LANDSCAPE LOGIC
LINKING LAND AND WATER MANAGEMENT TO RESOURCE CONDITION TARGETS

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The Tasmanian River Condition Bayesian Network

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LANDSCAPE LOGIC is a research hub under the Commonwealth Environmental Research Facilities scheme, managed by the Department of Sustainability, Environment, Water, Population and Communities.

It is a partnership between:

- **six regional organisations** – the North Central, North East & Goulburn–Broken Catchment Management Authorities in Victoria and the North, South and Cradle Coast Natural Resource Management organisations in Tasmania;
- **five research institutions** – University of Tasmania, Australian National University, RMIT University, Charles Sturt University and CSIRO; and
- **state land management agencies in Tasmania and Victoria** – the Tasmanian Department of Primary Industries & Water, Forestry Tasmania and the Victorian Department of Sustainability & Environment.

The purpose of Landscape Logic is to work in partnership with regional natural resource managers to develop decision-making approaches that improve the effectiveness of environmental management.

Landscape Logic aims to:

1. Develop better ways to organise existing knowledge and assumptions about links between land and water management and environmental outcomes.
2. Improve our understanding of the links between land management and environmental outcomes through historical studies of private and public investment into water quality and native vegetation condition.

The Tasmanian River Condition Bayesian Network

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Summary

Welcome to the Tasmanian River Condition Bayesian Network (BN) user manual. The River BN has been designed to allow the user to model the consequences of different environmental management scenarios (e.g. changes in land-use and/or riparian vegetation condition) for changes in the ecological condition of Tasmanian rivers at a chosen river location (reach, section or site).

It's focus is on exploring various mixtures of land use at catchment scale, of condition of riparian vegetation at catchment and reach scales, in combination with intensity of water use, sediment erosion and nutrient loss to streams.

It is not a strictly numerical model, but rather one that captures the dominant relationships between the key 'drivers' of change in catchments to the 'symptoms' of river 'health'. Various combinations of inputs can be explored and the user may choose to focus on individual stream ecological responses, or the composite 'condition score' which has been designed to simulate changes in the Tasmanian River Condition Index (NRM South 2009 a, b).

We have used locally and regionally relevant data and observations wherever possible to define the relationships in this network, so that it reflects 'real world' changes in the various responses, not just conceptual ones. Considerable effort has been made to develop the network using the best, regionally relevant and inferentially strongest evidence available.

This network cannot model effects of large dams, climate change, other intense local impacts like mining, urban or wastewater discharge. Nor does it cover all catchments in Tasmania. Nor does it model sequences of change through time – rather it represents a time-averaged response over several months to a year. Active development of this network is being pursued to allow some of these issues to be addressed.

The network can be used generically i.e. to evaluate various management options in a catchment with certain characteristics. It can also be used to evaluate specific Tasmanian catchments, for which the default current data inputs are provided as a starting point for evaluation.

The network has been specifically designed to provide natural resource managers with a tool to explore the likely magnitude and direction of river condition to a variety of changes that may be driven by planning (e.g. land and water use at catchment scale), large scale investment (riparian rehabilitation across a catchment), or small scale investment (restoring riparian forest in a single river reach). We encourage the exploration of multiple scenarios involving a number of such interventions simultaneously, and to contact the developers of this BN (Dr Regina Magierowski and Prof Peter Davies) with any queries.

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1. Overview

1.1 Model Structure

The basic architecture (Figure 1) of the model has been developed from the analysis of a number of Tasmanian datasets (see Section 2). The user must enter information for a number of input nodes that describe; 1) the region of interest; 2) catchment-scale information on land-use, soil type, riparian condition and the density of unsealed roads and 3) local-scale information on river slope, riparian condition and fluvial geomorphology. We have provided look-up tables containing catchment and sub-catchment level data extracted from a number of data sources to assist the user. However, data collected by the user can be substituted for this. In fact for the local-scale nodes data collected at the exact site of interest is likely to better than data extracted from our look-up tables which contain data averaged across river-sections within each (sub-) catchment.

The River BN integrates this multi-scaled input data to predict river ecological condition at the local scale (macroinvertebrate and algal condition). The main pathways for influencing river ecological condition are through changes to sediment, nutrients and light levels (Figure 2), although stream temperature and dissolved oxygen concentration can also be important.

The output from the River BN consists of a probability distribution for each node in the network under a particular set of input conditions (a scenario). Each distribution shows the probability of each state occurring in a node. The main output nodes are the Tasmanian River Condition Indices (TRCI) for macroinvertebrate and algae and the overall river condition score, TRCI: Aquatic Life (NRM South 2009a).

1.2 Model Applicability: Geographical

A full list of Tasmanian catchments and sub-catchments (as defined by the Tasmanian Conservation of Freshwater Ecosystems [CFEV] database [DPIW, 2005]) that can be modelled with the BN is listed in Table 1. A full list of Tasmanian catchments (Figure 3a) and sub-catchments (Figure 3b) that should not be modelled with the River BN are provided in Appendix 1.[1]

The model is applicable to Tasmanian streams of Order 3[2] or above (1:25,000 scale) in catchments (and sub-catchments) located outside of the World Heritage Area and King Island and that are ***not*** dominated by granitic geology. If more than 20% of the area of a sub-catchment was identified as urban or mining the sub-catchment was also excluded from the River BN.

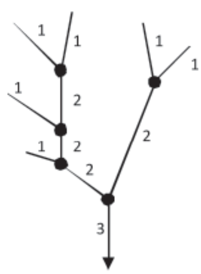
Given the constraints above, the River BN can be used for modelling scenarios for a wide range of catchment and sub-catchment contexts. Specific Tasmanian catchments and sub-catchments for which this BN is directly applicable are shown in Figure 3.

Catchments/sub-catchments with granite geologies have been excluded because the ecology and geomorphology of these river systems is too different from much of the data used to calibrate the River BN. This is largely due to the predominance of naturally occurring fine sediments in these systems. There are a few sub-catchments that are dominated by fine sediments from other geological types (e.g. coastal sand and gravel, dispersive clays and sand gravel and mud of alluvial, lacustrine and littoral origin), particularly the Duck, Montague and Welcome catchments. These can be modelled using the BN although the model outputs will be slightly less reliable for these than other catchments/sub-catchments.

1.3 Model Applicability: Scenarios

The River BN can be used to run a range of scenarios to evaluate a range of management options on river ecosystem health (as measured by changes in benthic macroinvertebrate and algae) of the most downstream reach in the catchment/sub-catchment. This is done by entering values for:

- % area of each land use in the catchment;
- the condition of riparian forest, at catchment and local river reach scales;
- % area of the catchment occupied by unsealed road surfaces.



1 The River BN may be used for excluded catchments/sub-catchments and for other catchments outside of Tasmania at the user's risk. We have not provided input data for catchments outside of Tasmania.

2 Stream order describes the relative position of stream segments in a catchment stream network. In the Strahler stream order system, all unbranched streams are classes as 1st order stream. When two 1st order streams meet, the stream segment below their confluence is a 2nd order stream. Likewise when two 2nd order streams meet, the stream segment below their confluence is a 3rd order stream (see left).

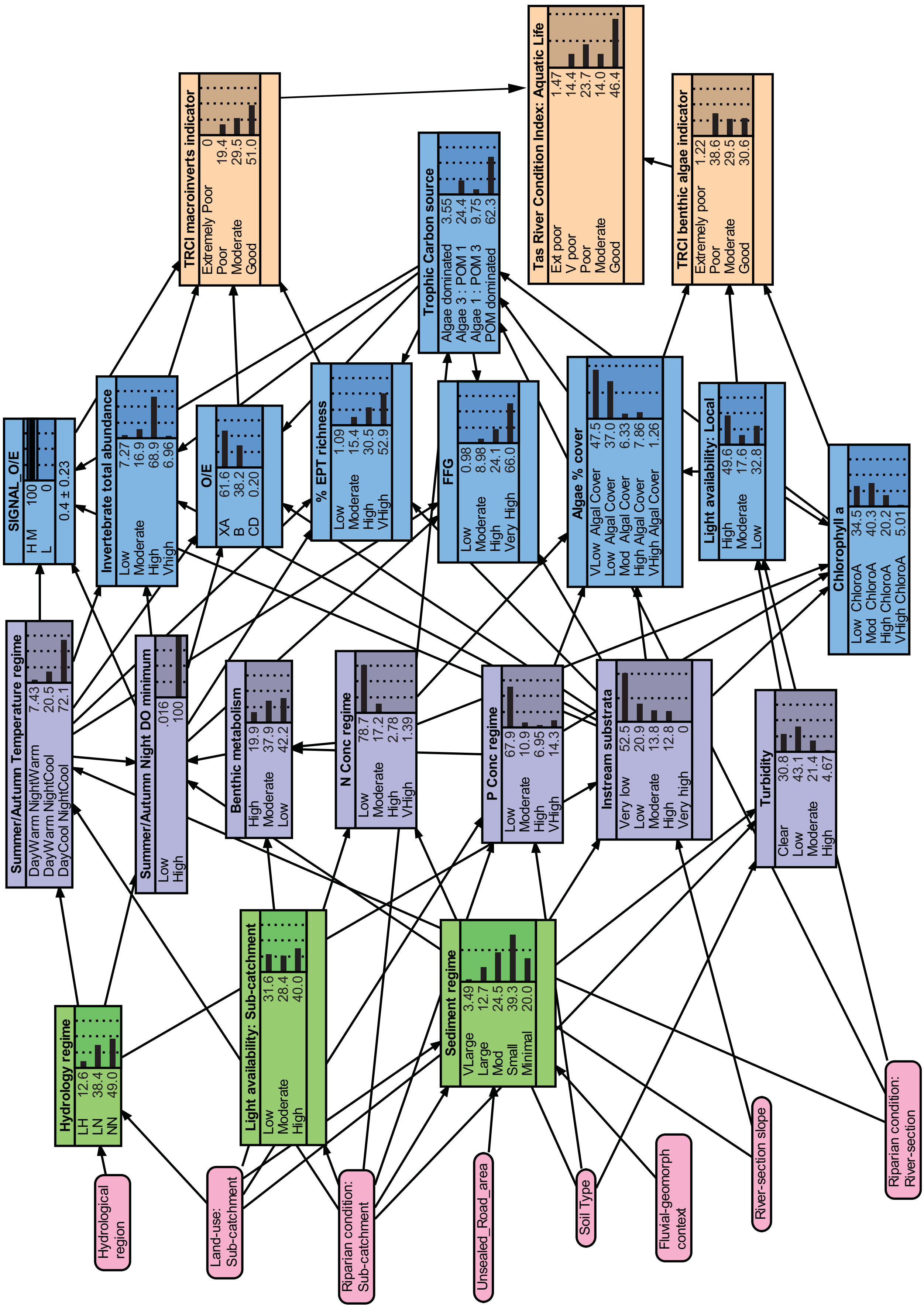


Figure 1. The Tasmanian River Condition BN basic architecture. Pink nodes represent nodes that must be set by the user and orange nodes show TRCI indices of river condition (NRM South 2009a), all other colours represent the spatial scale of the variable modelled by each node (green = landscape, purple= river, blue=site).

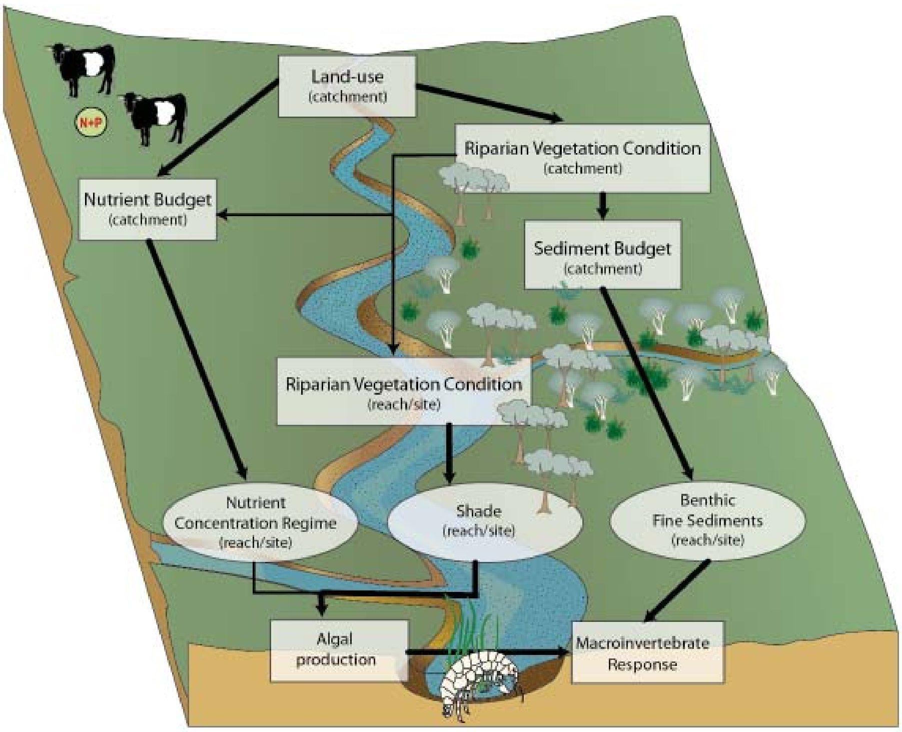


Figure 2. A conceptual model illustrating how land-use can influence algae and macroinvertebrate condition. The main pathways are via changes in sediment and nutrient budgets (catchment scale) and light (reach/ site scale). While high nutrient levels are a direct result of grazing, changes in sediments and light levels are primarily driven by changes in riparian vegetation condition. Arrow thickness is used here to show the relative strength of interactions.

In addition to these substantive scenarios, the following nodes can be used to evaluate the catchment scale effects of on-farm management:

- Sediment regime – representing change in the fine sediment load to streams from gully and sheet (land surface) erosion;
- Nitrogen and phosphorus concentration regime – altering these represents changing the loss of nitrogen and phosphorus from land surfaces to streams (and by inference on-farm nutrient management);
- Hydrology regime – representing the gross changes to flow regimes as affected by changes in on-farm water use.

The scenarios resulting from these manipulations include evaluating the effects of:

- Varying areas of grazing land with current management practice (i.e. with poor condition riparian zones at catchment and/or reach scales).
- Varying riparian vegetation condition for the entire catchment and/or the local river reach for catchments with fixed % areas under grazing and forestry.
- Nutrients and/or sediment control for catchments with fixed % areas under grazing.
- Nutrients and/or sediment control and river reach light control (by varying riparian forest condition) for catchments with fixed % areas under grazing.

A range of catchment and local reach contexts can be fixed for all the above scenarios:

- Catchment: hydrological region and dominant soil type.
- River reach: the slope and geomorphological responsiveness of the local stream channel.

Table 1. Nodes in the River BN.

Name	Type1	Description
Hydrological region	Discrete	Differentiation of the state of Tasmanian into 4 main natural river hydrological regions based on Hughes (1987).
Land-use: sub-catchment	Discrete	The proportion of each type of land-use in the catchment upstream of the river reach (section) of interest
Riparian vegetation condition: sub-catchment	Continuous	Riparian condition is based on the proportion of native vegetation occurring within the river riparian zone in a catchment.
Unsealed Roads	Discrete	Category representing the density of unsealed roads in the upstream (sub-) catchment.
Soil type	Discrete	The dominant soil group within the catchment upstream of the river reach (section) of interest. Note that there is little information available with which to develop relationships between soil groups and nutrient or turbidity regimes. As such this node, whilst included in the BN, does not influence the output data. This is a key information gap in the BN which should be updated when more data are available
Fluvial geomorphological context	Continuous	This variable represents the susceptibility of the channel of the river reach (section) of interest to anthropogenic changes in the flow and sediment regime.
River-section slope	Continuous	Gradient of the river-section of interest (rise/run).
Riparian vegetation condition: local	Continuous	This node reflects the riparian vegetation condition at the local scale, i.e. within the river reach (section) of interest (as % shading or the amount of native vegetation cover).
Hydrological regime	Discrete	The hydrological regime characterises anthropogenic changes in river flow caused by river abstraction associated with various land uses in the river reach (section) of interest.
Light availability: sub-catchment	Continuous	The percentage level of shading in the catchment stream network upstream of the river reach (section) of interest, used to reflect light availability to the catchment streams
Sediment regime	Continuous	Node with states that describe the relative magnitude of fine sediment input into the river reach (section) of interest
Summer/Autumn temperature regime	Discrete	This node describes the combination of night and day time maximum temperatures in the river reach (section) of interest
Summer/Autumn night DO minimum	Discrete	Dissolved Oxygen (DO) concentration ranges in the river reach (section) of interest.
Benthic metabolism	Discretised	Relative levels of gross primary productivity (P, $gO_2/m^2/day$) within the river reach (section) of interest.
Phosphorus concentration regime	Discretised	Ranges of total phosphorus concentration (mg/L) in the river reach (section) of interest.
Nitrogen concentration regime	Discretised	Ranges of total nitrogen concentration (mg/L) in the river reach (section) of interest
Instream substratum	Continuous	This variable represents the varying proportion of fines sediments (silt and sand) in the bed-load.
Turbidity	Discretised	Ranges of turbidity in the river reach (section) of interest
SIGNAL O/E	Continuous	This node represents ranges of the macroinvertebrate sensitivity grading index, SIGNAL2 score (Chessman 2003) used to rate anthropogenic impacts on aquatic macroinvertebrate communities. SIGNAL O/E (DPIW 2009) is the ratio of the SIGNAL2 score observed at a site (O) to that expected under reference or un-impacted conditions (E).
Invertebrate total abundance	Discretised	Ranges of total abundance of invertebrates (recorded per metre squared)
O/E	Continuous	Ranges (or Bands) of the AUSRIVAS O/E condition score (Krasnicki et al. 2001) used to rate anthropogenic impacts on aquatic macroinvertebrate communities
%EPT richness	Continuous	The proportion of the total macroinvertebrate familial richness represented by the disturbance sensitive aquatic insect orders Ephemeroptera, Plecoptera and Trichoptera (NRM South 2009a); mayflies, stoneflies and caddisflies respectively.
FFG	Continuous	The FFG (functional feeding groups) node represents the ratio of macroinvertebrate abundance represented by shredders to that of collectors and scrapers.

Name	Type1	Description
Trophic carbon sources	Discrete	This node identifies the dominant carbon source (from primary production) of the instream food-web.
Algae % cover	Continuous	Ranges of % area cover of the stream bed by benthic algae.
Light availability: local	Continuous	Local light availability represents the amount of shading from riparian vegetation in the river reach (section) of interest.
Chlorophyll a	Continuous	Ranges of benthic algal chlorophyll a (mg/m^2). Chlorophyll a is the molecule present in all plants and algae which makes photosynthesis possible. Chlorophyll a concentrations are used here as a surrogate measure of benthic algal biomass.
TRCI Macroinvertebrates indicator	Continuous	Ranges (bands) of scores of the Tasmanian River Condition Index (TRCI) Aquatic Life Macroinvertebrates indicator. This integrates the scores for SIGNAL O/E, total macroinvertebrate abundance, AUSRIVAS O/E and %EPT, based on the relevant TRCI rule set.
TRCI: Aquatic life	Continuous	Ranges (bands) of scores of the Tasmanian River Condition Index (TRCI) Aquatic Life Index. This integrates the scores of the TRCI Macroinvertebrate and benthic algal indicators, based on the relevant TRCI rule set.
TRCI Benthic algae indicator	Continuous	Ranges (bands) of scores of the Tasmanian River Condition Index (TRCI) Aquatic Life Benthic Algal indicator. This integrates the scores for algae % cover, chlorophyll a (algal biomass) and light availability, based on the relevant TRCI rule set..

1 All nodes in the River BN are either discrete categories ("discrete"), discretised versions of continuous variables ("discretised") or continuous ("continuous").

Figure 3. Tasmanian catchments that can (white) or cannot (grey) be modelled using the River BN.

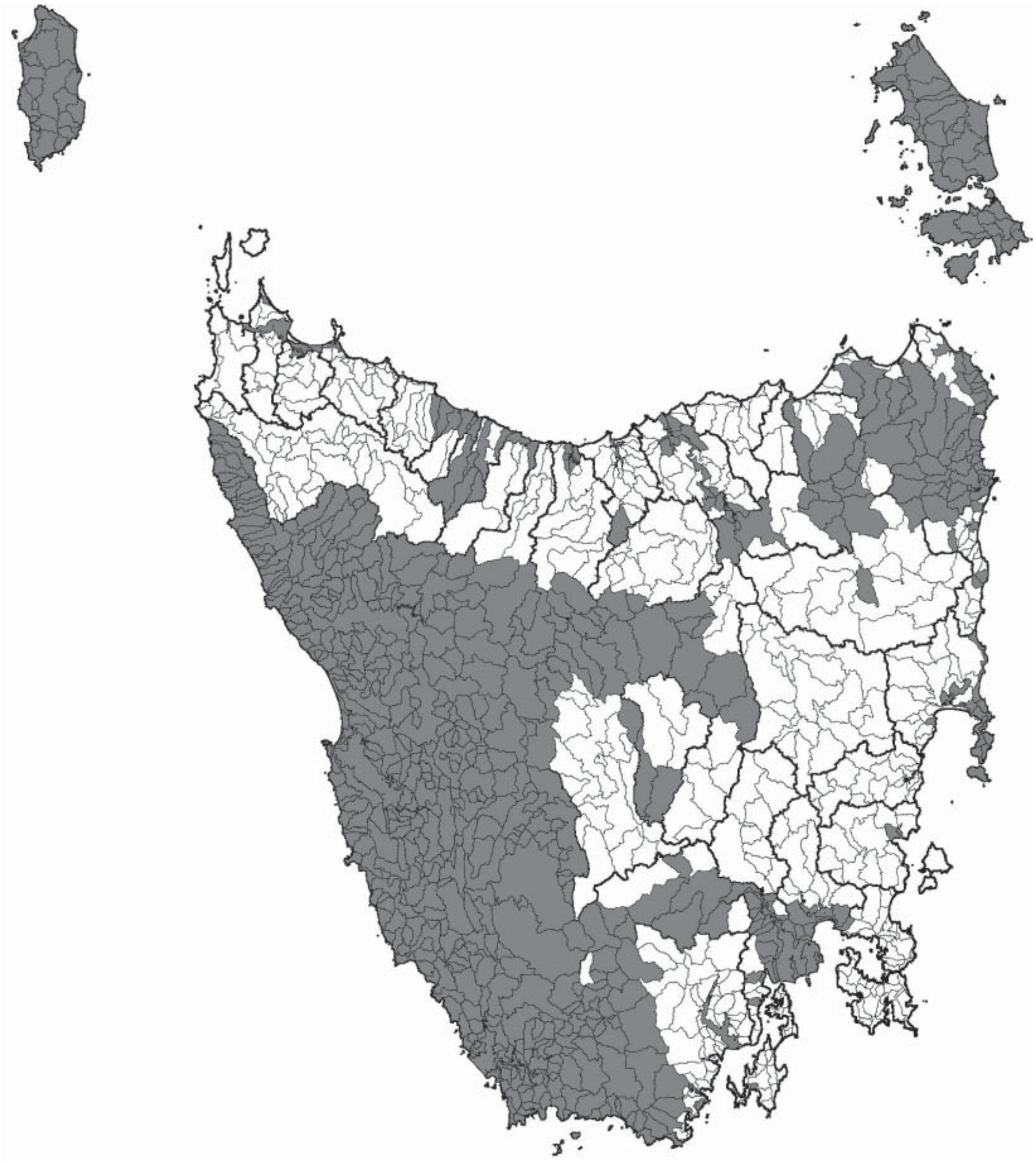


Figure 4. Tasmanian sub-catchments (b) that can (white) or cannot (grey) be modelled using the River BN.

2. Data sources

The following data sets were used to develop the relationships between variables in the River BN:

1. Gradient study examining changes in river ecological condition with land-use (primarily grazing by domestic livestock), conducted for Landscape Logic. (www.landscapelogicproducts.org.au)
2. Data on a range of river biophysical attributes sourced from the Tasmanian Conservation of Freshwater Ecosystem Values Project database, CFEV (DPIW 2005)
3. Paired sites river survey examining the influence of local riparian vegetation condition on river ecological condition, conducted for Landscape Logic (www.landscapelogicproducts.org.au)
4. Landscape Logic Tasmanian Land-use Layer (www.landscapelogicproducts.org.au)
5. AUSRIVAS (original data from the Tasmanian AUSRIVAS Database – Dept Primary Industries, Parks, Water and Environment, data analysis by Horrigan, Davies and Read)
6. Data on macroinvertebrate thermal tolerancesin used in Walsh et al. 2007 (C.J. Walsh, pers. comm.)
7. Tasmanian National River Health Project, Final Report (Krasnicki et al. 2002)
8. Land-use – nutrient load relationships and modelled nutrient data for Tasmanian river catchments supplied by Shane Broad et al., developed for Landscape Logic <www.landscapelogicproducts.ucts.org.au>
9. Gradient study examining changes in river ecological condition with variation in production forestry, conducted for the CRC for Forestry and the Tasmanian Forest Practices Authority (Davies, P.E. unpublished data).
10. Artificial stream experiments and associate neural networks used to examine the interacting effects of light, sediments and nutrients on river ecological condition (Davies, P.E. unpublished data)
11. Dataset used to examine relationships between riverine benthic algal biomass and cover and nutrient concentrations, conducted for the Tasmanian aquaculture industry (Davies 2010).
12. Data collected during development of the Tasmanian River Condition Index, especially the Aquatic Life component; and statistical relationships and rule sets developed from those data (NRM South 2009 a, b).

3. Model parameterisation

A Bayesian network or belief network is a probabilistic model that represents a set of random variables (nodes) and their conditional independencies (probabilities of the status of one node given the status of others) (**http://en.wikipedia.org/wiki/Bayesian_network**, June 2010). Bayesian networks can be used to link ecological outcomes with management activities and are particularly useful for this purpose because they are capable of integrating different types of information/data (Bromley et al. 2005, Davies 2007).

The first step in developing the River BN was to identify the important factors (network nodes) that may influence river ecological condition given changes in environmental management and to develop a conceptual framework to reflect the relationships between each factor (network arrows; Figure 1).The next step was to populate the BN (the relationships) with data. A range of evidence was obtained to structure and parameterise these relationships, with an emphasis on gathering local, regionally relevant data and evidence.

The same basic approach was used to generate/parameterise all conditional probabilities in the network:

1. Relationships (statistical and/or graphical) were built between the node of interest ('child node') and any node that is was dependent on ('parent nodes') using relevant data from the data sources listed above.
2. The frequency of occurrence was then used to generate probabilities of occurrence of each child state given the status of the parent nodes. The particular method used to build relationships varied depending on the nature of the source data. We used a combination of multiple and standard linear regression, multivariate analysis, and 2–3 dimensional plots in our analyses. Occasionally particular combinations of state nodes were not observed in any of the source data; in these circumstances extrapolation (based on expert opinion, published literature and/or related data sets) was used for parameterisation. Expert elicitation involved local stream ecologists and agricultural scientists with intensive knowledge of the problem area and geographic setting.

Specific details on how conditional probabilities were generated for each node in the network are provided below.

4. Model performance

Model performance was initially assessed through a sensitivity analysis conducted within the program Netica (www.norsys.com). The analysis results were consistent with our observations on the importance of sediments, nutrients and light in determining river ecological condition and on information we had collected through expert elicitation.

Internal consistency: To test the model we initially entered data from the two land-use gradient surveys that had been used to populate many of the relationships within the River BN. This was basically an error checking exercise. The overall relationship between actual land-use and river condition was similar to that predicted by the River BN which is based on a series of pair-wise relationships constructed from the same dataset.

Independent evaluation: To further test the River BN we ran a number of scenarios to compare river ecological condition under different land-use, hydrology, riparian vegetation and geomorphological conditions (the scenario results can be found in the Landscape Logic Products Library as fact sheets). The results from this scenario analysis were then compared to data extracted from the AUSRIVAS database that was independent of any data used to develop the River BN.

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Appendix 1: Node descriptions for the River BN

This appendix describes each node in the River BN and provides information about how each node was parameterised. The documentation of each node contains the following information:

1. Description – A brief description of what the node is, and what it represents.
2. States – A list of the state names and definitions for the node.
3. Input Links – A list of the nodes that influence the selected node in the River BN (''parent nodes'').
4. Output Links – A list of the nodes influenced by the selected node (''child nodes'').
5. Parameterisation Method and Data Analysis – A description of the data sourced to parameterise this node as well as a basic description of the results obtained from statistical analysis of the data. A variety of graph types have been used to display results from data analyses. Scatter plots were useful for correlations between two single variables. Contour plots are used to indicate relationships between three variables and for extrapolation to combinations of variables that were not found in any of the available datasets.
6. Review of Node

a. Assumptions – A description of any assumptions or extrapolations made to parameterise the selected node. This includes assumptions made to generate the data source.

b. Strengths, weakness and methods for improvement – This section may include alternative data sources for input nodes or suggestions for data types required to improve the parametisation of this node.

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Variable: Hydrological Region

Description

Differentiation of the state of Tasmanian into four main hydrological regions (Figure 5) based on Hughes (1987), using the CFEV database stream attribute RS_HYDROL (DPIW, 2005). (Sub-)catchments that spanned more than one hydrological region were categorised by the region that contained the greatest number of CFEV river-sections for that catchment/sub-catchment.

States

- H1 or H2: Rivers in eastern Tasmania characterised as being more stochastic and ephemeral than western Tasmanian rivers, with weak seasonality, highly variable base and flood flow magnitudes and timing, and often intense flood regimes.
- H3 or H4: Rivers in northern and western Tasmania, characterised as being predictable with marked seasonality, perennial base flows and moderate flood regimes.

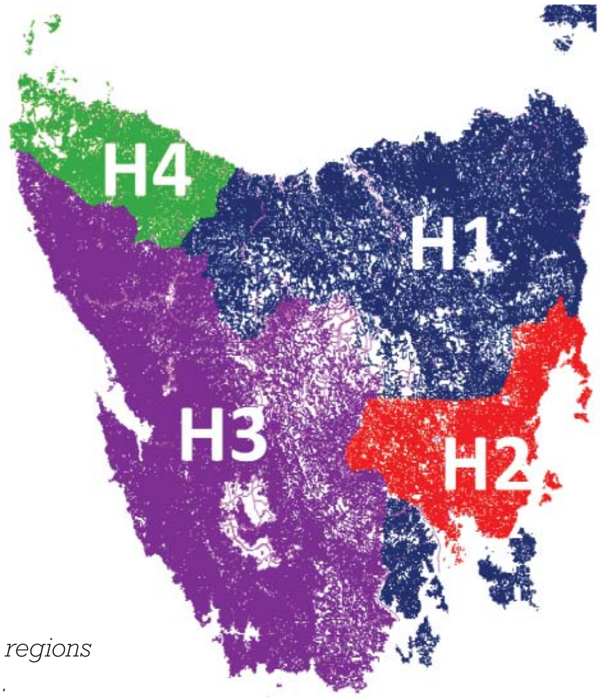


Figure 5. A map of Tasmania showing the 4 hydrological regions defined by Hughes (1987). Data from CFEV (DPIW 2005).

Input Links

N/A

Output Links

Hydrology Regime

Parameterisation method and mata analysis

Look-up tables are used to identify the hydrological region for a (sub-) catchment of interest.

Strengths, weaknesses and methods for improvement

The data for this input node could be sourced from references other than the CFEV. In this case, the user should choose the state definition (H1 or H2 vs. H3 or H4) that best represents the river of interest.

References

DPIW (2005). CFEV database, v1.0 Conservation of Freshwater Ecosystem Values Project. Water Resources Division, Department of Primary Industries and Water, Tasmania.

DPIW (2008) Conservation of Freshwater Ecosystem Values (CFEV) Project Technical Report. Conservation of Freshwater Ecosystem Values Program, Department of Primary Industries and Water, Hobart, Tasmania.

Hughes JMR (1987) .Hydrological Characteristics and Classification of Tasmanian Rivers. Australian Geographical Studies, 25: 61-82.

Review of node

Key Assumptions

Assumption	Validity of Assumption
There is no substantive difference between the hydrology regimes of H1 and H2 rivers, or between those of and H3 and H4 rivers.	While they fall along a gradient in natural river hydrological regime, H1 and H2 rivers are broadly hydrologically similar in terms of mean annual run-off, low flow run-off, coefficient of variation of annual flows, skew of annual flows and peak flow variability (DPIW 2008). This also applies to and H3 and H4 rivers. There are substantive hydrological differences however between H1 and H2 region rivers and those in the H3 and H4 regions.

Variable: Sub-catchment Land-use

Description

This node can be set to reflect the proportions of each type of land-use by area in the catchment upstream of the river reach/section/site of interest. It can therefore be used for scenario evaluation to compare the effect of a range of land use combinations.

Input Links

N/A

Output Links

Hydrology regime
Sediment regime
N concentration regime
P concentration regime
Turbidity

Parameterisation Method and Data Analysis

Look-up tables are used to identify the default land use for a (sub-)catchment of interest. The data provided in the look-up tables is based on GIS land-use data created by Landscape Logic. Construction of the shape file was based on existing land-use information (e.g. BRS, 1:25,000 maps), recent API imagery (DPIW), TasVeg and BRS land categories, see metadata for more information about this data layer.

Review of Node

All catchments with >20% mining, major dams and/or urbanisation were excluded from the analysis. The River BN is therefore not recommended in catchments with mining, major dams or substantial areas of urban land.

For detailed information on the accuracy of Land-use Layer classifications, see metadata associated with this Landscape Logic land-use layer. However, limited data on private forestry is available and some private forestry may be classified as non-production native vegetation in existing land use data layers.

The data used to create links between land-use and nutrients and sediments was based on a two Tasmanian **gradient surveys** that focused on grazing by domestic livestock and a range of forestry land use history and intensity. Thus relationships built between dairy and horticultural land-use types and nutrients and sediments are based on less data than for grazing and forestry.

References

BRS (2003) Australian Land Use and Management Classification (version 6).

Key Assumptions

Assumption	Validity of Assumption
Land-use is not assumed to change with time, and the network parameters represent the medium to longer term effects of these land-uses in the context of recent Tasmanian land management practice. Thus the model does not account for crop/grazing rotation or temporal changes in the hydrological and related effects of intensive forestry and plantation operations. See note in table below.	There were no data available to test the validity of this assumption. An alternative BBN has been developed for scenario evaluation of plantation and intensive forestry effects over time (for information, contact Prof Peter Davies, **p.e.davies@utas.edu.au**)

States

The description of each state (tabled below) includes the relevant Australian Land Use and Management (ALUM) categories (BRS 2003).

State	Description
Non-production native vegetation	Nature conservation, managed resource protection and other minimal use. ALUM codes 1.1, 1.2 and 1.3. This state includes all formal and informal reserves, and any areas of intact native vegetation. It also includes all aspects of non-production forest, such as formal and informal reserves on private and public land. In scenario evaluation, this land-use state should include the relevant proportion of land under forestry management. If this is unknown, enter the default values for the catchment, or a generic default of 70% of total forestry land use area.
Grazing by domestic live stock	Grazing natural vegetation and grazing modified pastures. ALUM codes 2.1 and 3.2. This state represents all forms of extensive and moderate intensity grazing land management. For scenario evaluation, the area of remnant vegetation embedded within grazing land could also be included, as most such land is grazed. For scenario evaluation, high intensity grazing management (including dairying and feedlots) should be allocated to the dairy farming and horticulture state.
Low intensity forestry	Commercial production from native forests and related activities on public and private land. ALUM code 2.2. This state represents low intensity forestry operations, such as thinning, selective harvesting, variable and aggregated retention, as well as late rotation previously intensive operations. For this BBN, the low intensity forestry state represents the average mix of such operations occurring at catchment scale across northern and eastern Tasmania in the period 1995 – 2008. For scenario evaluation, if this is unknown, enter the default values for the catchment, or a generic default of 10% of total forestry land use area.
Plantation forestry	Land on which plantations of trees or shrubs (native or exotic species) have been established for production or environmental and resource protection purposes. ALUM code 3.1. For this BBN, the plantation forestry state represents the average mix of plantation development (plantation ages, proportion of 1st and 2nd rotations, mix of softwood and hardwood etc.) occurring at catchment scale across northern and eastern Tasmania in the period 1995 – 2008. For scenario evaluation, if this area is unknown, enter the default values for the catchment, or a generic default of 20% of total forestry land use area. To assess the effects of differing ages of plantation, and/or dispersal of plantation establishment and harvesting through time, on Tasmanian river responses, a separate BBN has been developed – contact Prof Peter Davies (**p.e.davies@utas.edu.au**) for further information.
High intensity forestry	Commercial production from native forests and related activities on public and private land. ALUM code 2.2. This state represents high intensity forestry operations, especially clear-fell, burn and sow (CBS), but also conversion of forest to pasture/plantation, and more intensive forms of normally low intensity operations such as aggregated retention. For this BBN, the high intensity forestry state represents the average mix of CBS development (time since harvesting, proportion of 1st and 2nd rotations etc.) occurring at catchment scale across northern and eastern Tasmania in the period 1995 – 2008. For scenario evaluation, if this area is unknown, enter the default values for the catchment, or a generic default of 10% of total forestry land use area. To assess the effects of differing ages of CBS, and/or dispersal of CBS operations through time, on Tasmanian river responses, a separate BDN has been developed – contact Prof Peter Davies (**p.e.davies@utas.edu.au**) for further information.
Dairy Farming and horticulture	Includes cropping, irrigated perennial and seasonal horticulture and intensive plant production e.g. glasshouses. ALUM codes 3.3, 4.3, 4.4, 4.5 and 5.1; and Intensive dairy production. ALUM code 5.2.1 and associated grazing/pasture. For scenario evaluation, the combined total % area of both land uses must be entered.

Variable: Sub-catchment RiparianVegetation Condition

Description

This node represents the overall average riparian condition throughout the stream network of the catchment upstream of the river reach (section or site) of interest. Riparian vegetation condition values can be obtained from CFEV (the RS_ACNRIPV river section attribute) or estimated by the user (e.g. from GoogleEarth™).

Input Links

N/A

Output Links

Summer/Autumn temperature regime
Light availability: sub-catchment
Trophic carbon sources
P concentration regime
Turbidity
Sediment regime

Parameterisation Method and Data Analysis

RS_NRIPV is the proportional area of native riparian vegetation within a 50m buffer zone either side of all upstream river sections (accumulated as the stream-length-weighted average across all upstream river sections). Data supplied in the River BN look-up tables are the RS_ACNRIPV for each CFEV sub-catchment.

RS_NRIPV has been calculated within CFEV from river section length (RS_LENGTH) and the proportional area of native vegetation within a 50m buffer zone either side of each river section (RS_NRIPV).

$$RS\_ACNRIPV = \frac{\sum(RS\_NRIPV * RS\_LENGTH)}{\sum(RS\_LENGTH)}$$

RS_NRIPV was derived from information extracted from a CFEV modified TASVEG vegetation layer (DPIW 2008).

Review of Node

Strengths, weaknesses and methods for improvement

In the look-up tables supplied with this BN, RS_ACNRIPV is accumulated across all river-sections for the entire CFEV river catchment/sub-catchment selected i.e. it is only relevant to the most downstream river section of the designated river catchment or sub-catchment. A better estimate for a site which may fall elsewhere within these sub-catchments can be obtained by extracting RS_ACNRIPV for the exact river-section of interest directly from CFEV (i.e. thus condition is just for the relevant upstream catchment of that site rather than the entire CFEV sub-catchment within which it sits).

This node only takes into account native vegetation. You may like to increase the value if your catchment has a high degree of willow infestation.

WARNING: Check with CFEV (cfev@dpiw.tas.gov.au) before extracting RS_ACNRIPV directly from CFEV as there was initially an error in the calculation of this index (yet to be rectified as of July 2010). If in doubt calculate the index manually using the above formula.

References

DPIW (2005). CFEV database, v1.0 Conservation of Freshwater Ecosystem Values Project. Water Resources Division, Department of Primary Industries and Water, Tasmania.

DPIW (2008) Conservation of Freshwater Ecosystem Values (CFEV) Project Technical Report. Conservation of Freshwater Ecosystem Values Program, Department of Primary Industries and Water, Hobart, Tasmania.

States

The description of each state (tabled below) was extracted from the CFEV database (DPIW, 2005).

State	Description
Very Poor	(RS_ACNRIPV=0) No native vegetation occurring within the riparian zone (50m width strip each side of the river section) in the accumulated catchment (close to 0% or 0% of total riparian buffer zone as native vegetation)
Poor	(RS_ACNRIPV >0 - 0.2) Low proportional area of native vegetation occurring within the riparian zone (50m width strip each side of the river section) in the accumulated catchment (0 - 20% of total riparian buffer zone as native vegetation)
Moderate	(RS_ACNRIPV >0.2 - 0.8) Moderate to high proportional area of native vegetation occurring within the riparian zone (50m width strip each side of the river section) in the accumulated catchment (20 - 80% of total riparian buffer zone as native vegetation)
Good	(RS_ACNRIPV >0.8 - 1) Very to extremely high proportional area of native vegetation occurring within the riparian zone (50m width strip each side of river section) in the accumulated catchment (>80% of total riparian buffer zone as native vegetation)

Variable: Soil Type

Description

This node reflects the mix of broad soil types dominant within in the catchments that can be modelled using the River BN.

This node is essentially 'silent' in the current version of the River BN because the choice of soil type will not influence the output data. There is currently very little information on how these soil categories will influence river ecological condition. We hope to update this node when more data are available.

States

State	Description
Clay	Dermosol, Ferrosol and Kandosol
Wet	Hydrosol, Organosol, Podosol
Other	Chromosol, Kurosol, Rudosol, Sodosol, Tenosol and unknown

Input Links

N/A

Output Links

N concentration regime
P concentration regime
Turbidity

Parameterisation Method and Data Analysis

N/A

Review of Node

Key Assumptions

Assumption	Validity of Assumption
Soil type does not significantly influence turbidity and nutrient concentrations.	As stated previously there is little information available with which to develop relationships between soil groups and nutrient or turbidity regimes. As such this node, whilst included in the BN, does not influence the output data. This is a key information gap in the BN which should be updated when more data are available.

References

N/A

Variable: Fluvial Geomorphological Context

Description

This variable represents the susceptibility of the channel at the river site of interest to anthropogenic changes in the flow and sediment regime and is based on the CFEV RS_GEORESP river section attribute (DPIW, 2005).

States

The description of each state (tabled below) was extracted from the CFEV database (DPIW, 2005).

State	Description
Low (0)	(RS_GEORESP=0) Responsiveness of channel form to anthropogenic changes in flow and/or sediment regime is low (e.g. a bedrock controlled system).
Moderate (0.5)	(RS_GEORESP=0.5) Responsiveness of channel form to anthropogenic changes in flow and/or sediment regime is moderate.
High (1)	(RS_GEORESP=1) Responsiveness of channel form to anthropogenic changes in flow and/or sediment regime is high (e.g. an alluvial and fine sediment system).

Input Links

N/A

Output Links

Sediment regime

Parameterisation Method and Data Analysis

States are based on the RS_GEORESP data extracted from the CFEV (DPIW, 2005).

If no data are available the user can select from the below:

If the river lies in a catchment predominately made up of dolorite or bedrock then use a low value (0)

If the river lies in an alluvial catchment then use a moderate to high value (0.5–1). It is not recommended that you use the River BN in highly alluvial (granite dominated) catchments.

Review of Node

Key Assumptions

Assumption	Validity of Assumption
RS_GEORESP is an index derived from attributes of fluvial geomorphic mosaics developed for CFEV using the approach of Jerie et al. (2003); it gives an indication of the *likely* degree of responsiveness of channel form to changes in the water and sediment regime.	See CFEV database and associated manuals.

Strengths, weaknesses and methods for improvement

Data provided in the River BN look-up tables is an average of the geomorphic responsiveness of the river-sections within each CFEV catchment/sub-catchment. However, RS_GEORESP can vary within a catchment/sub-catchment. For a better value for a particular CFEV river-section it is better to extract the value directly from the CFEV database.

References

DPIW (2005). CFEV database, v1.0 Conservation of Freshwater Ecosystem Values Project. Water Resources Division, Department of Primary Industries and Water, Tasmania.

Jerie, K., Houshold, I., and D. Peters (2003). Tasmania's river geomorphology: stream character and regional analysis. Volume 1. Nature Conservation Report 03/5. Nature Conservation Branch, DPIWE, Hobart, Tasmania. June 2003. 66 pp.

Variable: River Section Slope

Description

Gradient of the river-section of interest (rise/run).

States

State	Description
Low	<0.005
Moderate	0.005–0.02
High	0.02–0.04
Very high	>0.04

Input Links

N/A

Output Links

Instream substrata
Night DO minimum

Parameterisation Method and Data Analysis

If data is unavailable for the site of interest the user can use the default value for their catchment from the River BN look-up tables. The default values provided in the look-up tables are derived from CFEV (DPIW, 2005) and are the average of all river-sections within each CFEV (sub-) catchment.

Review of Node

Strengths, weaknesses and methods for improvement

Data provided in the River BN look-up tables is the average slope for all river sections within each CFEV (sub-) catchment. By using this data the user assumes that the average slope is representative of slope at the site of interest. Users can use their own data to set this node rather than relying on the River BN look-up tables.

References

DPIW (2005). CFEV database, v1.0 Conservation of Freshwater Ecosystem Values Project. Water Resources Division, Department of Primary Industries and Water, Tasmania.

Variable: Local Riparian Vegetation Condition

Description

Quantifies the riparian vegetation condition at the reach scale for the reach/site of interest. It can be estimated by the user or populated with data from CFEV (RS_NRIPV river section attribute; DPIW 2005). RS_NRIPV is the proportional area of native riparian vegetation within a 50m buffer zone either side of a river-section.

Input Links

N/A

Output Links

Temperature regime
Light availability: local
Trophic carbon source

Parameterisation Method and Data Analysis

The average value of RS_NRIPV among all river-sections within each CFEV catchment/sub-catchment is provided in the River BN look-up tables.

States

The description of each state (tabled below) was extracted from the CFEV database (DPIW, 2005).

State	Description
Very Poor	(RS_NRIPV=0) No native vegetation occurring within the riparian zone (50m width strip each side of the river section) (close to 0% or 0% of total riparian buffer zone as native vegetation).
Poor	(RS_NRIPV >0-0.2) Low proportional area of native vegetation occurring within the riparian zone (50m width strip each side of the river section) (0-20% of total riparian buffer zone as native vegetation).
Moderate	(RS_NRIPV >0.2-0.8) Moderate to high proportional area of native vegetation occurring within the riparian zone (50m width strip each side of the river section) (20-80% of total riparian buffer zone as native vegetation).
Good	(RS_NRIPV >0.8-1) Very to extremely high proportional area of native vegetation occurring within the riparian zone (50m width strip each side of river section) (>80% of total riparian buffer zone as native vegetation).

Review of Node

Key Assumptions

Assumption	Validity of Assumption
That data on riparian vegetation condition in the CFEV rivers database (RS_NRIPV) is representative of actual riparian vegetation condition.	Native riparian vegetation was based on the TASVEG vegetation layer. See CFEV manuals (DPIW 2008) for more detail. Note that RS_NRIPV does not account for shading caused by non-native species (e.g. willows). Relationships between RS_NRIPV and on-ground measurement of % native vegetation and riparian native vegetation condition were evaluated and were broadly consistent with the assumption (Davies et al. 2007).

Strengths, weaknesses and methods for improvement

An alternative to RS_NRIPV is to estimate the degree of shading over the river by riparian vegetation, and/or the intactness of the riparian forest. Shading (%) can be estimated using the techniques described in the TRCI Stream-Side Zone Field Manual (NRM South 2009) or with the use of a densiometer or camera with fisheye lens (see also Davies-Colley and Payne 1998; Davies et al. 2004; Hawkins et al. 2003). Since this node predominately influences other River BN nodes through the alteration of the light environment within the river, the user might also consider whether high banks or adjacent hills can also influence the light environment (Davies et al. 2004) and adjust this index accordingly.

References

Davies PM, Cook B, Walshe T (2004) Managing high instream temperatures using riparian vegetation. A manual for river managers. University of Western Australia.
Davies-Colley RJ, Payne GW (1998) Measuring Stream Shade. Journal of the North American Benthological Society 17:250-260.
DPIW (2008) Conservation of Freshwater Ecosystem Values (CFEV) Project Technical Report. Conservation of Freshwater Ecosystem Values Program, Department of Primary Industries and Water., Hobart, Tasmania.
Hawkins C, Ostermiller J, Vinson M, Stevenson RJ, Olson J (2003) Stream Algae, Invertebrate, and Environmental Sampling Associated with Biological Water Quality Assessments: Field Protocols, Utah State University.
NRM South (2009) The Tasmanian River Condition Index Streamside Zone Field Manual.

Variable: Unsealed Road Area

Description

The density of unsealed road in the catchment (as % of catchment surface area occupied by unsealed road surfaces). This can be obtained from CFEV (RS_ACRD_U) or estimated by the user.

States

State	Description
Low	0 to 0.3% of catchment is made up of unsealed road surfaces
Moderate	0.3 to 1.0% is made up of unsealed roads
High	1.0 to 1.8% is made up of unsealed roads

Input Links

N/A

Output Links

Sediment regime

Parameterisation Method and Data Analysis

RS_ACRD_U is the proportional area of the upstream catchment occupied by unsealed road surfaces. Data supplied in the River BN look-up tables are the RS_ACRD_U for each CFEV catchment.

Review of Node

Key Assumptions

Assumption	Validity of assumption
That data supplied by CFEV adequately represents % catchment area as unsealed roads, actual density of unsealed roads as at 2003.	See CFEV database and associated manuals (DPIW 2005). This attribute was derived from an updated, comprehensive map of all roading classes (including forestry roads), with the area estimated by applying an average unsealed road width to all unsealed road classes and summing the values for each river section catchment and catchment.

Strengths, weaknesses and methods for improvement

In the look-up tables supplied, RS_ACRD_U is accumulated across all river-sections for the entire CFEV catchment/sub-catchment selected. A better estimate for a particular site can be obtained by extracting RS_ACRD_U for the exact river-section of interest directly from CFEV (i.e. so condition is just for the upstream catchment rather than the entire CFEV catchment within which the site is located).

References

DPIW (2005). CFEV database, v1.0 Conservation of Freshwater Ecosystem Values Project. Water Resources Division, Department of Primary Industries and Water, Tasmania.

Variable: Hydrological Regime

Description

The hydrological regime characterises anthropogenic changes in river flow caused by river abstraction. The flow regime is defined in terms of base and peak flows. Catchments with no water abstraction will have natural base and peak flows, while catchments with moderate abstraction will have reduced base flows and natural peak flows and catchments with high river abstraction will have reduced base flows and higher peak flows.

States

State	Description
LH	Reduced base flows and higher peak flows compared to the natural (or expected) flow regime.
LN	Reduced base flows compared to the natural (or expected) flow regime and natural peak flows.
NN	Natural base and peak flows.

Input Links

Hydrological context
Land-use: sub-catchment

Output Links

Temperature regime
Night DO minimum
Instream substrata.

Parameterisation Method and Data Analysis

Landscape Logic **land-use** data and **CFEV** Rivers data on water abstraction (the RS_ABSTI attribute, DPIW 2005) were used to build a relationship between land-use states in the River BN and water abstraction. These relationships were then adjusted for each hydrological region to account for varying sensitivities to river abstraction across Tasmania (Hughes 1987).

The general relationship between land-use intensity, hydrological region and hydrological regime are outlined in the table below. Land-use intensity categories (High, Medium and Low) refer to land-use types that vary in the associated amount of water diverted from river channels, i.e. the degree of diversion by abstraction. Rivers in hydrological regions H1 and H2 will be more hierologically sensitive to water abstraction/diversion than regions H3 and H4.

Multiple regression was used to determine the relationship between area of specific land-uses and the magnitude of abstraction (the value of RS_ABSTI). The analysis showed that grazing was the only land-use type associated with significantly elevated water abstraction (see table next page and Figure 6). However, expert opinion suggests that this was partly caused by a lack of statistical power to detect the impacts of other land-use types.

The above plot shows the relationship between proportion of the catchment under grazing and water abstraction (ABSTI from CFEV). Lines indicate least-squares linear regression with 95% confidence limits, see table below for summary statistics.

Expert opinion and correlation coefficients were therefore used to parameterise the River BN for the effects of non-grazing land-use types on water abstraction. Cropping and dairy farming were assumed to have a similar but larger effect to grazing on flow because they tend to have higher irrigation demands. Forestry was assumed to have less of an effect on flow and would vary with forest age structure and region, the following assumptions were made with respect to the effect of forestry on hydrological regime:

The age structure of production forest west and north-west Tasmanian catchments is: 10% <10 years old, 30% <90 years old, 60% >90 years old. The age structure of production forests in east and north-east Tasmanian catchments is older than on the west coast.

The age structure of a plantation forest west and north-west Tasmanian catchments is: 30% <10 years, 70% 10–40 years. The age structure of plantation forests in east and north-east Tasmanian catchments is younger than the age structure of plantation forests on the west coast.

Catchments in east and north-east Tasmania are more hydrologically responsive to changes in land-use than catchments on the west coast of Tasmania.

As forests and plantations age after clearing/site establishment and burning, their influence on stream hydrology moves from a condition of reduced base flows and raised peak flows (LH) to one of reduced base flows and natural peak flows (LN) and finally to natural base and peak flows (NN). These temporal patterns were combined with the above average age structure of production forest and of plantations within this BN to broadly represent the typical influence of forestry in Tasmanian catchments. A time-dependent version of this BN, aimed at representing the different phases of hydrological influence of forest operations within a catchment is under development (contact: Prof Peter Davies).

Review of Node

Key Assumptions

Assumption	Validity of Assumption
It is assumed that data on abstraction supplied by CFEV is representative of actual river abstraction.	RS_ABSTI was calculated for CFEV using data from the Water Information Management System (WIMS) database (DPIWE 2005), which includes all private and other licensed takes and diversions, as well as data supplied by Hydro Tasmania. Adjustments were made, with advice from DPIPWE Water Management, for the additional effect of unlicensed abstractions.

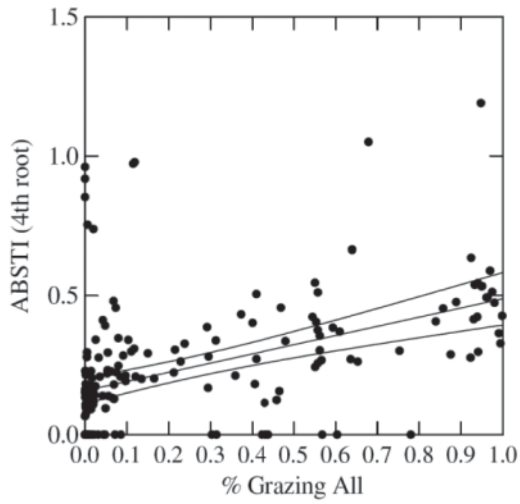


Figure 6. Plot showing the relationship between proportion of the catchment under grazing and water abstraction (ABSTI from CFEV). Lines indicate least-squares linear regression with 95% confidence limits, see table below for summary statistics.

Strengths, weaknesses and methods for improvement

To run a scenario with a different age structured plantation or production forest the user will need to change the probabilities associated with forestry land-uses.

References

DPIW (2005). CFEV database, v1.0 Conservation of Freshwater Ecosystem Values Project. Water Resources Division, Department of Primary Industries and Water, Tasmania.

DPIWE. (2005). Water Information Management System. Department of Primary Industries, Water and Environment. http://wims.dpiwe.tas.gov.au/.

Hughes JMR (1987) .Hydrological Characteristics and Classification of Tasmanian Rivers. Australian Geographical Studies, 25: 61-82.

Hydrological region	Land-use intensity	Hydrological regime
H1 and H2	High	LH
H1 and H2	Medium	LN
H1 and H2	Low	NN
H3 and H4	High	LN
H3 and H4	Medium	NN
H3 and H4	Low	NN

Land-use	Correlation coefficient	*df*	*F*	*P*
Grazing	0.33	1	50.28	<0.0001
Non-production native vegetation	0.03	1	0.19	0.66
Production forestry	–0.06	1	0.62	0.43
Plantation forestry	0.03	1	0.16	0.69
Dairy	–0.08	1	1.21	0.27
Cropping	–0.03	1	0.13	0.70

Variable: Sub-catchment Light Availability

Description

Light availability can influence stream temperature, riverine primary production and benthic algal abundance. The amount of light available will depend primarily on the degree of shading by riparian vegetation. This node represents levels of light availability across the (sub-)catchment upstream of the site of interest, as controlled by the condition of the riparian vegetation.

States

The categories for shading are based on those used in the Tasmanian River Condition Index (TRCI; NRM South 2009c).

State	Description
High	<60% shading
Moderate	60–80% shading
Low	>80% shading

Input Links

Riparian vegetation condition: sub-catchment

Output Links

Benthic metabolism (P/R)

Parameterisation Method and Data Analysis

The relationship between stream shading and riparian vegetation condition was developed using the **gradient survey, paired sites survey** and the RS_NRIPV data from the **CFEV Rivers database** (DPIW, 2005). The physical relationship between the amount of vegetation and shade at a local scale was applied at the catchment scale.

At the local scale there was a significant and positive relationship between riparian vegetation condition and shading ($F_{1,26}$ = 7.07, *P* = 0.01; see Figure 7) although the goodness-of-fit was poor (R^2=0.22).

Relationship between local riparian vegetation conditon (RS_NRIPV, CFEV) and % Shading.

Review of Node

Key Assumptions

Assumption	Validity of Assumption
The light regime is determined primarily by riparian vegetation shading, and stream orientation is assumed to be unimportant. It is assumed that when there is no riparian vegetation the channel banks provide a small amount of shading to the stream.	The validity of this assumption will depend on the particular river site. Users should consider surrounding hills, bank height and stream orientation to determine whether the River BN state settings are appropriate for determining the shade levels at their site.

Strengths, weaknesses and methods for improvement

For consistency with other Tasmanian river research, categories were the same as those used for the Tasmanian River Condition Index and are based on observations that a shading threshold on algal growth/production exists at approximately 60–80% overhead shading. Below this threshold light levels are assumed to not significantly limit instream production. This result is consistent with Mosisch et al. (2001) and Bunn et al. (1999) who described similar patterns in sub-tropical Australian rivers.

If CFEV data are used to set Riparian vegetation condition: sub-catchment (see relevant node), then the user should be aware that this index does not account for shading by non-native species (e.g. willows).

References

Bunn SE, Davies PM, Mosisch TD (1999) Ecosystem measures of river health and their response to riparian and catchment degradation. Freshwater Biology 41: 333-245.

DPIW (2005) CFEV database, v1.0 Conservation of Freshwater Ecosystem Values Project. Water Resources Division, Department of Primary Industries and Water, Tasmania.

Mosisch TD, Bunn SE, Davies PM (2001) The relative importance of shading and nutrients on algal production in subtropical streams. Freshwater Biology, 46: 1269-1278.

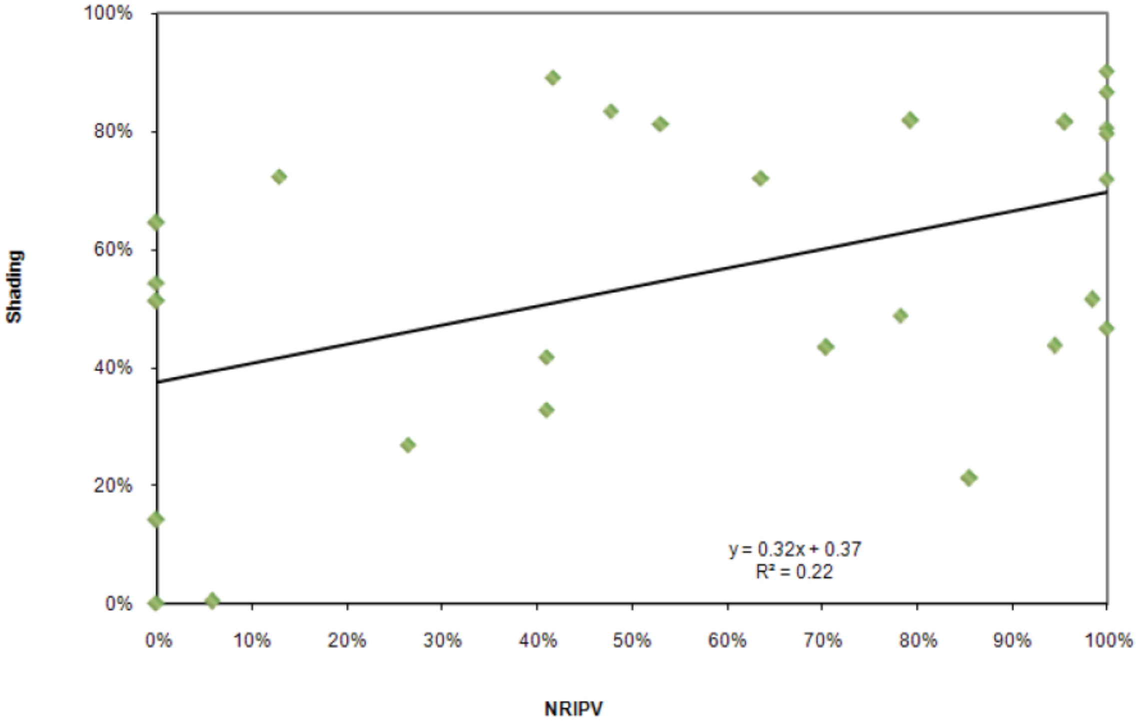


Figure 7. Relationship between local riparian vegetation conditon (RS_NRIPV, CFEV) and % Shading.

Variable: Sediment Regime

Description

This index describes the relative magnitude of fine sediment input into the river reach (section) of interest.

States

State descriptions for sediment regime based on the RS_SEDIN attribute from the CFEV Rivers database (DPIW, 2005) are tabled below.

State	Description
Very large	(RS_SEDIN=0) Very large anthropogenic change to sediment input for the river section.
Large	(RS_SEDIN=0–0.2) Large anthropogenic change to sediment input for the river section.
Moderate	(RS_SEDIN=0.2–0.4) Moderate anthropogenic change to sediment input for the river section.
Small	(RS_SEDIN=0.4–0.8) Small anthropogenic change to sediment input for the river section.
Minimal	(RS_SEDIN=0.8–1) Minimal to no anthropogenic change to sediment input for the river section.

Input Links

Fluvial-geomorphological context
Riparian vegetation condition: sub-catchment
Land-use: sub-catchment
Unsealed roads

Output Links

Instream substrata

Parameterisation Method and Data Analysis

Relationships were constructed from land-use data and RS_SEDIN attribute data from the CFEV Rivers dataset (DPIW, 2005) for a selection of sub-catchments within Tasmania. Sub-catchments were selected if they occurred in the gradient study or were modelled by the Landscape Logic-WQ Simulator.

Relationships were first developed between sediment inputs and sub-catchment riparian vegetation condition. These relationships were then modified for different land-uses.

Figure 8 shows the relationship between sediment inputs (the CFEV RS_SEDIN attribute) and catchment-scale riparian vegetation condition (RS_ACNRIPV attribute) for three different geomorphological contexts. While the relationship between riparian vegetation condition and sediments was the same for each level of geomorphological context, the goodness-of-fit was higher in more responsive river-sections.

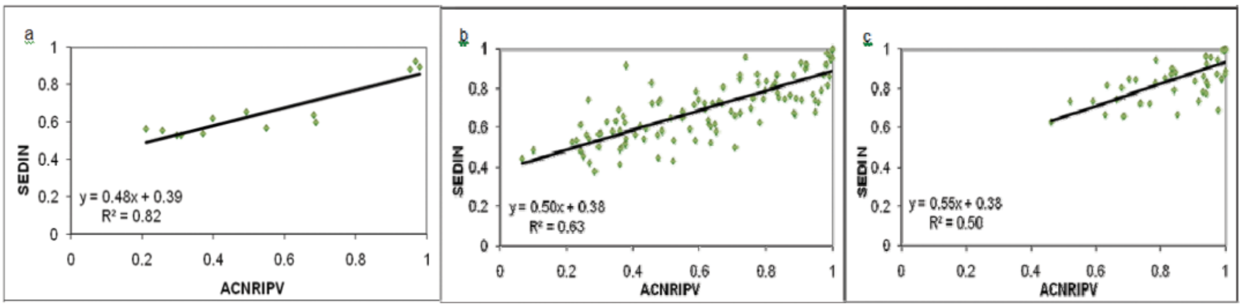


Figure 8. Relationship between sediment inputs (SEDIN) and catchment-scale riparian vegetation condition (ACNRIPV) for 3 different geomorphological contexts: a) high responsiveness (RS_GEORESP=1), b) Moderate responsiveness (RS_GEORESP=0.5) and c) Low responsiveness (RS_GEORESP=0).

Figure 9 shows relationships between land-use categories and the CFEV RS_SEDIN attribute. Land-use categories and their associated Spearman's rank correlations are: a) non-production native vegetation, ρ = 0.72; b) grazing, ρ = -0.70; c) production forestry, ρ = -0.14; d) plantation forestry, ρ = -0.41; e) dairy, ρ = -0.46; f) horticulture, ρ = -0.48.

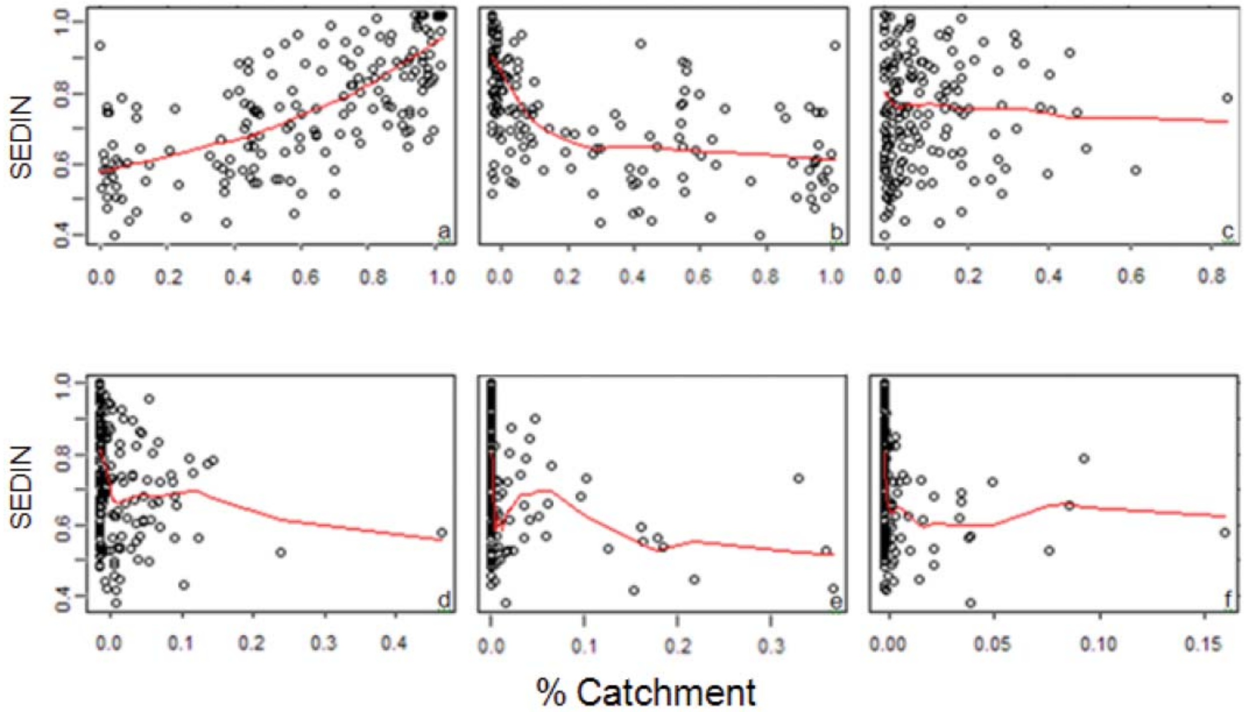


Figure 9. Relationships between land-use categories and SEDIN.

Review of Node

Key Assumptions

Assumption	Validity of Assumption
It is assumed that data on sediments supplied by CFEV is representative of changes in anthropogenically derived sediments.	CFEV developed a set of rules to relate changes in anthropogenic influences to instream condition based on an expert rule system. See DPIW (2008) for more detail
To estimate the impact of forestry we assumed that ~90% of production forests are >10 years old and 30–50% of plantation forests are <10 years old.	This assumption was based on information provided by Forestry Tasmania.

Strengths, weaknesses and methods for improvement

The data used to create links between land-use and sediments were sourced from within the CFEV Rivers database for a selection of CFEV sub-catchments. Some land-use types (grazing and production forestry) cover a greater area of Tasmania than others and thus a more representative relationship with sediment inputs could be constructed for these land-use types.

References

DPIW (2005) CFEV database, v1.0 Conservation of Freshwater Ecosystem Values Project. Water Resources Division, Department of Primary Industries and Water, Tasmania.

DPIW (2008) Conservation of Freshwater Ecosystem Values (CFEV) Project Technical Report. Conservation of Freshwater Ecosystem Values Program, Department of Primary Industries and Water., Hobart, Tasmania.

Variable: Summer/Autumn Temperature Regime

Description

Each state describes a combination of night and day time maximum temperatures in the river reach (section) of interest. Day-time temperatures are influenced by local riparian vegetation condition, and night time temperatures by hydrology regime and sub-catchment Riparian vegetation condition.

States

State descriptions for Summer/Autumn temperature regime:

State	Description
Day-warm: night-warm	Both day and night-time stream temperatures exceed 25˚C.
Day-warm: night-cool	Only day-time stream temperatures exceed 25˚C.
Day-cool: night-cool	Both day and night-time stream temperatures are below 25˚C.

Input Links

Hydrology regime
Riparian vegetation condition: sub-catchment
Riparian vegetation condition: local

Output Links

DO regime
SIGNAL O/E
Invertebrate total abundance
O/E, %EPT and FFG

Parameterisation Method and Data Analysis

A threshold of 25°C was set to differentiate ''warm'' from ''cold'' water temperature regimes. This was based on an analysis of thermal thresholds for four common indices of macroinvertebrate condition (Figure 10): a) %EPT, b) O/E, c) % Shredders (FFG) and d) SIGNAL O/E (see relevant nodes for descriptions of these indices) derived from a **data set of temperature and invertebrate family abundance** supplied by Chris Walsh (see Walsh et al. 2007).

The Tasmanian grazing land gradient survey sampled only a few sites with high temperatures, thus some expert opinion was also required to build relationships for this node.

The Walsh data indicated a threshold in the loss of taxa at about 25°C (i.e. a shift from a good to degraded condition state for all indices except SIGNAL O/E for which a continuous decline with temperature was observed (Figure 10).

Plots of relationship between four key macroinvertebrate indices and maximum temperature, derived using south-eastern Australian macroinvertebrate and habitat data provided by C Walsh.

Review of Node

Key Assumptions

Assumption	Validity of Assumption
A threshold of 25˚C was set to differentiate "warm" from "cold" temperatures	There is some evidence to suggest that in Tasmania the threshold may be closer to 21˚C (Davies et al. 2004). However, there were insufficient data to confirm this.
Local riparian vegetation condition is assumed to have a minimal effect on stream temperatures unless flow is low. Very poor local riparian vegetation condition is likely to influence day time temperatures only.	There are no data available to test this assumption.

Strengths, weaknesses and methods for improvement

Note the data used to set the 25°C temperature threshold was collected from across south-eastern Australia and there is some evidence to suggest that in Tasmania the threshold may be closer to 21°C (Davies et al. 2004). Unfortunately, we did not have sufficient data to run the analysis for Tasmanian macroinvertebrate communities to determine if a revised temperature threshold was most appropriate.

Results from the gradient survey suggest that few Tasmanian rivers will experience temperatures greater than 25°C. Rivers most likely to experience high instream temperatures have very poor riparian vegetation condition (very little shading) and low flows.

References

Davies PM, Cook B, Walshe T (2004) Managing high instream temperatures using riparian vegetation. A manual for river managers. University of Western Australia.

Walsh C, Stewardson M, Stein J, Wealands S (2007) Sustainable Rivers Audit Filters Project Stage 2, Report to Murray Darling Basin Commission. School of Enterprise, The University of Melbourne, Melbourne.

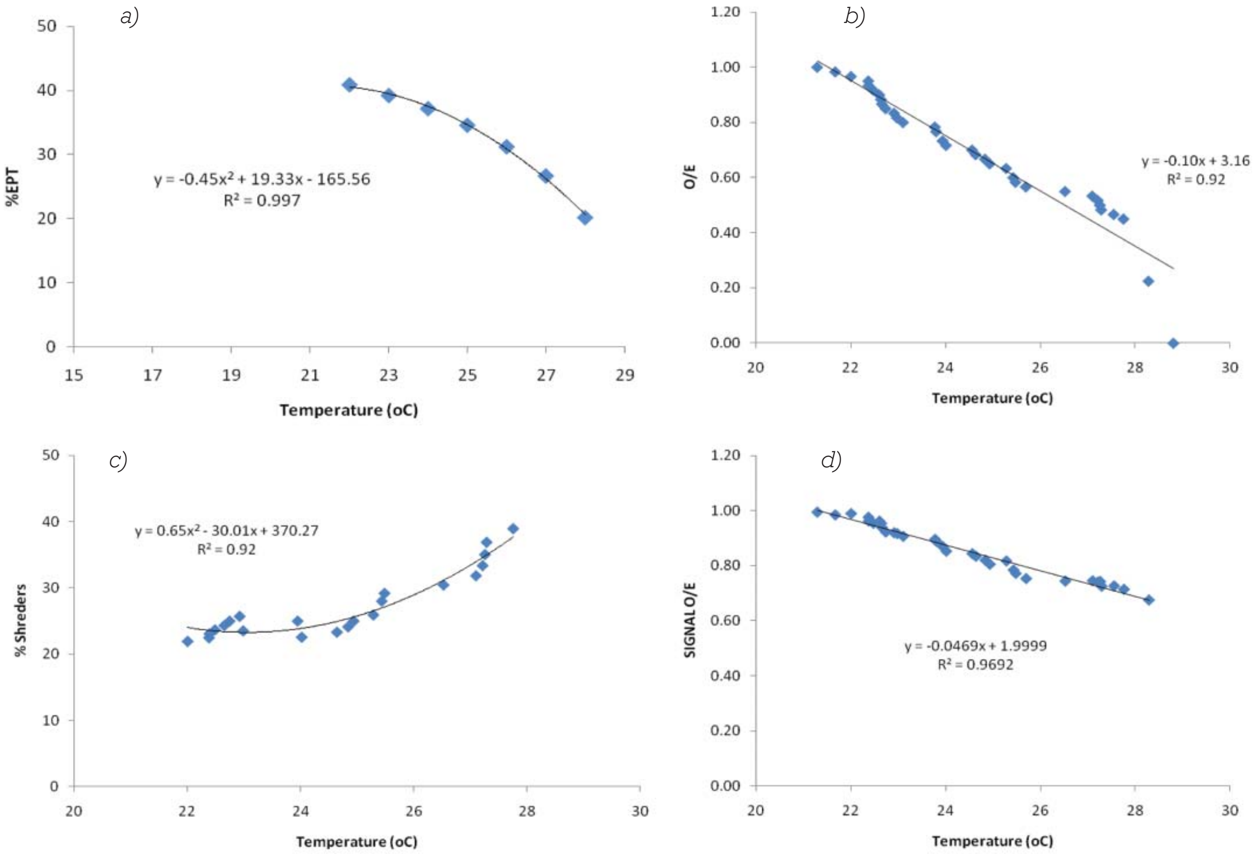


Figure 10. Figure 10 Relationships between in-stream temperature and common indices of macroinvertebrate condition: a) %EPT, b) O/E, c) % Shredders (FFG) and d) SIGNAL O/E. Data were supplied by Chris Walsh and are also analysed in Walsh et al. (2007).

Variable: Summer/Autumn Night DO Minimum

Description

Dissolved Oxygen (DO) concentration ranges in the river reach (section) of interest, in parts-per-million (ppm). Water DO concentrations will be influenced by slope, flow, temperature and the balance between production and respiration (P/R).

States

State	Description
Low	Dissolved oxygen concentration <4ppm
High	Dissolved oxygen concentration >4ppm

Input Links

Temperature regime
Hydrology regime
River-section slope
Benthic metabolism (P/R)

Output Links

SIGNAL O/E
Invertebrate total abundance
O/E, %EPT and FFG

Parameterisation Method and Data Analysis

Data from the grazing land use **gradient survey** was used to create relationships between DO and the input and output nodes. Night time minimum DO values were used to identify sites that could potentially suffer oxygen stress. Minimum DO readings are more likely to occur at night when instream plants and algae respire but are not photosynthesizing.

The relationship between slope and DO concentration (ppm) is shown in Figure 11. The figure highlights that there were little data for exploring these relationships. However, low DO values (~ 4 ppm) only occurred at sites that had a low stream slope, high night temperatures and a modified hydrological regime.

Review of Node

Key Assumptions

Assumption	Validity of Assumption
Oxygen stress to instream fauna was assumed to occur at DO concentrations less than 4 ppm.	This assumption is consistent with Connolly (2004) and other international literature (see citations in ANZECC 2000).

Strengths, weaknesses and methods for improvement

The gradient survey sampled only a few sites with low DO values, thus expert opinion was required to parameterise this node.

References

ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Connolly NM, Croassland MR, Pearson RG (2004) Effect of low dissolved oxygen on survival, emergence and drift of tropical stream macroinvertebrates. Journal of the North American Benthological Society 23: 251-270.

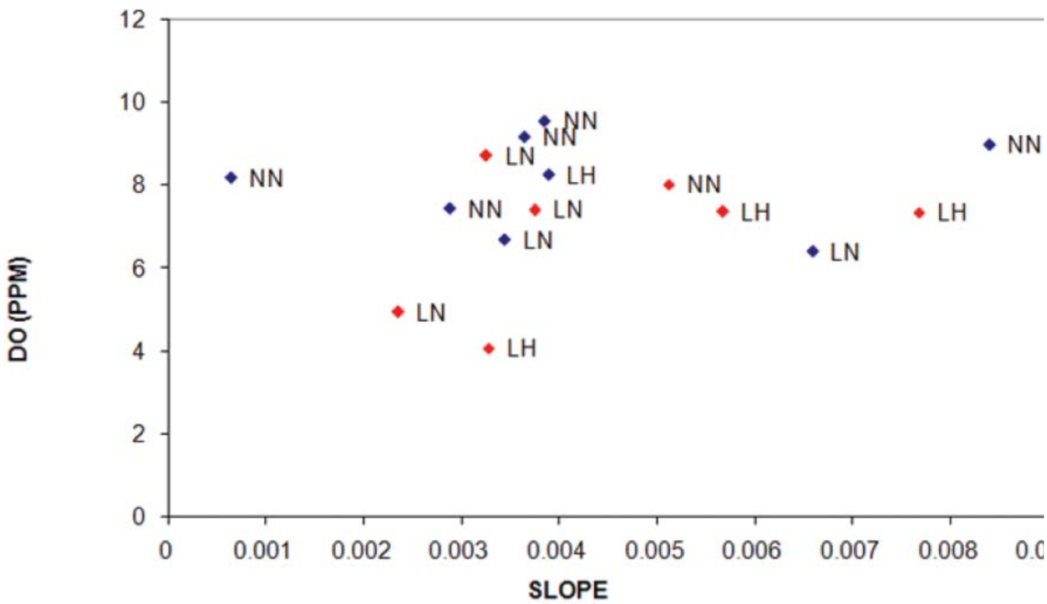


Figure 11. Relationship between slope and DO concentration (ppm). Symbol colour refers to the temperature regime experience at the site (red = warm nights; blue=cool nights and labels refer to the hydrological regime (see relevant node for definitions).

Variable: Benthic Metabolism

Description

Relative levels of gross primary productivity (P, $gO_2/m^2/day$) within the river reach (section) of interest.

States

State	Description
High	P > 6 $gO_2/m^2/day$
Moderate	P = 4–6 $gO_2/m^2/day$
Low	P < 4 $gO_2/m^2/day$

Input Links

Light availability: sub-catchment
Nitrogen concentration regime
Phosphorus concentration regime

Output Links

Night minimum DO

Parameterisation method and data Analysis

Metabolism data collected in the grazing land use **gradient survey** were used to generate relationships between primary production and light availability, nitrogen and phosphorus concentration regimes (see below). Primary production was estimated using a single-probe open-channel metabolism technique (Grace and Imberger 2006). A modified version of an Excel® tool used to estimate ecosystem metabolism and described in Young et al. (2006; 2004) was used to perform calculations. The modification resulted in slightly higher estimates of primary production than those predicted by the spreadsheet model (negative night time estimates of P were adjusted to zero). Nutrient limitation experiments were also used to determine whether nutrient addition enhanced the accumulation of algal biomass (an index of algal growth). Results varied across sites and ambient light conditions, however, there was sufficient evidence to suggest that phosphorus is limiting benthic algal production in some Tasmanian catchments. There was no evidence that nitrogen limitation occurs in Tasmanian catchments.

Relationships between shade, nutrients and gross primary productivity. Figure 12 shows that primary production is greatest at high nutrient concentrations and low levels of shading.

Review of Node

Key assumptions

Assumption	Validity of assumption
Benthic metabolism was estimated using an open-channel single station dissolved oxygen technique.	The open channel technique used is less precise than using metabolism chambers because oxygen re-aeration was estimated through night-time regression. This was the preferred technique because chambers only integrate production at a very small scale. See Grace and Imberger (2006) for a detail description of the assumptions of the use-of the open channel technique and a comparison of how this technique compares to the use of metabolism chambers to determine benthic metabolism.

Strengths, weaknesses and methods for improvement

Metabolism data was only available for a subset of the sites surveyed in the grazing land use gradient survey and thus there were limited data available for building relationships for this node. However, the data that were available covered a broad range of values of instream values for primary production.

References

Grace M and Imberger S (2006) Stream Metabolism: Performing and interpreting measurements, Monash University.

Young R, Townsend C, Matthaei C (2004) Functional Indicators of River Ecosystem Health - An interim guide for use in New Zealand. Prepared for the Ministry for the Environment.

Young R, Matthaei C, Townsend C (2006) Functional Indicators of River Ecosystem Health - Final Project Report. Prepared for Ministry for the Environment, p 38 pp.

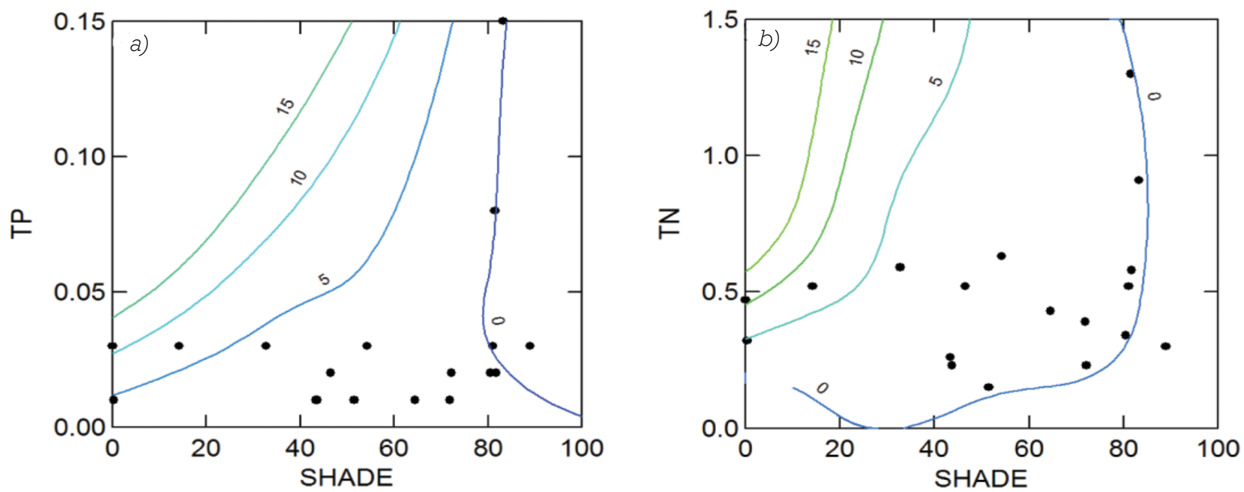


Figure 12. Relationships between shade, nutrients and gross primary productivity (contours). Nutrients are either a) total phosphorus or b) total nitrogen.

Variable: Phosphorus Concentration Regime

Description

Ranges of total phosphorus concentration (mg/L) in the river reach (section) of interest.

States

State	Description
Low	TP <0.05 mg/L
Moderate	TP = 0.05–0.07 mg/L
High	TP = 0.07–0.09 mg/L
Very High	TP <0.09 mg/L

Input Links

Land-use: sub-catchment
Riparian vegetation condition: sub-catchment
Soil type

Output Links

Algae % cover
Chlorophyll a
Benthic metabolism

Parameterisation Method and Data Analysis

We obtained modelled daily concentration estimates of total phosphorus (TP) for 13 of the 27 sites sampled in the grazing landuse **gradient study.** The median daily predicted TP concentration over 5 years (2005–2009) was used to generate a relationship between TP and the % area of grazing and production forestry in a catchment. Figure 13 shows the relationship between the log10 median total phosphorous (LOGMEDTP) and % grazing in upstream catchment and % production forestry in upstream catchment.

Nutrient generation rates supplied by the Water Quality Simulator were used to extrapolate to other land-use types.

Land use	TP (kg/ha/yr)
Irrigated perennial horticulture	10.3
Grazing modified pastures	8.9
Plantations	2.5
Production forestry	0.4
Dairy pastures	0.2
Non-production native vegetation	0.001

(Sub-)catchment riparian vegetation condition was used to modify the relationships observed above, because catchments with a high proportion of grazing, horticulture and/or dairy farming were associated with poor riparian vegetation condition and catchments with a high proportion of production forestry or non-production native vegetation were associated with good riparian vegetation condition (see below). In general, good quality riparian vegetation condition is associated with low total phosphorus concentrations because vegetation can inhibit the transport of nutrients and sediments into the river (e.g. Lowrance et al. 1984).

Figure 14 shows the relationship between catchment riparian vegetation condition (RS_ACNRIPV from CFEV) and the proportion of a catchment classified as grazing and the proportion of a catchment classified as production forestry. Data are for the 27 catchments sampled in the gradient survey.

Review of Node

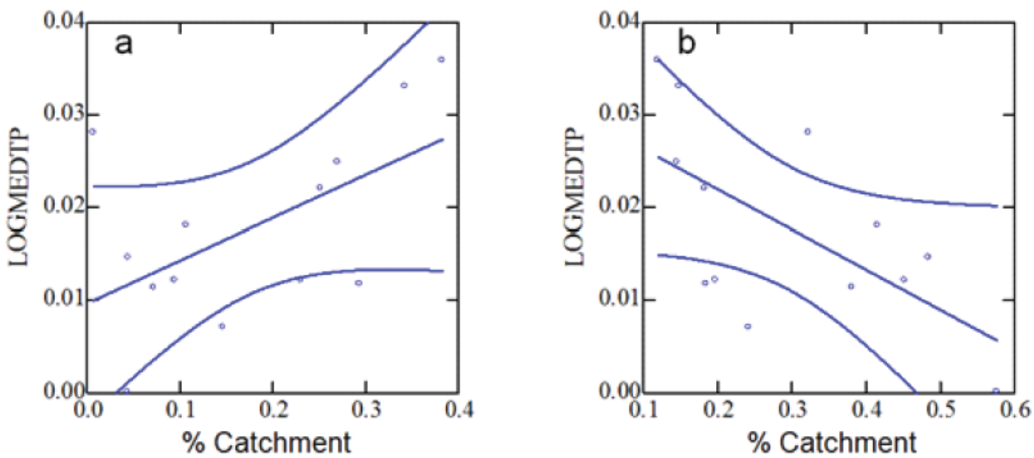


Figure 13. Figure 13 Relationship between log10 median total phosphorous (LOGMEDTP) and a) % grazing in upstream catchment and b) % production forestry in upstream catchment with 95% confidence limits.

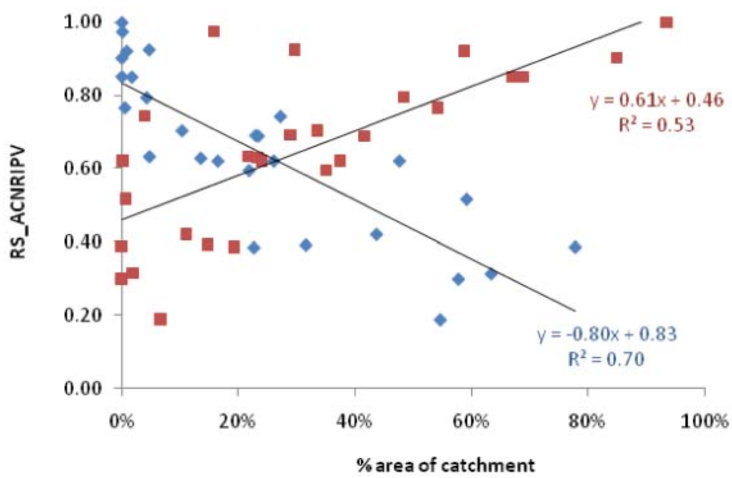


Figure 14. Figure 14 Relationship between catchment riparian vegetation condition (RS_ACNRIPV from CFEV) and the proportion of a catchment classified as grazing (blue), and the proportion of a catchment classified as production forestry (red).

Key Assumptions

Assumption	Validity of Assumption
Nutrient generation rates were appropriately estimated with the Landscape Logic Water Quality Simulator.	See assumptions relating to nutrient generation rates in the WQ Simulator and Landscape Logic publications by Broad et al. While the modelled data tended to overestimate peak nutrient concentrations and underestimate low nutrient concentrations, the median results were consistent with observed baseline DPIPWE water quality data as well as spot measurements taken at each of the grazing landuse gradient sites.
Soil type was assumed to have no effect on total phosphorus concentration as no effect could be detected in any of the available datasets.	New data are required to accurately parameterise this relationship.

Strengths, weaknesses and methods for improvement

Published nutrient generation rates (used in the initial development of the WQ simulator) and some expert opinion were used to separate the effects of the different land-use types as well as riparian vegetation condition.

The data used to create links between land-use and nutrients were also based on water quality results from a land use gradient survey that focused primarily on grazing by domestic life-stock.

References

Lowrance R, Todd R, Fail J, Jr., Hendrickson O, Jr., Leonard R, Asmussen L (1984). Riparian Forests as Nutrient Filters in Agricultural Watersheds. BioScience, 34: 374-377.

Variable: Nitrogen Concentration Regime

Description

Ranges of total nitrogen concentration (mg/L) in the river reach (section) of interest.

States

State	Description
Low	TN <0.5 mg/L
Moderate	TN = 0.5–0.7 mg/L
High	TN = 0.7–0.9 mg/L
Very high	TN >0.9 mg/L

Input Links

Land-use: sub-catchment
Soil type

Output Links

Algae % cover
Chlorophyll a
Benthic metabolism

Parameterisation Method and Data Analysis

Analysis of the available datasets indicated that the relationship between total nitrogen concentration (TN) and land-use was weaker (more variable) than that observed for total phosphorus. Modelled daily concentration estimates of TN for 13 of the 27 gradient sites did not significantly correlate with proportional area of any of the land-use categories.

The analysis of spot samples taken at 25 of the 27 sites showed that the area of several land-use types was weakly correlated with TN. In the table below, significance tests indicate whether the Spearmans correlations between TN and % area of land-use were significantly different from zero. A simple multiple regression incorporating all of the land-use types (squared) showed that % area of several land-uses was correlated with TN:
($F_{6,18} = 4.57$, $P = 0.006$, $R^2 = 0.60$).

Land-use	Spearmans, ρ	S	P
Non-production native vegetation	–0.037	2695	0.862
Grazing	0.29	1852	0.163
Production forestry	-0.31	3408	0.131
Plantation forestry	-0.18	3077	0.380
Dairy farming	0.60	1053	0.002
Horticulture	0.36	1656	0.07

These results, in combination with the nutrient generation rates developed for use by the Water Quality Simulator, were used to parameterise this node.

Land use	TN (kg/ha/yr)
Irrigated perennial horticulture	24.5
Grazing modified pastures	17.3
Plantations	12.8
Urban areas	7.6
Production forestry	6.9
Dairy pastures	3
Non-production native forest	1.5

Review of Node

Key Assumptions

Assumption	Validity of Assumption
Nutrient generation rates were appropriately estimated by the Landscape Logic Water Quality Simulator.	See assumptions relating to nutrient generation rates in the WQ Simulator and Landscape Logic publications by Broad et al.
That the effect of % area under dairy farming and horticulture on stream total nitrogen concentration is equivalent to that for grazing	Insufficient data to check this assumption.
Soil type was assumed to have no effect on total nitrogen concentration as no effect could be detected in any of the available datasets.	New data are required to accurately parameterise for this relationship.

Strengths, weaknesses and methods for improvement

Some of the data used to create links between % area land-use and nutrients were based on a land use gradient survey that focused primarily on grazing by domestic life-stock. Thus relationships built between % area of non-grazing land-use types and TN were based on less data than that for grazing.

References

N/A

Variable: Instream Substratum

Description

This variable represents the varying proportion of fines sediments (silt and sand) in the substrate of the river reach (section) of interest.

States

State	Description
Very low	Fine sediments make up 0–5% of benthic substrate area.
Low	Fine sediments make up 5–10% of benthic substrate area.
Moderate	Fine sediments make up 10–40% of benthic substrate area.
High	Fine sediments make up 40–60% of benthic substrate area.
Very high	Fine sediments make up >60% of benthic substrate area.

Input Links

Sediment regime
Hydrology regime
River-section slope

Output Links

SIGNAL O/E
Invertebrate total abundance
O/E
%EPT
FFG
Algae % cover
Chlorophyll a

Parameterisation Method and Data Analysis

The data collected for the forestry and grazing land use **gradient surveys** were used to parameterise this node. The proportion of fines was estimated using techniques consistent with the AUSRIVAS habitat assessment protocol. Four sites with naturally occurring fine sediments (contributed by area of granitic geology within their catchments) were excluded from the analysis.

River sections with a low slope and an altered sediment regime were more likely to have a high proportion of fines in the stream bed. These sites were also more likely to have an altered flow regime. Figure 15 below shows the relationship between river section slope (CFEV RS_SLOPE attribute), sediment inputs (RS_SEDIN attribute) and % bed-load fines (contours). A contour plot has been used to estimate the relationship surface where data were not available. The data shown were collected in a grazing land-use gradient surveys (24 catchments) and a forestry land-use gradient survey (39 catchments) across northern Tasmania. The plot shows that a high proportion of fines are expected when both slope and SEDIN are low.

Review of Node

Key Assumptions

Assumption	Validity of Assumption
Relationships between the input nodes and instream substrata were weak and data noisy, thus some exert opinion was required to fully parameterise this node.	Expert elicitation involved local stream ecologists and agricultural scientists with intensive knowledge of Tasmania and sediment dynamics.

References

N/A

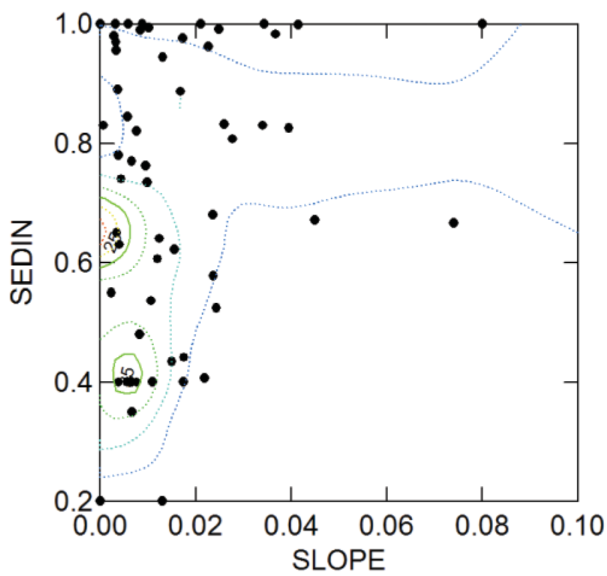


Figure 15. Relationship between river section slope (SLOPE), sediment inputs (SEDIN) and % bed-load fines (contours). The plot shows that a high proportion of fines are expected when both slope and SEDIN are low.

Variable: Turbidity

Description

Ranges of turbidity in the river reach (section) of interest. Turbidity is a measure of water clarity. It reflects the amount of light that is scattered and/or absorbed by molecules and particles suspended in the water column (e.g. clays and silts).(See www.ozcoasts.org.au/indicators/turbidity.jsp; Accessed 05/08/2010).

States

States were defined by considering the range of values observed in the grazing land use gradient survey and the ANZECC water quality guidelines (ANZECC 2000).

State	Definition
Clear	0–2 NTUs
Low	2–6 NTUs
Moderate	6–10 NTUs
High	>10 NTUs

[NTU = Nephelometric turbidity units]

Input Links

Land-use: sub-catchment
Riparian vegetation condition: sub-catchment
Soil type

Output Links

Light availability: local

Parameterisation Method and Data Analysis

The data collected for the gradient survey were used to parameterise this node. Turbidity was measured using a portable Hach turbidity meter in catchments across a range of % area under grazing land-use. The relationship between turbidity and % area of land-use and catchment riparian vegetation condition was weak, partly because turbidity levels were low in all of the rivers surveyed (maximum = 23 NTUs, mean = 4 NTUs). Expert opinion was used to extrapolate from the data collected. Higher turbidity levels were generally observed in rivers that had a high proportion of grazing in the upstream catchment and poor riparian vegetation condition. Figure 16 below shows the observed relationship between the amount of grazing in a catchment and turbidity across 27 Tasmanian river sites sampled in Summer 2009 and Summer 2010. The 2009 sampling occurred during a three year drought low flow spell and the 2010 sampling occurred shortly after higher than average spring rainfall.

Review of Node

Key Assumptions

Assumption	Validity of Assumption
Soil type was assumed to have no effect on turbidity as no effect could be detected in any of the available datasets.	It is known that the presence of dispersive clays in the catchment can strongly enhance stream turbidity. None of the gradient survey catchments contained significant area of dispersive clays. Additional data are required to accurately parameterise for this relationship for such catchments.

Strengths, weaknesses and methods for improvement

The data used to create links between land-use and turbidity were partially based on a gradient survey that focused primarily on grazing by domestic livestock. Thus relationships built between non-grazing land-use types and turbidity were based on less data than that for grazing.

References

ANZECC (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

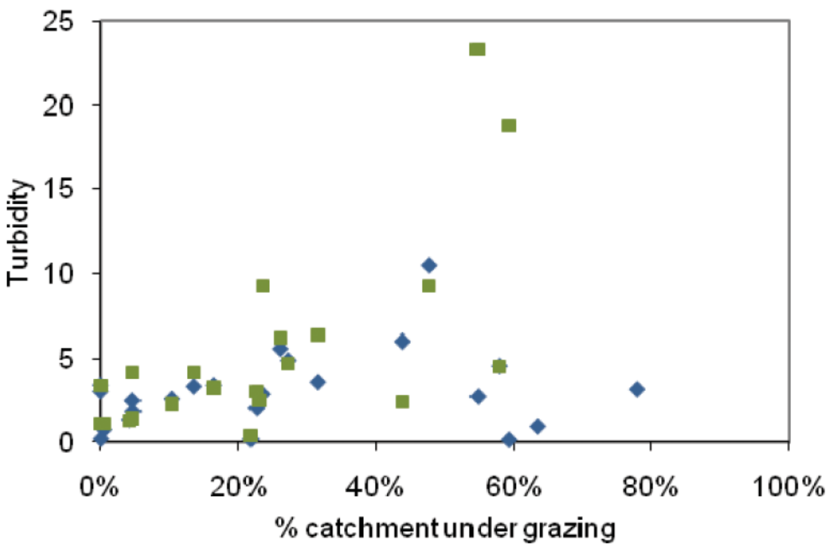


Figure 16. The relationship between turbidity and the amount of grazing in a catchment across 27 Tasmanian river sites sampled in Summer 2009 (blue) and Summer 2010 (green).

Variable: FFG

Description

The FFG (functional feeding groups) node represents the ratio of macroinvertebrate abundance represented by shredders to that of total abundance. (''Shredders''; see Gooderham and Tsyrlin 2002 for a description of trophic categories).

States

State	Description
Low	< 5% of total abundance as shredders
Moderate	5–20% as above
High	20–40% as above
Very High	> 40% as above

Input Links

Temperature regime
Night DO minimum
Instream substrata
Trophic carbon source

Output Links

TRCI: Macroinvertebrate indicator

Parameterisation Method and Data Analysis

FFG was selected as an index of macroinvertebrate community health as it indicates whether a substantial shift in trophic processes is occurring within the food web.

In the grazing **gradient survey** %Shredders was negatively correlated with the proportion of grazing in the upstream catchment of 27 sites in northern Tasmania (Figure 17), indicating that functional changes occurred in riverine food-webs within catchments dominated by grazing.

This node was parameterised using data from the grazing land use gradient survey. Macroinvertebrate families were categorised as collectors (filterers or gatherers), grazers/scrapers, parasites, piercers, predators or shredders according to classifications supplied by EPA Victoria (data sources: Campbell 1985; Campbell et al. 1998; Chessman 1986; Yule 1986; Dean, J.C. unpublished information and EPA Victoria unpublished information).

Review of Node

N/A

References

Gooderham J, Tsyrlin E (2002) The Waterbug Book : a guide to the freshwater macroinvertebrates of temperate Australia/ John Gooderham and Edward Tsyrlin. CSIRO Publishing, Collingwood, Vic.

Campbell IC (1985) Dietary habits of Australian siphlonurid and oligoneuriid ephemeropteran nymphs. **Verh.Internat.Verein. Limnol**, 22, 3250-3259.

Campbell IC, Parnrong S, Treadwell S (1998) Food availability and life history patterns of aquatic insects in evergreen eucalypt forest streams in southeastern Australia. **Verh.Internat. Verein.Limnol**, 26, 986-989.

Chessman BC (1986) Dietary studies of aquatic insects from two Victorian Rivers. Australian Journal of Marine and Freshwater Research, 37, 129-146.

Yule C (1986) Comparison of the dietary habits of six species of Dinotoperla (Plecoptera: Gripopterygidae) in Victoria. Australian Journal of Marine and Freshwater Research, 37,121-127.

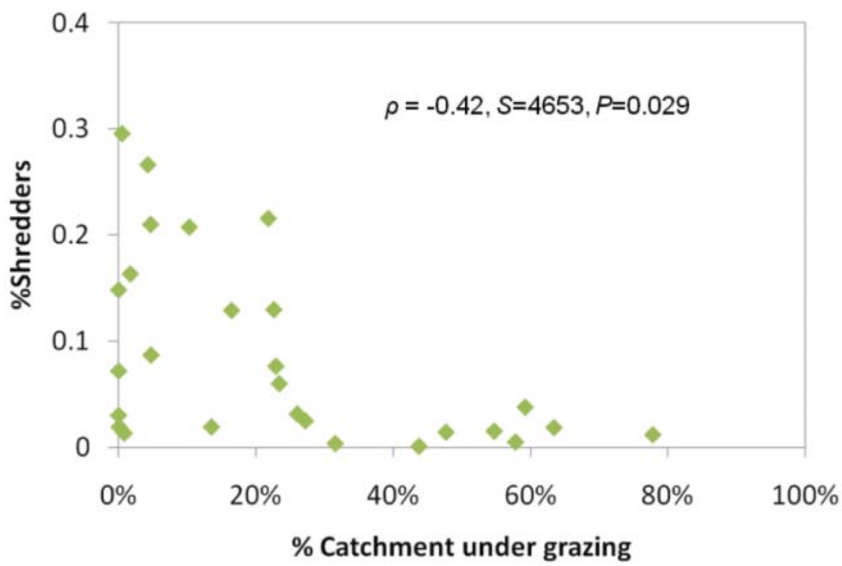


Figure 17. Relationship between %Shredders and the amount of grazing occurring in the upstream catchment of 27 sites in northern Tasmania.

Variable: SIGNAL O/E

Description

This node represents ranges of the macroinvertebrate sensitivity grading index, SIGNAL2 score (Chessman 2003) used to rate anthropogenic impacts on aquatic macroinvertebrate communities. SIGNAL O/E (DPIW 2009) is the ratio of the SIGNAL2 score observed at a site (O) to that expected under reference or un-impacted conditions (E).

States

State	Description
H-M	Score > 0.8, High to Medium
L	Score < 0.8, Low

Input Links

Temperature regime
Night DO minimum
Instream substrata
Trophic carbon source

Output Links

TRCI: Macroinvertebrates indicator

Parameterisation method and data analysis

SIGNALO/E was selected as an index of macroinvertebrate community health because of its use in AUSRIVAS and TRCI. In the grazing land use gradient survey SIGNAL O/E significantly declined as the proportion of area under grazing increased in the upstream catchment of 27 sites in northern Tasmania (Figure 18).

Relationship between SIGNAL O/E (Chessman 2003; DPIPWE 2009) and the amount of grazing occurring in the upstream catchment of 27 sites in northern Tasmania.

This node was parameterised using data from the grazing and forestry land use **gradient surveys**. The survey results indicated that low SIGNAL O/E scores were associated with high levels of fine sediment in the substrate, algal based food webs (high ratio of photosynthesis to respiration or P/R; Figure 19), high instream temperatures and low DO concentrations (see Figure 20). P/R was estimated using the open-channel metabolism technique (Grace and Imberger 2006).

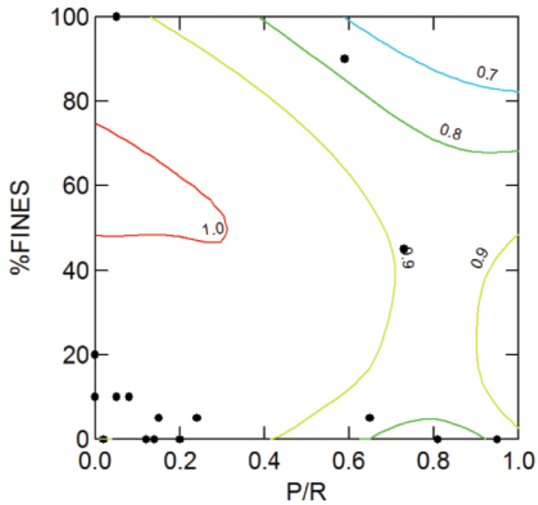


Figure 19. Results from the gradient survey indicated that low SIGNAL O/E scores (contours) occurred in sites that experienced a high proportion of fines in the benthic substrata and a high ratio of gross primary productivity to respiration (P/R).

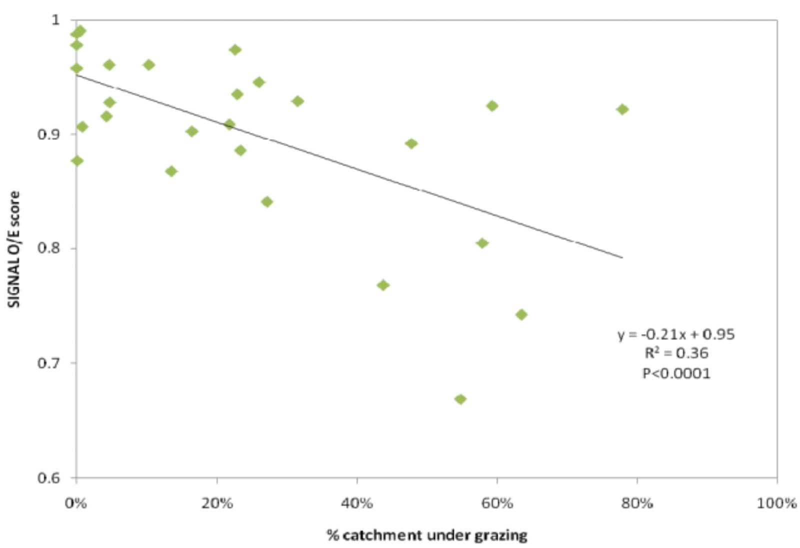
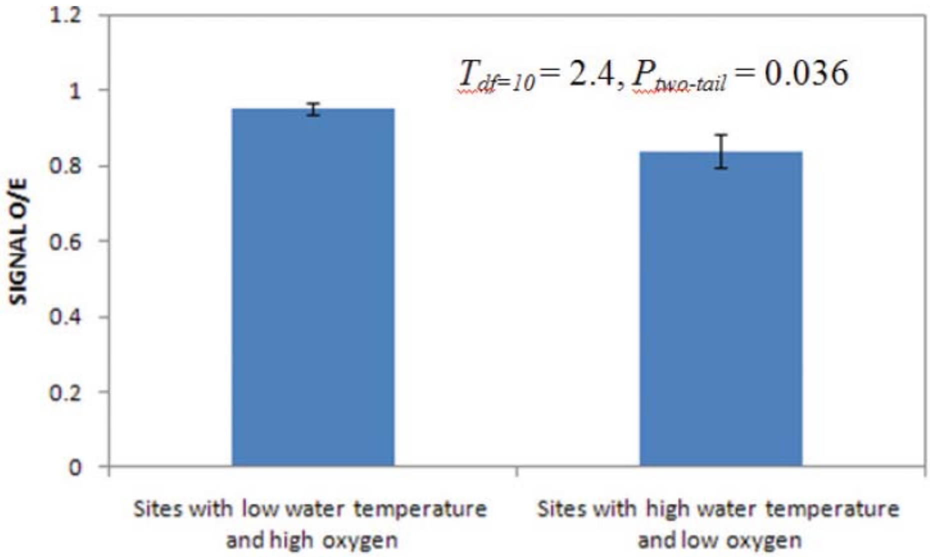


Figure 18. Relationship between SIGNAL O/E (Chessman 2003; DPIPWE 2009) and the amount of grazing occurring in the upstream catchment of 27 sites in northern Tasmania.

Figure 20.
Results from the gradient survey indicated that SIGNAL O/E scores were significantly higher in sites that had low in-stream temperatures (<20oC) and high night-time DO concentrations (>8 PPM) than in sites with high in-stream temperatures and low night-time DO concentrations.



Result from the grazing land use gradient survey indicated that SIGNAL O/E scores were significantly higher in sites that had low instream temperatures and high night-time DO concentrations than in sites with high instream temperatures and low night-time DO concentrations (see below). SIGNAL O/E scores were significantly higher in sites that had low in-stream temperatures (<20°C) and high night-time DO concentrations (>8 PPM) than in sites with high in-stream temperatures and low night-time DO concentrations. Expert opinion was used to gauge how much of the observed changes in SIGNAL O/E in the gradient survey were due to each of the individual input variables. Neural networks calibrated from the results of an artificial stream experiment examining the relative influence of light, nutrients and sediments (Davies unpub. data) were a useful guide in expert elicitation.

Review of Node

Strengths, weaknesses and methods for improvement

Expected/reference values of SIGNAL O/E for the gradient survey were calculated using a modified version of the Tasmanian riffle habitat AUSRIVAS models (Krasnicki et al. 2001), with adjustment because macroinvertebrates were collected using surber samples rather than the AUSRIVAS rapid assessment protocol. Scores were re-scaled by first calculating the mean score for sites at the low grazing end of the gradient and subtracting this from 1 (the mean for all reference sites in the AUSRIVAS model), this value was then subtracted from all raw SIGNAL O/E scores.

References

Chessman B (2003) SIGNAL 2 – A Scoring System for Macro-invertebrate ('Water Bugs') in Australian Rivers. Monitoring River Health Initiative Technical Report no 31, Commonwealth of Australia, Canberra.

Grace M, Imberger S (2006) Stream Metabolism: Performing and interpreting measurements, Monash University.

Krasnicki T, Pinto R, Read M (2001) Australia Wide Assessment of River Health: Tasmanian program : final report : submitted to Environment Australia January 2001. Dept. of Primary Industries, Water and Environment, Newtown, Tas.

Variable: Invertebrate Total Abundance

Description

Ranges of total abundance of invertebrates (per metre squared of benthic substrate in riffle habitats). Invertebrate total abundance was selected as an index of macroinvertebrate community health because substantial changes in abundance can occur due to poor water and habitat quality, or can be enhanced by organic pollution. This indicator is also used in the Tasmanian River Condition Index (TRCI). Total abundance is recorded per metre squared of substrate and the state definitions are based on the TRCI: Aquatic life index (NRM South 2009a; NRM South 2009b).

States

State	Description
Low	0–100 individuals per m^2
Moderate	100–700 individuals per m^2
High	700–4400 individuals per m^2
Very High	>4400 individuals per m^2

Input Links

Temperature regime
Night DO minimum
Instream substrata
Trophic carbon source

Output Links

TRCI: Macroinvertebrates indicator

Parameterisation Method and Data Analysis

This node was parameterised using data from the grazing land use **gradient survey**. The survey results indicated that low total abundances were associated with algal based food webs (high ratio of photosynthesis to respiration) and high total abundances were associated with a high proportion of fines in the benthic substrate. Total abundance (Figure 21) was high in sites that experienced a high proportion of fines in the benthic substrata and low when the ratio of gross primary productivity to respiration (P/R) was high. P/R was estimated using the open-channel metabolism technique (Grace and Imberger 2006).

There was no statistically significant difference in total abundance between sites that experienced high instream temperatures and low night-time DO concentrations and sites with low instream temperatures and high night-time DO concentrations (Figure 22). However, communities that experienced a combination of high temperature, low DO, high P/R and high fines tended to have low total abundances.

Expert opinion was used to gauge how much of the observed changes in total abundance in the gradient survey were due to each of the input variables individually. Neural networks calibrated from the results of an artificial stream experiment examining the relative influence of light, nutrients and sediments (Davies unpub. data) were a useful guide in expert elicitation.

Review of Node

N/A

References

Grace M, Imberger S (2006) Stream Metabolism: Performing and interpreting measurements, Monash University.

NRM South (2009a) Tasmanian River Condition Index Reference Manual.

NRM South (2009b) The Tasmanian River Condition Index Aquatic Life Field Manual.

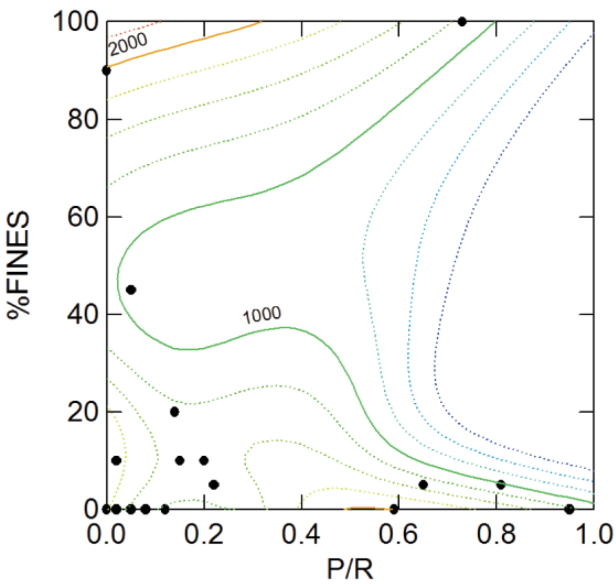


Figure 21. Result from the gradient survey indicated that total abundance (contours) was high in sites that experienced a high proportion of fines in the benthic substrata and low when the ratio of gross primary productivity to respiration (P/R) was high.

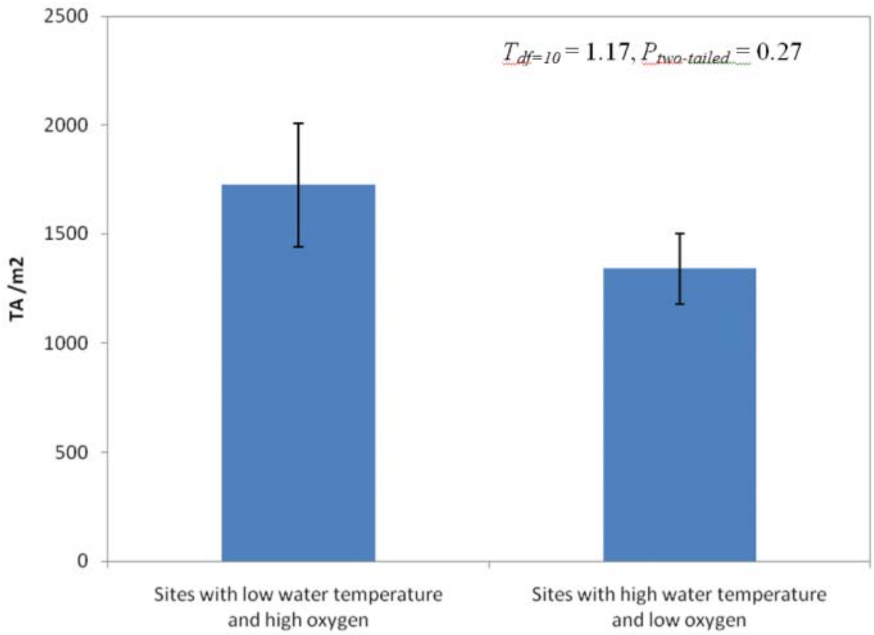


Figure 22.
Result from the gradient survey indicated that total abundance was not significantly different between sites that had low in-stream temperatures (<20°C) and high night-time DO concentrations (>8 PPM) and sites with high in-stream temperatures and low night-time DO concentrations.

Variable: O/E

Description

Ranges (or Bands) of the AUSRIVAS O/E condition score (Krasnicki et al. 2001) used to rate anthropogenic impacts on aquatic macroinvertebrate communities. O/E is an index of expectedness, contrasting the observed macroinvertebrate richness (family level) at a site (O) to that expected under reference or un-impacted conditions (E).

States

The state definitions for the O/E node in the River BN are from Gray (2004):

State (AUSRIVAS impairment bands)	Definition	Description
XA	Reference condition or better	Most expected macroinvertebrate families were found at the site. (O/E score falling within the X or A AUSRIVAS impairment bands)
B	Significantly impaired	Several expected macroinvertebrate families were not found at the site. (O/E score falling within the B AUSRIVAS impairment band)
CD	Severely to extremely impaired	Few expected macroinvertebrate families were found at the site. (O/E score falling within the C or D AUSRIVAS impairment bands)

Input Links

Temperature regime
Night DO minimum
Instream substrata
Trophic carbon source

Output Links

TRCI: Macroinvertebrate indicator

Parameterisation Method and Data Analysis

O/E was selected as an index of macroinvertebrate community health due to its general use in bioassessment of river condition (AUSRIVAS and TRCI assessments), and because in the grazing and forestry land-use gradient surveys, O/E significantly declined as the proportion of grazing and high intensity forestry operations increased in the upstream catchment of 27 and 35 sites, respectively, in northern Tasmania (Figure 23).

This node was parameterised using data from two Tasmanian land use **gradient surveys**. The survey results indicated that low O/E scores were associated with high sediment loads, algal based food webs (high ratio of photosynthesis to respiration), high instream temperatures and low DO concentrations. Low O/E scores occurred in sites that experienced a high proportion of fines in the benthic substrata and/or a high ratio of gross primary productivity to respiration (P/R) (see Figure 24). P/R was estimated using the open-channel metabolism technique (Grace and Imberger 2006).

O/E scores were also significantly higher in sites that had low instream temperatures and high night-time DO concentrations than in sites with high instream temperatures and low night-time DO concentrations (Figure 25).

Expert opinion was used to gauge how much of the observed changes in O/E in the gradient survey were due to each of the input variables individually. Neural networks calibrated from the results of an artificial stream experiment examining the relative influence of light, nutrients and sediments (Davies unpub. data) were a useful guide in expert elicitation.

Review of Node

Strengths, weaknesses and methods for improvement

Expected/reference values of O/E for the forestry and grazing land use gradient surveys were calculated using the AUSRIVAS model (Krasnicki et al. 2002), and were then adjusted because macroinvertebrates were collected using surber samples rather than the AUSRIVAS rapid assessment protocol. Scores were re-scaled by first calculating the mean score for sites at the low grazing end of the gradient and subtracting this from 1 (the mean for all reference sites in the AUSRIVAS model), this value was then subtracted from all raw O/E scores.

References

Grace M, Imberger S (2006) Stream Metabolism: Performing and interpreting measurements, Monash University.

Gray BJ (2004) Australian River Assessment System: National Guidelines for Mapping AusRivAS Macroinvertebrate Scores, Monitoring River Health Initiative Technical Report Number 38. Department of the Environment and Heritage, Canberra.

Krasnicki T, Pinto R, Read M (2001) Australia Wide Assessment of River Health : Tasmanian program : final report : submitted to Environment Australia January 2001. Dept. of Primary Industries, Water and Environment, Newtown, Tas.

Krasnicki T, Pinto R, Read M (2002) Australia-Wide Assessment of River Health: Tasmanian Bioassessment Report (TAS Final Report) Monitoring River Health Initiative Technical Report Number 5, Environment Australia. Department of Primary Industries, Water and Environment.

Figure 23. Relationship between O/E score (Krasnicki et al. 2001) and the amount of grazing occurring in the upstream catchment of 27 sites in northern Tasmania.

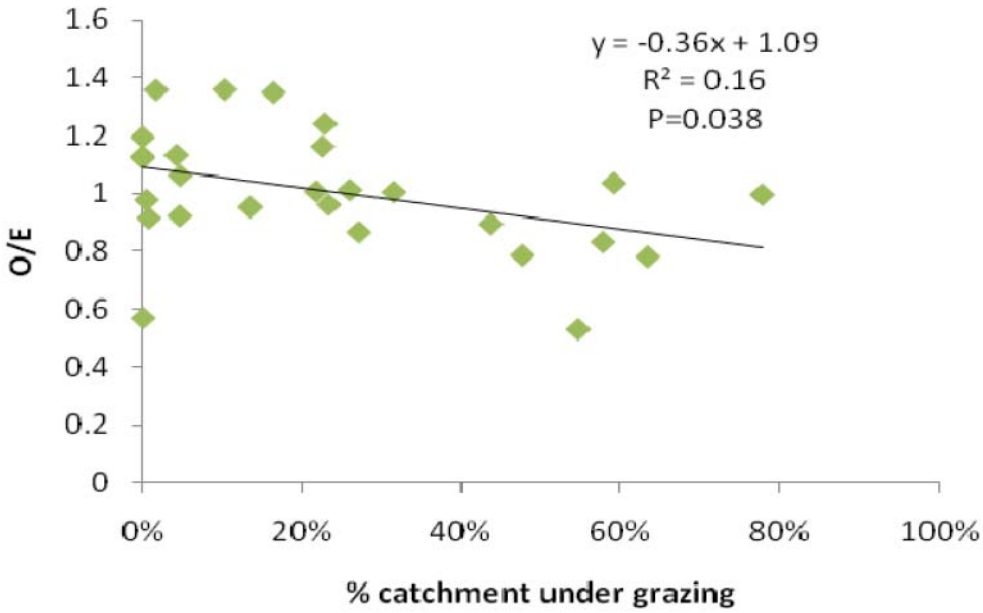


Figure 24. Results from the gradient survey indicated that low O/E scores (contours) occurred in sites that experienced a high proportion of fines in the benthic substrata and a high ratio of gross primary productivity to respiration (P/R).

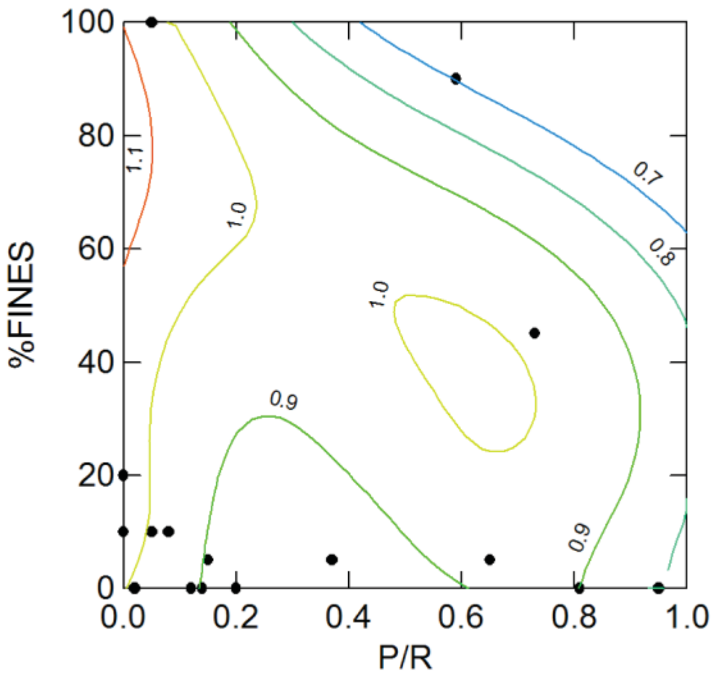
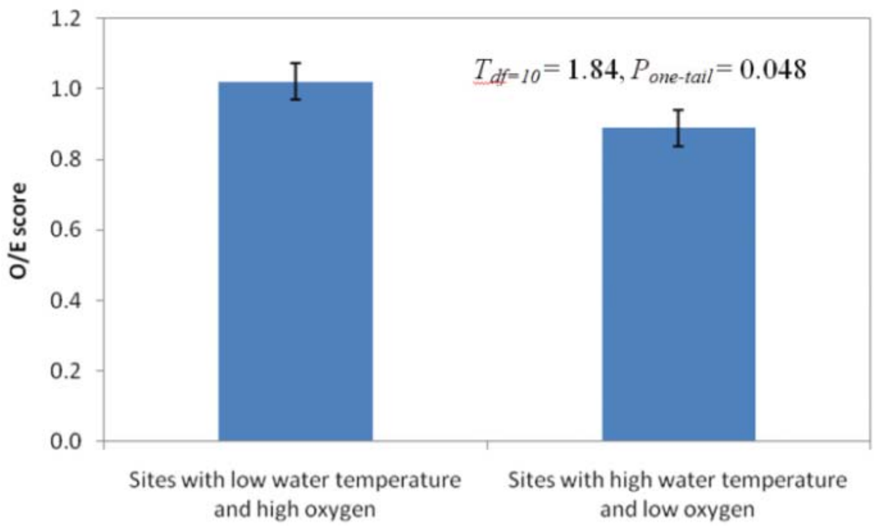


Figure 25. Results from the gradient survey indicated that O/E scores were significantly higher in sites that had low in-stream temperatures (<20°C) and high night-time DO concentrations (>8 PPM) than in sites with high in-stream temperatures and low night-time DO concentrations.



Variable: %EPT Richness

Description

The proportion of the total macroinvertebrate family richness represented by the aquatic insect orders Ephemeroptera, Plecoptera and Trichoptera (NRM South 2009); mayflies, stoneflies and caddisflies respectively. These orders are good biological indicators as they are species rich and sensitive to anthropogenic impacts (NRM South 2009).

States

State	Description
Low	0–15% of all families being from the EPT orders
Moderate	15–25% as above
High	25–35% as above
Very High	35–100% as above

Input Links

Temperature regime
Night DO minimum
Instream substrata
Trophic carbon source

Output Links

TRCI: Macroinvertebrate indicator

Parameterisation Method and Data Analysis

%EPT was selected as an index of macroinvertebrate community health. It is also used in the Tasmanian River Condition Index (TRCI). In the forestry and grazing land use gradient surveys, %EPT significantly declined as the proportion of high intensity forestry and grazing increased in the upstream catchment of 27 and 35 sites, respectively, in northern Tasmania (Figure 26).

This node was parameterised using data from the **gradient surveys**. Low %EPT scores occurred at sites with a high proportion of fines in the benthic substrate and a high ratio of gross primary productivity to respiration (P/R) (Figure 27). P/R was estimated using the open-channel metabolism technique (Grace and Imberger 2006).

There was no significant difference in %EPT between sites that experienced high instream temperatures and low night-time DO concentrations and sites with low instream temperatures and high night-time DO concentrations (Figure 28). However, communities that experienced a combination of high temperature, low DO, high P/R and high fines tended to have low %EPT scores.

Expert opinion was used to gauge how much of the observed changes in O/E in the gradient surveys were due to each of the individual input variables. Neural networks calibrated from the results of an artificial stream experiment examining the relative influence of light, nutrients and sediments (Davies unpub. data) were a useful guide in expert elicitation.

Review of Node

N/A

References

Grace M and Imberger S (2006) Stream Metabolism: Performing and interpreting measurements, Monash University.

NRM South (2009) Tasmanian River Condition Index Reference Manual.

Figure 26. Relationship between %EPT score and the amount of grazing occurring in the upstream catchment of 27 sites in northern Tasmania.

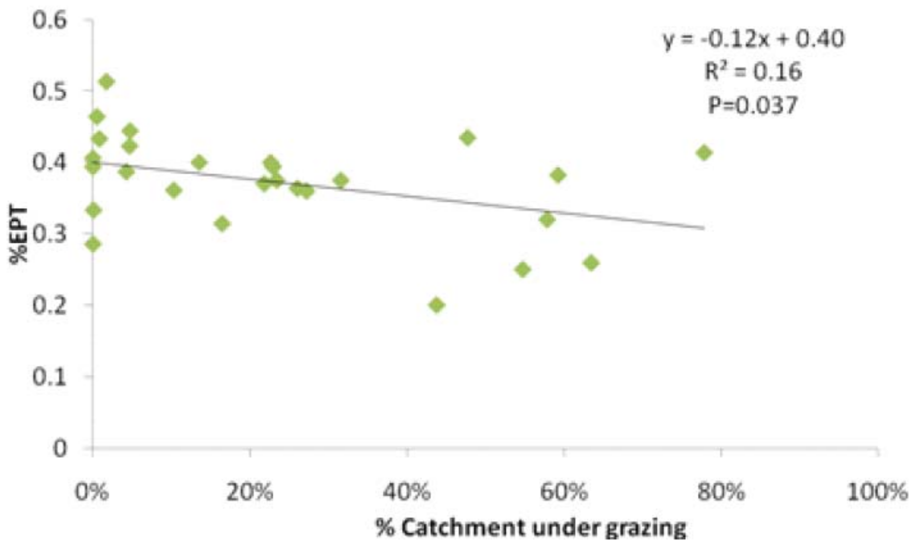


Figure 27. Results from the gradient survey indicated that low %EPT scores (contours) occurred at sites that experienced a high proportion of fines in the benthic substrata and a high ratio of gross primary productivity to respiration (P/R).

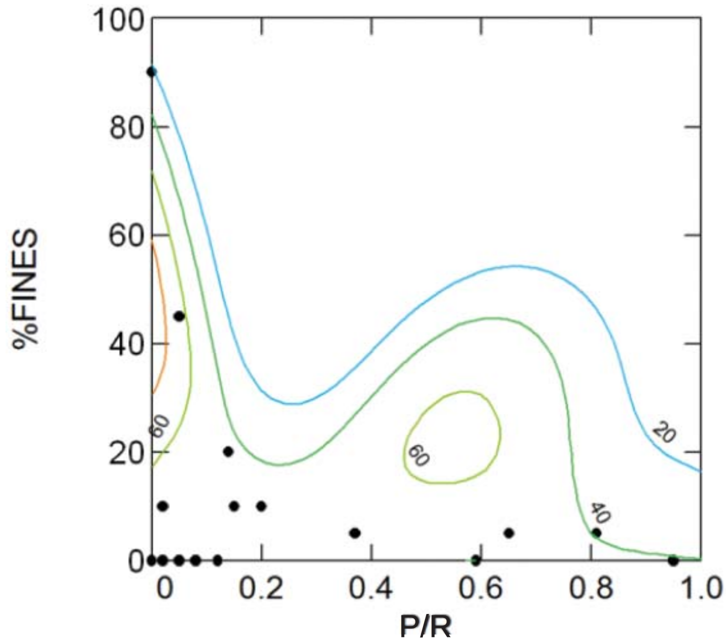
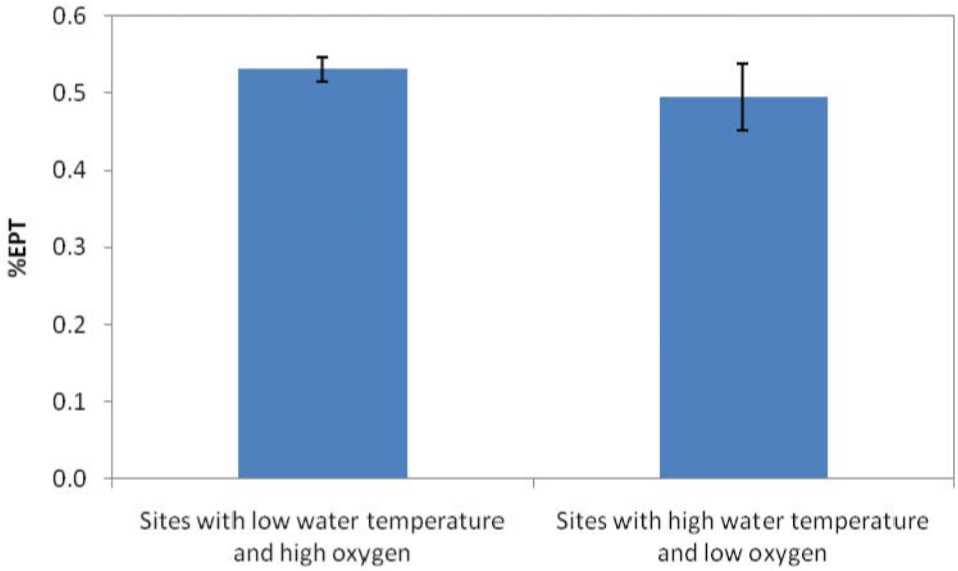


Figure 28. Results from the gradient survey indicated that %EPT was not significantly different between sites that had low in-stream temperatures (<20°C) and high night-time DO concentrations (>8 PPM) and sites with high in-stream temperatures and low night-time DO concentrations.



Variable: Trophic Carbon Sources

Description

This node identifies the dominant carbon source (from primary production) of the instream food-web. Potential stream food web carbon sources are periphyton (algae and diatoms or autochthonous production) and particulate organic matter (POM or allochthonous production). The primary origin of POM is leaf fall from the riparian zone.

States

State definitions for the Trophic carbon source node in the River BN:

State	Description	Expected P/R
Algae dominated	The predominant carbon source is algae	P/R >1
Mostly algae	Carbon sources include both algae and POM (Algae:POM = 3:1)	0.75> P/R <1
Mostly POM	Carbon sources include both algae and POM (Algae:POM = 1:3)	0.5> P/R <0.75
POM dominated	The predominant carbon source is POM	P/R <0.5

Input Links

Riparian vegetation condition: sub-catchment
Riparian vegetation condition: local
% Algae cover
Chlorophyll a

Output Links

SIGNAL O/E
Invertebrate total abundance
O/E, %EPT and FFG

Parameterisation Method and Data Analysis

This node was parameterised using open-channel metabolism data collected in the grazing land use gradient survey. The ratio of reach scale instream photosynthesis to respiration (P/R) can be used to infer whether a river relies on autochthonous vs. allochthonous sources of carbon. Reach-scale gross primary productivity (P, $gO_2/m^2/day$) and respiration (R, $gO_2/m^2/day$) were estimated using single-station, open-channel metabolism measurements (Grace and Imberger 2006). A modified version of an Excel® spreadsheet used to estimate ecosystem metabolism and described in (Young et al. 2006; Young et al. 2004) was used to perform calculations. The modification resulted in slightly higher estimates of P than those estimated by the Young et al. model (negative night time values of P were adjusted to zero).

P/R can be used to infer whether instream food webs require allochthonous production to sustain the metabolism of consumers (estimated from total respiration). P/R ratios greater than 1 indicate that primary production is sufficient to support respiration, ratios <0.5 indicate that other allochthonous carbon sources must be important.

High values of P/R were associated with poor riparian vegetation condition (low values of the CFEV RS_NRIPV and RS_ACNRIPV attributes) and high algal percent cover or biomass (Figure 29). Note that none of the sites sampled had extremely high levels of algal cover and biomass, thus Figure 29b does not accurately represent their relationship with P/R in the upper right quadrant. P/R was estimated using the open-channel metabolism technique (Grace and Imberger 2006).

Review of Node

Key Assumptions

Assumption	Validity of Assumption
Benthic metabolism was adequately estimated using the open-channel metabolism technique.	The open channel technique used is less precise than using benthic metabolism chambers because oxygen reaeration was estimated through night-time regression. However, this was the preferred technique as benthic chambers only measure production at a very small scale (individual rocks in riffle habitats), are highly spatially variable, and measurements cannot be readily re-scale to represent the whole river reach. See Grace and Imberger (2006) for a detail description of the assumptions of the use-of open channel technique and a comparison of how this technique compares to the use of metabolism chambers to determine benthic metabolism.

Strengths, weaknesses and methods for improvement

Metabolism data was only available for 18 of the 27 sites surveyed in the grazing land use gradient survey and thus there were limited data available for building relationships with this node. However, these data did include a broad range of P/R values.

References

Grace M and Imberger S (2006) Stream Metabolism: Performing and interpreting measurements, Monash University.
Young R, Matthaei C, Townsend C (2006) Functional Indicators of Rover Ecosystem Health – Final Project Report. Prepared for Ministry for the Environment, p 38 pp.
Young R, Townsend C, Matthaei C (2004) Functional Indicators of River Ecosystem Health – An interim guide for use in New Zealand. Prepared for the Ministry for the Environment.

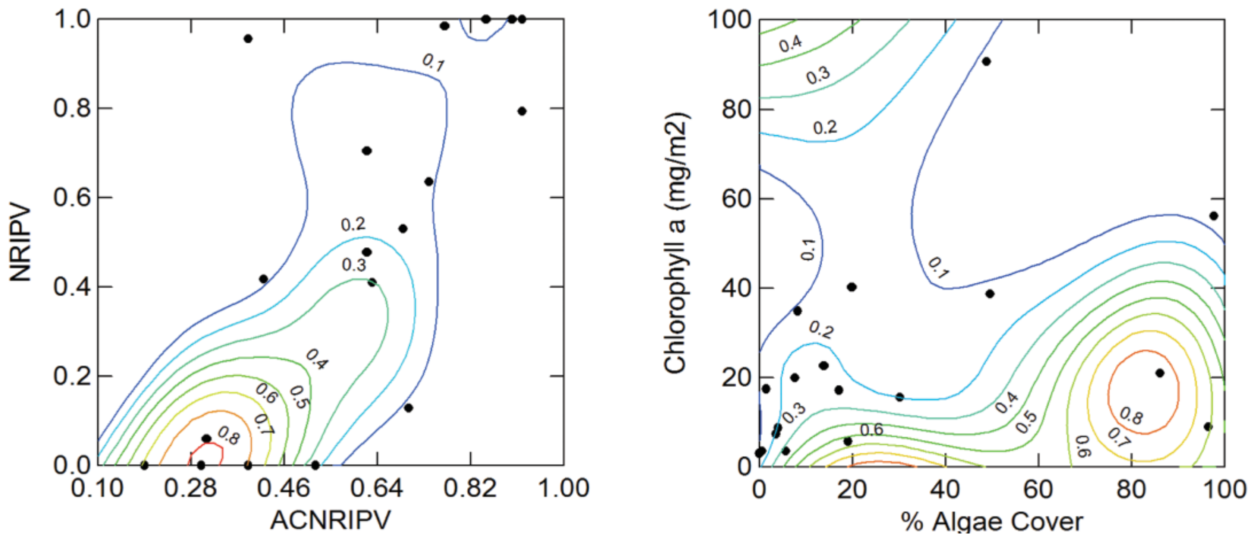


Figure 29. Results from the gradient survey indicated that higher P/R ratios (contours) occurred in sites that a) had low scores for local (NRIPV) and catchment (ACNRIPV) riparian vegetation condition and b) high algal cover or biomass (chlorophyll a).

Variable: Algae % Cover

Description

Ranges of % area cover of the stream bed by benthic algae.

States

State	Description
Very Low	0–20% of benthic area
Low	20–40%
Moderate	40–60%
High	60–80%
Very High	80–100%

Input Links

Instream substrata
N concentration regime
P concentration regime
Light availability: local

Output Links

TRCI: Benthic algae indicator
Trophic carbon source

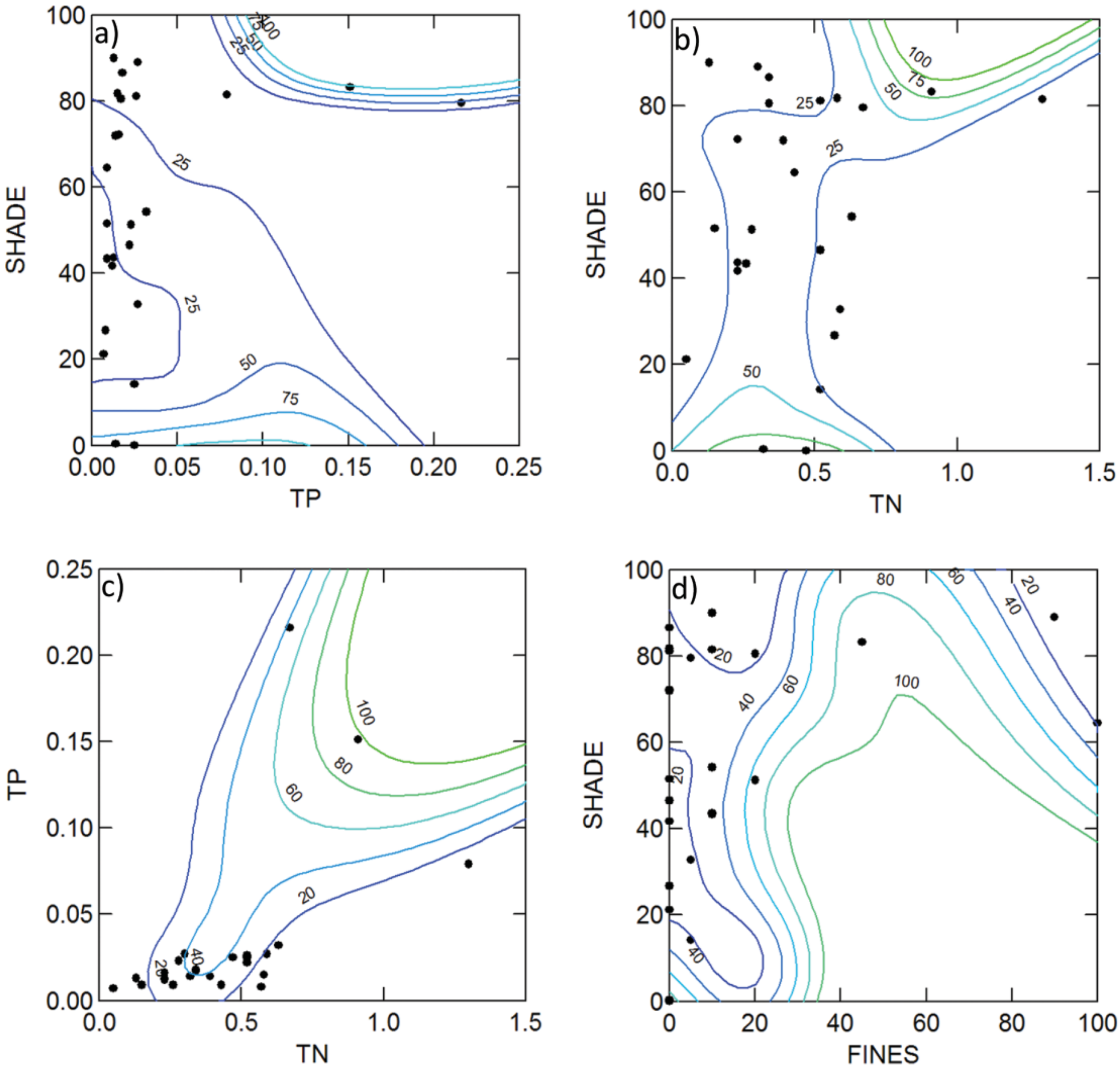
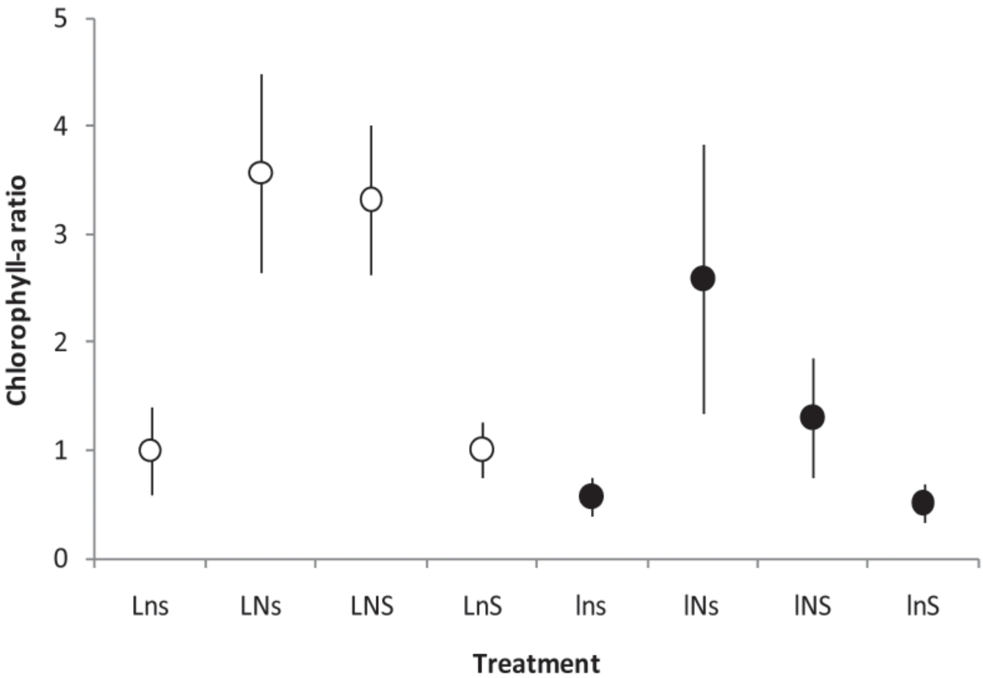


Figure 30. Variation in algae percent cover (contours) at gradient survey sites: a) algal cover was high at very high concentrations of total phosphorus (TP) or moderate concentrations of phosphorus and low % shade; b) algal cover was high at very high concentrations of total nitrogen (TN) or moderate concentrations of nitrogen and low % shade; c) Total nitrogen and phosphorus were correlated and high concentrations of both resulted in high algal cover and d) algal cover was highest at sites with a moderate amounts of fine sediment in the benthic substrata.

Figure 31. Results from an artificial stream experiment suggest that adding fine sediments to a river can reduce the effects of nutrient addition on algal biomass (chlorophyll a) under low light conditions. C= control; N= nutrients added, n=no nutrients added; L=ambient light levels, l= reduced light levels; S=sediments added, s= no sediments added.



Parameterisation Method and Data Analysis

Several data sources were available for the parameterisation of this node; a land use **gradient survey** and associated nutrient limitation experiments, the **AUSRIVAS database** (DPIPWE unpub. data), an **artificial stream experiment** (Davies unpub. data), **data collected from a nutrient and algae study in the Huon catchment** (Davies 2009), as well as a range of international literature on the effects of nutrients, light and sediments on algae (e.g. Biggs 2000, Mosisch et al. 2001, Francoeur and Biggs 2006,). All data sets indicated similar relationships between algae, nutrients, light and sediment (where tested), only results from the gradient survey and artificial stream experiment are presented here.

Algal cover was highest at sites with high nutrient concentrations (total nitrogen and phosphorus) and light levels and moderate fine sediment inputs (Figure 30a,b). Expert opinion and observations in the international literature was required to separate the individual effects of nitrogen and phosphorus because their concentrations were positively correlated across the gradient (Figure 30c). Phosphorus was considered to have a greater effect than nitrogen because low phosphorus concentrations limited algal production at some sites (nutrient limitation experiments).

There were limited data from the gradient survey available for parameterising the effect of fine sediments on algal cover. The results obtained did suggest that a very high proportion of fines in the benthic substrata may have a negative effect on algal cover. While the data coverage is poor, the contour plot suggests that algal cover is highest when sediments are moderate and light levels high (Figure 30d). This result is consistent with results from the Tasmanian artificial stream experiment (Davies unpub. data). In the experiment fine sediments reduced the effect of nutrients on algal biomass (chlorophyll a) when light levels were low (Figure 31).

Review of Node

N/A

References

Biggs BJF (2000) Eutrophication of streams and rivers: dissolved nutrient-chlorophyll relationships for benthic algae. Journal of the North American Benthological Society 19: 17-31

Francoeur SN, Biggs BJF (2006) Short-term effects of elevated velocity and sediment abrasion on benthic algal communities. Hydrobiologia 561: 59-69

Mosisch TD, Bunn SE, Davies PM (2001) The relative importance of shading and nutrients on algal production in subtropical streams. Freshwater Biology 46: 1269-1278

Variable: Local Light Availability

Description

Local light availability represents the amount of shading in the river reach (section) of interest. Shading can be caused by overhead vegetation, turbidity and surrounding topography (banks and hills). Topographic and vegetation shading are usually measured with a hemi-spherical densiometer or fish-eye lens (e.g. Davies-Colley and Payne 1998; Davies et al. 2004; Hawkins et al. 2003).

States

State	Description
High	<60% shading of stream bed
Moderate	60–80%
Low	>80%

Input Links

Riparian vegetation condition: local
Turbidity

Output Links

Algae % cover
Chlorophyll a
TRCI: Benthic algae indicator

Parameterisation Method and Data Analysis

This node was parameterised directly from the riparian vegetation condition: local node and then adjusted for the effect of turbidity (by expert opinion). Turbidity was assumed to only influence the light environment at values greater than 10 NTUs. This level of turbidity was rare in the gradient survey (average= 4 NTUs, max. = 23 NTUs).

Review of Node

Strengths, weaknesses and methods for improvement

In the River BN, topography is assumed to not influence the local light environment, and this may be incorrect for sites in confined valley settings. Users can alter this node or the value for riparian vegetation condition: local, if bank and hill shade are important at their site.

References

Davies-Colley RJ, Payne GW (1998) Measuring Stream Shade. Journal of the North American Benthological Society, 17: 250-260.

Davies PM, Cook B, Walshe T (2004) Managing high instream temperatures using riparian vegetation. A manual for river managers. University of Western Australia.

Hawkins C, Ostermiller J, Vinson M, Stevenson RJ, Olson J (2003) Stream Algae, Invertebrate, and Environmental Sampling Associated with Biological Water Quality Assessments: Field Protocols, Utah State University.

Variable: TRCI Macroinvertebrates Indicator

Description

Ranges (bands) of scores of the Tasmanian River Condition Index (TRCI) Aquatic Life Macroinvertebrates indicator. This integrates the scores for SIGNAL O/E, total macroinvertebrate abundance, AUSRIVAS O/E and %EPT, based on the relevant TRCI rule set.

Input Links

SIGNAL O/E
Invertebrate total abundance
O/E
%EPT

Output Links

TRCI: Aquatic life

Parameterisation Method and Data Analysis

This node was parameterised based on the TRCI rule sets, see NRM South 2009 and associated Excel® workbook.

Review of Node

N/A

References

NRM South (2009) Tasmanian River Condition Index Reference Manual.

States

State definitions for the TRCI (NRM South 2009) macroinvertebrate indicator node in the River BN are tabled below. The description provided indicates value ranges for the different input variables to this index; the exact score depends on the particular combination of values (NRM South 2009).

State	TRCI score	Description
Good	80–100	SIGNAL O/E: low – high; O/E = XA, total abundance = 700–4400 and %EPT > 0%.
Moderate	40–79	SIGNAL O/E: low – high; O/E = XA, B or CD, total abundance = > 0 and %EPT > 0%.
Poor	20–39	SIGNAL O/E: low – high; O/E = B or CD, total abundance = > 0 and %EPT > 0%.
Extremely poor	0–19	SIGNAL O/E: low – high; O/E = CD, total abundance = < 700 or > 4400 and %EPT ≥ 0%.

Variable: Chlorophyll a (Algal biomass)

Description

Ranges of benthic algal chlorophyll a (mg/m^2). Chlorophyll a is the molecule present in all plants and algae which makes photosynthesis possible. Chlorophyll a concentrations are used here as a surrogate measure of benthic algal biomass.

States

State	Description
Low	0–15 mg chlorophyll a/m^2 of stream bed
Moderate	15–30 mg/m^2
High	30–60 mg/m^2
Very High	>60 mg/m^2

Input Links

Instream substrata
N concentration regime
P concentration regime
Light availability: local

Output Links

TRCI: Benthic algae indicator
Trophic carbon source

Parameterisation Method and Data Analysis

Several data sources were available for the parameterisation of this node; two land use **gradient surveys** and an associated nutrient limitation assessment, the **AUSRIVAS database** (DPIPWE unpub. data), an **artificial stream experiment** (Davies unpub. data) and data collected from a **nutrient and algae study** in the Huon catchment (Davies 2010). All data sets indicated similar relationships between algae, nutrients, light and sediment (where tested), hence only results from the gradient survey and artificial stream experiment are presented.

Chlorophyll a (mg/m^2) was highest at sites with high nutrient (total nitrogen and phosphorus) concentrations and moderate fine sediment inputs. A response to nutrients was evident even at relatively low light levels (~80% shading). Nutrients had little effect unless nutrient concentrations of both nitrogen and phosphorus were extremely high (Figure 32a,b). The individual effects of nitrogen and phosphorus because their concentrations were both positively correlated across the gradient (Figure 32c). Phosphorus was considered to have a greater effect than nitrogen because low phosphorus concentrations limited algal production at some sites (as indicated by nutrient limitation experiments using nutrient diffusing substrates deployed at grazing land use gradient survey sites). This was particularly true in rivers experiencing high light conditions e.g. wide rivers where riparian vegetation only partially covers the river. Shading levels above 80% were assumed to limit the effects of nutrients on algal biomass.

There were limited data from the gradient survey available for parameterising the effect of fine sediments on algal biomass. The results obtained did suggest that a very high proportion of fines in the benthic substrata may have a negative effect on algal biomass (Figure 32d). While the data coverage is poor, the contour plot suggests that algal cover is highest when sediments are low-moderate and light levels high (Figure 33). This result is consistent with results from the artificial stream experiment (Davies unpub. Data; figure below) when nutrients are not limiting.

Review of Node

N/A

References

N/A

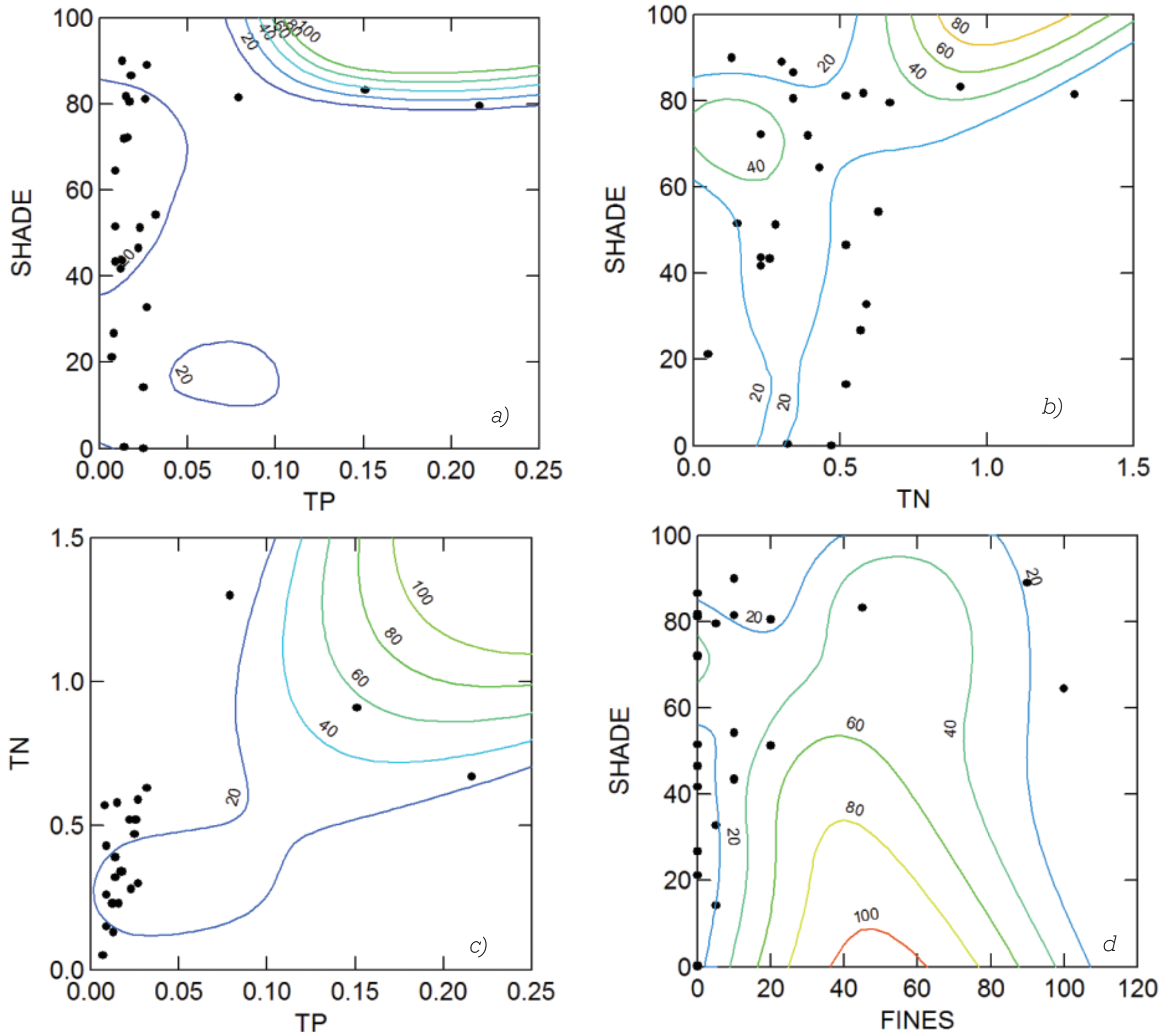
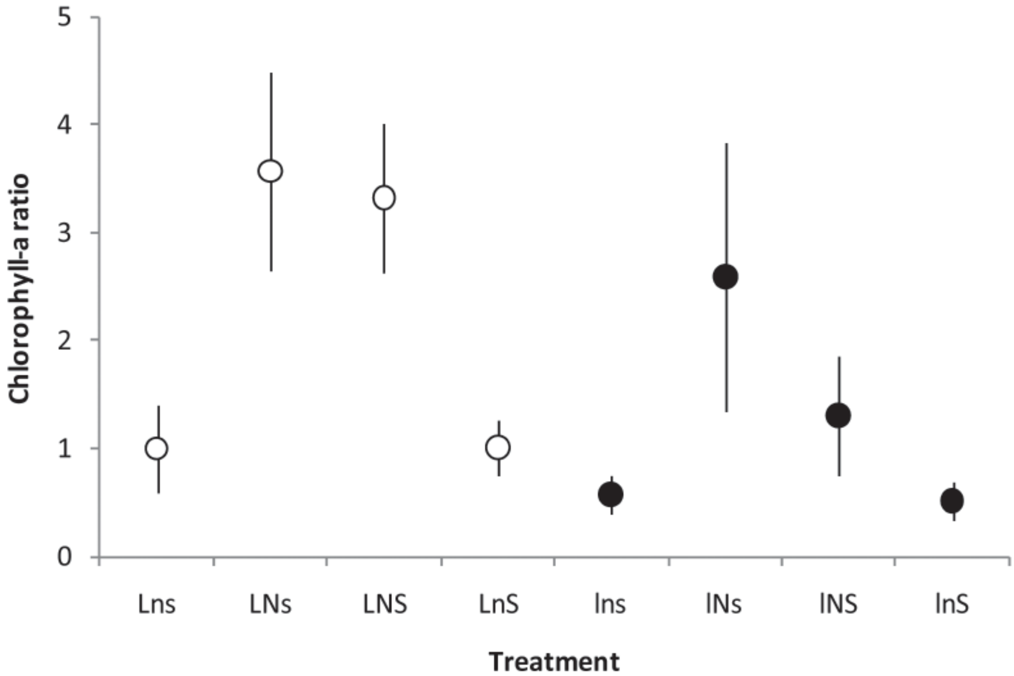


Figure 32. Variation in chlorophyll a concentration (mg/m²; contours) at gradient survey sites: a) chlorophyll a concentrations were high at very high concentrations of total phosphorus (TP) and at relatively high levels of shade; b) chlorophyll a concentrations were high at very high concentrations of total nitrogen (TN) and at relatively high levels of shade; c) Total nitrogen and phosphorus were correlated and high concentrations of both resulted in high chlorophyll a concentrations and d) chlorophyll a concentrations were highest at sites with a moderate amount of fine sediment in the benthic substrata, provided shading was low.

Figure 33. Results from an artificial stream experiment suggest that adding fine sediments to a river can reduce the effects of nutrient addition on algal biomass (chlorophyll a) under low light conditions. C= control; N= nutrients added, n=no nutrients added; L=ambient light levels, l= reduced light levels; S=sediments added, s= no sediments added.



Variable: TRCI Aquatic Life

Description

Ranges (bands) of scores of the Tasmanian River Condition Index (TRCI) Aquatic Life Index. This integrates the scores of the TRCI Macroinvertebrate and benthic algal indicators, based on the relevant TRCI rule set.

States

State definitions for the TRCI: Aquatic life node in the River BN are tabled below. The description provided indicates value ranges for the different input variables to this index; the exact score depends on the particular combination of values (NRM South 2009).

State	TRCI Score	Description
Good	80–100	Macroinvertebrate score high and algal score high.
Moderate	60–79	Macroinvertebrate score high and algal score moderate.
Poor	40–59	Macroinvertebrate score moderate-high and algal score low-high.
Very poor	20–39	Macroinvertebrate score low-moderate and algal score low-high.
Extremely poor	0–19	Macroinvertebrate score low and algal score low-moderate.

Input Links

TRCI Macroinvertebrates Indicator
TRCI Benthic Algae Indicator

Output Links

N/A

Parameterisation Method and Data Analysis

This node was parameterised according to the TRCI rules sets, see NRM South 2009 and associated Excel® workbook.

Review of Node

N/A

References

NRM South (2009) Tasmanian River Condition Index Reference Manual.

Variable: TRCI Benthic Algae Indicator

Description

Ranges (bands) of scores of the Tasmanian River Condition Index (TRCI) Aquatic Life Benthic Algal indicator. This integrates the scores for algae % cover, chlorophyll a (algal biomass) and light availability, based on the relevant TRCI rule set (NRM South 2009).

States

State definitions for the TRCI: Benthic algae node in the River BN are tabled below. The description provided indicates value ranges for the different input variables to this index, the exact score depends on the particular combination of values (NRM South 2009).

Rating	TRCI Index	Description
Good	80–100	Algal biomass score low and cover score low-high.
Moderate	40–79	Algal biomass score moderate and cover score low-high.
Poor	20–39	Algal biomass score high and cover score low-moderate.
Extremely poor	0–19	Algal biomass score and cover score high.

Input Links

Algae % cover
Chlorophyll a
Light availability: local

Output Links

TRCI: Aquatic life

Parameterisation Method and Data Analysis

This node was parameterised according to the TRCI rules sets, see NRM South 2009 and associated Excel® workbook.

Review of Node

N/A

References

NRM South (2009) Tasmanian River Condition Index Reference Manual.

Appendix 2: Tasmanian catchments and sub-catchments not included in the domain of the River BN.

All other Tasmanian catchments and sub-catchments fall within the domain of relevance to the BN.

Catchments		
CFEV identifier	**Catchment name**	**Reasons for exclusion**
1	Wanderer-Giblin	West coast catchment
2	Gordon-Franklin	Located in World Heritage Area
3	King-Henty	West coast catchment
4	Port Davey	Located in World Heritage Area
5	Pieman	West coast catchment
6	Nelson Bay	West coast catchment
10	King Island	Island
18	Blythe	Granite geology in 30% of catchment
19	Huon	Located in World Heritage Area
22	Ouse	Located on central plateau
31	Great Lake	Located on central plateau
41	Great Forester-Brid	Granite geology in 31% of catchment
44	George	Granite geology in 75% of catchment
45	Boobyalla-Tomahawk	Granite geology in 29% of catchment
46	Ringarooma	Granite geology in 47% of catchment
47	Furneaux	Granite geology in 29% of catchment
48	Musselroe-Ansons	Granite geology in 53% of catchment

Sub-catchments		
CFEV identifiers	**Catchment name**	**Reasons for exclusion**
1001, 1002, 1003, 1004, 1005, 1006, 1007, 1008, 1009, 1010, 1011, 1012, 1013, 1014, 1015, 1016, 1017, 1018, 1019, 1020, 1021, 1022, 1023, 1024, 1025, 1026, 1027, 1028, 1029, 1030, 1031, 1032, 1033, 1034, 1035, 1036, 1037, 1038, 1039, 1040, 1041, 1042, 1043, 1044, 1045, 1046, 1047, 1048, 1049, 1050, 1051, 1052	Wanderer–Giblin	Located in World Heritage Area
2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103	Gordon–Franklin	Located in World Heritage Area

3001, 3002, 3003, 3004, 3005, 3006, 3007, 3008, 3009, 3010, 3011, 3012, 3013, 3014, 3015, 3016, 3017, 3018, 3019, 3020, 3021, 3022, 3023, 3024, 3025, 3026, 3027, 3028, 3029, 3030, 3031, 3032, 3033, 3034, 3035, 3036, 3037, 3038, 3039, 3040	King–Henty	West coast catchment
4001, 4002, 4003, 4004, 4005, 4006, 4007, 4008, 4009, 4010, 4011, 4012, 4013, 4014, 4015, 4016, 4017, 4018, 4019, 4020, 4021, 4022, 4023, 4024, 4025, 4026, 4027, 4028, 4029, 4030, 4031, 4032, 4033, 4034, 4035, 4036, 4037, 4038, 4039, 4040, 4041, 4042, 4043, 4044, 4045, 4046, 4047, 4048, 4049, 4050, 4051, 4052, 4053, 4054, 4055, 4056, 4057, 4058, 4059, 4060, 4061, 4062, 4063, 4064, 4065, 4066, 4067, 4068, 4069, 4070, 4071, 4072, 4073, 4074, 4075, 4076, 4077, 4078, 4079, 4080, 4081, 4082	Port Davey	Located in World Heritage Area
5001, 5002, 5003, 5004, 5005, 5006, 5007, 5008, 5009, 5010, 5011, 5012, 5013, 5014, 5015, 5016, 5017, 5018, 5019, 5020, 5021, 5022, 5023, 5024, 5025, 5026, 5027, 5028, 5029, 5030, 5031, 5032, 5033, 5034, 5035, 5036, 5037, 5038, 5039, 5040, 5041, 5042, 5043, 5044, 5045, 5046, 5047, 5048, 5049, 5050, 5051, 5052, 5053, 5054, 5055, 5056, 5057, 5058, 5059, 5060, 5061, 5062, 5063, 5064, 5065, 5066, 5067, 5068, 5069, 5070, 5071, 5072, 5073, 5074, 5075	Pieman	West coast catchment
6001, 6002, 6003, 6004, 6005, 6006, 6007, 6008, 6009, 6010, 6011, 6012, 6013, 6014, 6015, 6016, 6017, 6018, 6019, 6020, 6021, 6022, 6023, 6024, 6025	Nelson Bay	West coast catchment
8013	Montagu	Land-use sums to small proportion of catchment (<80%)
8014	Montagu	Sub-catchment is an estuary
9012	Duck	Mostly estuarine/marsh/Wetland
10001, 10002, 10003, 10004, 10005, 10006, 10007, 10008, 10009, 10010, 10011, 10012, 10013, 10014, 10015, 10016, 10017, 10019, 10020, 10022, 10023, 10024, 10025	King Island	Island
10018, 10021		Sub-catchment is an estuary
11007	Welcome	Land-use sums to small proportion of catchment (<80%)
12018, 12019	Black–Detention	Sub-catchment is an estuary
14001	Emu	Granite geology in >20% of sub-catchment
18001, 18002, 18004, 18006	Blythe	Granite geology in >20% of sub-catchment
19001, 19002, 19003, 19004, 19005, 19006, 19007, 19008, 19009, 19011, 19012, 19016, 19017, 19021, 19022, 19023, 19024, 19025, 19028, 19031, 19032, 19033, 19034, 19035	Huon	Located in World Heritage Area
19070	Huon	Sub-catchment is an estuary
19071, 19072	Huon	Land-use sums to small proportion of catchment (<80%)
20001, 20002, 20003, 20004, 20005, 20007, 20009	Lower Derwent	Located in World Heritage Area
21013	Upper Derwent	>35% of sub-catchment is a dam
21022, 21023, 21024	Upper Derwent	Located in World Heritage Area
21027	Upper Derwent	>39% of sub-catchment is a dam

22001, 22002, 22003, 22004, 22005, 22006	Ouse	Sub-catchment located in central plateau
23007	Clyde	>35% of sub-catchment is a dam
24054, 24056	Derwent	Sub-catchment is an estuary
24055	Derwent	Land-use sums to small proportion of catchment (<80%)
26013	Pitt Water–Coal	Land-use sums to small proportion of catchment (<80%)
27041	Tasman	Land-use sums to small proportion of catchment (<80%)
28015	Prosser	Land-use sums to small proportion of catchment (<80%)
29018	Little Swanport	Land-use sums to small proportion of catchment (<80%)
30001, 30003, 30004, 30005, 30006, 30029, 30032	Swan–Apsley	Granite geology in >20% of sub-catchment
30021	Swan–Apsley	>30% of sub-catchment is marsh/ wetland
30023, 30025, 30030, 30031	Swan–Apsley	Land-use sums to small proportion of catchment (<80%) also granite >20%
30033	Swan–Apsley	Mostly estuarine
31001	Great Lake	Sub-catchment located in central Plateau
33008, 33010, 33018	South Esk	Granite geology in >20% of sub-catchment
35001, 35002, 35003, 35004, 35005, 35007	Brumbys–Lake	Sub-catchment located in central plateau
36021	Rubicon	Land-use sums to small proportion of catchment (<80%)
37028	Tamar	Mostly estuary; Land-use sums to small proportion of catchment (<80%)
38023	Mersey	Sub-catchment is an estuary
38024	Mersey	Land-use sums to small proportion of catchment (<80%)
39005, 39006, 39007, 39008	North Esk	Granite geology in >20% of sub-catchment
41005, 41007	Great Forester–Brid	Granite geology in >20% of sub-catchment
43006, 43010, 43011, 43023, 43024	Scamander–Douglas	Granite geology in >20% of sub-catchment
43021	Scamander–Douglas	20% of sub-catchment is water
44001, 44002, 44003, 44004, 44005, 44006, 44007, 44008, 44009, 44010, 44012, 44013, 44014, 44015, 44016, 44017, 44018, 44019	George	Granite geology in >20% of sub-catchment
44011	George	Land-use sums to small proportion of catchment (<80%) and granite geology in >20% of sub-catchment

45005, 45006, 45009, 45010	Boobyalla–Tomahawk	Granite geology in >20% of sub-catchment
46001, 46002, 46003, 46006, 46007, 46008, 46009, 46010	Ringarooma	Granite geology in >20% of sub-catchment
47001, 47002, 47004, 47005, 47006, 47007, 47008, 47011, 47012, 47013, 47014, 47015, 47016, 47017, 47018, 47019, 47020, 47021, 47022, 47023, 47025, 47026, 47027, 47028, 47029, 47030, 47031, 47032, 47033, 47034, 47035, 47036, 47037, 47038, 47040, 47041, 47042, 47043, 47044, 47046	Furneaux	Island
47003, 47009, 47010, 47024, 47039, 47045	Furneaux	Granite geology in >20% of sub-catchment
48002, 48003, 48004, 48006, 48007, 48008, 48009, 48010, 48012, 48013, 48014, 48016, 48018, 48019, 48020, 48021, 48022, 48023	Musselroe–Ansons	Granite geology in >20% of sub-catchment
13001, 13002	Forth–Wilmot	Located in World Heritage Area
34004, 34005	Meander	Located in World Heritage Area
38001, 38002, 38003, 38006, 38007, 38008, 38010	Mersey	Located in World Heritage Area
21001, 21002, 21003, 21004, 21005, 21026	Upper Derwent	Located in World Heritage Area
14003	Emu	>20% of sub-catchment mining or urbanisation
17006	Leven	>>20% of sub-catchment mining or urbanisation
24021, 24027, 24028, 24029, 24030, 24032, 24035, 24036, 24037, 24039, 24048, 24050, 24051	Derwent–Bruny	>20% of sub-catchment mining or urbanisation
30014, 30020	Swan–Apsley	>20% of sub-catchment mining or urbanisation
37006, 37010, 37012, 37013, 37019	Tamar	>20% of sub-catchment mining or urbanisation
38018, 38020, 38021	Mersey	>20% of sub-catchment mining or urbanisation