DEPARTMENT *of*
PRIMARY INDUSTRIES,
WATER *and* ENVIRONMENT

Aquatic Ecology of Rivers in the Inglis-Flowerdale Catchment

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

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December, 2003

Preferred Citation:

DPIWE (2003) *State of the River Report for the Inglis-Flowerdale Catchment.* Water Assessment and Planning Branch, Department of Primary Industries, Water and Environment, Hobart. Technical Report No. WAP 03/12

ISSN: 1449-5996

The Department of Primary Industries, Water and Environment

The Department of Primary Industries, Water and Environment provides leadership in the sustainable management and development of Tasmania's resources. The Mission of the Department is to advance Tasmania's prosperity through the sustainable development of our natural resources and the conservation of our natural and cultural heritage for the future.

The Water Resources Division provides a focus for water management and water development in Tasmania through a diverse range of functions including the design of policy and regulatory frameworks to ensure sustainable use of the surface water and groundwater resources; monitoring, assessment and reporting on the condition of the State's freshwater resources; facilitation of infrastructure development projects to ensure the efficient and sustainable supply of water; and implementation of the *Water Management Act 1999*, related legislation and the State Water Development Plan.

Executive Summary

This report details the aquatic ecology of the Inglis-Flowerdale catchment. It initially describes the threatened fauna found in the catchment, and then explains the biological assessment of macroinvertebrate communities (using the Australian River Assessment System) used to determine the ecological health of the Inglis and Flowerdale Rivers and their tributaries. It must be remembered that this report is based on a snapshot assessment conducted in 1999, and changes in the pattern and intensity of catchment activities since this time may have further altered river health in the Inglis-Flowerdale catchment.

The major findings of this report are:

While the spatial pattern of aquatic impacts found during this study generally agree with those found by the water quality assessment, the results also show that habitat availability is an important factor influencing macroinvertebrate community composition and ecosystem health in this catchment.

The upper Inglis and Flowerdale Rivers and their tributaries are generally in good health. The assessment of the macroinvertebrate communities indicated healthy waterways where the water quality and habitat availability was also found to be good.

The middle to lower reaches of the Inglis River have less healthy macroinvertebrate communities suggesting that they are impacted by increased sedimentation arising from catchment and river management activities upstream.

The lower reaches of the Inglis River and a couple of its tributaries (Mitchells Creek and Blackfish Creek) show less-than-healthy faunal communities and indicate negative impacts of sedimentation due to poor river management practices. Stock are allowed to access the river at these sites, increasing bank erosion and instream sedimentation, and willow-removal operations have also contributed to increased sedimentation in these areas.

One site in the upper reaches of the Calder River stands out and is negatively affected by land clearing and altered flow regimes due to an onstream dam upstream, both of which have negatively affected the quality of the available habitat.

Implementation of better river management practices is recommended to reduce the impacts of sedimentation and sustain the ecological health of this catchment. These practices include the maintenance or extension or current riparian boundaries in forestry areas, the fencing off of riverbanks and verges from stock access, and the minimisation of sediment disturbance during willow removal followed by immediate re-vegetation of banks with native vegetation.

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Glossary of Terms and Abbreviations

AusRivAS – Australian River Assessment System.

AWARH – Australia Wide Assessment of River Health.

Benthic – bottom-dwelling, refers to aquatic animals living on the surface of stones and rocks on the river bed.

Catchment – refers to 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 (eg limestone caves) may alter the perceived catchment suggested solely by topography.

Macroinvertebrate – refers to small aquatic organisms that are invertebrates (ie without a spine) but can still be seen with the naked eye, such as insects, snails and worms.

MRHI – Monitoring River Health Initiative.

NRHP – National River Health Program.

RBA – Rapid Biological Assessment.

Riffles – refer to areas in the main channel of rivers and streams where the flow is fast-moving and generally turbulent and broken due to cobbles and boulders under the surface.

Riparian– refers to the zone of vegetation (trees, shrubs, grasses and groundcover) along the banks and floodplains of a river, or the zone where it may have been cleared.

Substrate – refers to the stream bed, and generally describes the elements (eg sand, gravel, pebbles, cobbles, boulders and bedrock) that make up the bed surface.

Turbidity – turbidity describes the “cloudiness” of water and is caused by suspended materials such as clay, silt, fine organic and inorganic matter, soluble coloured compounds and plankton and microscopic organisms.

1. Introduction

The “State of Rivers” study of the greater Inglis-Flowerdale catchment commenced in 1999. The study comprised a general description of the catchment based on water quality monitoring and investigations, river condition assessment, hydrological characterisation, and aquatic ecology assessment. This part of the study comprises the aquatic ecology assessment (conducted in 1999) and provides a snapshot of the aquatic fauna found in the catchment, including potentially threatened species, and their habitat requirements. It also provides an assessment of catchment health using the rapid bioassessment techniques and predictive modelling of the Australian River Assessment System (AusRivAS). This part of the study should be viewed in context with the other parts to obtain an overall picture of the condition of the water resources and aquatic health of river systems within the Inglis-Flowerdale catchment.

1.1 The Current Study

Agriculture, mining, forestry and agriculture can all have significant effects on the water quality of a freshwater system (Boulton and Brock, 1999), however they can also impact other aspects of freshwater systems such as the habitat availability and the biological communities. For instance, sites that suffer from gross nutrient enrichment or toxic pollution generally have far fewer and less diverse macroinvertebrate communities than less disturbed sites, but a site of low diversity does not necessarily indicate a site of low water quality. Macroinvertebrates also respond to habitat availability, and if the habitat at a site is negatively affected by impacts such as channelisation, sedimentation or riparian vegetation removal, then the macroinvertebrate community will also be negatively affected. Biological communities respond to combinations of factors rather than single factors (such as water quality or habitat availability), and their measurement and characterisation can provide a more complete picture of system degradation, reflecting the prevailing conditions and accumulation of conditions over time (Resh and Rosenberg, 1993, and references therein). Consequently, the biological monitoring of streams has been developed to complement more traditional methods of physical and chemical monitoring.

The National River Health Program (NRHP) was formed in 1993 by the Federal Government to provide a nationally coordinated approach to the assessment of the ecological condition of Australia’s river systems. A major aim of the program was to develop and implement a standard methodology for monitoring benthic macroinvertebrates in freshwater systems using Rapid Biological Assessment (RBA) techniques. This methodology would therefore allow for the faster and cheaper evaluation of river health than fully quantitative methods, and would allow comparison between different systems across Australia.

As part of the NRHP, the Monitoring River Health Initiative (MRHI) commenced in Tasmania in 1994 with the primary objective to develop predictive models to assess river health using macroinvertebrates as biological indicators. Macroinvertebrates have been sampled from over 250 sites in Tasmania and the data used to build the models for the Australian River Assessment System (AusRivAS), the methodology developed for the Australia Wide Assessment of River Health (AWARH). These sites are known as “reference” sites, and the sites used in this study are the “test” sites. The macroinvertebrate communities from the test sites are compared with those in the reference sites, and the degree to which they differ from the reference sites gives an indication of degradation of the test sites. The AusRivAS methodology is explained in more detail in the Methods section.

1.2 General Catchment Description

The Inglis-Flowerdale catchment lies on the northern coast of Tasmania between Smithton and Burnie, draining an area of approximately 471 km^2, and discharges into Bass Strait at Wynyard, 5 km south of Table Cape. The Flowerdale River comprises the largest tributary system on the Inglis and rises from the northern end of the Campbell Range near West Takone. It drains an area of 161 km^2 (approximately a third of the Inglis River catchment), contributes nearly half the yield over its 65 km length, and discharges into the Inglis River at Flowerdale. The Inglis rises from the southern end of the Campbell Range, and flows northwards for 62 km over mostly basalt and mudstone soils. These soils are generally fertile and well-drained, although less so in the drainage lines. The topography changes from steep-sided valleys in the upper catchment, to deeply-incised hills in the middle catchment, and rolling hills with gentler slopes in the lower catchment.

The catchment is predominantly used for forestry operations (both native forestry and pine plantation forestry), although there has been land cleared for grazing and dairy agriculture in the lower catchment. Remnant native vegetation is stringybark (*Eucalyptus obliqua*) forest with peppermint (*E. salicifolia*) and mountain whitegum (*E. dalrympleana*) on upper slopes, swamp gum (*E. ovata*) and silver wattle (*Acacia dealbata*) on drainage lines, with a mid-storey of blackwood (*A. melanoxylon*), myrtle (*Nothofagus cunninghamii*) and sassafras (*Atherosperma moschatum*), and an understorey of manuka and tree-ferns (*Dicksonia antarctica*).

The Flowerdale also drains some areas of quartzite soils over a rugged topography with numerous rocky outcrops. The vegetation in these areas differs in characterising a scrub and heath community dominated by peppermint (*E. simmondsii*) and paperbark (*Melaleuca squarrosa*) with and understorey of *Banksia marginata*, silver wattle and blackboy (*Xanthorrhea australis*).

2. Methods

2.1 Aquatic Fauna

2.1.1 Threatened species

A species is regarded as endangered if the factors contributing to its endangered status continue to operate, thus rendering its long term survival unlikely, or it is already presumed extinct (Bryant and Jackson, 1999). A species is considered vulnerable if it is likely to become endangered while the factors contributing to its vulnerable status keep operating. Rare species are neither endangered nor vulnerable but are at risk due to their small population sizes. The aquatic threatened species in the Inglis-Flowerdale catchment are the giant freshwater crayfish, *Astacopsis gouldi*, and the Australian grayling, *Prototroctes maraena*.

The giant freshwater crayfish is listed as vulnerable and occurs in most river systems along the northern coast of Tasmania, below an altitude of 400 m, although today their distribution is more disjunct and significant declines have occurred in many of these northern catchments. The Inglis-Flowerdale catchment represents a key catchment for their continued survival. They have been recorded throughout the middle and upper catchments, particularly in the uppermost reaches of the main channels and tributaries, although they have also been found as far down as Big Creek and Nursery Road. Their ideal habitat is an intact stream catchment

incorporating streams of various sizes which meander and flow through a relatively undisturbed, well-vegetated catchment and which contain snags, pools and undercut (but not eroding) banks. Their decline has been caused by a steady increase in habitat disturbance due to catchment activities, combined with a long history of recreational fishing which has targeted larger individuals for eating and trophies (Bryant and Jackson, 1999). Key threats include any form of streamside or instream habitat disturbance (eg stock access, bank erosion, etc), conversion of native forest to pine plantation, removal of woody debris from streams, illegal fishing, water pollution by pesticides, fertilisers and sediment, and population fragmentation caused by barriers to movement (eg poorly constructed road culverts).

The Australian grayling is also listed as vulnerable and occurs in the middle and lower reaches of Tasmania's coastal rivers (they also occur in southeastern mainland Australia). Grayling have been recorded on two occasions from the lower Inglis River at the Bass Highway. Little is know of their biology, but spawning takes place in late spring to early summer in fresh flowing waters where they ley their eggs over gravelly stream beds. The larvae are probably swept to sea and return as whitebait in 4-6 months. Key threats include habitat loss and disturbance, especially to lower river reaches (eg de-snagging and channelisation), instream barriers to upstream movement (eg dams and weirs), water pollution (caused by forestry, agriculture and urban development), and changes in flow regimes (caused by dams and water abstractions)(Bryant and Jackson, 1999).

2.1.2 Fish

Fish surveys showed there are both native and introduced fish occurring throughout the catchment. Blackfish (*Gadopsis marmoratus*) have a similar distribution to the giant freshwater crayfish, occurring throughout the middle and upper reaches of the main channels of the Inglis and Flowerdale Rivers, and also in the lower reaches and tributaries.

The middle and lower reaches of the catchment support populations of native fish common in Tasmanian rivers: short-finned eels (*Anguilla australis*), freshwater flathead (*Pseudaphritis urvilii*), common jollytails (*Galaxias maculatus*) and spotted galaxias (*G. truttaceus*). Short-headed and pouched lampreys (*Mordacia mordax* and *Geotria australis* respectively) also occur in the lower reaches of tributaries of the Inglis River, including the Flowerdale River, but have not been recorded from the main channel itself. Most of these fish travel upstream at certain stages during their life cycles and are therefore likely to be affected by instream barriers to movement.

The introduced fish species in the catchment are goldfish (*Carassius auratus*), which has been recorded from Big Creek and its tributaries, and sea-run brown trout (*Salmo trutta*) which occurs throughout the entire catchment.

2.1.3 Macroinvertebrates

The macroinvertebrate fauna comprises the majority of the instream biological community in terms of species abundance and diversity. It is this part of the community that is used for biological monitoring and modelled to assess the ecological health of the catchment, and this is described in the following sections.

2.2 AusRivAS Methodology

2.2.1 Study sites

The river health survey was not intended to investigate point source pollution, but rather to assess the catchment's general health, thus sites were selected on the basis of being representative of the reach in which they occur. Forty sites were selected throughout the

catchment (Table 1, Figure 1); 10 on the mainstream of the Inglis River, and 30 on the major tributaries throughout the catchment. Seven of these latter sites were located on the Flowerdale River and four on its tributaries. These sites are the same as those used in the assessment of river condition which is presented as another part of this State of River report.

2.2.2 Sampling methods

The sites were sampled using the Rapid Biological Assessment (RBA) method developed for the MRHI and outlined in Davies (1994) and Oldmeadow *et al.* (1998). Different habitats are susceptible to different kinds of disturbance, so samples were collected from riffle or edgewater habitats at each site (100 m reach of river).

Riffles are defined as areas in the main channel that are fast-flowing, shallow, broken and turbulent, and usually flowing over stony or rocky substrates. Samples were collected by kicking over stones and disturbing the streambed over a 10 m length in the riffle. Benthic macroinvertebrates were dislodged by this disturbance and swept into a net by the current.

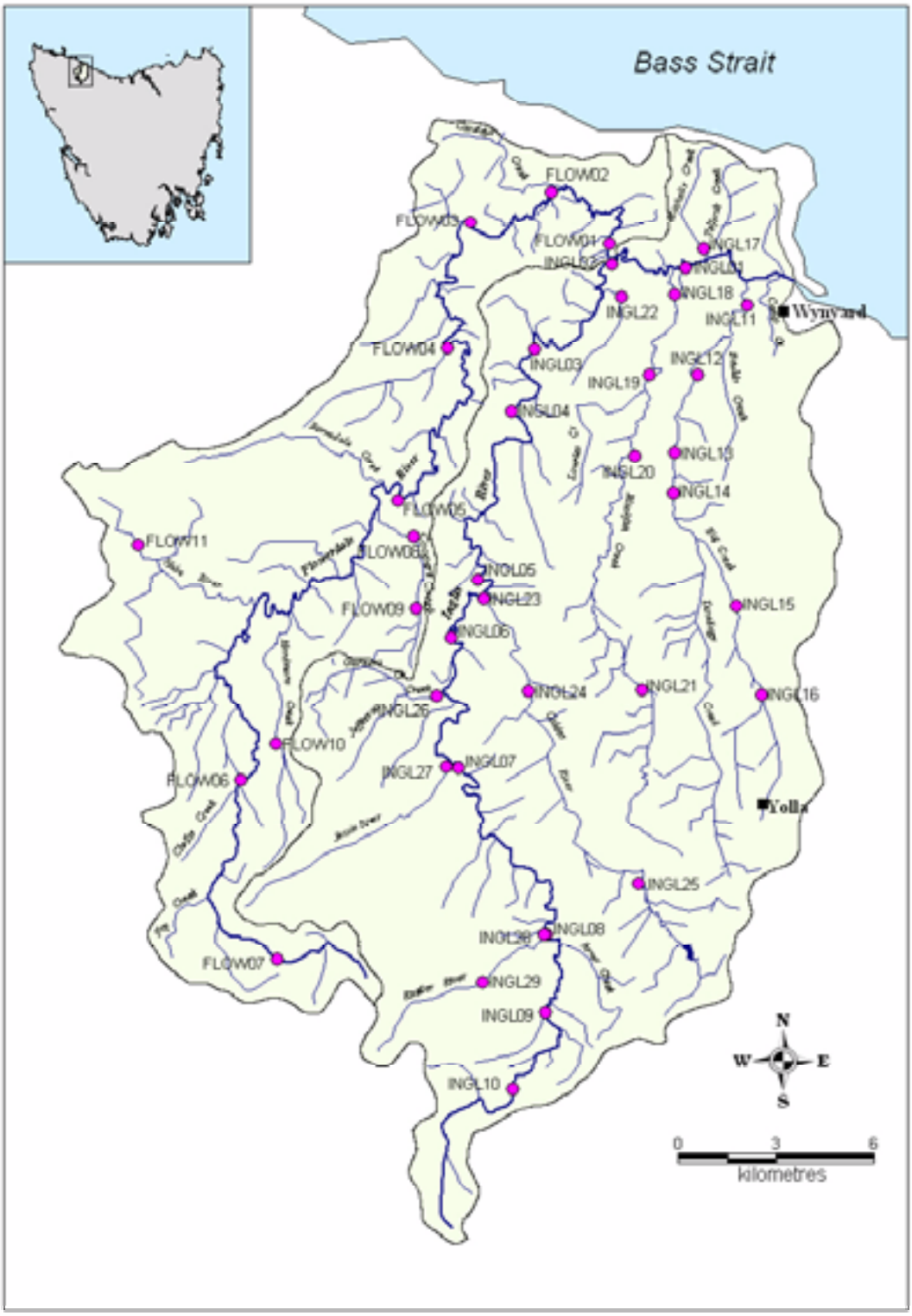
Edgewater samples were collected by sweeping a net through slow-flowing pools, backwaters and margins of the main channel. Aquatic plants are often found in these areas of slow or no flows, and are included in the sample as they also provide an important habitat for instream macroinvertebrates.

Each sample was emptied into a tray and live-picked for 30 minutes, ensuring a broad a range of macroinvertebrates as possible are collected. The macroinvertebrates are preserved in 70% ethanol for further identification in the laboratory. Macroinvertebrates were identified to family level except in the following cases: Chironomidae (midges) were identified to sub-family, and Oligochaeta (worms), Hirudinea (leeches), Acarina (mites) and Turbellaria (flatworms) were identified to order and class. To reduce confusion, the term “family” will be used to refer to identifications to these other levels.

Table 1 Site legend for Inglis-Flowerdale AusRivAS sites depicted in Figure 1.

Site Code	Site Name	Northing	Easting
INGL01	Inglis R @ Rd off Stennings Rd u/s Pumphouse	5462700	389350
INGL02	Inglis R @ Emerald Vale Rd @ railway bridge	5462800	387100
INGL03	Inglis @ Pages Rd	5460100	384750
INGL04	Inglis R @ end of Rd through gravel pits	5458200	384050
INGL05	Inglis R off Zig-Zag Rd	5453000	383100
INGL06	Inglis R @ picnic area Jefferson Rd	5451200	382300
INGL07	Inglis R @ Jessie Rd u/s Jessie R	5447200	382600
INGL08	Inglis R @ Takone Rd @ Takone	5442100	385400
INGL09	Inglis R @ Chouveaux Rd in plantation	5439700	385400
INGL10	Inglis R @ Viney Rd	5437300	384900
INGL11	Big Ck @ Wynyard	5461600	391300
INGL12	Big Ck @ Nursery Rd	5459400	389800
INGL13	Big Ck @ Tram Rd near picnic area	5457000	389100
INGL14	Big Ck @Tram Rd @ start Pine Plantation	5455800	389100
INGL15	Big Ck @ Cleveland Rd	5452300	391100
INGL16	Big Ck @ Smarts Rd	5449600	391900
INGL17	Mitchells Ck @ Bass H'way	5463300	389900
INGL18	Blackfish Ck @ Stennings Rd	5461900	389050
INGL19	Blackfish Ck @ Blackfish Rd	5459400	388300
INGL20	Blackfish Ck @ end of Blackfish Rd	5456900	387900
INGL21	Blackfish Ck @ Lowries Rd	5449700	388200
INGL22	Un-named trib @ end of Ballast Pit Rd	5461800	387400
INGL23	Calder R u/s confluence @ Zig Zag Rd	5452400	383300
INGL24	Calder R @ end of Bassets Rd	5449600	384700
INGL25	Calder R @ Takone Rd	5443700	388200
INGL26	Jefferson Ck off Jefferson Rd	5449400	381900
INGL27	Jessie R u/s confluence	5447200	382200
INGL28	Rattler R @ Takone	5442100	385300
INGL29	Rattler R @ Takone Rd	5440600	383450
FLOW01	Flowerdale R @ Preolenna Rd	5463400	387000
FLOW02	Flowerdale R @ railway 1.2km south of Boat Harbour	5465000	385200
FLOW03	Flowerdale R @ old SG stn @ Moorleah	5464000	382700
FLOW04	Flowerdale R @ Lapoinya Rd	5460100	382050
FLOW05	Flowerdale R @ Flying Fox off Ten foot track	5455400	380600
FLOW06	Flowerdale R @ Meunna Rd	5446700	375900
FLOW07	Flowerdale R @ West Takone Plantation	5441200	377100
FLOW08	Coopers Ck @ Ten Foot Track	5454300	381100
FLOW09	Coopers Ck @ ford (off Preolenna Rd)	5452050	381200
FLOW10	Hardmans Ck @ Preolenna Rd	5447850	376950
FLOW11	Hebe R @ Myalla Rd	5453900	372600

Figure 1 AusRivAS study sites in the Inglis-Flowerdale catchment.



2.2.3 Physico-chemical and environmental variables

Physico-chemical measurements and environmental descriptions were also collected as some of these are used in the AusRivAS models and assist in interpretation. Water quality measurements were taken at each site and included temperature, pH, dissolved oxygen, electrical conductivity and turbidity, and samples were taken for laboratory analyses for alkalinity. Environmental data collected included observations of riparian vegetation and aquatic habitat variables (Table 2), and detailed descriptions of land use, weeds present, local threats, channel alterations etc.

Table 2 Environmental variables measured for AusRivAS modelling.

Category	Variable
Substrate	% bedrock
	% boulder
	% cobble
	% pebble
	% gravel
	% sand
	% silt
	% clay
	% cover of substrate by algae
	% cover of substrate by detritus
	% cover of substrate by silt
	% cover of substrate by moss
Stream and banks	% riffle area
	% run area
	% pool area
	stream width (m)
	stream depth (m)
	bank width (m)
	bank height (m)
Map-based attributes	distance from source
	altitude
	catchment area (km^2)
	latitude (northing)
	longitude (easting)
	stream class
	bedslope
Riparian vegetation	% cover overhanging vegetation (shading)
	% cover trailing bank vegetation
	% cover native vegetation
	% cover exotic vegetation
	width of riparian zone (m)

2.2.4 AusRivAS modelling

The AusRivAS models essentially predict the macroinvertebrate fauna that would be expected to occur at a given site by comparing it to the fauna occurring in the reference sites. The first step of the model-building process is to classify reference sites which have similar macroinvertebrate compositions (based on family presence/absence data) into broad groups using the agglomerative clustering technique Flexible Unweighted Pair-Group Arithmetic

Averaging (UPGMA) (Belbin, 1993). The reference site groups are then entered into the reference habitat data set and stepwise multiple discriminant function analysis (MDFA) is used to select the predictor variables used in a model (Simpson and Norris, 2000). This procedure selects a subset of habitat variables which best discriminate between groups of sites formed from the faunal classifications. These habitat variables are used as predictor variables for the AusRivAS model being constructed, and together with the reference site macroinvertebrate classification, form the foundation of AusRivAS, allowing predictions of taxa which should be found at test sites. The Tasmanian models that have been built are Autumn Edgewater, Autumn Riffle, Spring Edgewater, Spring Riffle, Combined Edgewater and Combined Riffle.

All sites on the Inglis-Flowerdale were sampled in autumn, and edgewater habitats were sampled from 6 sites while riffle habitats were sampled from the remainder. Thus, the Autumn Edgewater and Riffle models were used for the Inglis-Flowerdale assessment of ecological health.

Once the test site data is included, the model outputs consist of lists of taxa expected at each site, their probability of occurrence, ratios of taxa observed to taxa expected (OE ratios), and the OESIGNAL index. The OE ratio provides a measure of biological impairment at the tested sites (Simpson *et al.*, 1996).

2.2.5 OE Indices

The OE ratio compares the number of taxa that actually occurred at a site (the observed taxa) with those that were predicted to occur (the expected taxa). They were calculated for all taxa that had a probability of occurrence >0.49, which is the threshold probability (thus not all taxa observed were necessarily included in the OE ratio). The use of this threshold is justified on the basis that the occurrence of families below this probability is random and could make the results too “noisy” (Barmuta *et al.*, 1998). Each site is classified into one of five categories or bands depending on the value of the OE ratio (Table 3). For example, a site with an OE ratio of 1.00 would be considered unimpaired or similar to the reference site because the observed taxa equalled the expected taxa, whereas a site with an OE of 0.7 would be considered significantly impaired, having fewer taxa observed than those expected. Therefore, the OE ratios not only indicate the presence of an impact but also the magnitude of the impact. The OE ratio is sensitive to a variety of disturbances that result in the loss of macroinvertebrate families from a site and thus detects family loss due to both deteriorated water quality and physical habitat degradation.

Table 3 River Health categories and associated OE ratios for the autumn edgewater model.

Band label	OE ratios	Band name	Band description
X	> 1.19	Richer than Reference	• more families than expected • potentially biodiverse site • possible mild organic enrichment
A	0.82 – 1.19	Similar to Reference	• ratio within the range of the central 80% of reference sites
B	0.45 – 0.81	Significantly Impaired	• fewer families than expected • potential mild to moderate impact on water quality, habitat or both
C	0.08 – 0.44	Severely Impaired	• considerably fewer families than expected • loss of families due to severe impact on water and/or habitat quality
D	< 0.07	Impoverished	• very few families collected • highly degraded • very poor water and/or habitat quality

The OESIGNAL is the ratio of the observed Stream Invertebrate Grade Number Average Level (SIGNAL) score to the expected SIGNAL score; the SIGNAL score is based on the sensitivity of macroinvertebrates to pollution. Each macroinvertebrate family is assigned a grade according to their pollution tolerance where a grade of 10 represents a high sensitivity/low tolerance to pollution and 1 represents a low sensitivity/high tolerance. The observed SIGNAL score is the sum of the grades divided by the number of observed taxa, the expected SIGNAL score is the sum of the grades divided by the number of expected taxa, and both are used for the OESIGNAL ratio. The OESIGNAL ratio can therefore detect situations where water pollution has resulted in the loss of only a few, very sensitive, macroinvertebrate families. Plotting the OE ratio against the OESIGNAL can show where there are mismatches in band allocation and provide valuable diagnostic information into the nature of the impact.

3. Results

3.1 General faunal characteristics of the catchment

The riffle habitats of the Inglis-Flowerdale catchment were far more abundant and diverse than the edgewater habitats, which is typical of freshwater systems. The riffle fauna comprised 87% of the total number of macroinvertebrates collected, and 60 of the 72 taxa collected were from the riffles. Twenty-three families were exclusively found in the riffles. The edgewater fauna comprised only 13% of the total macroinvertebrate abundance, and while there were 49 families present in the edgewaters, only 12 families were exclusive to this habitat.

Overall, insects were the most dominant group, representing about 75% of the taxa collected; they comprised 67% of individuals collected from edgewaters and 85% from riffles. The riffle fauna was very diverse with numerous families occurring in relatively large abundances, but the among most common were Leptophlebiidae (mayflies), Hydrobiosidae (predatory

caddisflies), Orthocladiinae (midges), Paramelitidae (amphipods), Scirtidae (beetles) and Elmidae (riffle beetles). The riffle fauna was fairly typical of riffle communities found elsewhere. Edgewater fauna was more depauperate, the most common families being Chironominae (midges), Leptoceridae (caddisflies) and Oligochaeta (worms), and was typical of communities found in slow-flowing habitats.

3.2 AusRivAS outputs

Only eight sites of the 40 sites sampled were considered impaired, the remaining 32 sites falling into Bands A (similar to reference) and X (richer than reference; Table 4). This indicates that overall, the Inglis-Flowerdale catchment was in relatively good health when assessed in 1999. Of the impaired sites, four occurred on the main channel of the Inglis River in the mid to lower reaches, three occurred on tributaries of the Inglis River, and one occurred on the Flowerdale River at the old stream gauging station at Moorleah (Figure 2).

Visual analysis of the OE vs OESIGNAL plot for edgewater habitats (Figure 3) indicates the edgewaters in the Flowerdale River are generally healthier than those in the Inglis River in that they have both OE and OESIGNAL scores around 1.0 (ie the taxa collected matched those predicted). The edgewater habitats in the Inglis River have lower OE scores, indicating there were less taxa collected than those predicted. The two sites at the bottom of the catchment, INGL02 and INGL17 also had lower OESIGNAL scores which suggests they may be impacted by poor water quality as well as poor habitat quality.

The OE vs OESIGNAL plot for riffle habitats (Figure 4) shows all the riffle sites had an OESIGNAL score around 1.0. This means there was no loss of families which have a high sensitivity / low tolerance to poor water quality, and suggests the water quality in riffle habitat in the catchment is very good. Moreover, most riffle sites had an OE score around or above 1.0 indicating more families were collected than predicted. Sites that are richer than reference can potentially be affected by mild nutrient enrichment, however this appears to be unlikely in this catchment as Band A and X sites are scattered across the entire catchment rather than a concentration of Band X sites at one locality. It is more likely this scatter reflects the catchment is in very good ecological health.

3.2.1 The Inglis River

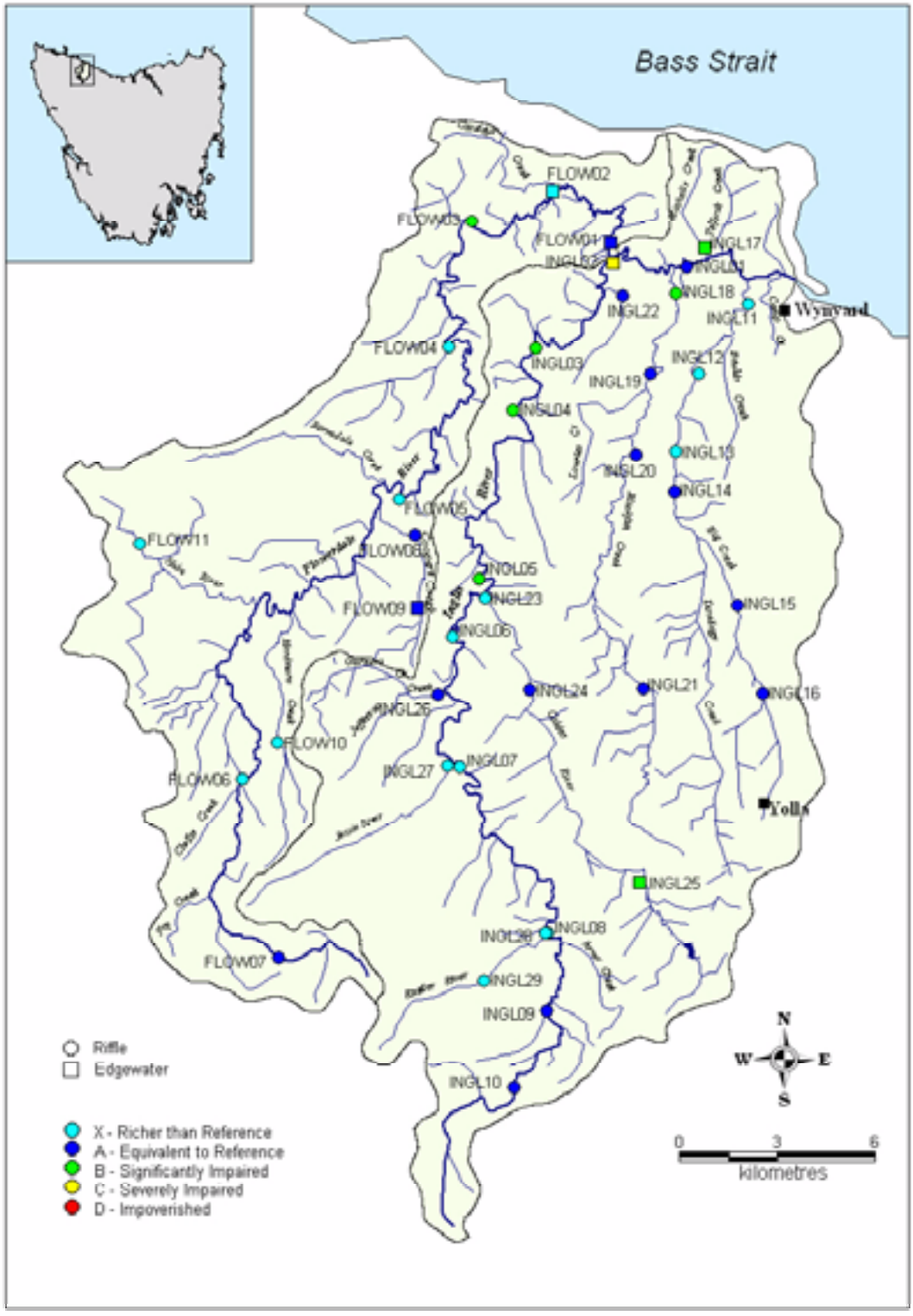
Four sites of ten on the main channel of the Inglis River were considered impaired. Three sites in the middle reach were placed in Band B and considered significantly impaired; these were INGL05 at Zig-Zag Road, INGL04 at the end of the road through gravel pits, and INGL03 at Pages Road. The bottom-most site before the confluence of the Flowerdale River was INGL02 at the railway bridge on Emerald Vale Road, and this site was the most impaired of the entire catchment, falling in Band C (severely impaired).

Table 4 Summary of AusRivAS outputs (OE scores, OESIGNAL scores and Band) for the riffle and edgewater sites sampled in the Inglis-Flowerdale.

Habitat	Site	Name	OE50	OE50 Signal	Band
Edgewater	FLOW01	Flowerdale R @ Preolenna Rd	1	0.94	A
	FLOW02	Flowerdale R @ railway 1.2km south of Boat Harbour	1.22	0.99	X
	FLOW09	Coopers Ck @ ford (off Preolenna Rd)	1.05	0.94	A
	INGL02	Inglis R @ Emerald Vale Rd @ railway bridge	0.24	0.44	C
	INGL17	Mitchells Ck @ Bass H'way	0.56	0.73	B
	INGL25	Calder R @ Takone Rd	0.73	0.84	B
Riffle	FLOW03	Flowerdale R @ old SG stn @ Moorleah	0.85	0.9	B
	FLOW04	Flowerdale R @ Lapoinya Rd	1.34	0.99	X
	FLOW05	Flowerdale R @ Flying Fox off Ten foot track	1.19	0.95	X
	FLOW06	Flowerdale R @ Meunna Rd	1.23	1	X
	FLOW07	Flowerdale R @ West Takone Plantation	1.05	0.98	A
	FLOW08	Coopers Ck @ Ten Foot Track	1	0.92	A
	FLOW10	Hardmans Ck @ Preolenna Rd	1.15	0.95	X
	FLOW11	Hebe R @ Myalla Rd	1.3	1	X
	INGL01	Inglis R @ Rd off Stennings Rd u/s Pumphouse	0.98	0.93	A
	INGL03	Inglis @ Pages Rd	0.57	0.95	B
	INGL04	Inglis R @ end of Rd through gravel pits	0.8	0.91	B
	INGL05	Inglis R off Zig-Zag Rd	0.82	1.02	B
	INGL06	Inglis R @ picnic area Jefferson Rd	1.3	0.99	X
	INGL07	Inglis R @ Jessie Rd u/s Jessie R	1.17	0.98	X
	INGL08	Inglis R @ Takone Rd @ Takone	1.28	0.99	X
	INGL09	Inglis R @ Chouveaux Rd in plantation	0.98	0.91	A
	INGL10	Inglis R @ Viney Rd	1.01	0.96	A
	INGL11	Big Ck @ Wynyard	1.14	1	X
	INGL12	Big Ck @ Nursery Rd	1.23	0.98	X
	INGL13	Big Ck @ Tram Rd near picnic area	1.14	0.97	X
	INGL14	Big Ck @Tram Rd @ start Pine Plantation	1	0.94	A
	INGL15	Big Ck @ Cleveland Rd	1.11	1.04	A
	INGL16	Big Ck @ Smarts Rd	1.01	0.97	A
	INGL18	Blackfish Ck @ Stennings Rd	0.78	0.89	B
	INGL19	Blackfish Ck @ Blackfish Rd	0.93	0.92	A
	INGL20	Blackfish Ck @ end of Blackfish Rd	1.08	0.96	A
	INGL21	Blackfish Ck @ Lowries Rd	1.12	0.98	A
	INGL22	Un-named trib @ end of Ballast Pit Rd	0.89	1.01	A
	INGL23	Calder R u/s confluence @ Zig Zag Rd	1.14	0.96	X
	INGL24	Calder R @ end of Bassets Rd	1.07	1.01	A
	INGL26	Jefferson Ck off Jefferson Rd	1.09	0.97	A
	INGL27	Jessie R u/s confluence	1.22	0.99	X
	INGL28	Rattler R @ Takone	1.15	0.97	X
	INGL29	Rattler R @ Takone Rd	1.28	0.99	X

At each of these sites, fewer families were collected than that predicted by the AusRivAS models. However, OESIGNAL scores at each of these sites were all between 0.9 and 1.0 (Table 4), which suggests that the families missing from these sites were not particularly sensitive to pollution and that factors other than water quality were contributing to the impairment observed. The most likely factor causing impairment to the riffle communities at these sites is habitat degradation, which is exhibited as extensive sediment deposition that has smothered and greatly reduced instream habitat diversity. Heavy sediment deposition eliminates the interstitial spaces between rocks and stones on the streambed utilised by many macroinvertebrates and fish species, and also directly affects instream fauna by impeding filter-feeding behaviour and smothering gills (Wood and Armitage, 1999).

Figure 2 AusRivAS heath ratings for sites sampled on the Inglis-Flowerdale catchment in Autumn 1999.



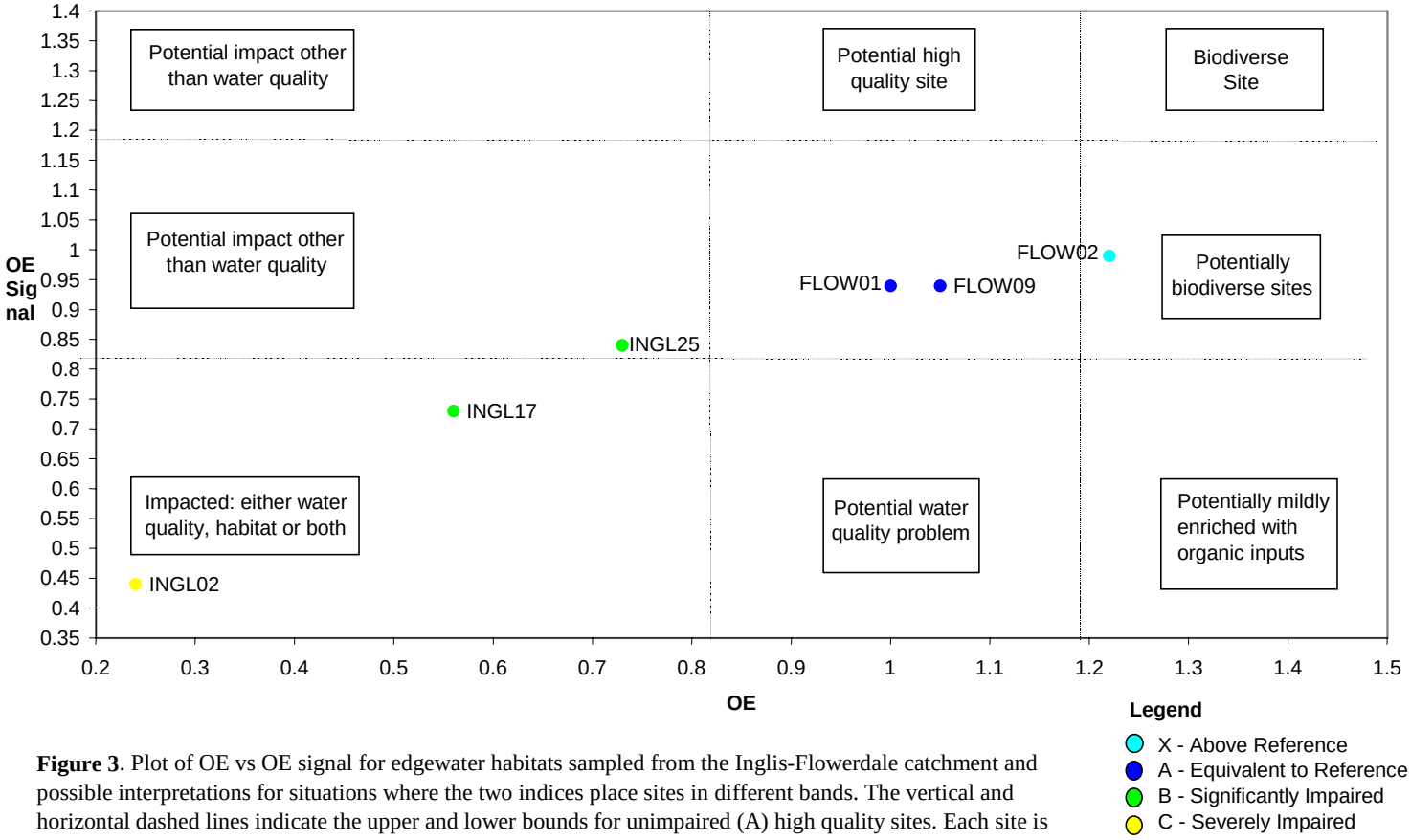


Figure 3. Plot of OE vs OE signal for edgewater habitats sampled from the Inglis-Flowerdale catchment and possible interpretations for situations where the two indices place sites in different bands. The vertical and horizontal dashed lines indicate the upper and lower bounds for unimpaired (A) high quality sites. Each site is labelled with a letter denoting the river and the site number.

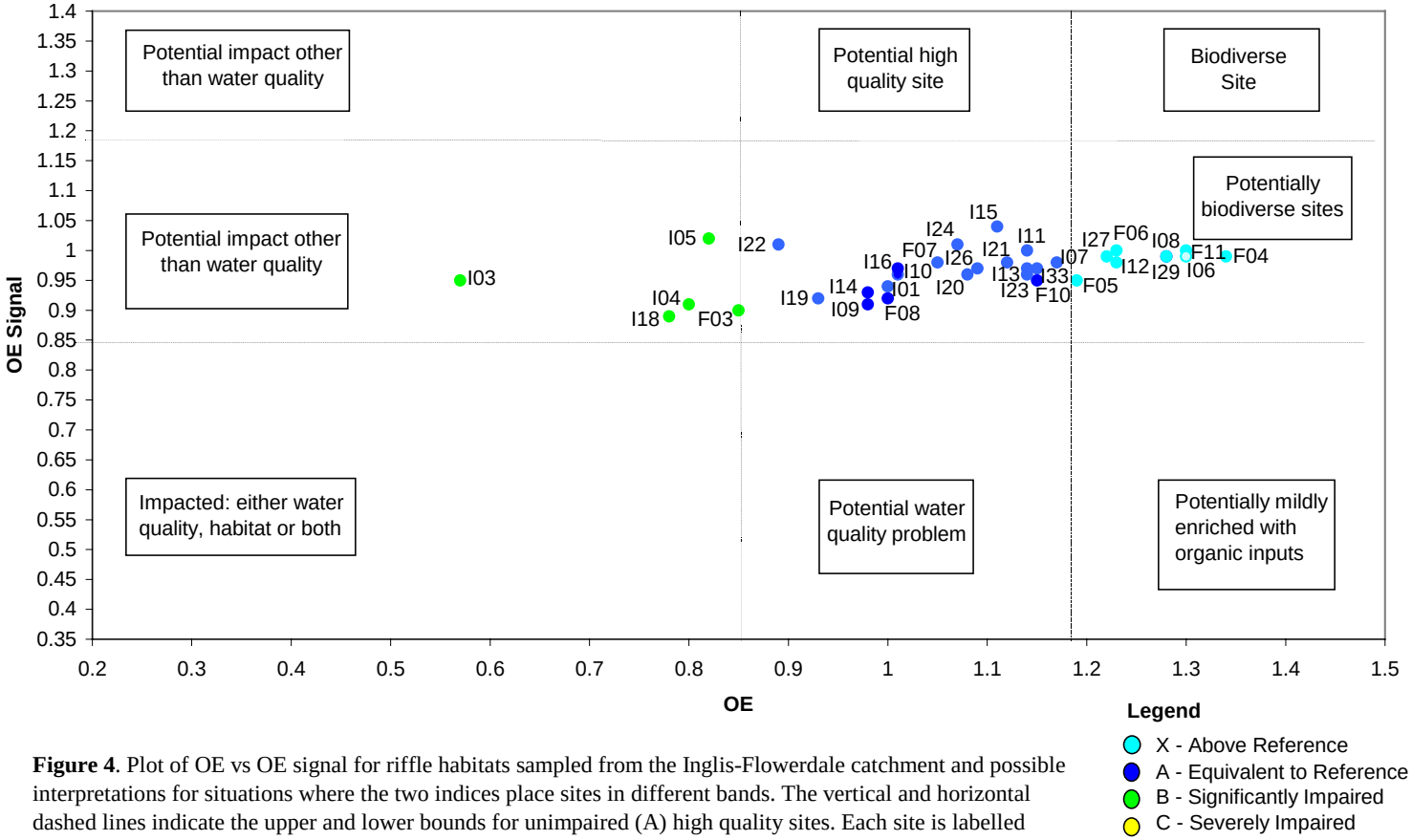


Figure 4. Plot of OE vs OE signal for riffle habitats sampled from the Inglis-Flowerdale catchment and possible interpretations for situations where the two indices place sites in different bands. The vertical and horizontal dashed lines indicate the upper and lower bounds for unimpaired (A) high quality sites. Each site is labelled with a letter denoting the river and the site number.

Above these sites, and throughout the area drained by the middle and upper part of the catchment, the major land use is forestry, particularly plantation forestry. Forestry operations are known to increase the sediment loads to creeks and rivers through the removal of vegetation and the construction of roads (Boulton and Brock, 1999; Davies and Nelson, 1994). Furthermore, there are numerous gravel pits located throughout the middle Inglis River ware likely to have contributed significant sediment loads to the main river. The delivery of sediment from both these sources is greatly assisted during high rainfall events by road drainage conduits. Water sampling conducted during parallel studies clearly showed this.

The lower site (INGL02) is severely impaired, falling into Band C, and the community at this site has only 4 taxa; 83% of the macroinvertebrates are Chironominae (midges) which are tolerant of poor quality conditions. Although this site was an edgewater habitat, which is expected to have a less diverse fauna than riffle habitats, it was still severely impaired. A low OE ratio combined with a low OESIGNAL potentially indicates both the water quality and the habitat quality are negatively impacted. This lower site (just above the confluence of the Flowerdale River) receives the accumulated impact of forestry operations and gravel-pit discharge from the middle and upper reaches, and has also been heavily modified by local willow-removal operations and stock access. These local impacts decrease bank stability and increase bank erosion, thereby further increasing sediment inputs at this site and the subsequent impairment of the macroinvertebrate community. Given that edgewater habitats are natural deposition zones in a river, this may further explain the severity of impairment at this site because the sediments are more likely to settle out in these habitats than be flushed out of the system.

Interestingly, the lowest site on the main channel if the Inglis River, INGL01 at the road off Stennings Road, falls in Band A indicating the riffle community here is similar to the reference community and is relatively unimpaired. This site is below the confluence of the Flowerdale River and it is possible the input of this additional discharge (which is also of reasonably good quality), is enough to contribute to flushing the sediments from this reach of the river.

3.2.2 Tributaries of the Inglis River

There were three sites on tributaries of the Inglis River (not including the Flowerdale tributary system) which were significantly impaired, falling in Band B. Mitchells Creek at Bass Highway (INGL17) drains a coastal area to the north which has well-drained, fertile, basalt soils good for agriculture. The land has been cleared for grazing and dairy farming and this, combined with a relatively steep topography of rolling hills, has lead to significant erosion and soil slumping. This has potentially led to sedimentation and the loss of habitat quality in this tributary. An OESIGNAL of 0.73 also suggests that the water quality is poor and has negatively affected more sensitive taxa so they do not appear in the community. While there is no detailed water quality data available for this creek, the use of fertiliser and input of dairy effluent are potential mechanisms that may be contributing to nutrient enrichment of this tributary.

The lowest site on Blackfish Creek at Stennings Road (INGL18) was also severely impaired, falling into Band B. The community at this site had an OESIGNAL of 0.89, and an OE ratio of 0.78, which suggests an impact on both water and habitat quality. This site has been highly modified for grazing: there is significant bank erosion caused by stock access and the little riparian vegetation present is comprised of willows and blackberries. As with the other impaired sites, impact is potentially due to increased sedimentation and nutrient run-off associated with the local land use. The other three sites on this tributary were placed in Band A and considered similar to reference sites.

The last significantly impaired site in the Inglis River catchment was in the uppermost reaches of the Calder River at Takone Road, and with relatively low OE and OESIGNAL scores was potentially impacted by poor water and habitat quality. This site lies within a heavily cleared and grazed part of the upper catchment where, given the steeper topography, sediment run-off due to clearing is potentially a significant impact. Furthermore, the river itself is heavily modified, having undergone channelisation operations in the past, and has therefore had significant amounts of instream habitat provided by large woody debris removed. There is a large on-stream dam approximately 3 km upstream which appears to have significantly altered the flow regime, eliminating flushing flows and creating a slow-flowing system. The water quality (contained in a separate part of this report) shows that dissolved oxygen can drop to very low levels at this site, due to reduced flows, a lack of riparian vegetation and stock access creating an anoxic environment over summer.

3.2.3 The Flowerdale River

Only one of the seven sites in the Flowerdale system was considered to be impaired, the rest fell into Band A or X. The site on the main channel at the old stream gauging station (FLOW03) fell into Band B and was therefore considered significantly impaired. While there has been some clearing in the local catchment for grazing, it does not appear to be heavily modified or suffering from obvious local land-use impacts. However, the topography is locally steep and deeply incised, suggesting the natural drainage of these poor soils may be contributing to poor water quality or slight siltation of instream habitat. The lower OE score at this site suggests an impact of habitat degradation rather than water quality.

4. Discussion

Overall, the Inglis-Flowerdale catchment appears to be relatively good ecological health; only a few sites are impaired. On the main channel of the Inglis River the impaired sites appear to be due to the accumulated sedimentation from forestry operations and gravel pits, and on the lower site and the tributaries, the impacts appear to be due to local agricultural and modified habitat impacts. Most sites are relatively unimpaired, and as these sites occur throughout the catchment, indicate a generally healthy catchment in terms of ecological health. However, it is important to remember that this is a snapshot assessment conducted in 1999, and the continuation of current catchment activities since this time may potentially decrease river health in the Inglis-Flowerdale catchment.

Using macroinvertebrates as indicators of river health can provide more information about a freshwater system than using water quality alone. Water quality impacts do not necessarily transfer to equivalent impacts on faunal communities, and similarly, faunal communities can respond to impacts other than those affecting water quality. For example, the water quality section of this State of Rivers report showed the Hebe River (a tributary of the upper Flowerdale River) to be high in aluminium and periodically quite acidic, however this did not appear to have any significantly negative effects on the macroinvertebrate community in this stream. Conversely, the upper site on the Calder River had a significantly impaired macroinvertebrate community, but this was not reflected in water quality. The community was therefore more likely to have been affected by the habitat loss caused by channelisation and an altered flow regime from an on-stream dam.

The major impact on river health in this catchment identified by macroinvertebrate assessment is essentially a sedimentation impact, and is supported by the water quality analyses from this report. Sediment loads have increased in the system from a combination of

land use practices: forestry operation, gravel roads and gravel-pits throughout the middle Inglis catchment, and land clearing, riparian vegetation removal and modification and stock access in the lower catchment. Sediment loads affect water quality by increasing turbidity, and also alter habitat quality (by covering substrates and eliminating some habitat resources) for both macroinvertebrates and fish (Boulton and Brock, 1999).

In order to reduce the effects of sedimentation in the Inglis-Flowerdale system, certain improvements in river management practices are recommended. In the lower reaches, the river should be fenced off to prevent stock access, and therefore bank erosion and sedimentation. Willow removal operations should be carefully planned to minimise the amount of sediment disturbance, and re-planting of the banks with more suitable vegetation should occur as soon as possible. In the upper and middle reaches where there are forestry operations, it is crucial to preserve and maintain adequate buffers of riparian vegetation which are able to catch sediment run-off, improve infiltration and help stabilise soils, thereby minimising forestry impacts. These measures will lead to significant local improvements at specific sites, and thereby contribute to the sustainability of an overall healthy river system.

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Appendix 1: List of Taxa Sampled From AusRivAS Sites

Appendix 2: Predictor Variables used in the AusRivAS Models

Site Code	Site Name	Elevation	Catchment Area	Cobble Score	Conductivity	Distance from Source	Northing	Easting	Riffle Area	Stream Class
FLOW03	Flowerdale R @ old SG stn @ Moorleah	30	140.5	3	105.6	49.5	5464000	382700	50	4
FLOW04	Flowerdale R @ Lapoinya Rd	70	124.6	3	97	43	5460100	382050	0	4
FLOW05	Flowerdale R @ Flying Fox off Ten foot track	90	107.9	3	111.8	32.75	5455400	380600	20	4
FLOW06	Flowerdale R @ Meunna Rd	230	25.4	2	66.2	12	5446700	375900	45	3
FLOW07	Flowerdale R @ West Takone Plantation	450	5	5	73	4	5441200	377100	40	2
FLOW08	Coopers Ck @ Ten Foot Track	130	5.3	3	97	4.5	5454300	381100	10	2
FLOW10	Hardmans Ck @ Preolenna Rd	300	4.4	3	83.2	2.75	5447850	376950	55	2
FLOW11	Hebe R @ Myalla Rd	220	3.2	4	78	3	5453900	372600	40	2
INGL01	Inglis R @ Rd off Stennings Rd u/s Pumphouse	10	396.4	0	115.1	58.35	5462700	389350	15	5
INGL03	Inglis @ Pages Rd	30	162.3	3	94.9	47.35	5460100	384750	10	4
INGL04	Inglis R @ end of Rd through gravel pits	30	157.2	3	92.2	44.25	5458200	384050	80	4
INGL05	Inglis R off Zig-Zag Rd	60	139.8	3	91.6	33.5	5453000	383100	60	4
INGL06	Inglis R @ picnic area Jefferson Rd	70	100.8	3	85.9	30.75	5451200	382300	15	4
INGL07	Inglis R @ Jessie Rd u/s Jessie R	100	52.7	3	80.2	23	5447200	382600	35	4
INGL08	Inglis R @ Takone Rd @ Takone	290	14.5	4	75.3	13.35	5442100	385400	0	3
INGL09	Inglis R @ Chouveaux Rd in plantation	300	14.7	1	74.6	10.25	5439700	385400	60	3
INGL10	Inglis R @ Viney Rd	430	9.9	3	66.5	6.5	5437300	384900	10	3
INGL11	Big Ck @ Wynyard	10	51	3	107.7	23	5461600	391300	30	3
INGL12	Big Ck @ Nursery Rd	30	43.6	4	104.6	18.75	5459400	389800	30	3
INGL13	Big Ck @ Tram Rd near picnic area	40	39.6	3	103.4	14.75	5457000	389100	20	3
INGL14	Big Ck @Tram Rd @ start Pine Plantation	50	36.7	3	101.2	13.25	5455800	389100	15	2
INGL15	Big Ck @ Cleveland Rd	90	10.3	3	112	8.25	5452300	391100	15	2
INGL16	Big Ck @ Smarts Rd	160	4.1	4	116.5	4.5	5449600	391900	40	1
INGL18	Blackfish Ck @ Stennings Rd	10	43	0	115.6	18	5461900	389050	5	2
INGL19	Blackfish Ck @ Blackfish Rd	30	36.7	1	112.7	14.5	5459400	388300	20	2
INGL20	Blackfish Ck @ end of Blackfish Rd	50	28.2	1	109.4	11.25	5456900	387900	10	2
INGL21	Blackfish Ck @ Lowries Rd	200	7.6	4	99.3	7	5449700	388200	50	2
INGL22	Un-named trib @ end of Ballast Pit Rd	30	2.8	1	158.8	5.25	5461800	387400	10	1
INGL23	Calder R u/s confluence @ Zig Zag Rd	60	39.4	4	97.6	17.5	5452400	383300	35	2
INGL24	Calder R @ end of Bassets Rd	90	31	4	93.7	13.25	5449600	384700	35	2

Site Code	Site Name	Elevation	Catchment Area	Cobble Score	Conductivity	Distance from Source	Northing	Easting	Riffle Area	Stream Class
INGL26	Jefferson Ck off Jefferson Rd	80	13.7	1	98.2	5.9	5449400	381900	35	3
INGL27	Jessie R u/s confluence	100	23.4	3	94.4	17.25	5447200	382200	50	3
INGL28	Rattler R @ Takone	290	13.6	4	76.9	7.75	5442100	385300	40	3
INGL29	Rattler R @ Takone Rd	340	7.2	4	73.2	4.75	5440600	383450	55	2

Predictor variables used in the Tasmanian Autumn Riffle AusRivAS model.

Site Code	Site Name	Boulder Score	Conductivity	Mean Depth (cm)	Northing	Easting
FLOW01	Flowerdale R @ Preolenna Rd	0	113.3	20	5463400	387000
FLOW02	Flowerdale R @ railway 1.2km south of Boat Harbour	0	108.5	20	5465000	385200
FLOW09	Coopers Ck @ ford (off Preolenna Rd)	0	90.5	20	5452050	381200
INGL02	Inglis R @ Emerald Vale Rd @ railway bridge	0	103.5	40	5462800	387100
INGL17	Mitchells Ck @ Bass H'way	0	259	25	5463300	389900
INGL25	Calder R @ Takone Rd	0	85.7	15	5443700	388200

Predictor variables used in the Tasmanian Autumn Edgewater AusRivAS model.