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Tasmania

Aquatic Ecology of Rivers in the North Esk Catchment

A Report Forming Part of the Requirements for State of Rivers Reporting

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Natural Heritage Trust
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Executive Summary

This report deals with aspects of the aquatic ecology of the North Esk River and associated tributaries. The first section provides a brief overview of the aquatic fauna found in the catchment and provides some detail of the habitat requirements and potential threats to some of the more vulnerable and endangered species found in the North Esk catchment. The main focus of the chapter details work carried out in the North Esk catchment in March 2000 using AUSRIVAS (Australian River Assessment System) to assess riverine health using macroinvertebrates as bio-indicators. Algal community composition at selected sites in the North Esk catchment is examined in respect to potential impacts. Data for this component of the investigation was collected concurrently with macroinvertebrates under the MRHI program in spring and autumn of 1997.

Some of the major findings of this report are:

- There is a clear pattern of river health deterioration down the North Esk River. Of the 13 sites sampled, 6 sites received an unimpaired rating, 6 sites were classed as significantly impaired and 1 site as severely impaired. The decline in river health scores was marked by dramatic changes in species composition, particularly of taxa that are regarded as being sensitive to various types of pollutants. Output from the model suggests that impaired sites are impacted by factors other than water quality, however water quality deterioration accumulates along the river’s length so that sites at the bottom of the catchment are impacted by both poor water quality and habitat degradation.

- Tributaries in the upper catchment as well as the St Patricks River and all of its associated tributaries are in good to excellent condition. Water quality is good and habitat degradation is limited to the presence of exotic species in the riparian zone and mild sedimentation, particularly on streams flowing though agricultural areas. Tributaries in the lower catchment are in poorer condition, with many sites recording higher turbidity and conductivity. The severity of these impacts is likely to be exacerbated by a seasonal reduction in flow.

- Implementation of better riparian management practices, decreasing agricultural runoff, providing adequate environmental flows especially during periods of low flows and effectively managing sewerage and stormwater systems have been identified as positive measures essential for sustaining the health of waterways in the North Esk catchment.

- Ninety-six genera of algae were recorded from the 6 sites sampled on the North Esk catchment. The number of alga genera recorded per site ranged from 13 to 33. There was an increase in the number of taxa collected during the spring round of sampling. The composition and diversity of the algal communities are characteristic of healthy unimpacted streams, however much more research is required before algae can be used to assess water quality and river health within and between rivers.

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Glossary of Terms

Catchment
The land area which drains into a particular watercourse (river, stream or creek) and is a natural topographic division of the landscape. Underlying geological formations may alter the perceived catchment area suggested solely by topography. Limestone caves are an example of this).

Macroinvertebrate
Invertebrate (without a backbone) animals which can be seen with the naked eye. In rivers common macroinvertebrates are insects, crustaceans, worms and snails.

Riparian Vegetation
Riparian vegetation are plants (trees, shrubs, ground covers and grasses) which grow on the banks and floodplains of rivers. A 'healthy' riparian zone is characterised by a homogeneous mix of plant species (usually native to the area) of various ages. This zone is important in protecting water quality and sustaining the aquatic life of rivers.

Anadromous

Refers to fishes which migrate from saltwater to freshwater to spawn.

Diadromous
Refers to fishes that migrate freely between freshwater and saltwater in either direction.

1. Introduction

This report deals with aspects of the aquatic ecology of the North Esk River and associated tributaries. It provides a brief overview of the aquatic fauna found in the catchment and provides some detail of the habitat requirements and potential threats to some of the more vulnerable and endangered species found in the North Esk catchment. The main focus of the report details work carried out in the North Esk catchment in March 2000 using AUSRIVAS (Australian River Assessment System) to assess riverine health using macroinvertebrates as bio-indicators. The models used to assess river health were developed under the Monitoring Riverine Health Initiative (MRHI). These models are comprehensive in their development and allow a relatively rapid assessment of riverine health at specific sites along the river and surrounding tributaries. Finally, algal community composition at selected sites in the North Esk catchment is examined in respect to potential impacts. The algal data was collected concurrently with macroinvertebrate sampling carried out under the MRHI program in autumn and spring of 1997.

1.1 General Description

The North Esk River rises in the hills west of Ben Nevis in North Eastern Tasmania at some 900 m altitude and joins the Tamar River at Launceston (see Figure 1). It is approximately 91 km long and has a catchment area of 1065 km^2. It falls steeply from its source through granodiorite to 500 m within the first 5 km. The river then meanders through the turbidite soils of the foothills of Ben Nevis. The river follows a similarly low gradient and meandering path through the alluvial and mudstone sediments of the agricultural flats downstream of the Ford River confluence (Pinkard, 1980).

At Ballroom the river begins a steeper descent through dolerite to its confluence with St Patrick's River and down to Corra Linn. Below this it flattens out and meanders across the tertiary sediments of the Tamar Valley flood plain.

The upper catchment of the river is dominated by cool temperate rainforest species, consisting of a canopy of *Eucalyptus* spp. with an understorey of myrtle (*Nothofagus cunninghamii*), sassafras (*Atherosperma moschatum*), blackwood (*Acacia melanoxylon*), dogwood (*Pommaderris apetala*), woolly tea tree (*Leptospermum lanigerum*) and silver wattle (*Acacia dealbata*). Ground cover is dominated by fishbone water fern (*Blechnum nudum*).

From here to Burns Creek Road the river is primarily lined with crack willow (*Salix fragilis)* and small patches of remnant rainforest, particularly more hardy species such as blackwood (*Acacia melanoxylon*). The riparian zone of the river is almost completely cleared between Burns Creek Road and the Musselboro Bridge at "Elverton". With the exception of some isolated small willow trees (< 3 m) on both reaches, vegetation on the banks consists of a mixture of introduced and native grass species and isolated patches of blackberry (*Rubus fruticosus*). From "Elverton" to the river's confluence with the Tamar River, the riparian zone is dominated by crack willow and European gorse (*Ulex europaeus*) with some reaches, such as the section of river at Watery Plains, retaining remnant native vegetation. In these lower reaches land use includes broad acre cropping, which includes the cultivation of poppies and potatoes, and some horticulture.

An important trout fishery exists in the North Esk River, and canoeing and swimming are important recreational activities in the lower reaches.

2. Aquatic Fauna

At least six different species of frogs have been recorded in the North Esk catchment including the brown froglet *(Crinia signifera)*, the Tasmanian froglet *(Crinia tasmaniensis)*, the spotted marsh frog (*Limnodastes tasmaniensis)*, the brown tree frog, (*Littoria ewingii)*, the southern toadlet, *(Pseudophryne semimarmorata)*, and the green and gold frog *(Litoria raniformis)* (Brown, 1996).

There are 18 freshwater fish species found in northeast Tasmania (Chilcott and Humphries, 1995), ten of which have been recorded from the North Esk catchment (Table 1). Most of these species are diadromous and have a Tasmania wide distribution. *Gadopsis marmoratus* is the only species confined entirely to freshwater and has the most limited natural distribution of the species occurring in the North Esk catchment.

The only species currently requiring conservation attention is the Australian grayling *(Prototroctes maraena)*, which is considered 'vulnerable' under Tasmania's *Threatened Species Protection Act 1995.*

Table 1: Freshwater Fish of northeast Tasmania

Life History: M = migrates to and from sea or estuary, F = freshwater only
Habitat: R = rivers, L = lake, W = wetlands

Common Name	Scientific Name	Life History	Habitat
Native Fish			
short-headed lamprey	*Mordacia mordax*	M	R
pouched lamprey	*Geotria australis*	M	R
short-finned eel	*Anguilla australis*	M	R/L/W
jollytail	*Galaxias maculatus*	M	R/L
climbing galaxias	*Galaxias brevipinnus*	M	R
Australian grayling	*Prototroctes maraena*	M	R
river blackfish	*Gadopsis marmoratus*	F	R/L
sandy flathead	*Pseudaphritis urvillii*	M	R
Introduced Fish			
brown Trout	*Salmo trutta*	M	R/L
rainbow trout	*Oncorhynchus mykiss*	M	R/L

There are two major genera of freshwater crayfish found in the northeast region: *Astacopsis* (including the Giant Freshwater Crayfish, *Astacopsis gouldi*) and *Engaeus* (a smaller burrowing crayfish) which consist of about eight species in northeast Tasmania (Horwitz, 1996). There is very little data on *Astacopsis gouldi*, and *Astacopsis franklinii* in the North Esk catchment. However *A. gouldi* has been recorded from the St Patricks River and Seven Time Creek where it has been introduced by translocation and it is highly probable that *A. franklinii* is also present given it's distribution in the northeast region of Tasmania (Hamr, 1992). A number of species of the burrowing crayfish, *Engaeus* are known to occur, the most threatened of which is the Mt. Arthur burrowing crayfish (*Engaeus orramakkunna*). It is presently registered as 'vulnerable' due to its very restricted distribution and disturbance of its habitat. *Astacopsis gouldi* is also registered as a 'vulnerable' species and is now protected under the Rare and Threatened Species Act and will be discussed in the next section.

3. Threatened Species

A species is regarded as “endangered” if it is in danger of extinction because long term survival is unlikely while the factors causing them to be endangered continue operating. A species is considered to be “vulnerable” if it is likely to become endangered while the factors causing to be vulnerable continue operating. “Rare” species are neither endangered nor vulnerable but are at risk due to small population size. Approximately 5 threatened aquatic species occur in the North Esk catchment. The best known of these is *Astacopsis gouldi* (the Giant Freshwater Crayfish). Although *A. gouldi* does not occur naturally in the North Esk catchment, it has been recorded from the St Patricks River and Seven Time Creek where it has been introduced by translocation. *A. gouldi* is listed as “vulnerable” under Tasmanian *Threatened Species Protection Act* 1995. At the beginning of 1998 *A. gouldi* was declared a “protected fish” under the *Inland Fisheries Act* 1995 ending recreational fishing for the species.

Astacopsis gouldi has been the subject of numerous scientific studies (Hamr, 1990; Horwitz, 1994; Growns, 1995) and a draft recovery plan currently exists for the species (Bluhdorn, 1997). *A. gouldi* is a lowland wet forest/rainforest species with a preferred habitat in heavily forested stream and creeks. Distribution is limited between sea level and around 400m altitude although most animals are found below 200m (Horwitz, 1994). *A. gouldi* requires streams with high quality water (low nutrients and sedimentation), a stable thermal regime of relatively low water temperature, and habitat cover in the form of woody debris, undercut banks and ample canopy cover (Growns, 1995; Bluhdorn, 1997). Large scale habitat disturbance from agricultural and urban landuse, forestry activity and fishing pressure has reduced both the species abundance and viability of some populations.

(Bryant, 1998b) listed key issues associated with the protection of the habitat of *A. gouldi* as follows:

- Protection of stream side vegetation
- Appropriate willow removal and retention of stumps and rehabilitation of native riparian vegetation
- Retention of large woody debris
- Management of stock access
- Appropriate use of fertilisers and chemicals

The current status of the green and gold frog *Litoria raniformis*, is “vulnerable” due to its restricted distribution and decline in population. It is estimated that the range of *L. raniformis* has contracted by over 50% in the last 20 years (Bryant and Jackson, 1999). Wetlands, particularly in the lower reaches of the North Esk catchment have been identified as key habitats for the green and gold frog. Loss of habitat through drainage of wetlands is perhaps the greatest single threat to this species survival. Other significant pressures include the spread of trout and a decline in water quality due to pollution by pesticides and fertilisers.

The Mt Arthur burrowing crayfish (*Engaeus orramakunna*) is listed as “vulnerable” under the Tasmanian *Threatened Species Protection Act* 1995. It is restricted to an area centered on Mt. Arthur and bounded approximately by Lilydale, Nabowla, the Sideling Range and Nunamara. The crayfish has been found in a variety of habitats including undisturbed rainforest, eucalypt forest, open pasture, roadside gutters and pine plantation. The burrows are made in areas of high soil moisture and clay content, and can be some distance from streams. Threats to *E. orramakunna* include drainage of swamps and factors affecting water quality (Bryant and Jackson, 1999).

The Hydrobiidae family of aquatic snails is the most diverse family of freshwater molluscs in the world. There are over 62 species in the genus *Beddomeia*, several of which are locally endemic to the northeast of the state. However most of these species are very restricted in their distribution, with many species known only from one or a few sites. One of these, *Beddomeia ronaldi* is known from only a few specimens collected from three sites on the St Patrick’s river (Ponder, 1996). *B. ronaldi* is listed as rare under the Tasmanian *Threatened Species Protection Act* 1995.

The survival of hydrobiid snail populations primarily depends on the retention of native riparian vegetation and maintenance of good water quality. Ponder (1988) also suggests that landuse impacts and competition with introduced species such as *Potamopyrgus antipodarium* are also having a deleterious effect on snail populations and these impacts are primarily in lowland rural and urban streams (Davies, 1995).

The Australian Grayling (*Prototroctes maraena*) lives in coastal streams and rivers around Tasmania and occurs most commonly in clear gravelly streams with a moderate flow. It has been recorded from the North Esk River at Corra Linn. Its need to migrate to and from the sea makes it vulnerable to depletion in rivers that prevent fish passage as a result of barriers to upstream and downstream migration (McDowall, 1986). Spawning takes place in autumn and once larvae have hatched, they are swept downstream towards the sea. Larval life is marine and juveniles return to rivers from the sea during spring and the rest of their life is spent in rivers. The current status of this species is vulnerable due to a decline in its population resulting in decreased numbers across much of its former range. The Australian Grayling requires free movement between freshwater and marine habitats, therefore construction of objects (i.e. dams, weirs and culverts) which prevent fish passage should be avoided. Other threats to the distribution of this species include the removal of riparian vegetation and deterioration in water quality.

In summary, many of these species are affected by habitat degradation. Management prescriptions in the form of retention and rehabilitation of native riparian vegetation and minimal disturbance to instream habitat of the North Esk River will increase the chances of recovery for many of these species.

4. River Health

4.1 Methodology

The National River Health Program was formed in 1993 by the Federal Government to provide a means of assessing the ecological condition of Australia’s river systems. The Monitoring River Health Initiative (MRHI) in Tasmania commenced in 1994 and the programs primary objectives were to develop predictive models to allow assessment of river health using macroinvertebrates as biological indicators. Over 250 sites in Tasmania were sampled in order to build the bioassessment models. As part of this sampling, six reference sites and eight test sites were sampled at various times from spring 1994 to spring 1999 in the North Esk catchment. Reference sites are defined as sites that are least disturbed and are suitable for use in the construction of predictive models. Test sites are those sites defined to be of importance in assessing the condition of a river known or thought to be experiencing an impact from water quality or habitat degradation. Because the selection of sites in the North Esk catchment was primarily aimed at the development and testing of river health models, the overall coverage of the catchment was not extensive. However, a snapshot survey of 44 sites was carried out under the State of River (SOR) study in March 2000, ranging from small tributaries in both the upper and lower catchment as well as the mainstream channel of the North Esk River (see Fig. 1).

The sites were sampled using the rapid bioassessment technique outlined in CEPA (1994) and Oldmeadow *et al*.(1998). This involved collecting biological samples from riffle and edgewater habitats where possible. Riffles are defined as areas of shallow, fast-flowing broken water usually stony or rocky substrates. Samples were collected from riffles by disturbing the substrate by the sampler’s feet to dislodge animals which were swept into a net by the current. The edgewater sample was collected by sweeping the net along the lateral margins of the river and in backwaters and pools which have slow currents or no flow. Aquatic plants (macrophytes), which provide additional habitat for aquatic macroinvertebrates, are often found in these edgewater habitats and were included in the sweep sample.

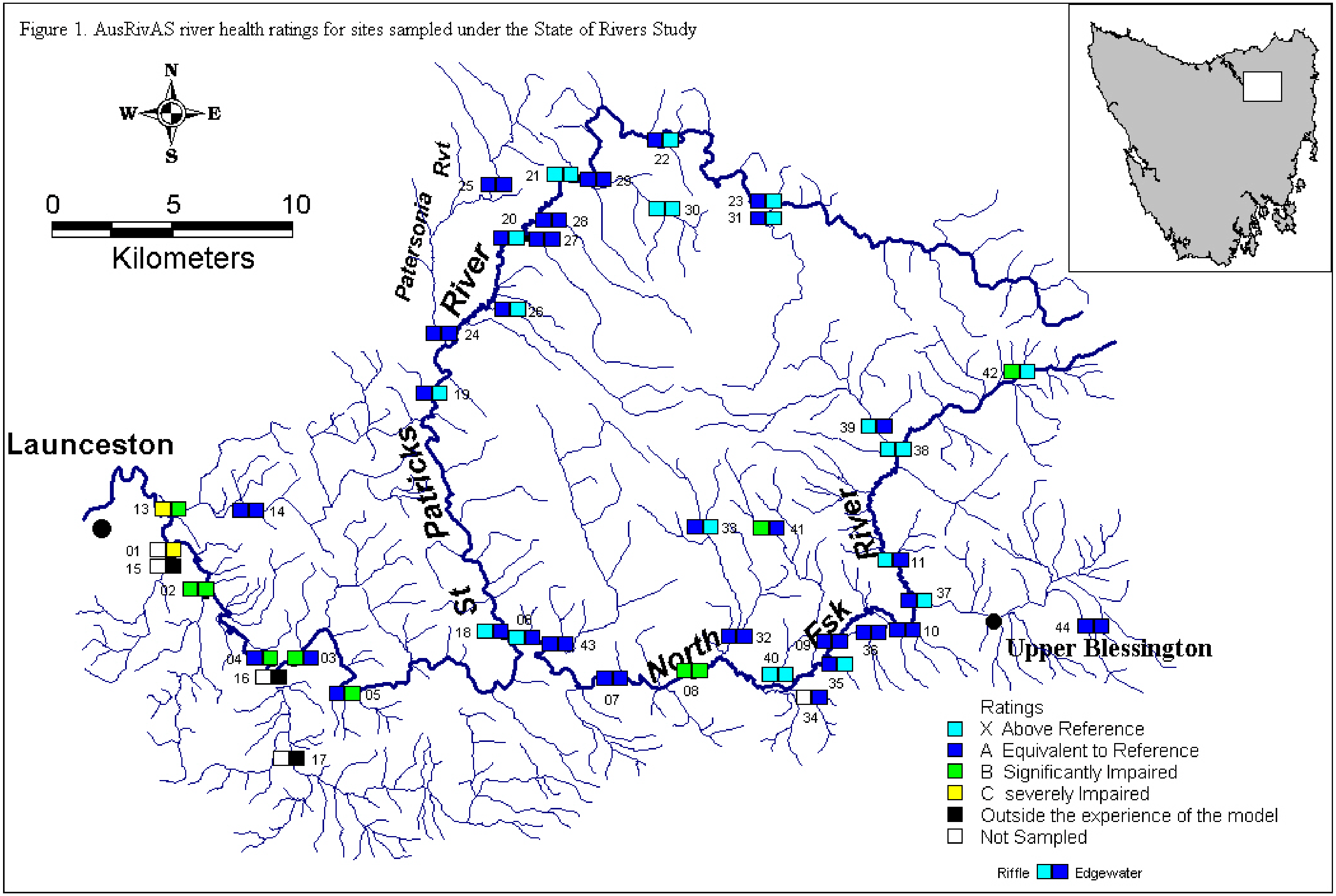

Figure 1. AusRivAS river health ratings for sites sampled under the State of Rivers Study

Water quality measurements- including temperature, pH, dissolved oxygen, electrical conductivity and turbidity were made at each site and water samples were taken for laboratory analysis of nutrients and alkalinity. Observations were also made on the vegetation along the river banks (riparian zone), aquatic habitat (substrate, depth, velocity) and surrounding land use. The samples were live-sorted and preserved in the field and transported to the laboratory for further identification. All macroinvertebrates were identified to family level except in the following cases: Chironomidae (midges) were identified to sub-family level Oligochaeta (worms), Hirudinea (leeches), Acarina (mites) and Turbellaria (flatworms) were identified to order and class level. The biological monitoring package AUSRIVAS (Australian River Assessment System) was used to provide a broad scale picture of the health of sites in the North Esk catchment.

4.2 AUSRIVAS Modelling

The AUSRIVAS model is essentially a tool that predicts the aquatic macroinvertebrate fauna that would be expected to occur at a site in the absence of environmental stress such as pollution or habitat degradation. The first step of the model building process is classifying reference sites into groups which have similar invertebrate composition, based on family level presence/absence data. This is done using the agglomerative clustering technique, flexible unweighted pair-group arithmetic averaging (UPGMA). The reference site groups from the classification are entered into the reference habitat data set and a stepwise multiple discriminant function analysis (MDFA) is used to select the predictor variables used in a model. This procedure selects a subset of habitat variables which best discriminate between the groups of sites formed from the faunal classifications. The subset of habitat variables obtained from the stepwise MDFA is used as predictor variables for the AUSRIVAS model being constructed. The predictor variables and the reference site invertebrate classification form the foundation of AUSRIVAS, allowing predictions of which taxa should be found at new sites to be made. A comparison of the invertebrates predicted to occur at the test sites with those actually collected provides a measure of biological impairment at the tested sites (Simpson *et al*.,1996).

4.3 OE Indices

Each site is classified into five categories based on the ratio of macroinvertebrates “Observed” (or sampled) to the macroinvertebrates “Expected”. This ratio is known as the observed / expected score or “OE”. Table 2 presents the categories used and the OE ratio ranges for each cut off. The OE ratio represents the percentage of taxa sampled at a site. From the table below, a site with less than 85 percent of the taxa expected to be present at the site is considered to be impaired to some degree. The advantage of these river health models is that not only the presence of an impact but also the magnitude can be determined for a specific site.

Another biotic index is incorporated into the model output to provide an insight into the nature of the disturbance or impact at a site. OESIGNAL (Stream Invertebrate Grade Number Average Level, (Chessman, 1995) is a ratio of the observed (sampled) SIGNAL score to the expected SIGNAL score. The index is based on the sensitivity of macroinvertebrates to pollution. Each family of macroinvertebrates is assigned a grade according to their tolerance where a grade of 10 represents a high sensitivity to pollution and a grade of 1 represents a high tolerance to pollution. The “observed” SIGNAL score is the sum of the grades divided by the number of taxa collected and the “expected” score is the sum of the grades divided by the number of taxa expected.

OE is sensitive to a wide variety of disturbances provided they result in the loss of families of macroinvertebrates from the habitats sampled at a site. Thus this index should detect not only loss of families due to deteriorated water quality, but also loss because of physical habitat degradation. OE SIGNAL weights the families by their sensitivity to water pollution. Accordingly, OESIGNAL can detect situations where water pollution has resulted in the loss of only a few, but very sensitive, families of macroinvertebrates.

Table 2: River Health categories and Associated OE scores

Band Label	OE Scores	Band Name	Comments
X	>1.15	Richer than Reference	• More families than expected • Potentially biodiverse site • Possible mild organic enrichment
A	0.85-1.14	Reference	• Index value within range of the central 80% of reference sites
B	0.52-0.84	Significantly Impaired	• Fewer families than expected • Potential mild to moderate impact on water quality, habitat or both, resulting in the loss of families
C	0.12-0.54	Severely Impaired	• Considerably fewer families than expected • Loss of families due to moderate to severe impact on water and/or habitat quality
D	<0.12	Impoverished	• Very few families collected • Highly degraded • Very poor water and/or habitat quality

As macroinvertebrate samples were collected from both riffle and edgewater habitats, the autumn riffle and autumn edgewater models were chosen as the most appropriate models for computing the indices. Five sites (NESK1, NESK15, NESK16, NESK17 and NESK34) were deemed to have insufficient or unsuitable riffle habitat. These sites were analysed only by the autumn edgewater model. The predictor variables for the autumn edgewater model are percentage boulder cover, conductivity, depth, latitude and longitude. The predictor variables for the autumn riffle model are altitude, catchment area, percentage cobble cover, conductivity, distance from source, latitude, longitude, percentage riffle area and stream order (see Appendix 2).

4.4 Results

A total of 80 taxa were identified from edgewater habitats and 63 taxa from riffle habitats. These taxa represented all the major taxonomic groups typical of freshwater streams. Insects were the most dominant, representing around 77% of the total number of taxa collected and accounting for approximately 85% of the total number of individuals collected. In the edgewater habitat, the most dominant families both in terms of distribution and abundance were Leptoceridae (caddisflies), Chironomidae (midges), Leptophlebiidae (mayflies) and Notonemouridae (stoneflies). Dominant families in riffle habitats included Leptoceridae and Hydrobiosidae (caddisflies), Leptophlebiidae and Baetidae (mayflies), Elmidae (riffle beetles) and Scirtidae (marsh beetles) (see Appendix 1).

The number of invertebrate taxa found in streams can give a reasonable representation of the health of a stream, though it is an oversimplification of data to be adequate on its own. The total number of taxa recorded per site ranged from 11 to 35 with a mean of 29 taxa per site. However, the number of taxa found at a site did not always appear to reflect the ecological health of the river at that site. For example, sites that received a poor environmental aquatic habitat rating such, as Old Mill Creek, could still support a relatively large number of aquatic macroinvertebrate taxa. Conversely, some sites that were rated as good could only

Table 3. Number of families, AUSRIVAS OE and OESIGNAL scores for autumn riffle and autumn edgewater models for sites in the North Esk catchment

Site Code	Site Name	Northing	Easting	Edgewater No. of taxa	Edgewater OE50	Edgewater OESignal	Edgewater Band	Riffle No. of taxa	Riffle OE50	Riffle OESignal	Riffle Band	Final Band Allocation
NESK01	North Esk d/s Kingsmeadows Rt	5411100	514200	11	0.12	0.7	C					C
NESK02	North Esk u/s Clarkes Ford Bridge	5409600	515700	14	0.53	0.85	B	13	0.68	0.88	B	B
NESK03	North Esk @ Corra Linn Gorge	5406800	519300	22	1.03	0.82	A	16	0.6	0.82	B	B
NESK04	North Esk below Corra Linn	5406800	518400	23	0.6	0.74	B	23	0.9	0.87	A	B
NESK05	North Esk @ White Hills	5405400	521450	22	0.71	0.77	B	24	0.96	1	A	B
NESK06	North Esk above St Patricks	5407850	528400	24	1.13	1	A	31	1.24	1	X	A
NESK07	North Esk @ Ballroom	5406100	532500	28	1.07	1.07	A	19	0.9	1	A	A
NESK08	North Esk @ Musselboro Rd	5406300	535800	28	0.75	0.98	B	12	0.65	1.09	B	B
NESK09	North Esk @ Burns Ck Rd	5407550	541900	29	1.08	1.13	A	19	0.92	1.03	A	A
NESK10	North Esk @ Wattle Corner	5408100	544500	17	1.08	1.07	A	22	1.13	0.98	A	A
NESK11	North Esk off Camden Rd	5410950	543900	25	1.13	1.09	A	25	1.19	0.96	X	A
NESK12	North Esk @ Ben Nevis Gates	5415600	544200	25	1.36	0.99	X	22	1.07	1	A	A
NESK13	Distillery Creek above North Esk	5413050	514300	17	0.71	0.86	B	15	0.38	0.65	C	C
NESK14	Distillery Creek u/s filtration plant	5413000	517800	18	1.01	0.89	A	24	1.13	1.04	A	A
NESK15	Kings Meadows Rivulet @ Punchbowl	5410800	514250	This site is outside the experience of the model								
NESK16	Rose Rivulet above north Esk	5406200	518500	This site is outside the experience of the model								
NESK17	Rose Rivulet @ Lower White Hills Rd	5402700	519200	This site is outside the experience of the model								
NESK18	St Patricks River @ Watery Plains	5407900	528000	21	1.16	0.93	A	30	1.16	0.97	X	A
NESK19	St Patricks River @ Nunamara	5417800	525000	28	1.37	1	X	25	1.1	1.01	A	A
NESK20	St Patricks River @ Pecks Hill Rd	5424300	528700	22	1.31	0.99	X	23	1.12	0.98	A	A
NESK21	St Patricks River @ Targa Hill Rd	5426800	530900	26	1.39	0.99	X	25	1.22	0.98	X	X
NESK22	St Patricks River @ Corkery's Rd	5428300	534600	22	1.2	0.99	X	22	1.13	0.99	A	A
NESK23	St Patricks River @ East Diddlium Rd	5425800	538900	25	1.2	1.01	X	20	1.05	1.04	A	A
NESK24	Patersonia Rivulet / Patersonia Rd	5420400	525400	26	1.04	0.97	A	25	1.06	1.05	A	A
NESK25	Patersonia Rivulet @ Targa Hill	5426500	527700	21	1.12	0.99	A	25	0.98	0.99	A	A
NESK26	Coquet Creek @ Tasman Hwy	5421300	528200	21	1.26	1.02	X	24	1.03	0.99	A	A
NESK27	Barrow Ck @ Tasman Highway	5424300	529200	23	0.84	0.97	A	21	1.11	1	A	A
NESK28	Bennies Ck @ Tasman Highway	5425000	530000	24	1.03	1.12	A	29	1.11	1.01	A	A
NESK29	Seven Time Ck @ Tasman Highway	5426700	531400	23	0.96	1.05	A	24	1.14	0.98	A	A
NESK30	Seven Time Ck off Camden Hill Rd	5425500	534600	20	1.24	1.03	X	26	1.29	0.99	X	X
NESK31	Camden Rivulet @ Diddleum Rd	5425200	538700	27	1.2	0.98	X	23	0.92	1.04	A	A
NESK32	Musselboro Ck U/S North Esk	5407850	537600	22	0.96	0.89	A	19	1.11	1.03	A	A
NESK33	Musselboro Ck off Musselboro Rd	5412300	536300	21	1.19	1.04	X	23	1	0.95	A	A
NESK34	Old Mill Creek @ Blessington Rd	5405250	540700	33	0.97	0.85	A					A
NESK35	River O' Plain Ck @ Blessington Rd	5406600	541800	29	1.24	0.98	X	23	1.11	1.01	A	A
NESK36	Pig Run Ck @ Blessington Rd	5407900	543000	22	1.07	0.99	A	21	1.03	0.97	A	A
NESK37	Ford below Upper Blessington	5408800	544700	21	1.25	0.98	X	19	1.05	0.99	A	A
NESK38	Becketts Ck @ Camden Rd	5415600	544200	26	1.35	0.99	X	23	1.16	1.04	X	X
NESK39	Becketts Ck @ Simons Rd	5416500	543400	25	1.12	1.06	A	25	1.19	1.04	X	A
NESK40	Burns Creek @ Elverton property	5406200	539400	21	1.2	0.99	X	24	1.15	1	X	X
NESK41	Burns Creek upper site	5412250	538900	21	0.96	0.99	A	21	0.72	1	B	B
NESK42	North Esk Above Northallerton	5418700	549350	26	1.2	0.97	X	17	0.72	0.87	B	B
NESK43	Weavers Creek u/s North Esk	5407450	529850	26	1.03	1.09	A	26	1.14	1.04	A	A
NESK44	Ford above Upper Blessington	5408240	552410	16	0.9	1.17	A	22	1.1	0.97	A	A

support a relatively low number of families. This shows that it is not only the number of taxa alone that is important but the type of families and whether they are indicative of healthy or degraded rivers. In this respect, the AUSRIVAS outputs are better indicators of river health since, as biological assessments, they consider factors other than physical habitat condition. These factors include tolerance or intolerance to pollution and a range of physico-chemical, geographical and habitat variables.

Assessment of the riffle samples classed 33 of the 39 or 84% of the sites as equivalent to reference (Band A) or above (Band X), 13% of the sites as significantly impaired (Band B) and 3% of the sites as severely impaired (Band C). Assessment of the edgewater samples showed a similar pattern with 35 of the 44 or 79% of the sites as equivalent to reference or above 11% of the sites as below reference and 2% of the sites as well below reference (Table 3). Three of the sites (NESK15, NESK16 and NESK17) or approximately 7% were assessed as outside the experience of the model. This indicates that one or more of the habitat variables measured at these sites fall outside of the predictive capabilities of the model. On closer examination of the habitat data for sites NESK15, NESK16 and NESK17 showed that they had conductivity levels of 2420, 2570 and 2090µS/cm respectively which is approximately 20 times the average conductivity of other sites in the catchment. The elevated salt concentrations at these sites can be partially explained by the underlaying geology of the area, which consists of Tertiary sediments that have high levels of exchangeable sodium and magnesium. Extensive clearing for agricultural purposes in Rose Rivulet catchment and the effects of urbanisation and stormwater runoff in Kings Meadows Rivulet will have further contributed to the high salinity in these sub-catchments (see water quality report).

In general, the riffle and edgewater assessments allocated sites to the same band. This was deemed to be the final band allocation for the site. Where there was a mismatch in band allocation from the two habitats, then the site was allocated to the lower band. This was considered to be a more conservative and precautionary approach. The final band allocations for each site are presented in Table 3.

4.4.1 North Esk River Mainstream

Thirteen sites were sampled on the North Esk mainstream (see Fig. 1). In terms of overall diversity, the number of taxa did not drop significantly down the catchment until site NESK03 (North Esk below Corra Linn). However specific faunal groups such as the Ephemeroptera (mayflies) displayed dramatic changes in species composition down the length of the river (Figure 2).

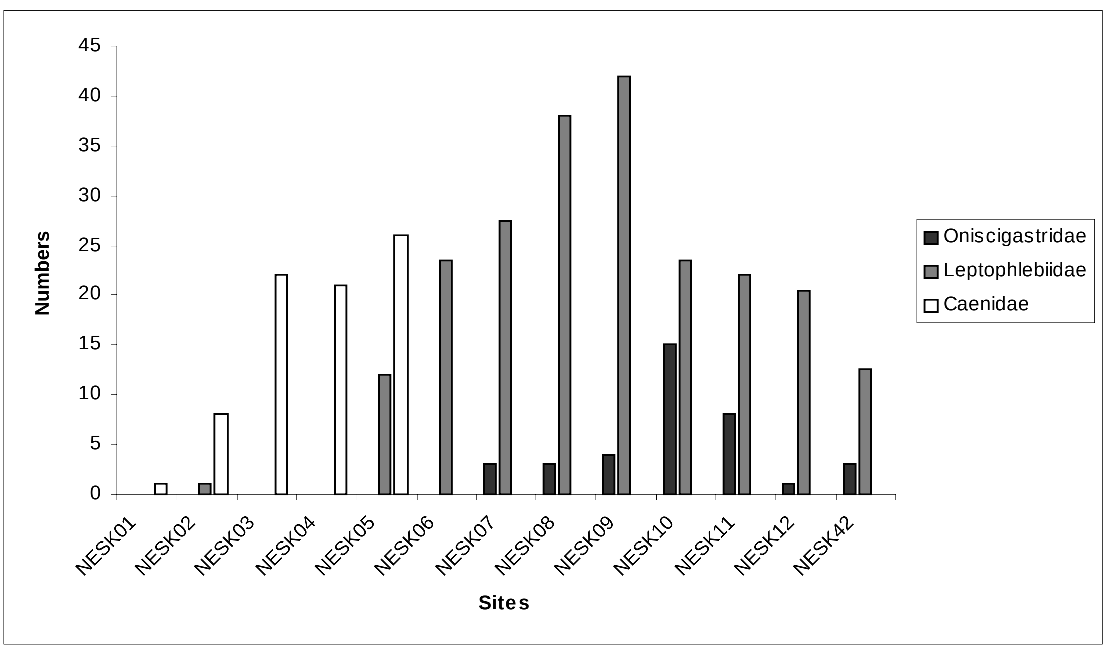

Figure 2. Total number of individuals of selected Ephemeroptera families present in both edgewater and riffle habitats at sites on the North Esk River.

The mayfly family Leptophlebiidae gradually increase in abundance from the top of the catchment to a peak of 42 individuals, representing 12% of the total individuals collected, at site NESK09 (North Esk at Burns Creek Rd). Their numbers gradually decline downstream to 12 individuals, accounting for only 4% of the total number of individuals, at site NESK05 (North Esk at White Hills). Apart from 1 individual at site NESK02 (North Esk upstream of Clarkes Ford Bridge), no leptophlebiid larvae were found downstream of NESK05.The pattern is similar for the mayfly family Oniscigastridae. Conversely, the mayfly family Caenidae is absent from the upper reaches of the North Esk River. It was first collected at NESK05 and their numbers gradually declined to a single individual at NESK01 (North Esk downstream of Kingsmeadows Rivulet). The pattern of distribution of the mayfly families correlates well with the pollution sensitivity grades presented by Chessman (1995). Leptophlebiidae and Oniscigastridae are widely regarded as very sensitive to various pollutants whereas the family Caenidae is regarded as being moderately tolerant to these pollutants. This would therefore tend to suggest that water quality does deteriorate with distance from source, particularly below about NESK08 or NESK09.

AUSRIVAS outputs of the riffle habitat classed 2 sites on the North Esk River as above reference (Band X), 6 sites as equivalent to reference (Band A) and 4 sites as significantly impaired (Band B). One site (NESK01) was not sampled due to the absence of a riffle at the site. There is a clear pattern of river health deterioration down the catchment. With the exception of sites NESK08 and NESK42, the impaired sites were found in the lower reaches of the catchment. The significantly impaired sites (NESK02, NESK03, NESK08 and NESK42) had OE scores ranging from 0.60 to 0.72. Interpretations for the possible causes of the lower OE scores are presented in Figures 3 and 4 which plot the OE scores against the OESIGNAL scores for the riffle habitat for all sites collected under the State of River study. This type of plot demonstrates the usefulness of including OESIGNAL for interpretation and diagnosis. All of the impaired sites on the North Esk mainstream indicate that the lower health ratings are due to a potential impact other than water quality. For example site NESK08 (North Esk at Musselboro Rd.) has an OE value of 0.65 indicating a substantial loss of taxa (35%) relative to the reference sites, whereas OESIGNAL (1.09) shows that the taxa collected were mostly sensitive taxa. Inspection of the diagnostic data shows that taxa that were expected but not found at this site included Eustheniidae and Gripopterygidae (stoneflies), and Philorheithridae and Conoesucidae (caddisflies) and Parameletidae (amphipods). All of these taxa are adapted to life in fast flowing water either by having a streamlined shape and/or some means of attachment to such as claws, suckers, hooks or fixed retreats. These taxa are generally found under cobbles or boulders or submerged objects such as coarse woody debris. However NESK08 and many of the impacted sites are dominated by a sand or silt substrate, in some cases approaching 90%. The few boulders and cobbles at these sites tend to be completely surrounded by finer sediment, thus restricting the available habitat for the aforementioned taxa. It has long been recognized that macroinvertebrate diversity and abundance increase with increasing substrate size and substrate heterogeneity (Minshall, 1984). This lack of substrate diversity at site NESK08, in addition to clearance of riparian vegetation, may be the primary factor in determining the lower river health rating observed at this site.

Site NESK42 also has a naturally sandy streambed and it is this reduced habitat quality which may explain the low OE score in what is essentially an undisturbed site. In contrast, the edgewater model classed this site as above reference with an OE score of 1.2. This may be a more accurate reflection of the condition of the river at this site. The low OE scores at sites NESK02 and NESK03 also appear to be habitat related, although NESK03 had a borderline OESIGNAL score indicating water quality could be a concern.

The two sites classed as above reference (NESK06 and NESK11) could be due to high biodiversity or mild nutrient enrichment at these sites. As the OESIGNAL scores are high at both of these sites, it is assumed that they have naturally high diversity.

The AUSRIVAS outputs for the edgewater habitat classed 2 sites as above reference, 6 sites as equivalent to reference, 4 sites as slightly to moderately impaired and 1 site as severely impaired. River health deterioration longitudinally down the catchment for the edgewater habitat generally followed the same pattern as the riffle habitat. Sites in the upper catchment were in excellent condition and had diverse macroinvertebrate faunas. Observed:Expected scores were at reference level or above and OESIGNAL scores were in the good to excellent range indicating no water quality problems. At NESK08 there is a decline in OE scores from reference to slightly to moderately impaired conditions which is also mirrored in OESIGNAL scores, although not to the same extent. Although NESK08 was particularly diverse with 28 taxa, only 9 of the 12 taxa predicted by the model were collected. This discrepancy highlights the requirement for informed scrutiny of the outputs. In this case, an unexpected assemblage of families was collected from NESK08. This is evident in the low number of key families and AUSRIVAS predicted families in proportion to the total number of families collected. The differences are probably attributable to the lack of riparian vegetation that influences the amount of suitable edgewater habitat. Further downstream, OE and OESIGNAL scores rise again. This phenomenon reflects the change in the state of the riparian zone, although in the lower reaches, the riparian zone is dominated by exotic species such as willows. Compared with Australian native trees, the different leaf types and leaf fall patterns of willows make them less suitable as riparian vegetation because they alter stream habitat conditions.

Downstream from NESK05 there is a decline in edgewater OE scores from reference to below reference conditions, which is also mirrored in the OESIGNAL scores. Site NESK03 was classed as equivalent to reference but it had a borderline SIGNAL score, indicating that water quality may be a problem. Water quality degradation tends to accumulate along a river's length, so that damage suffered at one point is compounded further downstream by more impacts. Site NESK01 was the lowest site on the North Esk River and was clearly the worst affected. It had the lowest number of taxa as well as the lowest OE and OESIGNAL scores. Few of the taxa expected to be present at the site were found, indicating a severe impact on the habitat, water quality or both. As this reach of the North Esk flows through urbanised and industrialised areas, it is subject to the many stresses a large city places on its waterways. Higher levels of stormwater runoff are characteristic of extensively paved urban areas. Runoff carries high loads of litter and other pollutants such as oil and brake dust from cars. Leaking and overloaded sewers are also likely to contribute to the decline in water quality. However, there is also considerable degradation of habitat quality in the lower reaches. At NESK01 and NESK02, silt deposits blanket the substrate, reducing the type and availability of habitat for stream biota.

4.5.2 North Esk River Tributaries

Upper Catchment Tributaries

Sites on tributaries in the upper regions of the catchment were generally in good condition and had moderately to highly diverse macroinvertebrate faunas. AUSRIVAS scores classed all twelve edgewater habitats at reference level or above. OESIGNAL scores were generally high, although two sites (NESK32 and NESK34) had lower OESIGNAL scores indicating mild organic enrichment. Both of these sites are in agricultural areas and the increased level of nutrients is probably due to sediment erosion, agricultural runoff and unrestricted stock access. Elevated nutrient levels can cause increased plant growth. Macrophytes provide an important habitat and food source for macroinvertebrates and can promote an increase in their numbers. Large quantities of macrophytes were recorded at Old Mill Creek (NESK34) and this may explain why Old Mill Creek, which had a very poor habitat rating, was the most biologically diverse site (33 taxa) in the entire catchment.

As with the edgewater habitat, AUSRIVAS scores for the riffle habitat classed all sites as equivalent to reference condition or above with the exception of the upper site on Burns Creek (NESK41) which was significantly impaired. Although the site is moderately diverse, with 21 taxa collected, there was a low number of AUSRIVAS predicted families collected. The difference is due to the general lack of large substrate. This site has a naturally sandy streambed which is likely to limit riffle habitat availability. This is a natural condition and the low OE score does not reflect human impact. This is supported by the OESIGNAL score which is 1.0, indicating good water quality.

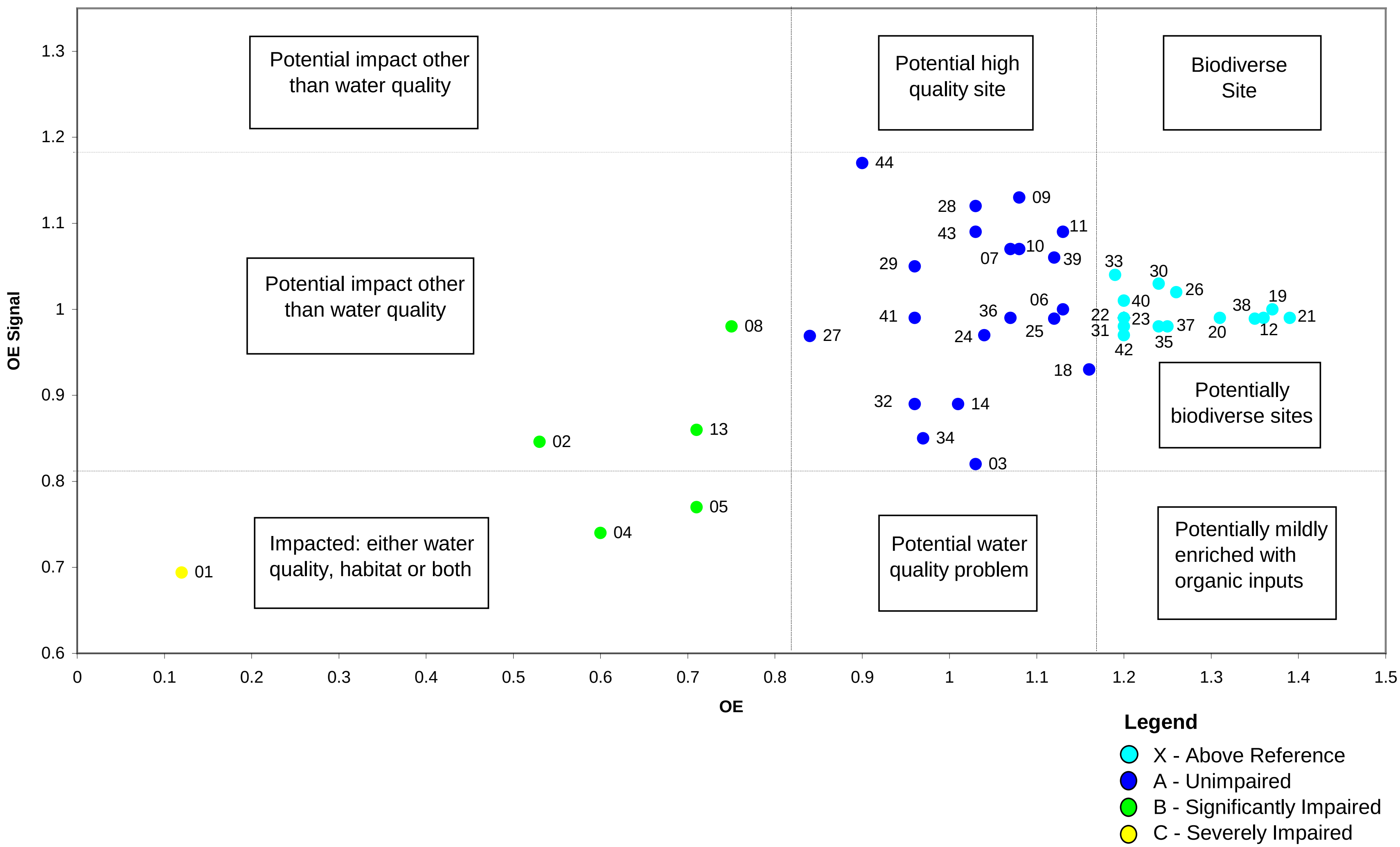

Figure 3. Plot of OE vs OE signal for edgewater habitats at each site sampled under theState of Rivers study and possible interpretations for situations where the two indices place sites in different bands. The vertical and horizontal dashed lines indicate the upper and lower bounds for unimpaired (A) high quality sites .

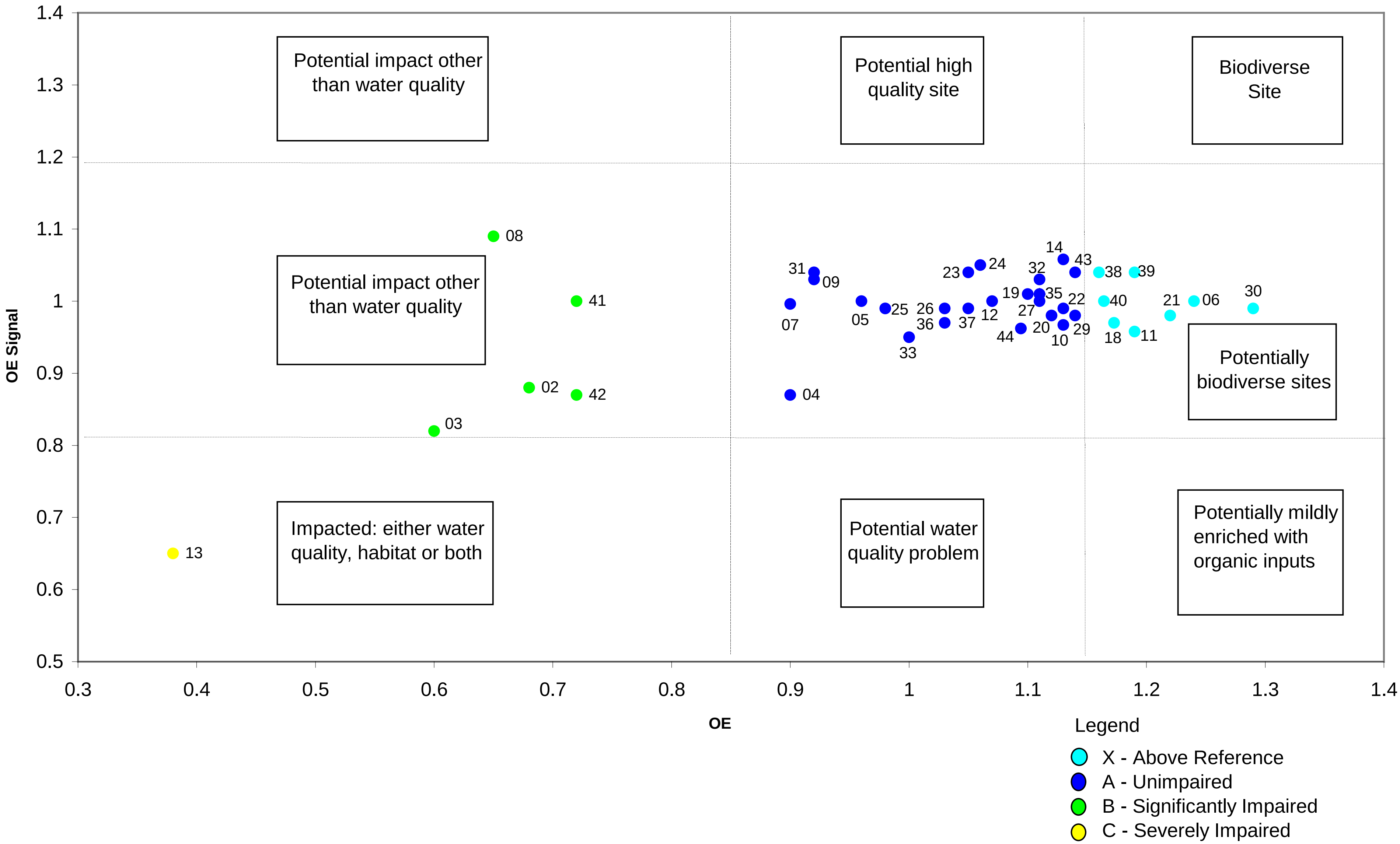

Figure 4. Plot of OE vs OE signal for riffle habitats at each site sampled under theState of Rivers study and possible interpretations for situations where the two indices place sites in different bands. The vertical and horizontal dashed lines indicate the upper and lower bounds for unimpaired (A) high quality sites

St Patricks River

The 14 sites sampled in the St Patricks River catchment were in excellent condition. Both edgewater and riffle models classed all sites at reference condition or above. OESIGNAL scores ranged from 0.93 to 1.12 indicating that the high OE scores are due to naturally high biodiversity rather than mild nutrient enrichment. Four sites (NESK18, NESK19, NESK22 and NESK24) were sampled under the MRHI program from 1995 to 1997. On each occasion, the riffle and edgewater models classed each site as equivalent to reference or above. OESIGNAL scores also remained high indicating that there has been little or no deterioration in habitat or water quality nor a decrease in the diversity of the macroinvertebrate community.

Rose Rivulet (NESK16 and NESK17)

Only edgewater samples were included in this survey as neither site had riffle habitats. Both sites were found to be "outside the experience of the model" and so no AUSRIVAS scores could be obtained for these sites. This was due to the fact that one of the predictor variables (in this case conductivity) used by the AUSRIVAS edgewater model to predict the fauna expected to occur at these sites lay outside the range of values found at the AUSRIVAS reference sites. While both sites have electrical conductivities exceeding 2000µs/cm it is still below levels likely to have an impact on the fauna (Metzling, 1993). Dissolved oxygen at NESK16 and NESK17 was very low at 2.3 and 5.0 mg/L respectively and thick mats of filamentous green algae were observed at both sites. These factors indicate that these sites are subject to nutrient enrichment from agricultural runoff, although the severity was probably magnified by the seasonal lack of flow in the rivulet. Only 12 taxa consisting primarily of molluscs, leeches, chironomids and other nutrient tolerant taxa were collected from NESK17. The macroinvertebrate fauna at NESK16 was moderately diverse (18 taxa collected) but again, the fauna was mostly very tolerant of nutrient enrichment. Kings Meadows Rivulet (NESK15) had an electrical conductivity value of 2420µS/cm and was also assessed as being outside the experience of the model. However, worms, leaches, snails and chironomids accounted for over 75% of the individuals collected, indicating that this site was severely degraded.

Distillery Creek (NESK13 and NESK14)

Distillery Creek shows a marked deterioration in habitat and water quality between NESK14 and NESK13. The changes that occur between NESK14 and NESK13 are dramatic both in terms of number of taxa collected and taxa composition. A number of species present in the upstream site are absent from NESK13. The loss is especially apparent in taxa which are considered to be particularly sensitive to changes in water quality such as the mayflies and stoneflies. Many beetles and caddisflies were either also absent from this site or were greatly reduced in numbers (see Appendix 1). NESK14 was classed as equivalent to reference with OE scores of 1.01 and 1.13 for the edgewater and riffle habitats respectively. At NESK13, the OE scores were 0.71 for the edgewater habitat and 0.38 for the riffle habitat, indicating severe impairment. OESIGNAL scores indicate that the impairment is due to reduced habitat and/or water quality. A reduction in streamside vegetation, together with erosion, urban runoff and regulated stream flows is the most probable cause of the reduced biological health of the stream.

4.5 Summary

Streams in the North Esk catchment vary considerably in quality ranging from pristine sites to highly degraded tributaries in urban areas. The North Esk River is in reasonably good condition despite being subject to forestry, agricultural, and urban impacts. In general, AUSRIVAS OE and OESIGNAL scores as well as the number of families indicate increased impact with distance downstream. Sites on the upper to middle reaches of the North Esk River, upper catchment tributaries, and St Patricks River and all its associated tributaries were all in good condition. According to AUSRIVAS scores, all but two of the sites were at reference level or above. Water quality was generally good and habitat degradation was limited to mild erosion at some sites and the presence of exotic species, predominantly willow, in the riparian zone.

Sedimentation appears to be a problem in the lower reaches of the North Esk River and to a lesser extent in rural tributaries in the middle of the catchment. Runoff from cleared land and tilled areas and from gravel roads and drains can carry high levels of sediment which can blanket the stream substrate and limit available habitat. There are also large amounts of filamentous algae and macrophytes at some sites suggesting nutrient enrichment. Three sites also had electrical conductivities exceeding the maximum recommended by the Australian and New Zealand Environment and Conservation Council (ANZECC).

Edgewater habitats, in general, received better OE scores than riffle habitats, however a comparison between sites analysed by different models cannot be made because of the different sensitivity of the models used. Edgewater models are thought to less sensitive than riffle models because edgewaters are likely to harbour a more tolerant fauna. Many taxa that are able to live in depositional environments are 'pre adapted' to cope with moderate impacts on rivers such as mild sedimentation and organic enrichment (Oldmeadow *et al*. 1998). The edgewater habitat is closely linked to the riparian zone. Riparian vegetation provides a habitat and food source for many macroinvertebrates by dropping leaves, branches and logs into the stream and protecting bank structure. It also provides an important filtering mechanism which reduces the level of contaminants entering the stream. Degradation of the riparian zone often leads to deterioration of the edgewater habitat and a decrease in water quality.

Physical degradation of the stream habitat can be compounded by chemical and organic pollution. Nutrients, fertilisers, pesticides and herbicides are major pollution sources in rural areas. In urban areas chemical pollution originate from storm water runoff, industrial spills and leaching or overloaded sewers.

Implementation of better riparian management practices, decreasing agricultural runoff, providing adequate environmental flows especially during periods of low flow and effectively managing sewerage and stormwater systems have been identified as positive measures essential for sustaining the health of water ways in the North Esk catchment. Such measures will greatly benefit not just macroinvertebrate communities but the whole stream ecosystem.

5. Algae

Algae are simple plants that vary considerably in size, shape and colour, and are found in a range of habitats. They are a natural part of the surface water ecosystem and are encountered in every water body that is exposed to sunlight. While a few algae are found in soils and in surfaces exposed to air, the great majority are truly aquatic and grow submerged in ponds, lakes, water supply storages, streams, estuaries and oceans. In water storages the phytoplankton, or floating microscopic plants, are of major importance, and are the basic food source of small aquatic animals. There are four main types of freshwater algae: Green Algae (Chlorophyceae), of which the threadlike filamentous form is the most common, Blue-green Algae (Cyanophyceae), Diatoms (Bacillariophyceae) and Euglenoids (Euglenieae). Excessive growth of algae can cause numerous problems in waterways. Blooms can severely reduce the oxygen content of the water and cause the death of fish and other aquatic animals. Mats of filamentous algae can clog irrigation channels and pipes and severely reduce flow and certain blue-green algal blooms (in particular *Anacystis cyanea*) are toxic and have been known to kill live stock, including cattle, sheep, horses and domestic fowl.

The use of algae has many advantages over traditional indicators of water quality particularly in an urban setting (Round, 1991). Unlike macroinvertebrates, algae are a ubiquitous component of a water environment and are even found in concrete drains (common in urban environments). Algae have particular advantages as bio-indicators over other animals such as fish and macroinvertebrates in that they are often present before and after pollution incidents, reflect nutrient composition of the water more closely than animals and are often different to macroinvertebrates in their sensitivity to toxic materials (Whitton & Kelly, 1995).

In many Australian states, algae have been used on small spatial scales for bio-monitoring (Chessman, 1986; Sonnerman and Breen, 1997; Read and Seamer, 1998). There have been investigations into the feasibility of using algal taxa to assess river health and many researchers have suggested various protocols for bioassessment of rivers using algae as indicators (Hotzel and Croome, 1998). The development of river health models such as AUSRIVAS, the current platform for using macroinvertebrates to assess river health, has prompted various workers to investigate the feasibility of developing similar models using algae as the indicator taxa.

The potential objectives of phytoplankton bioassessment would be to:

- Monitor abundance and composition of major phytoplankton groups to assess water quality within and between rivers
- To identify changes in species composition in response to environmental conditions.

With this information in mind, DPIWE has been udertaking opportunistic sampling of algal communities at sites where macroinvertebrates have been sampled for the Monitoring Riverine Health Initiative (MRHI) and the First National Assessment of River Health (FNARH) since late 1996 with the long term plan to develop bioassessment models for algae similar to those currently being developed for macroinvertebrates. To date, over 247 genera have been identified from over 350 sites around Tasmania.

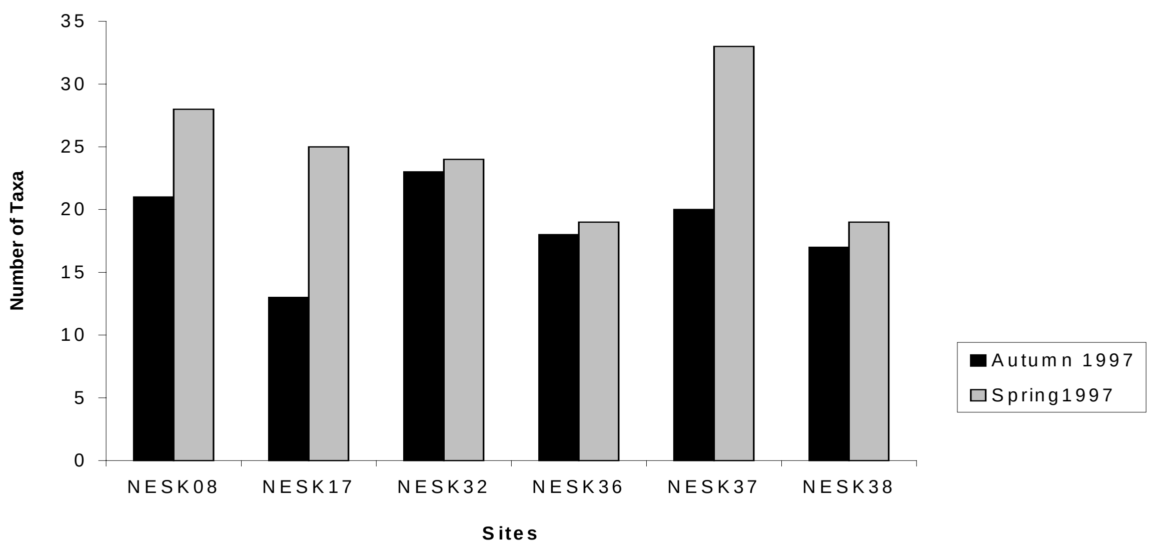

Figure 5: Number of algal genera sampled at each site in the North Esk catchment in autumn 1997 and spring 1997.

As part of this program algal samples were collected from 7 sites in the North Esk catchment in autumn and spring 1997. Samples were taken from both riffle and edgewater habitats by scraping the top surface of the substrate. They were preserved in 5% formalin and identified to genus level under a compound microscope in the laboratory.

Ninety-six genera of algae were identified from the North Esk catchment, including Diatoms, Green algae, Blue-green algae and Euglenoids. These species are common throughout Tasmania and as such pose no public risk.

Phytoplankton species composition and abundance are mainly influenced by flow conditions (discharge, volume and velocity) and correlated parameters such as light penetration, turbidity, nutrient availability and to a lesser extent pH, electrical conductivity and dissolved oxygen (Hotzel and Croome, 1998). The number of genera of algae recorded per site ranged from 13 to 23 in autumn and 19 to 33 in spring (see Fig. 5). At each site, algal diversity increased in the spring. This was probably due to elevated nutrient levels associated with runoff from agricultural areas. The types of algae encountered at all sites in this study such as *Acnanthes*, *Cymbella*, *Navicula* and *Synedra* are generally characteristic of healthy unimpacted streams (Chessman, 1986). However to make further comments on the composition of algal communities and how these relate to specific water quality impacts or habitat degradation in the North Esk catchment would be inappropriate as a more rigorous sampling protocol is required. Hotzel and Croome, (1998) suggest a weekly or at least a fortnightly sampling frequency to delineate population changes in accordance with the organisms life span.

Sampling phytoplankton and environmental data for a river over several years under different flow conditions is required before significant correlations can be made between environmental variables and phytoplankton data can be made. This historical dataset can then form the basis of predictive models used to assess changes in water quality and environmental conditions.

6. References

Bluhdorn, D.R. (1997) Recovery plan for the Tasmanian Giant Freshwater Lobster *Astacopsis gouldi* Clark. Inland Fisheries Commission, Hobart. 21pp.

Brown, P.B. (1996) The frogs of northeast Tasmania. *Biogeography of northeast Tasmania*. Edited by Robert Mesibov, Queen Victoria Museum and Art Gallery, Launceston, pp.139-144.

Bryant, S. (1998a). Tasmania's Giant Freshwater Lobster *Astacopsis gouldi* (Part one). Inland Fisheries Commission Newsletter. Vol. 27 p. 3.

Bryant, S. (1998b). Tasmania's Giant Freshwater Lobster *Astacopsis gouldi* (Part Two). Inland Fisheries Commission Newsletter. Vol. 27 pp. 3-8.

Bryant, S. L. and Jackson, J., (1999). Tasmania’s Threatened Fauna Handbook: what, where and how to protect Tasmania’s threatened animals. Threatened Species Unit, Parks and Wildlife Service, Hobart.

CEPA (1994) National River and Management program Monitoring River Health Initiative: River Bio-assessment Manual. Commonwealth Environmental Protection Agency, Canberra.

Chessman, B.C. (1986) Diatom flora of an Australian river system: spatial patterns and environmental relationships. *Freshwater Biology,* Vol. 16, pp. 805-819.

Chessman, B.C. (1995) Rapid assessment of rivers using macroinvertebrates: a procedure based on habitat -specific sampling, family level identification and a biotic index. *Australian Journal of Ecology,* Vol. 33**,** pp.122-129.

Chilcott, S.J.& Humphries, P. (1995). Freshwater fish of northeast Tasmania with notes on the Dwarf Galaxias. *Biogeography of northeast Tasmania*, Edited by Robert Mesibov, Queen Victoria Museum and Art Gallery, Launceston. pp.145-150.

Davies, P.E. (1995) Effect of logging operations on hydrobiid snails in Tasmanian streams: a before versus after study. Freshwater Systems, Hobart. pp.1-15.

Fulton, W. (1990) *Tasmanian Freshwater Fishes*. Edited by Alistair Richardson, University of Tasmania, Hobart First edition. pp. 1-80.

Growns, I.O. (1995) *Astacopsis gouldi* Clark in streams of the Gog Range, Northern Tasmania: the effects of catchment disturbance. *Papers and Proceeedings of the Royal Society of Tasmania*, Vol. 129, pp. 1-6.

Hamr, P. (1990). Comparative Reproductive Biology of the Tasmanian Freshwater Crayfishes *Astacopsis gouldi* Clark, *Astacopsis franklinii* Gray and *Parastacoides tasmanicus* Clark (Decapoda: Parastacidae). PhD thesis, Zoology Department, University of Tasmania. 153pp.

Hamr, P. (1992) A revision of the Tasmanian Freshwater Crayfish Genus *Astacopsis* Huxley (Decapoda:Parastacidae). *Papers and Proceedings of the Royal Society of Tasmania,* Vol. 126, pp. 91-94.

Horwitz, P. (1996) Biogeographical affinities of macrocrustacean groups in northeast Tasmania. *Biogeography of northeast Tasmania*. Edited by Robert Mesibov, Queen Victoria Museum and Art Gallery, Launceston. pp.171-178.

Horwitz, P.H.J. (1994) Distribution and conservation status of the Tasmanian giant freshwater lobster *Astacopsis gouldi* (Decapoda: Parastacidae). *Biological Conservation,* Vol 69, pp.199-206.

Hotzel, G. & Croome, R. (1998) A phytoplankton methods manual for Australian rivers. Land and Water Resources Research and Development Corporation, Canberra. Occasional paper No. 18/98.

Metzling, L. (1993) Benthic Macroinvertebrate structure in streams of different salinities. Australian Journal of Marine and Freshwater Research, Vol. 44, pp.335-351

McDowall, R.M. (1996) Southern graylings. *Freshwater Fishes of southeastern Australia*. Edited by R.M. McDowall , Reed, Sydney. 2nd edition pp. 96-98.

McDowall, R.M. & Fulton, W. (1996) Galaxiids. *Freshwater Fishes of south- eastern Australia*. Edited by R.M.Mcdowall Reed, Sydney. 2nd edition pp 52-77.

Minshall, G. W. (1984) Aquatic Insect Substrate Relationships. *Ecology of Aquatic Insects.* Edited by V. H. Resh and A. M. Rosenberg. Praeger. pp358-400

Oldmeadow, D., Krasnicki, T. & Fuller, D. (1998) Monitoring River Health Initiative. Department of Primary Industry and Fisheries, Hobart. Technical Report No. WRA 98/03

Pinkard, G.J., 1980. Land Systems of Tasmania Region 4. Tasmanian Dept of Agriculture, Hobart.

Ponder, W.F. (1988) *Potamopyrgus antipodarum*-a molluscan coloniser of Europe and Australia. *Journal of Molluscan Studies*, Vol. 54, pp.271-285.

Ponder, W.F. (1996) Freshwater molluscs of northeast Tasmania. *Biogeography of northeast Tasmania*. Edited by Robert Mesibov, Queen Victoria Museum and Art Gallery, Launceston, pp.185-191.

Read, M. and Seamer, D. (1998) Survey of Algae in Waterways in the City of Launceston. Department of Primary Industry and Fisheries, Hobart. Technical Report No. WRA 98/05

Round, F.E. (1991) Diatoms in river water monitoring studies. *Journal of Applied Phycology*, Vol. 3**,** pp.129-145.

Simpson, J., Norris, R., Barmuta, L., and Blackman, P. (1996) AUSRIVAS- National River Health Program - User Manual. CRC for Freshwater Ecology, University of Canberra.

Sonnerman, J. and Breen, P. (1997). *Factors influencing benthic diatom community patterns in urban and non-urban streams.* Australian Society for Limnology Annual Congress, Albury/Woodonga, Australian Society for Limnology.

Whitton, B.A. & Kelly, M.G. (1995) Use of Algae and other plants for monitoring rivers. *Australian Journal of Ecology*, Vol. 20, pp. 45-56.

Appendix 1: Taxa List for sites sampled as part of the State of Rivers survey

	Order	Platyhelminthes		Nematomorpha		Mollusca		Mollusca		Mollusca		Mollusca		Mollusca		Hirudinea		Oligochaeta		Hydracarina	
	Family	Turbellaria		Gordiidae		Hydrobiidae		Ancylidae		Planorbidae		Physidae		Sphaeriidae							
	Subfamily																				
Site	Taxa Code	IF999999		IJ019999		KG029999		KG069999		KG079999		KG089999		KP039999		LH999999		LO999999		MM999999	
Code	Name Edgewater/ Riffle	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R
NESK01	North Esk d/s Kingsmeadows Rt	66				32						13		1		1				4	
NESK02	North Esk U/S Clarkes Ford Bridge		1															4	1	10	3
NESK03	North Esk @ Corra Linn Gorge					10	2		1					7		1		3	2	48	1
NESK04	North Esk below Corra Linn	1				3	1		5					1				7	19	14	3
NESK05	North Esk @ White Hills					9	6	2	8					2	1			2	10	8	
NESK06	North Esk above St Patricks		2			2	14		10					2				1	8		
NESK07	North Esk @ Ballroom					1	1	1	1					22				1	23	1	
NESK08	North Esk @ Musselboro Rd		1			1		4		3				18							
NESK09	North Esk @ Burns Ck Rd	1				9	5							8					6	6	
NESK10	North Esk @ Wattle Corner	1					1							3				1	4	2	1
NESK11	North Esk off Camden Rd			2	2		1												4	2	1
NESK12	North Esk @ Ben Nevis Gates				1	9								5	2			3	11	3	
NESK13	Distillery Creek above North Esk	5	6			11	82							1		3	2	11	7		1
NESK14	Distillery Creek u/s filtration plant		4				19							2		1		22	4	1	2
NESK15	Kings Meadows Rivulet @ Punchbowl	7				97						16		3		40		20			
NESK16	Rose Rivulet above north Esk	9				83				6		18		13		21		4		2	
NESK17	Rose Rivulet @ Lower White Hills Rd					50				1		46		23		2		4		12	
NESK18	St Patricks River @ Watery Plains		1		1	25	15							1				1	12	4	1
NESK19	St Patricks River @ Nunamara				1	4	7	2	1					4				2	15	2	
NESK20	St Patricks River @ Pecks Hill Rd		1											11	1			1	5	1	1
NESK21	St Patricks River @ Targa Hill Rd					2	3							7				3	10	1	
NESK22	St Patricks River @ Corkery's Rd	1												4				1	12	2	
NESK23	St Patricks River @ East Diddlium Rd													12				2	13	2	
NESK24	Patersonia Rivulet / Patersonia Rd					2	26		1					8				3		1	4
NESK25	Patersonia Rivulet @ Targa Hill				1									7	2			1	5		4
NESK26	Coquet Creek @ Tasman Hwy		1															1	2	8	1
NESK27	Barrow Ck @ Tasman Highway	1					7							1						1	7
NESK28	Bennies Ck @ Tasman Highway						1											1	3		4
NESK29	Seven Time Ck @ Tasman Highway	1			1		1							4					5		1
NESK30	Seven Time Ck off Camden Hill Rd																	2	4	1	2
NESK31	Camden Rivulet @ Diddleum Rd													2				1	1	9	1
NESK32	Musselboro Ck U/S North Esk		2											22				17		3	
NESK33	Musselboro Ck off Musselboro Rd		5											1					1	2	1
NESK34	Old Mill Creek @ Blessington Rd	7				83				5				5		1		1		6	
NESK35	River O' Plain Ck @ Blessington Rd		2	1		17	6			1				2				8	7	4	3
NESK36	Pig Run Ck @ Blessington Rd								3					1	2			2	19		
NESK37	Ford below Upper Blessington													5				14	17	2	
NESK38	Becketts Ck @ Camden Rd													1				1	8	6	
NESK39	Becketts Ck @ Simons Rd	1	1															1	1	3	2
NESK40	Burns Creek @ Elverton property						2							7	1			4	1	2	
NESK41	Burns Creek upper site		1			1	4								4			3	20		
NESK42	North Esk Above Northallerton													7				2	1	1	
NESK43	Weavers Creek u/s North Esk		1			20	15											3	2	3	1
NESK44	Ford above Upper Blessington		1																2	2	2

Order	Amphipoda		Amphipoda		Isopoda		Isopoda		Decapoda		Coleoptera		Coleoptera		Coleoptera		Coleoptera		Coleoptera		Coleoptera		Coleoptera		Coleoptera		Diptera	
Family	Ceinidae		Parameletidae		Phreatoicidae		Janiridae		Atyidae		Noteridae		Dytiscidae		Dytiscidae		Hydrophilidae		Scirtidae		Elmidae		Elmidae		Psephenidae		Tipulidae	
Subfamily													Adults		Larvae						Adults		Larvae					
Code	OP029999		OP069999		OR039999		OR189999		OT019999		QC089999		QC09999A		QC09999L		QC119999		QC209999		QC34999A		QC34999L		QC379999		QD019999	
	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R
NESK01									1												13							
NESK02	6																					19						
NESK03	7												3		2						1	10		3				
NESK04	8		4			1			14						5						1	21	3	3				3
NESK05																				4	1	12	1	7				5
NESK06													1	2					15	20	3	13	3	26		4	1	4
NESK07													1		1				17	16	2	18	1	12			5	13
NESK08	17										1		1							72	1	64		88			3	13
NESK09			5		2	1													1	30		58	1	50		3	2	5
NESK10						1													16	21		22		19			2	8
NESK11						2													11	21	1	23	1	30				18
NESK12																			6	21	1	19	2	25			1	15
NESK13									7	2																1		
NESK14			3										4						1	12		10		1		12		
NESK15	1																											
NESK16	45						2						4				5				1							
NESK17	52						20																					
NESK18														2					2	14	4	18		12		2		3
NESK19													1						2	26	1	34		35		1	2	15
NESK20			7	3															6	54		17		11		2	5	17
NESK21			16	1		1										1			4	27	2	26	1	9		1	2	12
NESK22																			12	18		22	1	12		2		13
NESK23			2																9	17	2	27	1	14		1		17
NESK24			3	38		12					2		4						7	7	1	29		16				3
NESK25													1							25		46		1				2
NESK26													1						8	12		2		1		2		
NESK27											1		1		1				1	15		35	1	9			1	4
NESK28						2							1						2	15		13		3				5
NESK29			1																	18		27		15				6
NESK30				4															17	11		23	1	9				4
NESK31																			11	22	2	31	1	43		1	1	20
NESK32													2							3		19	1	4			1	4
NESK33			2	21	2	1													19			5					1	1
NESK34			7										2		6		1										2	
NESK35											1								8	12		13		4				
NESK36															2					32		23		1			2	4
NESK37																	1		11	21		23		24			1	21
NESK38			2	2															17	14	5	19	5	13				16
NESK39			1	1															16	6	9	19	3	17			2	7
NESK40																			16	34	2	62	1	29			2	6
NESK41																			32	45		29	1	26				9
NESK42	1																		20	34	1	42		31				7
NESK43																			6	2	2	14	18	5	2	23		
NESK44													1						4	5		1	1	1				

Order Family Subfamily Code	**Diptera** Chaoboridae QD059999		**Diptera** Dixidae QD069999		**Diptera** Culicidae QD079999		**Diptera** Ceratopogonidae QD099999		**Diptera** Simuliidae QD109999		**Diptera** Thaumeleidae QD119999		**Diptera** Athericidae QD229999		**Diptera** Stratiomyidae QD249999		**Diptera** Empididae QD359999		**Diptera** Chironomidae Podonominae QDAD9999		**Diptera** Chironomidae Tanypodinae QDAE9999		**Diptera** Chironomidae Orthocladiinae QDAF9999	
	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R
NESK01																								
NESK02								5		45											5		14	13
NESK03							1			7											8		2	74
NESK04							1	6	1	29								2					5	78
NESK05							4	3										1			10		8	13
NESK06							2	18		25										1	10		5	19
NESK07			3				3	2		18											27			6
NESK08					1		1			1											33			
NESK09			1				3							3							20		1	5
NESK10										18											6			10
NESK11			1				2			15				6							3		1	3
NESK12			2				3	3		16				4							4		3	5
NESK13							1							2				1			8		3	14
NESK14	1				11		2			12				3				1		1	7			21
NESK15							1		29												3		4	
NESK16							1														6			
NESK17																					1			
NESK18							1	2	1	89				3				1			11	1	5	18
NESK19			6					5	2	16											14	1	3	2
NESK20				1			1		2	18											1		5	7
NESK21							1			19										2	4		13	8
NESK22			1				3	2		29			1							4	2			5
NESK23			13				5		2	34								1		4			4	16
NESK24			22				1	3		18											6	6		2
NESK25			1	2			1	11										4			2			14
NESK26			1					1		8				1							7		7	21
NESK27			9						1	1											8	3		27
NESK28			15				2	1		5				1	1						10	1	1	22
NESK29			9				1	1		8										1	8		11	14
NESK30			1	2						20			2							7	1			5
NESK31			1				1	5	2	2				2							4		41	31
NESK32			2				7			8											18			3
NESK33										2											3			24
NESK34					7		3		39		2										7		1	
NESK35							3	1	4	6			1								7		2	8
NESK36			19				2	4		3											33		3	5
NESK37			1							21								1			14		2	7
NESK38			1				4	3	1	9								1	1	2	1			2
NESK39								1		30			1					1	1	9				3
NESK40			7					1	4	14				5						1	25			4
NESK41									4	6			1	14			4	2		1	2			
NESK42			2				1		3	18			2	13							5		1	5
NESK43							6	1									1			2	8		1	10
NESK44										11										8	15		1	12

Order Family Subfamily Code	**Diptera** Chironomidae Chironominae QDAJ9999		**Ephemeroptera** Baetidae QE029999		**Ephemeroptera** Oniscigastridae QE039999		**Ephemeroptera** Leptophlebiidae QE069999		**Ephemeroptera** Caenidae QE089999		**Hemiptera** Mesoveliidae QH529999		**Hemiptera** Veliidae QH569999		**Hemiptera** Gerridae QH579999		**Hemiptera** Corixidae QH659999		**Hemiptera** Naucoridae QH669999		**Hemiptera** Notonectidae QH679999		**Hemiptera** Pleidae QH689999	
	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R
NESK01			1						1															
NESK02								1	2	14							7							
NESK03	3	3							16	28							34							
NESK04	1	2		6					8	34							24							
NESK05	30			8			6	18	26				4				40							
NESK06	2	1	2	67			5	42							12		2	1						
NESK07			1	24	3		23	32					21		3		15							
NESK08	1		15	29	3		17	59					88		1		26				18			
NESK09			1	13	4		52	32					7		11		7							
NESK10		1	8	24	15		21	26					9	1										
NESK11	2	1	8	41	8		30	14					9		2		1							
NESK12	1	3		56	1		22	19					13											
NESK13	2	2					4																	
NESK14	34			11			33	44					45				3							
NESK15	32																							
NESK16											1		11				16							
NESK17	17																							
NESK18	2	8	35	54			19	59									37							
NESK19	11		22	24			17	46					23		1		20							
NESK20	4	11	6	34			18	64					14		2									
NESK21	7	17	3	26			24	42					5		18									
NESK22	1	6		61	5		26	31					8											
NESK23	3		6	50	4		18	32					3											
NESK24			30	21			38	55					10		1		50				4		1	
NESK25	1	4		3	3		21	42					18	4	2									
NESK26	5	16	9	7	1		41	26					1	2			1							
NESK27	13	7	13	11	1		14	28					30				1							
NESK28	27	22		1			38	39					22	1							1			
NESK29	23	13	1	25	3		8	40					12				2							
NESK30	24	4		21	1		8	20					3	1										
NESK31	2		2	42	12		14	15																
NESK32	1	4	1	23	3		25	48					46		25		12							
NESK33	12	4		6			21	10																
NESK34	2		5				5						6				22		2		2		1	
NESK35	2	1	4	21			47	30					19	3	15									
NESK36	25	19	5	15			16	36					6				9							
NESK37	11	13	4	5	20		30	39					20		2									
NESK38	2		7	35	4		15	22						1										
NESK39	9		4	61	2		7	19					4											
NESK40	2	4	26	36			17	36					14											
NESK41	2	11	2	28	18		15	15																
NESK42	20	23	1	65	3		16	9																
NESK43	2	6	7	45			54	20					4											
NESK44	22	4		9			18	20					18											

Order	**Mecoptera**		**Lepidoptera**		**Neuroptera**		**Neuroptera**		**Odonata**		**Odonata**		**Odonata**		**Odonata**		**Odonata**		**Plectoptera**		**Plectoptera**		**Plectoptera**	
Family	Nannochoristidae		Pyralidae		Osmylidae		Sisyridae		Coenagrionidae		Lestidae		Aeshnidae		Gomphidae		Corduliidae		Eustheniidae		Austroperlidae		Gripopterygidae	
Subfamily																								
Code	QK019999		QL019999		QN039999		QN059999		QO029999		QO059999		QO129999		QO139999		QO169999		QP019999		QP029999		QP039999	
	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R
NESK01													2											
NESK02															1								2	6
NESK03													1	4	3		3						1	8
NESK04													1	3			1						1	2
NESK05														4	3		3			5				9
NESK06																				14				2
NESK07																				1			2	
NESK08			1						6				2											
NESK09																			1				2	
NESK10																							1	2
NESK11	3																						12	1
NESK12																			1				10	2
NESK13																	1						2	
NESK14																				20				3
NESK15									9				4				10							
NESK16							1		3		2		1											
NESK17											6													
NESK18																				15				5
NESK19																				1			2	
NESK20																							3	5
NESK21					1																		1	1
NESK22																				4			5	
NESK23																				5			6	3
NESK24																								1
NESK25	3																		1				1	2
NESK26														2						10		8	11	10
NESK27																								1
NESK28	1	2			1														1	7		1	4	2
NESK29																							11	1
NESK30	1													1						5	4	19	1	4
NESK31	3	1																		1			11	21
NESK32																				6				1
NESK33	3													3					1	15	2	1	2	21
NESK34			1						20		4												1	
NESK35																				9			16	5
NESK36	1	1																					4	
NESK37																							3	2
NESK38	1																						8	4
NESK39	8																			4			2	3
NESK40																							2	2
NESK41	6												1						1				15	6
NESK42	2																				1	1	12	18
NESK43													1						8	19			1	24
NESK44																				11		4	28	26

Order Family Subfamily Code	**Plectoptera** Notonemouridae QP049999		**Trichoptera** Hydrobiosidae QT019999		**Trichoptera** Glossosomatidae QT029999		**Trichoptera** Hydroptilidae QT039999		**Trichoptera** Philopotamidae QT049999		**Trichoptera** Hydropsychidae QT069999		**Trichoptera** Polycentropodidae QT079999		**Trichoptera** Ecnomidae QT089999		**Trichoptera** Limnephilidae QT109999		**Trichoptera** Tasimiidae QT139999		**Trichoptera** Conoesucidae QT159999	
	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R	E	R
NESK01																						
NESK02							1					3			1							1
NESK03							8	6				54										
NESK04				2			5	1				77										1
NESK05				12		5	41	1			1	25			2							5
NESK06	8		6	11		4					13	39			13	2				2		4
NESK07	7			14								41									2	
NESK08	12			36		1						7			3							
NESK09	18		1	13		1						5	1								4	36
NESK10	16		5	18								6										11
NESK11	10		5	18		7						29									2	35
NESK12	15		6	26		18					1	18										6
NESK13		1					25	1														
NESK14	9			5								6			1							2
NESK15	1																					
NESK16																						
NESK17																						
NESK18	4		2	17		8						24			21							9
NESK19	12		8	39	1	3					1	21			7	2						3
NESK20	14		6	17											2	1						2
NESK21	23		9	28		1						2			1							2
NESK22	18		3	27		5						9										5
NESK23	19		17	28		4					2	28									1	13
NESK24	14	2		15				11				8	19		1						1	24
NESK25	27		3	33			1	1														1
NESK26	18		3	10											2							1
NESK27	26	18		30								1			14	4						18
NESK28	7	1	2	36			4	11					1									6
NESK29	25		5	28		1	5	1				6			2						2	7
NESK30	4		1	24			5	1				7										
NESK31	19		10	30		13						8					1				3	15
NESK32	35	1	3	11								32			12							5
NESK33	13		2	11			1			1		38							1			
NESK34							8															
NESK35	5		6	13			43	2				5	3								2	1
NESK36	28	1	1	57								3			12							13
NESK37	16		1	9								8										7
NESK38	18		8	29		6					2	2									2	2
NESK39	11		1	21		7	3				1	5										3
NESK40	9	1	5	17								7										7
NESK41			2	8																		
NESK42	23			13		1	1															
NESK43	3		3	3		2					1	28			30				1	1	1	18
NESK44	8			7			9	5				17										

Order Family Subfamily Code	**Trichoptera** Helicopsychidae QT179999		**Trichoptera** Calocidae QT189999		**Trichoptera** Helicophidae QT199999		**Trichoptera** Philorheithridae QT219999		**Trichoptera** Atriplectididae QT239999		**Trichoptera** Calamoceratidae QT249999		**Trichoptera** Leptoceridae QT259999	
	E	R	E	R	E	R	E	R	E	R	E	R	E	R
NESK01														
NESK02									1		3		7	2
NESK03									1				30	1
NESK04									3		1			54
NESK05				3									28	15
NESK06	4	2	1	3			9	1					31	32
NESK07			3	12			4	3	2				39	8
NESK08							2						64	20
NESK09			16	46			4	8	5				14	5
NESK10			9	20			6	9					34	9
NESK11		2	8	15			23	3	6				18	5
NESK12			17	18	1		8	1					62	12
NESK13				4					6	1	2		18	
NESK14		15		10				7					55	20
NESK15													3	
NESK16													43	
NESK17														
NESK18	1	4					16	1					25	44
NESK19				11			1	16					51	64
NESK20				26			4	28	1				18	32
NESK21			6	16			9	25	1				14	6
NESK22			13	9			16	12	1				37	12
NESK23			8				6	2					35	17
NESK24		10	1	45				11	1				83	19
NESK25		1	4	39			4	12					14	12
NESK26		3	2	7			3						35	4
NESK27				8				6	1				33	7
NESK28			2	25			8	7					54	18
NESK29			2	19			10	14					61	15
NESK30			16	6		3	2	1					46	7
NESK31			9			3	2	1	4				14	6
NESK32				6			4	18					29	27
NESK33			25	3		14	4	1					27	
NESK34													8	
NESK35	6		7	13			5	5					7	15
NESK36			2	14			8	4					67	26
NESK37			8	29			8	3					28	5
NESK38			21	8	3	3	11	5					37	5
NESK39			31	1	4	4	7	7					38	9
NESK40		1	3	6			11	1	1				21	4
NESK41			23	4		5	13	4					24	1
NESK42			50		14	1	1						13	1
NESK43	7	15		4				1					47	17
NESK44	2	1	17	5									14	1

Appendix 2: Habitat Variables and Water Quality Measurements

Code	Name	Elevation (m)	Catchment Area (km2)	Cobble Score	Conductivity (μS/cm)	Distance from Source (km)	Northing	Easting	Riffle Area (%)	Stream Class
NESK02	North Esk U/S Clarkes Ford Bridge	5	893.6	0	88.7	67.5	5409600	515700	10	5
NESK03	North Esk @ Corra Linn Gorge	25	778.8	2	84.7	62	5406800	519300	60	5
NESK04	North Esk below Corra Linn	18	801.8	5	89.2	63	5406800	518400	40	5
NESK05	North Esk @ White Hills	88	769.5	1	63.2	47	5405400	521450	70	5
NESK06	North Esk above St Patricks	218	434.5	4	64	46	5407850	528400	75	4
NESK07	North Esk @ Ballroom	325	362.6	1	65.8	37	5406100	532500	20	4
NESK08	North Esk @ Musselboro Rd	342	346.5	1	65.2	33	5406300	535800	10	4
NESK09	North Esk @ Burns Ck Rd	375	313.2	3	58.9	24	5407550	541900	40	4
NESK10	North Esk @ Wattle Corner	390	203	4	65.6	20	5408100	544500	20	4
NESK11	North Esk off Camden Rd	405	112.3	2	64.6	16	5410950	543900	30	4
NESK12	North Esk @ Ben Nevis Gates	440	45	4	70.4	10	5415600	544200	45	3
NESK13	Distillery Creek above North Esk	10	51.1	4	77.3	16	5413050	514300	30	3
NESK14	Distillery Creek u/s filtration plant	120	36.4	4	58.6	12.5	5413000	517800	40	3
NESK18	St Patricks River @ Watery Plains	210	335	3	54.5	54	5407900	528000	70	5
NESK19	St Patricks River @ Nunamara	350	292	4	59.8	40	5417800	525000	30	5
NESK20	St Patricks River @ Pecks Hill Rd	375	202	3	49.5	31	5424300	528700	60	5
NESK21	St Patricks River @ Targa Hill Rd	390	165	4	47	25	5426800	530900	45	5
NESK22	St Patricks River @ Corkery's Rd	435	125	4	47	15	5428300	534600	30	4
NESK23	St Patricks River @ East Diddleum Rd	540	108.5	5	47.4	10	5425800	538900	15	4
NESK24	Patersonia Rivulet / Patersonia Rd	355	53.7	4	97.8	15	5420400	525400	40	4
NESK25	Patersonia Rivulet @ Targa Hill	400	17.6	2	54.1	7	5426500	527700	30	3
NESK26	Coquet Creek @ Tasman Hwy	374	9.3	5	38.6	9	5421300	528200	50	3
NESK27	Barrow Ck @ Tasman Highway	380	13.5	3	79	8.5	5424300	529200	40	2
NESK28	Bennies Ck @ Tasman Highway	385	9.6	5	58	7.5	5425000	530000	60	2
NESK29	Seven Time Ck @ Tasman Highway	390	20.6	4	63	6	5426700	531400	35	3
NESK30	Seven Time Ck off Camden Hill Rd	560	9.5	4	63	2	5425500	534600	45	3
NESK31	Camden Rivulet @ Diddleum Rd	555	35.5	0	64.9	10.5	5425200	538700	20	3
NESK32	Musselboro Ck U/S North Esk	355	30.4	4	60.5	10.2	5407850	537600	55	3
NESK33	Musselboro Ck off Musselboro Rd	480	14.5	4	38.5	4	5412300	536300	75	3
NESK35	River O' Plain Ck @ Blessington Rd	385	31.9	4	68.2	13	5406600	541800	45	2
NESK36	Pig Run Ck @ Blessington Rd	380	19.7	3	56.8	13	5407900	543000	25	2
NESK37	Ford below Upper Blessington	410	59	3	63.4	18	5408800	544700	30	4
NESK38	Becketts Ck @ Camden Rd	440	30.7	3	56.8	11	5415600	544200	40	3
NESK39	Becketts Ck @ Simons Rd	470	29.5	4	57.2	9	5416500	543400	40	3
NESK40	Burns Creek @ Elverton property	365	19.4	2	75.6	12	5406200	539400	35	3
NESK41	Burns Creek upper site	488	4.3	0	84	3.8	5412250	538900	0	2
NESK42	North Esk Above Northallerton	475	7.2	0	58.6	4	5418700	549350	35	3
NESK43	Weavers Creek u/s North Esk	270	43.5	3	118.9	13.2	5407450	529850	80	3
NESK44	Ford above Upper Blessington	525	13.6	3	29.4	9.8	5408240	552410	50	1

Predictor variables used for the spring riffle model

Code	Name	Boulder Score	Conductivity (µS/cm)	Mean Depth (cm)	Northing	Easting
NESK01	North Esk d/s Kingsmeadows Rt	0	120.6	60	5411100	514200
NESK02	North Esk U/S Clarkes Ford Bridge	0	88.7	10	5409600	515700
NESK03	North Esk @ Corra Linn Gorge	3	84.7	20	5406800	519300
NESK04	North Esk below Corra Linn	1	89.2	40	5406800	518400
NESK05	North Esk @ White Hills	0	63.2	40	5405400	521450
NESK06	North Esk above St Patricks	1	64	20	5407850	528400
NESK07	North Esk @ Ballroom	0	65.8	30	5406100	532500
NESK08	North Esk @ Musselboro Rd	0	65.2	25	5406300	535800
NESK09	North Esk @ Burns Ck Rd	0	58.9	30	5407550	541900
NESK10	North Esk @ Wattle Corner	0	65.6	30	5408100	544500
NESK11	North Esk off Camden Rd	0	64.6	20	5410950	543900
NESK12	North Esk @ Ben Nevis Gates	0	70.4	20	5415600	544200
NESK13	Distillery Creek above North Esk	0	77.3	40	5413050	514300
NESK14	Distillery Creek u/s filtration plant	0	58.6	30	5413000	517800
NESK15	Kings Meadows Rivulet @ Punchbowl	0	2420	30	5410800	514250
NESK16	Rose Rivulet above north Esk	0	2570	10	5406200	518500
NESK17	Rose Rivulet @ Lower White Hills Rd	0	2090	30	5402700	519200
NESK18	St Patricks River @ Watery Plains	4	54.5	30	5407900	528000
NESK19	St Patricks River @ Nunamara	2	59.8	15	5417800	525000
NESK20	St Patricks River @ Pecks Hill Rd	0	49.5	30	5424300	528700
NESK21	St Patricks River @ Targa Hill Rd	0	47	20	5426800	530900
NESK22	St Patricks River @ Corkery's Rd	0	47	30	5428300	534600
NESK23	St Patricks River @ East Diddlium Rd	0	47.4	30	5425800	538900
NESK24	Patersonia Rivulet / Patersonia Rd	2	97.8	30	5420400	525400
NESK25	Patersonia Rivulet @ Targa Hill	0	54.1	15	5426500	527700
NESK26	Coquet Creek @ Tasman Hwy	2	38.6	30	5421300	528200
NESK27	Barrow Ck @ Tasman Highway	0	79	30	5424300	529200
NESK28	Bennies Ck @ Tasman Highway	2	58	30	5425000	530000
NESK29	Seven Time Ck @ Tasman Highway	0	63	40	5426700	531400
NESK30	Seven Time Ck off Camden Hill Rd	0	63	15	5425500	534600
NESK31	Camden Rivulet @ Diddleum Rd	0	64.9	40	5425200	538700
NESK32	Musselboro Ck U/S North Esk	0	60.5	25	5407850	537600
NESK33	Musselboro Ck off Musselboro Rd	0	38.5	30	5412300	536300
NESK34	Old Mill Creek @ Blessington Rd	0	161	20	5405250	540700
NESK35	River O' Plain Ck @ Blessington Rd	0	68.2	25	5406600	541800
NESK36	Pig Run Ck @ Blessington Rd	0	56.8	25	5407900	543000
NESK37	Ford below Upper Blessington	0	63.4	25	5408800	544700
NESK38	Becketts Ck @ Camden Rd	0	56.8	15	5415600	544200
NESK39	Becketts Ck @ Simons Rd	0	57.2	15	5416500	543400
NESK40	Burns Creek @ Elverton property	0	75.6	30	5406200	539400
NESK41	Burns Creek upper site	0	84	30	5412250	538900
NESK42	North Esk Above Northallerton	0	58.6	80	5418700	549350
NESK43	Weavers Creek u/s North Esk	3	118.9	10	5407450	529850
NESK44	Ford above Upper Blessington	3	29.4	20	5408240	552410

Predictor variables used for the spring edgewater model

Water Quality measurements for sites sampled under the State of River sampling program

Code	Name	Temperature °C	Conductivity (µS/cm)	Turbidity NTU	Dissolved O2 mg/l	pH
NESK01	North Esk d/s Kingsmeadows Rt	17.7	120.6	4.52	10.1	6.68
NESK02	North Esk U/S Clarkes Ford Bridge	17.6	88.7	1.8	6.6	7.44
NESK03	North Esk @ Corra Linn Gorge	16.8	84.7	1.32	9.2	7.86
NESK04	North Esk below Corra Linn	18.3	89.2	1.27	8.6	7.99
NESK05	North Esk @ White Hills	13.8	63.2	4.2	9.5	7.43
NESK06	North Esk above St Patricks	14.2	64	4.2	10.8	7.64
NESK07	North Esk @ Ballroom	14.3	65.8	4.47	9	5.99
NESK08	North Esk @ Musselboro Rd	13.9	65.2	3.32	8.7	6.91
NESK09	North Esk @ Burns Ck Rd	13.6	58.9	3.28	9.5	7.11
NESK10	North Esk @ Wattle Corner	12	65.6	2	10.2	7.36
NESK11	North Esk off Camden Rd	12.1	64.6	2.4	10.1	7.58
NESK12	North Esk @ Ben Nevis Gates	12.1	70.4	2.48	10.4	7.53
NESK13	Distillery Creek above North Esk	17.3	77.3	8.31	8.7	6.78
NESK14	Distillery Creek u/s filtration plant	16.6	58.6	6.59	9.3	7.33
NESK15	Kings Meadows Rivulet @ Punchbowl	15.2	2420	10.9	5	7.02
NESK16	Rose Rivulet above north Esk	15.9	2570	1.26	5	8.11
NESK17	Rose Rivulet @ Lower White Hills Rd	15.2	2090	7.57	2.3	7.75
NESK18	St Patricks River @ Watery Plains	11.4	54.5	3.08	9.5	7.36
NESK19	St Patricks River @ Nunamara	13.9	59.8	7.34	8.9	7.32
NESK20	St Patricks River @ Pecks Hill Rd	15	49.5	6.8	9.7	7.07
NESK21	St Patricks River @ Targa Hill Rd	11.7	47	3.47	8.3	7.1
NESK22	St Patricks River @ Corkery's Rd	11.4	47	2.7	9.9	7.12
NESK23	St Patricks River @ East Diddlium Rd	11.7	47.4	2.1	10	7.37
NESK24	Patersonia Rivulet / Patersonia Rd	14.5	97.8	50.6	8.2	7.45
NESK25	Patersonia Rivulet @ Targa Hill	13	54.1	3.2	8.8	6.8
NESK26	Coquet Creek @ Tasman Hwy	11.8	38.6	2.34	10.7	7.45
NESK27	Barrow Ck @ Tasman Highway	16.7	79	7.1	9.7	7.6
NESK28	Bennies Ck @ Tasman Highway	11.7	58	3	9.5	6.7
NESK29	Seven Time Ck @ Tasman Highway	11.1	63	2.33	10.7	7.5
NESK30	Seven Time Ck off Camden Hill Rd	11.6	63	4.8	10.8	7.14
NESK31	Camden Rivulet @ Diddleum Rd	12.8	64.9	3.48	10	7.37
NESK32	Musselboro Ck U/S North Esk	15.1	60.5	7.27	9.2	7.11
NESK33	Musselboro Ck off Musselboro Rd	9.2	38.5	2.28	10.4	7.05
NESK34	Old Mill Creek @ Blessington Rd	19.8	161	16.7	8.3	7.52
NESK35	River O' Plain Ck @ Blessington Rd	13.6	68.2	17.8	9.6	7.63
NESK36	Pig Run Ck @ Blessington Rd	14.3	56.8	15.2	9.2	7.2
NESK37	Ford below Upper Blessington	11.9	63.4	1.52	9.7	7.12
NESK38	Becketts Ck @ Camden Rd	12.1	56.8	1.43	10.3	7.37
NESK39	Becketts Ck @ Simons Rd	12.1	57.2	2.92	10.5	7.37
NESK40	Burns Creek @ Elverton property	13	75.6	8.85	9.5	7.25
NESK41	Burns Creek upper site	10.4	84	2.83	9.7	6.67
NESK42	North Esk Above Northallerton	11.4	58.6	1.3	9.7	7.37
NESK43	Weavers Creek u/s North Esk	12	118.9	1.36	11	7.98
NESK44	Ford above Upper Blessington	12.4	29.4	0.55	10.2	7.11

Appendix 3: Algal Taxa List

Code	Name	Date	Achnanthes	Actinella	Actinotaenium	Amphora	Anabaena	Anisonema	Ankistrodesmus	Anthophysa	Aphanizomenon	Arthrospira
NESK04	Nth Esk/Below Cora Linn	29/04/97	1			1			1			
NESK04	Nth Esk/Below Cora Linn	10/10/97	1			1						
NESK08	Nth Esk/Musselboro Rd	29/04/97				1					1	
NESK08	Nth Esk/Musselboro Rd	27/10/97	1		1	1						
NESK17	Rose Rt/Above Nth Esk	30/04/97										
NESK17	Rose Rt/Above Nth Esk	27/10/97										
NESK32	Musselboro Creek	29/04/97	1			1		1	1	1		
NESK32	Musselboro Creek	27/10/97	1			1	1					
NESK36	Pig Run Creek/Blessington Road	29/04/97	1	1		1						
NESK36	Pig Run Creek/Blessington Road	27/10/97	1									
NESK37	Ford/Below Upper Blessington	27/10/97	1			1			1			
NESK37	Ford/Below Upper Blessington	29/04/97	1			1	1		1			1
NESK38	Beckett Crk/Camden Rd	29/04/97	1									
NESK38	Beckett Crk/Camden Rd	28/10/97	1			1						

Code	Date	Batrachospermum	Caloneis	Campylodiscus	Centritractus	Chamaesiphon	Characium	Chilomonas	Chlorhormidium	Chlorosarcina	Cladophora	Closteriopsis	Closterium
NESK04	29/04/97						1	1		1			1
NESK04	10/10/97										1		
NESK08	29/04/97		1		1								1
NESK08	27/10/97	1											1
NESK17	30/04/97					1	1					1	
NESK17	27/10/97			1			1						1
NESK32	29/04/97												1
NESK32	27/10/97						1						1
NESK36	29/04/97		1								1		
NESK36	27/10/97												1
NESK37	27/10/97										1		
NESK37	29/04/97						1		1		1		1
NESK38	29/04/97										1		
NESK38	28/10/97												1

Code	Date	Cocconeis	Coelastrum	Cosmarium	Crucigenia	Cryptomonas	Cyclotella	Cymbella	Dactyloccopsis	Diatomella	Dicellula	Diploneis	Draparnaldia	Draparnaldiopsis	Elakatot
NESK04	29/04/97	1	1	1	1			1	1		1				
NESK04	10/10/97							1							1
NESK08	29/04/97	1		1				1							
NESK08	27/10/97			1			1	1							
NESK17	30/04/97	1													
NESK17	27/10/97	1						1				1	1		
NESK32	29/04/97							1		1					
NESK32	27/10/97	1		1				1					1		
NESK36	29/04/97	1						1						1	
NESK36	27/10/97	1		1				1							
NESK37	27/10/97	1		1		1		1							
NESK37	29/04/97	1		1											
NESK38	29/04/97	1						1							
NESK38	28/10/97	1						1							

Code	Date	Epithemia	Euastrum	Euglena	Eunotia	Fragillaria*	Frustulia	Gloeocystis	Gloeothece	Gomphoneis	Gomphonema	Gomphosphaeria	Gyrosigma	Helicodictyon	Heteroner
NESK04	29/04/97		1		1			1			1				
NESK04	10/10/97								1						
NESK08	29/04/97														
NESK08	27/10/97				1		1							1	
NESK17	30/04/97												1		
NESK17	27/10/97			1	1	1									
NESK32	29/04/97	1		1											1
NESK32	27/10/97				1		1								
NESK36	29/04/97	1			1						1				
NESK36	27/10/97	1				1									
NESK37	27/10/97					1									
NESK37	29/04/97			1							1	1			
NESK38	29/04/97				1		1								
NESK38	28/10/97				1					1					

Code	Date	Lepocinclis	Lyngbya	Melosira	Meridion	Merismopedia	Microcystis	Mougeotia	Navicula	Netrium	Nitzschia	Oedogonium	Opehora	Oscillatoria	Ourococcus	Pandorin
NESK04	29/04/97	1				1	1	1	1	1			1	1	1	
NESK04	10/10/97								1							
NESK08	29/04/97			1		1			1		1	1		1		
NESK08	27/10/97			1				1	1					1		
NESK17	30/04/97								1				1			
NESK17	27/10/97	1						1	1			1	1			1
NESK32	29/04/97	1	1	1					1			1	1	1		
NESK32	27/10/97			1					1			1	1	1		
NESK36	29/04/97		1						1			1	1	1		
NESK36	27/10/97							1	1			1	1	1		
NESK37	27/10/97			1					1							
NESK37	29/04/97	1	1	1	1				1		1	1	1	1		
NESK38	29/04/97		1	1					1			1	1			
NESK38	28/10/97		1		1				1				1			

Code	Date	Pediastrum	Peranema	Phacus	Phormidium	Pinnularia	Pleurotaenium	Raphidiopsis	Rhizoclonium	Rhodochorton	Rhoicosphenia	Rivularia	Scenedesmus	Sirogonium	Spir
NESK04	29/04/97	1				1	1	1					1		
NESK04	10/10/97														
NESK08	29/04/97			1									1		
NESK08	27/10/97				1	1				1	1				
NESK17	30/04/97								1		1			1	
NESK17	27/10/97								1		1	1			
NESK32	29/04/97		1												
NESK32	27/10/97									1					
NESK36	29/04/97														
NESK36	27/10/97					1									
NESK37	27/10/97					1				1	1	1			
NESK37	29/04/97							1							
NESK38	29/04/97					1					1				
NESK38	28/10/97					1					1	1			

Code	Date	Spirulina	Spondylosium	Staurastrum	Stauroneis	Stigeoclonium	Surirella	Synedra	Tabellaria	Tetraedriella	Tetraedron	Trachelomonas	Trichodesmium	Trochiscia	Ulothri
NESK04	29/04/97	1	1	1				1	1	1	1			1	
NESK04	10/10/97											1			1
NESK08	29/04/97	1		1			1	1				1			
NESK08	27/10/97	1		1	1	1	1	1	1				1		1
NESK17	30/04/97							1	1						
NESK17	27/10/97	1					1	1	1						
NESK32	29/04/97			1			1	1	1						
NESK32	27/10/97	1		1			1	1	1						1
NESK36	29/04/97					1		1							
NESK36	27/10/97			1	1		1	1	1						
NESK37	27/10/97	1		1					1						1
NESK37	29/04/97	1		1			1	1	1		1	1			1
NESK38	29/04/97	1		1			1	1							
NESK38	28/10/97	1			1				1			1			1

Code	Date	Vaucheria	Zygnema	Zygogonium
NESK04	29/04/97			
NESK04	10/10/97			
NESK08	29/04/97			
NESK08	27/10/97			
NESK17	30/04/97			
NESK17	27/10/97		1	
NESK32	29/04/97			
NESK32	27/10/97			1
NESK36	29/04/97			
NESK36	27/10/97			
NESK37	27/10/97	1		
NESK37	29/04/97	1		
NESK38	29/04/97			
NESK38	28/10/97			