extension of the methodology to some but not all other elements of riverine values would also appear to be feasible. Some river values (Table 2.10) are less amenable, however, to the conservation criteria used for the biota. The study provided evidence of conservation values (Chapter 7) but some limitations have been identified in Chapter 8.

The assessment conducted in this study satisfied the feasibility standard.

10.2.2 Standard 2: valid

Was the assessment a true reflection of the conservation value of these rivers?

The choice of criteria and attributes was based on previously established criteria that are widely accepted in the general scientific community so the conservation significance may be considered valid, at least as far as the macroinvertebrates of riffles are concerned.

However, as an overall assessment of the conservation values of the rivers, the assessment is limited because it did not address many other elements of riverine environments that have potential conservation value. The study also did not resolve the problem of the geographic extent of the significance of the sites in the river as a whole because for the most part only single sites on each river were surveyed.

'replicability'.

The assessment conducted in this study satisfied the validity standard for the specified conservation values and riffle macroinvertebrate attributes.

10.2.3 Standard 3: reliable

Could the assessment procedure be replicated elsewhere?

If the assessment is reliable, replication of the process would give the same results and the method could be applied with confidence to other areas. Reliability is important both as a check on the quality of the present data and to provide confidence in analysis of other sites using the same methodology. Because the methodology has been made explicit by establishing criteria and thresholds and for data collection, analysis and comparisons with other contextual data, the assessment process is considered to meet standards of reliability for conservation evaluation. Similar assessments of conservation value could be undertaken in other areas of Tasmania, and in a similar way elsewhere.

The assessment is considered reliable as a conservation assessment process, since the sampling procedures are standard and explicit, and the criteria and thresholds used are also clear. However, if changes in conservation status were to be formally monitored, a different, more extensive, and statistically rigorous sampling regime would be required.

10.2.4 Standard 4: ethical

Was the assessment conducted and the results presented in an ethical manner?

An ethical assessment is one which adopts the core principles of the particular discipline it draws upon and one in which the analysis is presented in a clear and transparent fashion. Ethical standards for ecological research might include minimizing harm to fauna and flora and the environment generally as well as presentation of results. Macroinvertebrate sampling is often destructive, and stream sampling almost invariably so, given that microscopic examination is required for much of the identification. At present, under animal ethics guidelines for research 'destructive' sampling and preservation of invertebrates is not considered in contravention of those guidelines, whereas fish may be so considered and such collection of other vertebrates are certainly controlled. It may be possible to reduce these impacts of the conservation assessment process by reducing sampling frequency (since no inter-annual variability in taxonomic composition was observed), or by introducing a wider approach to river conservation assessment which incorporates other types of measure such as geomorphic type or naturalness.

A greater concern is the presentation of results, if summary scores alone are presented. It is unethical to present results in a form which does not provide adequate representation of the evidence for the conservation assessment. The issues of presentation and interpretation of results were discussed in Chapter 7 and the outcomes were presented as only being indicative.

A range of institutional and social issues might be considered to have relevance to the ethical standard: it is beyond the scope of the present study to explore these issues. However, if a process for conservation assessment is to be implemented, then such issues should be addressed.

The assessment conducted in this study satisfied the standard of being ethical on the basis of presentation of results. There are ethical issues in the biological sampling but these do not contravene current guidelines.

10.2.5 Standard 5: adequate

Does the assessment adequately reflect the conservation values of the rivers studied?

An adequate evaluation is one which serves the purpose for which it was undertaken and provides the information necessary for action. Clearly, the assessment is not sufficiently adequate to reflect the range of conservation values of rivers. Those elements of the instream biota that have been omitted were outlined earlier. In addition, riverine values are considered to include hydro-geomorphic values, ecosystem values in floodplain and catchment, riparian values and roles in the landscape (Dunn 2000; Phillips 2000).

As far as assessment of the macroinvertebrates of a given stream or sub-catchment, the assessment method is limited because it deals only with point source data in most cases. As a basis for protection, information along the length of the streambed is likely to be necessary, or at least a methodology to integrate point data with landscape scale assessment should be developed. The direct use of MRHI data as a surrogate for conservation assessment is inappropriate and inadequate, unless an integration protocol is developed and some use is made of the material archived from these collections is identified to species level. The AUSRIVAS database and procedures may be useful for indicative purposes but it was not designed as a tool for conservation assessment (P. Davies pers. comm.). Indicative information from the study suggests that identifying representative rivers using macroinvertebrate communities alone is probably inadequate, at least in Tasmania.

The limited focus on macroinvertebrates adopted in this study clearly is not adequate for the identification of all rivers of high conservation value. Many other values assessed in other schemes (Boon *et al* 1997, 1998) and signalled as significant in Australia (Dunn 2000) were not included as criteria or attributes in the field study. Some of these values present a challenge for definition and for assessment which will be understood and accepted in the wider ecological and conservation communities. These riverine conservation values include catchment scale processes, functional roles of rivers, and instream riverine processes (Corkum 1999; Moss 2000). Boon (2000) has highlighted the need for an integrated approach to river assessment, a view endorsed by many river scientists and managers in Australia (Dunn 2000).

The assessment conducted in this study failed the standard of adequacy.

10.2.6 Standard 6: useful

Was the assessment process useful for exploring river conservation assessment issues and processes?

Boon (2000) highlights the need to have an explicit purpose for a conservation assessment. 'Conservation assessment is not an end in itself, but it is undertaken in response to a particular need' (Boon 2000 p 415). The four common aims which Boon identifies are therefore also management objectives:

- to conserve representative examples of all major river types;
- to conserve rare or threatened riverine species;
- to devise appropriate management strategies for species rivers, and
- to ensure sustainability in the ecological structure and function of all rivers.

Dunn (2000) also listed different purposes for identification of rivers of high ecological value:

- reserve design - to protect a representative suite of rivers,
- river classification; - to group rivers according to their management requirements or priorities,
- indices, - to compare values and status of a number of rivers, and
- ecological value profiling - to assess values of a single river in the context of catchment management planning.

Within these broad aims, each of these approaches to assessment was seen to have several possible purposes or uses. Thus, conservation assessment can fulfil different purposes, and different decision rules and protocols should be delineated for different objectives.

The present assessment was limited to exploring the issues associated with an assessment process and evaluating the critical parameters for such processes to be applied in real river management settings. It is unlikely that any formal protection of those sites identified as of high value will flow directly from this conservation assessment exercise for two reasons. The study was not undertaken within any recognized conservation assessment process supported by local river managers. In addition, the constraint of the Tasmania Regional Forest Agreement (1997) precludes any new reserves during its twenty-year life.

The study has indeed highlighted many of the issues, the strength and weaknesses of the application of a set of conservation criteria to river macroinvertebrate fauna, and has provided indicative data on other possible dimensions of river conservation assessment in Australia.

The assessment conducted in this study satisfied the utility standard, within its specific purpose.

10.3 Summary

The data collection and analysis of riverine macroinvertebrate values for two regions of northern Tasmania was undertaken in order to explore and demonstrate issues associated with river conservation assessment in Australia. Of the six quality standards nominated, the assessment process was found to meet, at least partially or within defined limits, five of the six standards.

The assessment failed on Standard 5: 'adequate'. As an assessment of conservation values of riverine systems, it was inadequate, being limited in its scope. This was anticipated to a degree since the study was clearly delimited to riffle macroinvertebrates. Integration of other dimensions of riverine value is a critical point in discussion of proposals for river conservation assessment and protection in Australia. The assessment of macroinvertebrate values also highlights the limitations of traditional terrestrially based approaches developed for the protection of places of high conservation value.

The assessment was considered to only partially meet Standard 1:'feasible'. The coarse levels of taxonomic resolution used, the imperfect nature of the databases for statewide comparison and the taxonomic impediment all limited the quality of the assessment. Although more taxonomic keys have become available since this study commenced, few groups can be identified to species level in their immature forms. The efficacy of the assessment was further eroded by the constraints and principles of Tasmanian Threatened Species legislation where thresholds have been established within parameters appropriate to terrestrial species. A further major constraint on feasibility of conservation assessment lies in the resources required to undertake such an exercise. In reality, time, human resources, expertise and costs for a systematic conservation assessment of rivers using riffle macroinvertebrates would be prohibitive. In effect, assessment of macroinvertebrate conservation values is theoretically feasible, but has difficulties and limitations in practice. These limitations would be multiplied if all biotic and non-biotic values of riverine systems were to be assessed for conservation value using an assessment process which met appropriate quality standards.

Overall, this study of the assessment of conservation values served its purpose. Many issues and requirements for a river conservation assessment process in Tasmania and Australia have been elucidated. These may now be addressed and management of a conservation assessment process can be demonstrated to river managers from a real and practical perspective. These implications are now summarized.

10.4 Implications of the study for river conservation assessment

This study of a conservation assessment and the evaluation of the assessment process have suggested a number of issues and implications for the future development of river conservation assessment protocols in Australia.

- The four criteria used to assess the study data - rarity, richness, representativeness and biogeographic values - can confidently be applied to the assessment of macroinvertebrates, and should equally well apply to other elements of the biota and, with some modifications could be applied to non-biotic elements of rivers.

- Macroinvertebrate values extending beyond the four criteria, including criteria for values within the landscape context of the river, were demonstrated to be important in the overall assessment of river conservation value. As yet, these criteria are not well articulated and, because they are manifested in different ways in terrestrial ecosystems, they require conceptual development and field trialling.

- Other conservation values of importance for rivers such as the roles played by the river itself within the landscape and the functional roles of the in-stream environment have not been addressed. Once again, these need definition and classification and attributes of high value rivers demonstrated.

- Most of the study sites, which were chosen for their low levels of disturbance, exhibited some conservation value. Although the study was not designed to demonstrate correlation with levels of river disturbance, it was clear that these less-disturbed rivers do display high conservation value. If conservation assessment is to proceed, the opportunities offered by the available information on river disturbance in the national Wild Rivers database could prove a useful starting point, particularly since it relates to river reaches or sections rather than point data sources.

- There is a dilemma in aiming for river protection as a consequence of assessment of individual biological groups, because of the constraints on species level analysis. These constraints include the level of resources available as well as the taxonomic impediment. Even if full species analysis could be achieved, knowledge of ecological requirements is limited and making provision for protection is problematic.

- Family level analysis provides a broad overview of the macroinvertebrate communities but, for Tasmania, there is a low level of distinction between community types and sites of higher taxon richness are distributed unevenly across the state.

- The study data set and the MRHI data set were shown to be broadly similar.

However, there were sufficient differences and caveats resulting from the use of the MRHI data set as a statewide reference set to alert the audience to the difficulties associated with making comparisons between unlike databases.

- While the existing MRHI data set has limited value as a conservation assessment in itself (without species level identification), it could be used for various purposes to support other field studies. Indicative sites of high taxon richness might be subject to more detailed identification, and hypotheses could be generated to explain the higher diversity of those sites. The material from the MRHI survey could be identified to lower taxonomic levels, or selected taxon groups might be determined as a priority for assessment.

- If resources have to be directed in a conservation assessment program, priority should be given to cost-effective use of existing landscape-scale data such as the Wild Rivers database, together with a focus on selected taxonomic groups considered to have high conservation value. The latter might include those groups which are known to be highly endemic or to show distinctive geographical distributions.

- The study was time-consuming yet only one aspect of river values was considered (riffle macroinvertebrates). Some compromises or efficiencies will need to be made if wider integrated assessment is to be undertaken. There are a number of possible routes to achieve this: use of surrogates, selection of significant taxon groups, classificatory approaches such as the US Wild and Scenic Rivers Act, and so on. However, each of these potential alternatives also requires evaluation and justification, and the end result does not guarantee protection of a full suite of riverine values. Other options for assessment include the use of landscape triage (Samways 1999), domain analysis (Kirkpatrick & Brown 1993), complementarity (Reyers *et al* 2000), and gap analysis (Flather *et al* 1997).

- An assessment process is likely to become less reliable and more complex as the ecological scale for the analysis is increased.

- This study was undertaken using a method which provided only point data. If a management decision were to be made to protect such sites, there is no indication of the area or length of the waterway which should be protected.

10.5 River conservation assessment in an Australian context

Boon (2000) urged an integrated approach to assessment for conservation in response to the European Commission's forthcoming Water Framework Directive. This will require a 'more integrated assessment to ensure that "good ecological quality" can be reliably defined' (Boon 2000 p 412). Integrated assessment is used to 'refer to a holistic approach in which nature conservation value is assessed against multiple criteria for habitats and biota' (Boon 2000 p 415). Boon suggests an integrated approach will need:

- to address differences in perception of 'conservation value';
- to define conservation criteria many of which are to a degree subjective;
- to establish weighting systems to differentiate between significance of different conservation values; ensure rigorous methodologies;
- to have available extensive data sets and
- to provide clear guidelines for interpretation of outputs of the conservation assessment process.

Boon's propositions are entirely consistent with the themes emerging in this study. However, a direct adoption in Australia of the UK SERCON approach is inappropriate because of:

- differing interpretations and thresholds for values and attributes;
- differing levels of taxonomic and ecological knowledge of the diverse stream biota;
- limited availability of large and comparable national data sets, and
- the absence to date of a national approach to river habitat classification.

There are also significant differences in institutional issues between the UK and Australia (Schofield *et al* 2000). In Australia, there is no equivalent of the European Commission and its directives, and there has been a congenital resistance by the states to Commonwealth government initiatives in natural resource management. In recent years a more collaborative approach to issues of national importance is reflected in bi-lateral agreements on various environmental (and other) issues. Even so, land and water management is constitutionally a state responsibility, and interpretation of bi-lateral agreements and priorities for action are done at state level. At this point in time, there has been no coordinated national initiative towards assessment or protection of riverine conservation values which might have occurred within the broad parameters of the Biodiversity Strategy and indirectly through the Water Reform Agenda.

The first of Boon's issues - perceptions of conservation value - were addressed in a survey of river scientists and managers across Australia by Dunn (2000). This showed a remarkable consistency in what people with an interest in rivers in Australia regarded as key criteria and attributes for rivers of high ecological value. All elements of river environments, river functioning, and biota were included. Weighting of criteria and attributes was considered to be dependent upon the purpose of the assessment process and should be determined in consultation with a wide range of stakeholders as part of that process.

The present study took only those criteria and attributes relevant to macroinvertebrates as a case and explored other matters raised by Boon, including methodological rigour, and data availability. The critique or evaluation of the conservation assessment process conducted here has highlighted some special constraints in the Tasmanian situation which are probably also true in the wider Australian context. Clearly, any moves to 'integrated assessment' will need to be tempered with a pragmatic approach and landscape scale assessments. If Australia waits to achieve taxonomic certainty for riverine biota and reliable long-term and extensive data sets, it will be too late for the protection of many riverine environments.

10.6 A model for river conservation assessment

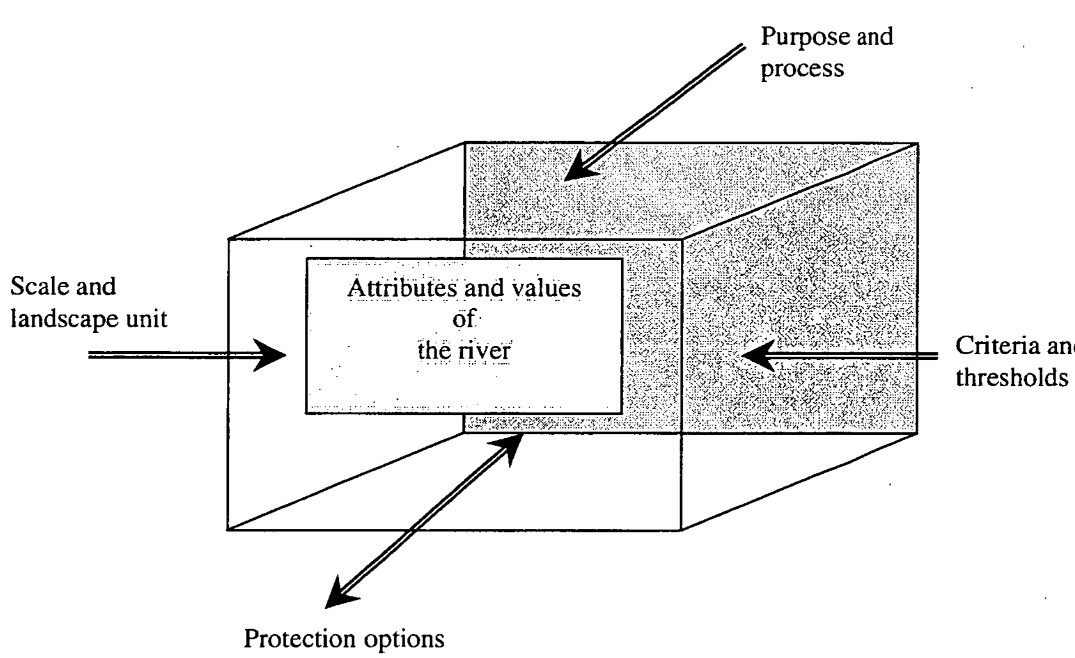
Five core elements of a model for conservation assessment can now be identified:

- the conservation assessment purpose and process
- the criteria and attributes
- the scale for analysis and comparison

- the evidence of values, and
- the options for protection

The five dimensions of conservation assessment may be demonstrated in a flow chart or in a conceptual model as shown in Figure 10.1. The starting point is the purpose of the assessment. This determines the structure and nature of the assessment process. The purpose also establishes the criteria and attributes, as well as consideration of the scale of the assessment. This in turn determines the data sets required for comparison. Scale, specific criteria and attributes and the relative importance of these dimensions will be defined in an iterative fashion as the process becomes defined. There is likely to be some consistency of criteria and attributes. Indeed, this is desirable in order to develop and maintain endorsement for the nature of riverine conservation values.

Figure 10.1 A model for conservation assessment of rivers



Once these parameters are determined, the evidence required from a river assessment can be determined and data collection and analysis undertaken.

The fifth element shown in Figure 10.1 is the range of options available for protection. Availability of protection options such as protection of threatened species or communities, a policy decision to protect representative river sections or a desire to protect a whole river system under a catchment management plan, can be important drivers of the conservation assessment purpose and processes. Protection options and the purpose of the assessment set the parameters for weighting of values. In turn, a conservation assessment process lacks an endpoint if it is not carried through to protection of rivers of high value. The integral nature of conservation and protection is addressed in more detail in Chapter 9.

10.7 Requirements for a river conservation assessment process for Tasmania

If river conservation is to be pursued in Tasmania and elsewhere in Australia in response to the National Biodiversity Strategy and/or as part of the Water Reform Agenda, then certain requirements can now be identified.

Technical issues that need addressing are:

- a hydro-geomorphic classification of Tasmania's rivers
- an interim regional framework to reflect the diversity of Tasmania's riverine environments
- a strategy to gather macroinvertebrate and other data at appropriate scales and to appropriate reference points
- appropriate data access

Institutional issues that should be resolved include:

- a state policy commitment to river conservation and management, in response to the Water Reform agenda, national Biodiversity Strategy and Tasmanian Nature Conservation Strategy
- a commitment to assessment within those processes which will result in some form of protection
- a multi-disciplinary approach to setting thresholds and weightings
- interagency commitment to the assessment and management process.

The future progress of river conservation assessment and protection is a matter of urgency. While still considered a well-watered state with largely healthy rivers, there are increasing threats to Tasmanian river environments many of which can be attributed to trends in farming which place ever-increasing demands on water supply for irrigation. Other pressures include the globalisation of hydro-electric power resources, current forestry practices including massive catchment-scale conversions to plantation and a code of practice which does not protect headwater streams, and the deliberate or uncontrolled spread of exotic plant and animal species in waterways.

Chapter 11

Findings of the study

11.1 Introduction

The study commenced with a survey of macroinvertebrate fauna of streams and smaller rivers in northern Tasmania and carried on to assess their conservation value. It then identified possible means for protection and evaluated both the conservation assessment procedure and resulting implications for conservation of riverine ecosystems in Australia. There are two key elements to the study:

- the ecology and biogeography of macroinvertebrate fauna of streams and rivers in two areas of Tasmania, their conservation values and possible measures for protection, and

- the results of the evaluation of the assessment process and the implications for developing strategies for river conservation assessment and protection in Tasmania, and in the wider Australian context.

The outcomes of the study are now summarized.

11.2 Stream invertebrate communities in Tasmania

- Analysis of statewide Monitoring River Health Initiative (MRHI) data showed that the community structure of most relatively undisturbed streams in Tasmania was typical of fast-flowing, well-oxygenated streams generally. Comparison with New Zealand suggested that Tasmanian rivers at all altitudes were most similar to several categories of communities from New Zealand headwater streams.

- The analysis of MRHI sites by taxon richness reported in the Regional Forest Agreement (RFA) study (Davies & McKenny 1997) underestimated site richness because of at least two factors: survey protocols and exclusion of rare taxa. Further work is required to elucidate patterns in taxon (and species) richness of aquatic macroinvertebrate assemblages in Tasmania.

- Apparent evidence from the MRHI data of a distinct TWINSPAN group in the south-west may be confounded by higher mean bankful widths. Lower in-stream habitat diversity may be a correlate.

- Assessment of invertebrate conservation value using only family level taxon richness data is inadequate for Tasmania. The MRHI data set cannot directly identify rivers of high conservation value, and needs to be supplemented with species level data.

11.3 Ecology and biogeography of stream macroinvertebrates in two regions of northern Tasmania.

- The overall community structure of the macroinvertebrate assemblages is similar in both north-east and north-west regions sampled.

- There was little seasonal difference in species occurrence.

- Classification and ordination did not yield a clear classification of macroinvertebrate communities, suggesting that there is little differentiation at family level. There was some indication of higher community similarity within sub catchments or at close geographic proximity. This warrants further investigation.

- The same major taxonomic groups appear in most communities, with the exception of molluscs, baetid mayflies and phreatoicid isopods.

- The streams of both survey areas are well-oxygenated, and moderate to fast-flowing. Classification of TWINSPAN groups using a taxonomic/functional feeding group analysis showed that these streams were generally similar to TWINSPAN groups evident from the analysis of all the MRHI data. This confirmed that the communities at the survey sites were generally representative of Tasmanian stream macroinvertebrate communities

- The taxonomic/functional feeding group analysis showed that the Tasmanian streams, even at low altitude, were similar to upland streams in New Zealand. Unlike lowland rivers of New Zealand, Tasmanian waterways are not subject to seasonal snowmelt. Comparative data from other Australian states was unavailable.

- The stream communities were not generally differentiated by altitude (between 50 and 950 m altitude) or by riparian vegetation.

- In the north-west, low altitude streams in areas with natural vegetation, with no or minimal catchment clearance and no flow regulation are similar to upland streams. The existence of such undisturbed streams at low altitude is unusual on a world scale. There are no undisturbed low-altitude streams in the north-east survey area.

- Molluscs only occurred in the north-west streams, confirming Ponder's findings for the absence of freshwater molluscs in north-east highlands area.

- The sampled sites typically had high taxon richness when compared with the MRHI data, though this comparison must be made with caution. A number of possible explanations may account for this. However, evidence from other sources suggests that the north-west in particular does have high species richness for some taxa.

- Acid blackwater streams of the northwest are demonstrably less diverse than all other survey sites. Some taxa such as baetid mayflies and phreatoicid isopods are absent. Trichopteran families are less well represented. Although streams of the north-east had a similarly low pH, the macroinvertebrate data did not group with that from the northwest sites in the TWINSPAN analysis.

- Class 4 or headwater streams were shown to be important with high taxon diversity, the presence of outlying populations, and the only incidence of several taxa. One hypothesis to account for these high values is that such small streams may exclude invasion by exotic trout species.

- Trichoptera at north-west sites tended to have a greater taxon diversity than at north-east sites. Some families, including Hydroptilidae, Conoseucidae and Helicophidae are less well-represented in the north-east and occurred at few sites.

- At species level, the Plecoptera were as diverse in the north-east as the north-west. Some species were restricted in distribution, while several taxa were identified as having outlying populations in the north-east highlands.

- Grassland sites did not generally group separately from forested sites, except in the Plecoptera species analysis. If stream fauna reflects earlier land use patterns, it is possible that instream carbon sources are still derived from old instream woody debris dating from some decades ago when there was more forest cover.

- The north-east highlands area was habitat for some outlying populations of taxa previously known exclusively from the west of the state, notably *Crypturoperla paradoxa* (Plecoptera: Austroperlidae). It may be an important refugial area, concurring with the tentative invertebrate bioregion called 'Plomley's Island'.

- There was no evidence in the invertebrate data, at least at family level, of such refugial status for the Blue Tier area, which has been suggested as a possible glacial refugium based on climate and vegetation modelling.

- There was also no evidence of differences in macroinvertebrate assemblages, which might result from differences in hydrological regimes, despite a more strongly seasonal rainfall pattern in the north-east.

- It was not possible to establish any correlations between macroinvertebrate TWINSPAN community groupings and the Wild Rivers Index or its component indices. Since minimally disturbed sites had been selected for study, this was not surprising, and does not indicate that the Wild River Index is not a useful element of river assessment on a broader scale.

11.4 Assessing conservation value of riverine systems and implications for protection

- The criteria and thresholds examined here provided an appropriate basis on which to assess conservation value for aquatic macroinvertebrates in Tasmania.

- The analysis of conservation value of the survey sites showed that several sites were of high conservation value.

- The conservation assessment was evaluated as feasible, valid, reliable, ethical, adequate and useful for the immediate purpose of testing a methodology. However, the process is not sufficiently adequate to assess conservation of river systems or sections as a whole, nor is it useful unless applied in a genuine and purposeful collaborative river management process.

- The survey data has suggested the significance of Class 4 or headwater streams as specialized habitats for certain taxa and as refugial sites. Further work is urgently required to better understand their role in sustaining elements of the catchment.

- The survey endorses the need for holistic and integrated assessment based on defined river segments or sections rather than only point sources of data collection.

- Threats exist to the conservation values of the study stream sites in Crown Land even where riverine values are considered to be protected within reserves or under the provisions of the Forest Practices Code.

- The four criteria for conservation assessment - rarity, richness, representativeness and biogeographic significance - although standard and widely adopted criteria, they did not capture important aspects of the values of the riverine fauna in a landscape context.

11.5 Protection measures for riverine ecosystems in Tasmania

- Options for the protection of rivers and streams in Tasmania are very limited and are severely constrained by the Regional Forest Agreement and the overall directions and purposes of the Water Act.

- The Forest Practices Code is inadequate for the protection of riverine values, particularly for Class 4 streams. An urgent need has been identified to provide protection for sites identified with high conservation value in areas currently subject to forest operations.

- Streams with very high conservation values were identified as being subject to impacts of cable logging upstream, demonstrating the limitations of the Code in protecting riverine conservation values along the length of a waterway.

- There is currently no conservation strategy in Tasmania targeting river systems whereas representative areas of forest have been protected under the Regional Forest Agreement, and other types of terrestrial habitats and even geomorphic systems are being provided with protection under the Commonwealth Biodiversity Strategy. At present, rivers classified as 'Wild Rivers' are largely only protected within the south-west (World Heritage Area). There are no other provisions for the protection of unregulated or largely undisturbed rivers in Tasmania.

- There is an urgent need for protection of a representative suite of riverine habitats based on interim assessment using existing databases and a framework of ARC river basins.

- Immediate opportunities exist to pursue such conservation measures through the draft Tasmanian Nature Conservation Strategy, Water Plans and Natural Heritage Trust programs.

- The study has detailed the various options for protection of river sites of significance in Tasmania. The broad suite of protection tools is common to most jurisdictions: analysis of each state or local region will be necessary to establish what is available and appropriate. Similarly, analysis of the threats must be undertaken at the local level.

11.6 Conclusions: Implications for river conservation assessment & protection in Australia

In order to meet the present and imminent threats to further degradation of conservation values of Australia's outstanding and distinctive riverine ecosystems, action is essential on several fronts. Opportunities exist within provisions of the National Biodiversity Strategy, Water Reform agenda and community-oriented environmental programs, despite the constraints of the range of institutional arrangements and the nature of riverine environments. The necessity of water for human use is a constraint on protection for ecological values and there is an opportunity to encourage commitment from the community to the protection of riverine values.

The study illustrated some of the current constraints with respect to data sets, the bases for making regional and other comparisons, taxonomic resolution, point source data, and the absence of a readily accessible categorization of rivers. The issue of providing for a Comprehensive, Adequate and Representative Reserve system for riverine environments is compounded by the lack of any meaningful regionalization, which is appropriate for river habitats.

Nevertheless, it would be quite feasible and justifiable to develop proposals for a representative classification of rivers using existing information referenced to, in the first instance, mapping of major river basin regions and geomorphological features or characteristics. A generalized predictive model such as those used in cultural value assessment, reinforced by more specific data where available, would be a reasonable approach. While protection of river section is important for specific values, landscape and catchment scale assessment and protection is the ideal. Rivers that are presently relatively undisturbed are a high priority for protection.

There is general agreement amongst river conservation scientists internationally that an integrated approach to assessment is most appropriate, that is one which includes the full scope of riverine conservation values and adopts the same suite of criteria as the core of the assessment.

There is a growing body of river scientists and natural resource managers with a common understanding of, and support for, a suite of criteria and attributes of the ecological value of rivers. Probably more so than amongst the equivalent groups of terrestrial specialists and managers, a holistic view of river values is widely accepted, incorporating geomorphic, hydrological and biotic elements. Beyond this, river function has a high priority, both in terms of instream processes and landscape roles. River dynamics and their multi-dimensional character and variability are additional perspectives on river conservation values, protection, and management.

Assessment of river conservation values can be conducted for a variety of purposes while broadly applying the same suite of criteria. Depending on the purpose of the assessment, different weighting may be given to particular criteria or attributes, or these may be treated as filters or hierarchies. Different thresholds may be appropriate particularly when dealing with individual river sections for management purposes rather than general river-reserve planning. Where resources are limited, taxa likely to be of high significance, especially for their endemism and biogeographic values should be selected for intensive survey.

The nature of riverine environments and their place in the physical and socio-economic landscape demands different approaches to protection. River assessment and protection needs to occur at spatial scales ranging from catchment to river to section to reach. Consistency can be achieved through common criteria: provided comparisons are made with data collected at similar scales. Complementary protection measures must be explored across the full range of jurisdictions and land tenure classifications

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APPENDICES

APPENDIX I

Study sites: Latitude/longitude

Site	Code	Easting	Northing
Northwest sites			
Animal Creek	AN	384500	5389700
Biscuit Creek	BC	379900	5399600
Blackwater trib.	BT	325900	5439900
Cableway Creek	CB	375500	5367700
Coldstream @ Husk	CH	375600	5392900
Coldstream forest	CF	377300	5403400
Coldstream grassy	CG	377500	5404400
Conliffe Creek	CC	374900	5366700
Farm Creek	FA	382700	5380900
Guthrie Creek	GU	340400	5390900
Hatfield @ Husk	HH	375900	5393200
Hellyer @ Guildford	HG	389000	5413900
Hellyer @ Moorey	HM	391700	5405400
Holder Rivulet	HR	352400	5443600
Julius River	JU	334500	5442050
Lindsay River	LR	330900	5422700
Netherby Creek	NE	379400	5402900
Pineapple Creek	PC	351700	5415800
L.Donaldson trib	PD	352600	5418300
Clearwater Creek	PP	355500	5424500
Ring Mt Read	RR	377300	5366500
Southwell River	SO	396600	5398700
Stephens forest	SF	328400	5441200
Stephens road	SR	327800	5443900
Sterling River	ST	384400	5374700
Sumac Rivulet	SU	337800	5440800
Vale River	VA	406500	5400400
Northeast sites			
Becketts Creek	BE	543300	5416500
Bonnies Creek	BO	533500	5421000
Cascade Creek	CA	551200	5412400
Dorest River	DR	566500	5426700
Full Moon Creek	FM	584400	5439000
Farrells Creek	FR	556100	5418000
Gravel Pit Creek	GP	559500	5421800
Memory Creek	MM	558900	5416100
Merry Creek	MR	567200	5411400
Newitts Creek	NW	557700	5421500
ParadiseCreek	PA	556600	5421500
Ringarooma River	RG	550800	5424600
South Esk River	SE	560000	5414300
St Patricks River	SP	544800	5424100
Sweets Creek	SW	560500	5416600
Wellington Creek	WL	581600	5439400
Wyniford River	WY	583400	5439400

Sampling dates Northeast sites

Site	Date	Code	Date	Code	Date	Code	Date	Code
Becketts	23/4/99	BEA3	23/11/98	BES3	28/5/97	BEA2	24/10/97	BES2
Bonnies	23/4/99	BOA3	23/11/98	BOS3	16/4/97	BOA2	26/10/97	BOS2
Cascade	8/6/96	CAA1	1/11/96	CAS1	12/3/97	CAS2	23/19/97	CAS2
Dorset	23/4/99	DRA3	23/11/98	DRS3	27/5/97	DRA2	25/10/97	DRS2
Farrell	8/6/96	FRA1	31/10/96	FRS1	12/3/97	FRA2	23/10/97	FRS2
Full Moon	8/5/99	FMA3	7/11/98	FMS3	29/6/97	FMA2	4/11/97	FMS2
'Gravel Pit'	9/6/96	GPA1	31/10/96	GPS1	11/3/97	GPA2	23/10/97	GPS2
Memory	22/4/99	MMA3	5/10/98	MMs3	15/4/97	MMA2	3/11/97	MMS2
Merry	23/4/99	MRA3	5/10/98	MRS3	28/5/97	MRA2	3/11/97	MRS2
Newitts	9/6/96	NWA1	31/10/96	NWS1	11/3/97	NWA2	25/10/97	NWS2
'Paradise'	9/6/96	PAA1	31/10/96	PAS1	11/3/97	PAA2	25/10/97	PAS2
Ringarooma	9/6/96	RGA1	25/11/96	RGS1	11/3/97	RGA2	24/10/97	RGS2
South Esk	22/4/99	SEA3	5/10/98	SES3	15/4/97	SEA2	24/10/97	SES2
St Patricks	8/6/96	SPA1	31/10/96	SPS1	11/3/97	SPA2	24/10/97	SPS2
Sweets	23/4/99	SWA3	5/10/98	SWS3	28/5/97	SWA2	3/11/97	SWS2
Wellington	8/5/99	WEA3	7/11/98	WES3	29/6/97	WEA2	4/11/97	WES2
Wyniford	8/5/99	WYA3	7/11/98	WYS3	29/6/97	WYA2	4/11/97	WYS2

North-West Tasmania Rivers Sampling dates

Region	River	Code	1995	1995	1996	1996
Guildford	Vale	VA	22/2	1/11	27/5	7/10
	Southwell	SO	22/2	3/10	27/5	24/9
	Hellyer .@ Moorey	HM	6/3	5/10	29/5	7/10
	Hellyer .@ Guildford	HG	6/3	5/10	29/5	8/10
	Netherby	NE	6/3	3/10	28/5	8/10
	Coldstream grassy	CG	7/3	3/10	28/5	8/10
	Coldstream forest	CF	7/3	3/10	28/5	8/10
Rosebery	Ring @ Mt Read	RR	---	1/11	31/5	27/11
	Farm	FA	22/2	1/11	31/5	25/9
	Animal	AN	---	2/11	30/5	24/9
	Sterling	ST	---	31/10	31/5	25/9
Sumac	Stephens road	SR	31/5	10/11	27/9	21/10
	Stephens forest	SF	17/8	10/11	24/4	22/10
	Sumac	SU	30/5	9/11	24/4	21/10
	Julius	JU	16/8	9/11	24/4	21/10
	Holder	HO	16/8	---	---	22/10
	Blackwater trib.	BT	31/5	9/11	25/4	22/10
Huskisson	Biscuit	BC	5/3	4/10	30/5	9/10
	Hatfield @ Husk.	HH	5/3	4/10	30/5	9/10
	Coldstream @ Husk.	CH	5/3	4/10	30/5	9/10
Pipeline	Pineapple	PC	30/5	9/11	24/4	---
	L. Donaldson.trib	PD	30/5	9/11	24/4	13/11
	Clearwater	PP	30/5	9/11	24/4	13/11
Tarkine	Lindsay	LR	---	---	7/9/96	13/11
	Guthrie	GC	---	---	7/9/96	13/11

Site variables: Altitude, physical and chemical properties

River	Code	Altitude m	Depth cm	Width m	pH	Conductivity µS
Northwestern sites						
Animal Ck	AN	400	15	4	5.69	48.9
Biscuit Ck	BC	580	10	1.5	5.84	45.6
Blackwater trib.	BT	100	15	2	6.72	126.8
Cableway Ck	CB	400	10	1	6.02	69.5
Conliffe Ck	CC	260	20	3	6.53	54.7
Coldstream forest	CF	600	35	6	6.70	47.2
Coldstream grassy	CG	600	30	6	6.90	48.7
Coldstream @ Husk.	CH	180	40	13	6.80	60.4
Farm Ck	FA	160	35	15	4.65	61.3
Guthrie Ck	GU	50	15	3	7.30	160.0
Hellyer @ Guildford	HG	560	30	20	6.95	53.2
Hatfield @ Husk.	HH	180	20	17	6.77	56.2
Hellyer @ Moorey	HM	650	10	3.5	6.75	41.8
Holder	HR	230	10	20	4.70	77.6
Julius	JU	130	25	6	7.52	146.8
Lindsay	LR	160	35	20	4.7	59.0
Netherby Ck	NE	630	10	3	6.79	47.1
Pineapple Ck	PC	300	25	4	6.74	56.6
L Donaldson trib	PD	300	30	9	6.85	65.1
Clearwater Ck	PP	480	25	3.5	6.14	56.0
Ring @ Mt Read	RR	900	10	1	5.00	49.9
Stephens @ forest	SF	150	20	4	6.92	124.1
Southwell	SO	690	10	2	6.74	56.3
Stephens @ road	SR	50	40	5	7.03	124.9
Sterling	ST	170	20	15	6.10	51.9
Sumac	SU	120	20	3	7.53	169.0
Vale	VA	790	25	5	7.22	280.0
Northeast sites						
Beckett Creek	BE	470	25	5	6.50	46.5
Bonnies Creek	BO	890	10	1	6.50	39.4
Cascade Creek	CA	810	30	3	6.67	44.0
Dorset River	DR	350	70	4	5.72	36.5
Full Moon Creek	FM	730	20	1	5.10	35.8
Farrell's Creek	FR	720	15	5	6.04	26.3
Gravel Pit Creek	GP	825	10	.5	5.70	30.0
Memory Creek	MM	400	40	2	6.76	38.2
Merry Creek	MR	330	25	4	6.60	39.8
Newitts Creek	NW	790	15	1	6.18	24.6
Paradise Creek	PA	810	25	.5	6.00	25.4
Ringarooma River	RG	870	40	3.5	5.80	23.6
South Esk	SE	380	30	8	6.50	38.1
St Patrick's River	SP	630	30	11	6.50	33.7
Sweets Creek	SW	430	35	2.5	6.29	32.4
Wellington Creek	WE	720	30	1	5.20	44.4
Wyniford River	WY	710	30	3	4.84	35.7

Study sites: slope, riparian vegetation and percentage cover

Site	Code	% slope	Vegetation type	% cover
Northwest sites				
Animal Creek	AN	0.8	m	50
Biscuit Creek	BC	4.0	m	20
Blackwater trib.	BT	1.7	m	100
Cableway Creek	CB	5.7	m	5
Conliffe Creek	CC	5.7	r	100
Coldstream forest	CF	0.3	r	0
Coldstream grassy	CG	0.3	g	0
Coldstream @ Husk	CH	2.1	r	0
Farm Creek	FA	0.7	r	80
Guthrie Creek	GU	4.0	r	40
Hellyer @ Guildford	HG	1.6	r	20
Hatfield @ Husk	HH	1.2	m	0
Hellyer @ Moorey	HM	1.2	g	0
Holder Rivulet	HR	2.5	m	5
Julius River	JU	1.1	m	40
Lindsay River	LR	0.7	m	0
Netherby Creek	NE	1.1	g	0
Pineapple Creek	PC	2.0	r	0
L.Donaldson trib	PD	1.5	r	0
Clearwater Creek	PP	2.0	r	5
Ring Mt Read	RR	6.7	a	0
Stephens forest	SF	4.0	r	10
Southwell River	SO	1.0	r	80
Stephens road	SR	0.4	m	30
Sterling River	ST	1.0	m	0
Sumac Rivulet	SU	0.4	m	80
Vale River	VA	1.2	g	0
Northeast sites				
Becketts Creek	BE	1.1	m	10
Bonnies Creek	BO	10.0	r	100
Cascade Creek	CA	3.6	m	70
Dorest River	DR	2.7	m	30
Full Moon Creek	FM	2.0	r	90
Farrells Creek	FR	2.0	m	70
Gravel Pit Creek	GP	2.7	g	0
Memory Creek	MM	3.3	r	80
Merry Creek	MR	1.7	m	60
Newitts Creek @ Ding Dong Road	NW	1.7	g	0
ParadiseCreek	PA	1.7	g/heath	10
Ringarooma River	RG	1.2	r	80
South Esk River	SE	0.4	m	0
St Patricks River	SP	0.5	r	80
Sweets Creek	SW	1.4	r	80
Wellington Creek	WE	1.4	r	80
Wyniford River	WY	2.7	g/heath	15

Site variables: substrate characteristics

Site	code	% silt	% sand	% gravel	% pebbles	% cobbles	% boulders	Surface type
Northwest sites								
Animal Creek	AN		5	70	15	10		rough
Biscuit Creek	BC		5	15	35	45		rough
Blackwater trib.	BT		10	15	65	10		rough
Cableway Creek	CB			5	30	65		rough
Conliffe Creek	CC		10	15	70	5		rough
Coldstream forest	CF		10	15	55	20		rough
Coldstream grassy	CG		5	15	65	15		rough
Coldstream @ Husk	CH		15	10	75			smooth
Farm Creek	FA		10	35	55			rough
Guthrie Creek	GU		5	10	5	80		rough
Hellyer @ Guildford	HG		5	70	20	5		smooth
Hatfield @ Husk	HH			15	10	70	5	smooth
Hellyer @ Moorey	HM			10	10	80		rough
Holder	HR			10	30	60		rough
Julius	JU					95	5	rough
Lindsay River	LR		5	10	45	40		smooth
Netherby Creek	NE			10	15	75		rough
Pineapple Cr	PC				15	85		rough
L Donaldson trib	PD				5	80	15	rough
Clearwater Ck	PP			20	10	70		rough
Ring Mt Read	RR	10				90		rough
Stephens forest	SF		5	10	20	65		rough
Southwell	SO		5	10	65	20		rough
Stephens road	SR			10	50	40		rough
Sterling River	ST		5	10	80	5		smooth
Sumac	SU			10	40	50		rough
Vale River	VA			5	25	70		rough
Northeast sites								
Beckett Creek	BE		10	5	30	55		smooth
Bonnies Creek	BO							smooth
Cascade Creek	CA	5	10	20	35	30		rough
Dorset River	DR		10	15	25	30	20	smooth
Full Moon Creek	FM							rough
Farrell's Creek	FR			15	15	70		smooth
Gravel Pit Creek	GP		10	20	70			rough
Memory Creek	MM					100		smooth
Merry Creek	MR			5	40	50	5	smooth
Newitts Creek	NW		20	60	20			rough
Paradise Creek	PA		5	50	45			rough
Ringarooma River	RG			60	20	20		rough
South Esk	SE			15	15	60	10	smooth
St Patrick's River	SP			25	30	40	5	smooth
Sweets Creek	SW			5	35	50	10	smooth
Wellington Creek	WE			50	50			rough
Wyniford River	WY				10	90		rough

Study sites: Catchments, bioregions and hydrological regions

Site	Code	Catchment	IBRA region	Orchard region	Hydrological group
Northwest sites					
Animal Creek	AN	Pieman	West/SW	West Coast	3
Biscuit Creek	BC	Coldstream/Huskisson	West/SW	West Coast	3
Blackwater trib.	BT	Blackwater/Arthur	West/SW	West Coast	4
Cableway Creek	CB	Ring/Pieman	West/SW	West Coast	3
Conliffe Creek	CC	Ring/Pieman	West/SW	West Coast	3
Coldstream forest	CF	Coldstream/Huskisson	Central Plateau	North West	3
Coldstream grassy	CG	Coldstream/Huskisson	Central Plateau	North West	3
Coldstream @ Husk	CH	Coldstream/Huskisson	West/SW	West Coast	3
Farm Creek	FA	Pieman	West/SW	West Coast	3
Guthrie Creek	GU	Donaldson/Pieman	West/SW	West Coast	3
Hellyer @ Guildford	HG	Hellyer/Arthur	Central Plateau	North West	3
Hatfield @ Husk	HH	Huskisson/Pieman	West/SW	West Coast	3
Hellyer @ Moorey	HM	Hellyer/Arthur	Central Plateau	Cent H'lands	3
Holder	HR	Arthur	West/SW	West Coast	4
Julius	JU	Arthur	West/SW	West Coast	4
Lindsay River	LR	Frankland/Arthur	West/SW	West Coast	3
Netherby Creek	NE	Coldstream/Husk	Central Plateau	Cent.H'lands	3
Pineapple Cr	PC	Donaldson/Pieman	West/SW	West Coast	3
L Donaldson trib	PD	Donaldson/Pieman	West/SW	West Coast	3
Clearwater Ck	PP	Donaldson/Pieman	West/SW	West Coast	3
Ring Mt Read	RR	Ring/Pieman	Central Plateau	Cent H'lands	3
Stephens forest	SF	Arthur	West/SW	West Coast	4
Southwell	SO	Mackintosh/Pieman	Central Plateau	Cent.H'lands	3
Stephens road	SR	Arthur	West/SW	West Coast	4
Sterling River	ST	Pieman	West/SW	West Coast	3
Sumac	SU	Arthur	West/SW	West Coast	4
Vale River	VA	Mackintosh/Pieman	Central Plateau	Cent. H'lands	3
Northeast sites					
Beckett Creek	BE	N. Esk	Ben Lomond	Ben Lomond	4
Bonnies Creek	BO	St Patricks/N.Esk	Ben Lomond	Ben Lomond	4
Cascade Creek	CA	N.Esk	Ben Lomond	Ben Lomond	4
Dorset River	DR	Ringarooma	Ben Lomond	Ben Lomond	4
Full Moon Creek	FM	Gt Musselroe	Ben Lomond	Ben Lomond	4
Farrell's Creek	FR	S. Esk	Ben Lomond	Ben Lomond	4
Gravel Pit Creek	GP	S. Esk	Ben Lomond	Ben Lomond	4
Memory Creek	MM	S.Esk	Ben Lomond	Ben Lomond	4
Merry Creek	MR	S.Esk	Ben Lomond	Ben Lomond	4
Newitts Creek	NW	S.Esk	Ben Lomond	Ben Lomond	4
Paradise Creek	PA	S.Esk	Ben Lomond	Ben Lomond	4
Ringarooma River	RG	Ringarooma	Ben Lomond	Ben Lomond	4
South Esk	SE	S.Esk	Ben Lomond	Ben Lomond	4
St Patrick's River	SP	St Patricks/N. .Esk	Ben Lomond	Ben Lomond	4
Sweets Creek	SW	S.Esk	Ben Lomond	Ben Lomond	4
Wellington Creek	WE	Wyniford/Ringarooma	Ben Lomond	Ben Lomond	4
Wyniford River	WY	Wyniford/Ringarooma	Ben Lomond	Ben Lomond	4

Disturbance indices for sites, Wild Rivers database.

Site	Code	CDI	SCDI	FRDI	RDI
Northwest sites					
Animal Creek	AN	4	4	1	3
Biscuit Creek	BC	4	2	1	3
Blackwater trib.	BT	2	2	1	3
Cableway Creek	CB	5	5	1	4
Conliffe Creek	CC	3	3	1	4
Coldstream forest	CF	4	4	1	3
Coldstream grassy	CG	4	4	1	3
Coldstream @ Husk	CH	3	2	1	3
Farm Creek	FA	3	3	1	5
Guthrie Creek	GU	2	2	1	2
Hellyer @ Guildford	HG	5	5	1	4
Hatfield @ Husk	HH	4	3	1	3
Hellyer @ Moorey	HM	5	5	1	4
Holder Rivulet	HR	1	1	1	1
Julius River	JU	4	4	1	3
Lindsay River	LR	2	2	1	2
Netherby Creek	NE	4	4	1	3
Pineapple Creek	PC	1	1	1	2
L.Donaldson trib	PD	1	1	1	2
Clearwater Creek	PP	2	2	1	1
Ring Mt Read	RR	3	3	1	3
Stephens forest	SF	2	2	1	3
Southwell River	SO	3	3	1	3
Stephens road	SR	3	4	1	3
Sterling River	ST	2	2	1	2
Sumac Rivulet	SU	4	4	1	4
Vale River	VA	5	5	1	4
Northeast sites					
Becketts Creek	BE	4	5	1	3
Bonnies Creek	BO	4	5	1	3
Cascade Creek	CA	5	5	1	4
Dorest River	DR	5	5	1	4
Full Moon Creek	FM	3	4	1	3
Farrells Creek	FR	5	4	1	4
Gravel Pit Creek	GP	4	5	1	4
Memory Creek	MM	5	5	1	4
Merry Creek	MR	5	5	1	4
Newitts Creek @ Ding I	NW	4	5	1	4
ParadiseCreek	PA	4	5	1	4
Ringarooma River	RG	3	3	1	3
South Esk River	SE	4	6	1	4
St Patricks River	SP	3	5	1	4
Sweets Creek	SW	4	4	1	4
Wellington Creek	WL	5	5	1	4
Wyniford River	WY	3	3	1	3

Study sites: Wild Rivers values

Site	Code	LUF	CDI	RDI
Northwest sites				
Animal Creek	AN	0.72900	0.37700	0.18800
Biscuit Creek	BC	0.00000	0.00004	0.00002
Blackwater trib.	BT	0.25400	0.13200	0.06580
Cableway Creek	CB	0.27600	0.15400	0.07720
Conliffe Creek	CC	0.04350	0.02180	0.01090
Coldstream forest	CF	0.00000	0.10000	0.02500
Coldstream grassy	CG	0.00000	0.10000	0.02500
Coldstream @ Husk	CH	0.52900	0.05670	0.02830
Farm Creek	FA	0.75000	0.40500	0.20200
Guthrie Creek	GU	0.22400	0.11700	0.05840
Hellyer @ Guildford	HG	0.00000	0.00166	0.00083
Hatfield @ Husk	HH	0.05000	0.02560	0.01280
Hellyer @ Moorey	HM	0.00000	0.20000	0.10000
Holder Rivulet	HR	0.28400	0.15656	0.07828
Julius River	JU	0.75000	0.38200	0.19100
Lindsay River	LR	0.00000	0.00000	0.00000
Netherby Creek	NE	0.02080	0.03900	0.01950
Pineapple Creek	PC	0.00000	0.00000	0.00500
L.Donaldson trib	PD	0.00000	0.00000	0.20000
Clearwater Creek	PP	0.00000	0.00500	0.00000
Ring Mt Read	RR	0.27600	0.15400	0.07720
Stephens forest	SF	0.10500	0.10200	0.05100
Southwell River	SO	0.00000	0.00894	0.01670
Stephens road	SR	0.64200	0.23200	0.11600
Sterling River	ST	0.22800	0.10800	0.05400
Sumac Rivulet	SU	0.22300	0.11800	0.05920
Vale River	VA	0.00000	0.20000	0.10000
Northeast sites				
Becketts Creek	BE	0.00000	0.10000	0.02500
Bonnies Creek	BO	0.00000	0.10000	0.02500
Cascade Creek	CA	0.00000	0.02940	0.01470
Dorset River	DR	0.00000	0.10000	0.10000
Full Moon Creek	FM	0.47600	0.31200	0.15600
Farrells Creek	FR	0.00000	0.10000	0.10000
Gravel Pit Creek	GP	0.00000	0.20000	0.10000
Memory Creek	MM	0.00000	0.00289	0.00145
Merry Creek	MR	0.00000	0.20000	0.10000
Newitts Creek	NW	0.00000	0.00058	0.00029
ParadiseCreek	PA	0.00000	0.00058	0.00029
Ringarooma River	RG	0.00109	0.00004	0.00002
South Esk River	SE	0.00000	0.01190	0.00593
St Patricks River	SP	0.22000	0.00973	0.50500
Sweets Creek	SW	0.00000	0.00018	0.00009
Wellington Creek	WL	0.47600	0.31200	0.15600
Wyniford River	WY	0.47600	0.31200	0.15600

CDI=Catchment Disturbance Index; RDI=River Disturbance Index; LUF=Land Use Factor

APPENDIX II

Group assignment of taxa in taxonomic/feeding group analyses

Oligochaeata	Oligochaeata	**Other**	
		Turbellaria	Tricladida
Mollusca	Hydrobiidae	Nematomorpha	Gordiidae
	Lymnaeidae	Hirudinea	Hirudinea
	Ancylidae	Hydracarina	Hydracarina
	Planorbidae		Veliidae
	Physidae	Hemiptera	Gerridae
	Sphaeriidae		Corixidae
		Mecoptera	Nannochoristidae
Coleoptera	Noteridae	Megaloptera	Sialidae
	Dytiscidae Adults	Neuroptera	Osmylidae
	Dytiscidae Larvae	Odonata	Lestidae
	Gyrinidae Adults		Aeshnidae
	Gyrinidae Larvae		Gomphidae
	Hydrophilidae		Corduliidae
	Staphylinidae		
	Scirtidae	**Crustacea**	Anaspidae
	Elmidae Adults		Ceinidae
	Elmidae Larvae		Eurisidae
	Psephenidae		Corophidae
	Chrysomelidae Adult		Parameletidae
	Curculionidae		Phreatoicidae
			Janiridae
Simuliidae	Simuliidae		Atyidae
			Parastacidae
Chironomidae	Chironomidae		Hymenosomatidae
Other Diptera	Tipulidae	**TrichCB**	Hydrobiosidae
	Blephariceridae		Philorheithridae
	Dixidae		
	Culicidae	**Trichoptera**	Glossosomatidae
	Ceratopogonidae		Hydroptilidae
	Thaumaleidae		Polycentropodidae
	Athericidae		Ecnomidae
	Stratiomyidae		Limnephilidae
	Empididae		Plectrotarsiidae
			Oeconesidae
			Tasimiidae
Ephemeroptera	Siphlonuridae		Conoesucidae
	Baetidae		Helicopsychidae
	Oniscigastridae		Calocidae
	Leptophlebiidae		Helicophidae
	Caenidae		Odontocerida
			Atriplectididae
Plectoptera P	Eustheniidae		Calamoceratidae
			Leptoceridae
Plectoptera CB	Austroperlidae		
	Gripopterygidae	**Trich N**	Philopotamidae
	Notonemouridae		Hydropsychidae

Appendix III

Deletion of taxa for Marchant virtual sub-sampler reduction

1. Probability of missing taxa in MRHI live-pick protocol

Taxon code	Taxon	Probability of missing taxon	Taxon code	Taxon	Probability of missing taxon
CHIRZZZP	Chironomidae pupae	.765564	UACAZZZX	Unid. Acarina	.234452
SPHAZZZX	Sphaeridae	.689028	CAENZZZN	Caenidae nymphs	.195907
EMPIZZZL	Empididae	.677438	SIMUZZZL	Simuliidae larvae	.150567
HPTIZZZL	Hydroptilidae	.616631	SCIRZZZL	Scirtidae larvae	.134601
CERAZZZL	Ceratopogonidae	.513792	GRIPZZZN	Gripopterygidae larvae	.08024
ELMIZZZL	Elmidae larvae	.505619	ELMIZZZA	Elmidae Adults	.078056
UOLIZZZX	Unid. Oligochaeta	.35081	CHIRZZZL	Chironimidae Larvae	.055795

Source: Humphrey & Thurtell (1997)

2. In reduction of data for analysis under 'Marchant reduction' the following decisions were made to realigning study data to samples collected under MRHI protocol.

2.1 Taxa not recorded in samples, not applicable: UOLIZZZX, UACAZZZX, CHIRZZZP

2.2 Taxa deleted for Marchant modification because of probability of missing taxa : SPAZZZX, EMPIZZZL, CERAZZZL, HPTIZZZL, CAENZZZN

2.3 Taxa considered to be common and well-recognised in Tasmania and left in the database: SIMUZZZL, GRIPZZZN, ELMIZZZA, ELMIZZZL, SCIRZZZL CHIRZZZL