Measuring and modelling the impacts of land use and climate change on river ecological condition

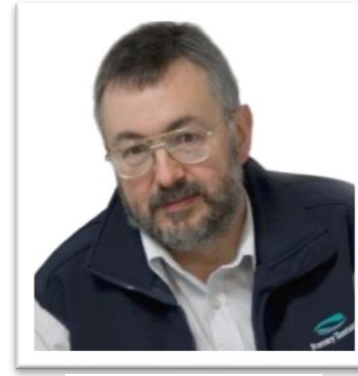
Regina Magierowski &
Peter Davies

National Environmental Research Program

LANDSCAPES & POLICY hub

LANDSCAPE LOGIC
LINKING LAND AND WATER MANAGEMENT TO RESOURCE CONDITION TARGETS

UTAS



Link:

- Land use & management
- Water quality
- River ecosystem health

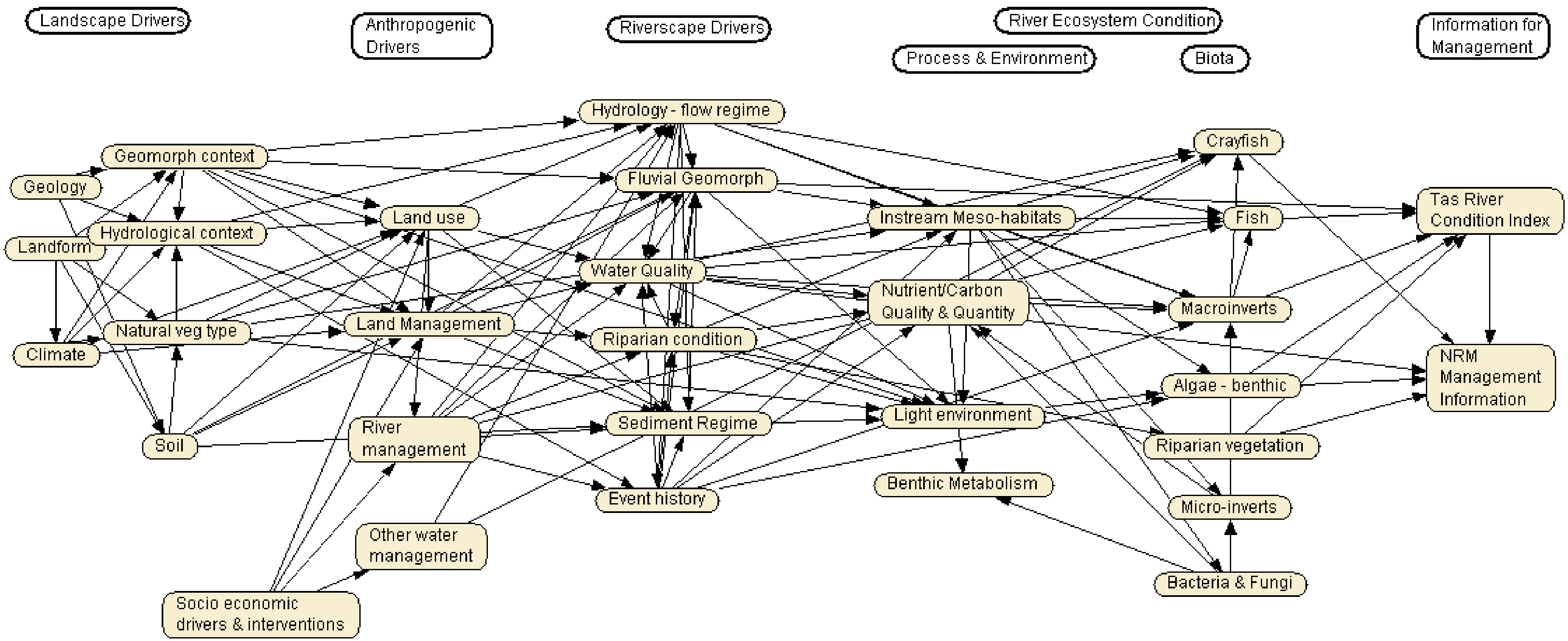
Project Phases

1. Develop a conceptual model
2. Find evidentiary support
3. Develop BBN

Phase 1: Conceptual model

- To guide thinking & interaction, and build team understanding
- Identify major drivers of river ecosystem condition
- Focus on benthic macroinvertebrate and algal responses

Complex Conceptual Model



Landuse & Catchment Drivers

River Ecosystem Responses

Phase 2: Evidentiary Support

a. Mine existing data

b. Conduct ‘gradient’ field surveys

c. Diagnostic information

Phase 2a: Data Mining

Stream Biota & Habitat Data:

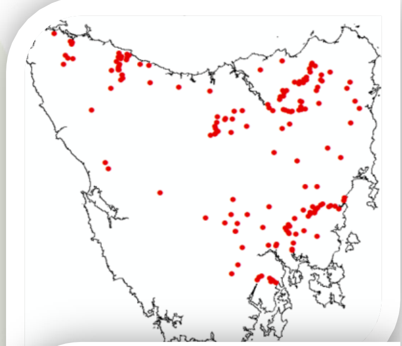
– *AUSRIVAS 1996-2003*

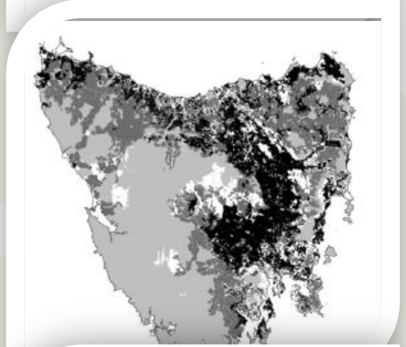
Land Use Data:

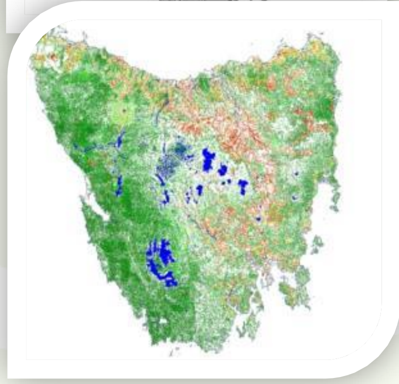
– *BRS 2003*

Catchment & Stream Feature data:

– *Conservation of Freshwater Ecosystem Values (CFEV) GIS database 2006*



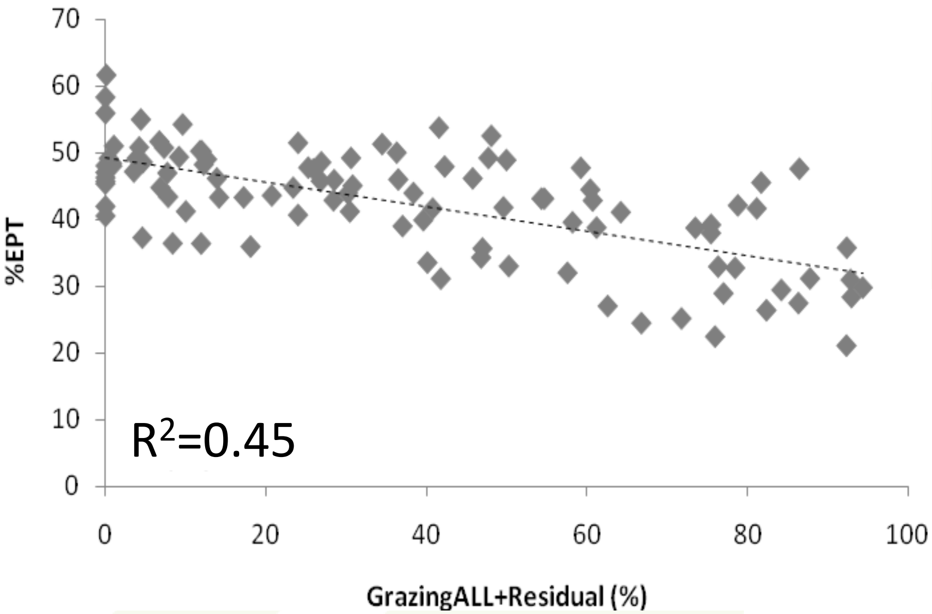


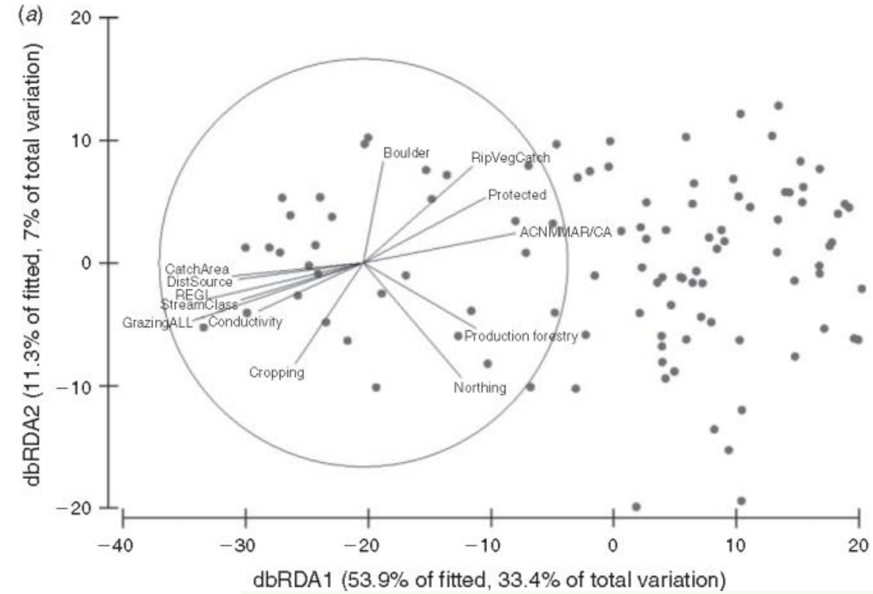


Magierowski et al. 2012 *Marine and Freshwater Research*, 2012, **63**, 762–776

Data mining: Correlations

Macroinvertebrate composition = F[% grazing land]





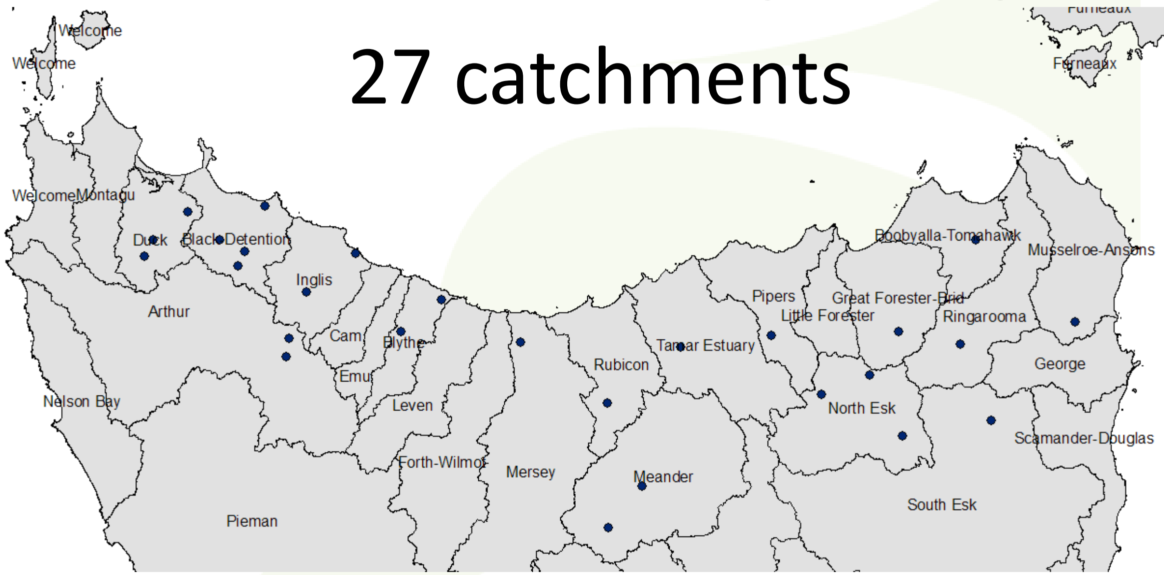
Phase 2b: Gradient surveys

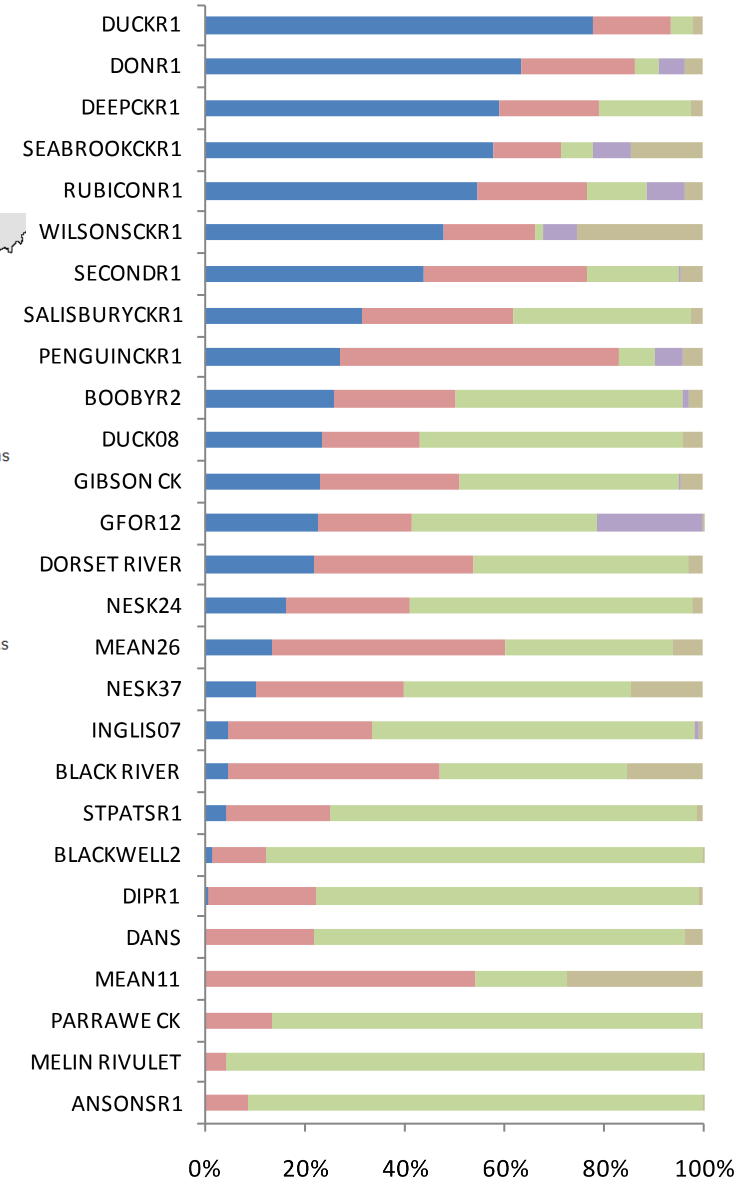
- Two designed field surveys across catchments with varying :
  - grazing landuse area (n = 27)
  - forest management history (n = 41)
- Correlate ecosystem measures with landuse & intermediate drivers (e.g. nutrient regime)

Agricultural gradient:

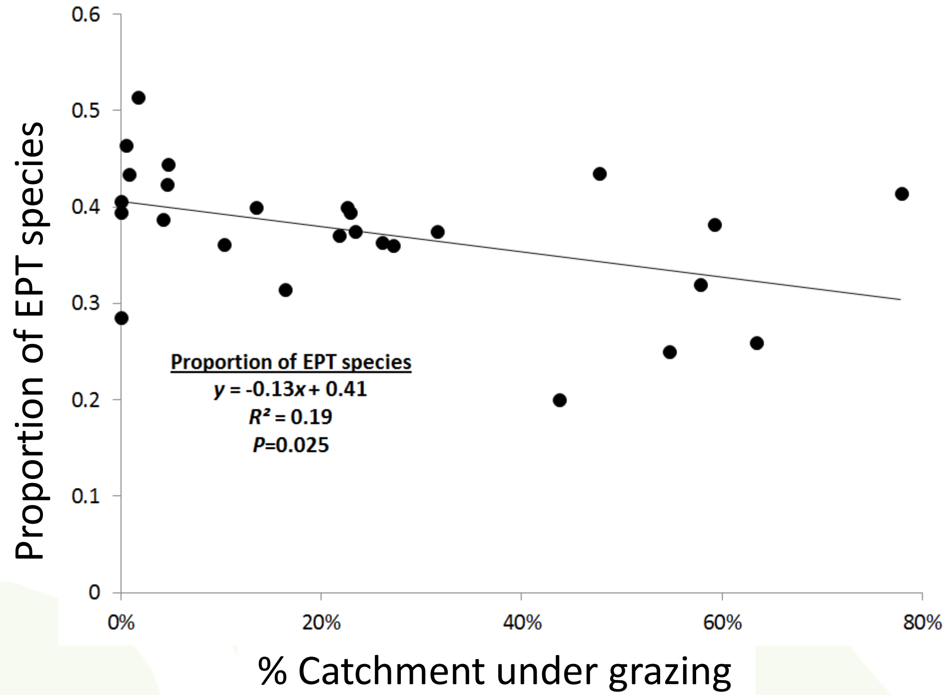
% area under grazing

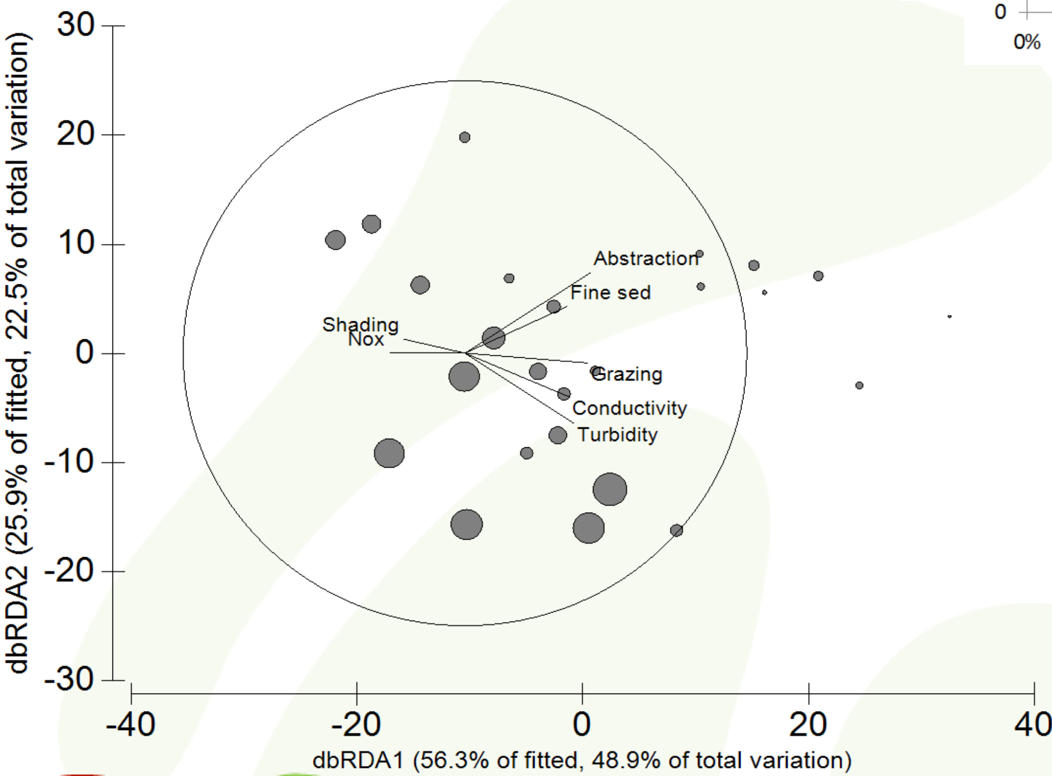
27 catchments





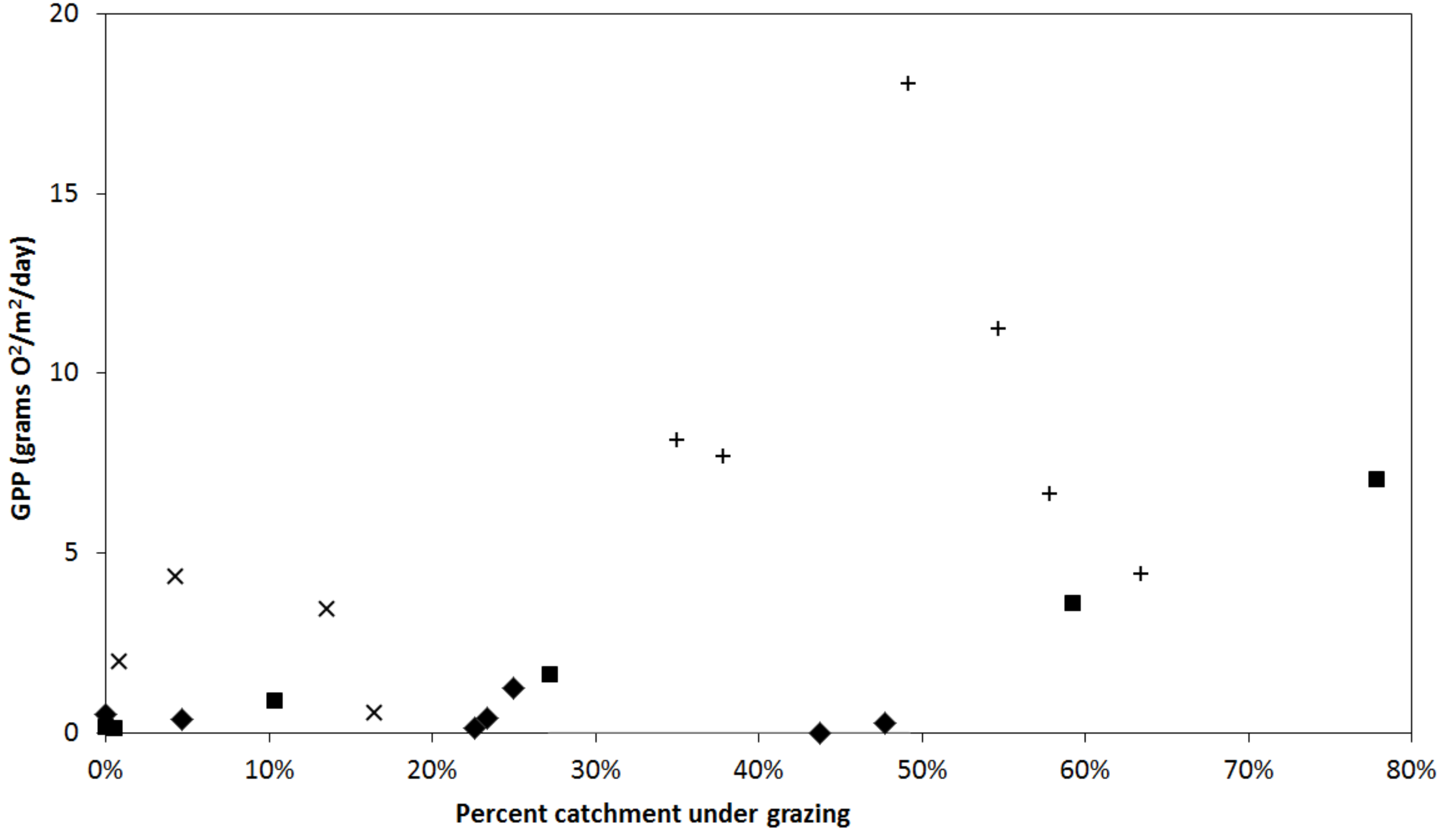
Grazing
Cropping
Protection
Other
Forest mgt





Variable	Multiple partial correlations (ρ) with dbRDA1
Water abstraction	0.45
Grazing	0.43
Turbidity	0.39
Conductivity	0.37
Fine sediment	0.36

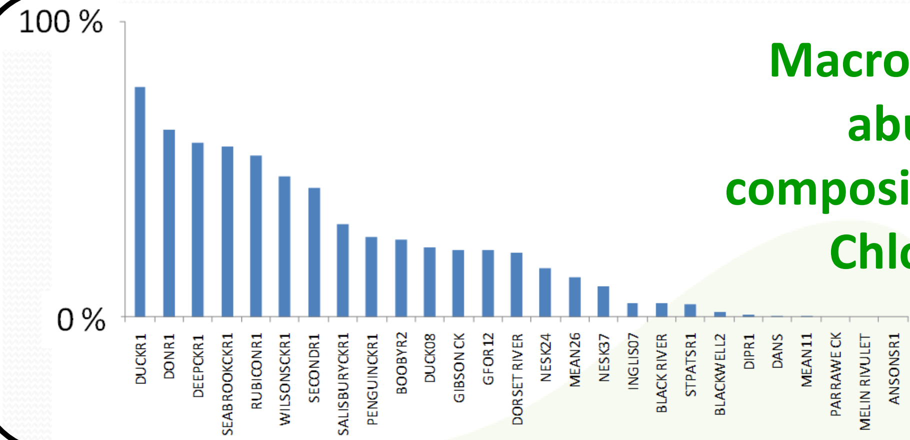
Instream Primary Production



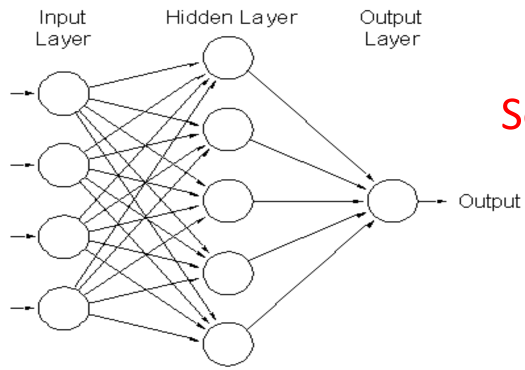
Phase 2c: Diagnostic tools

- Neural networks
  - Trained on experimental data (artificial stream experiments)
  - predict physical condition based on biological response
  - apply to gradient field-survey data

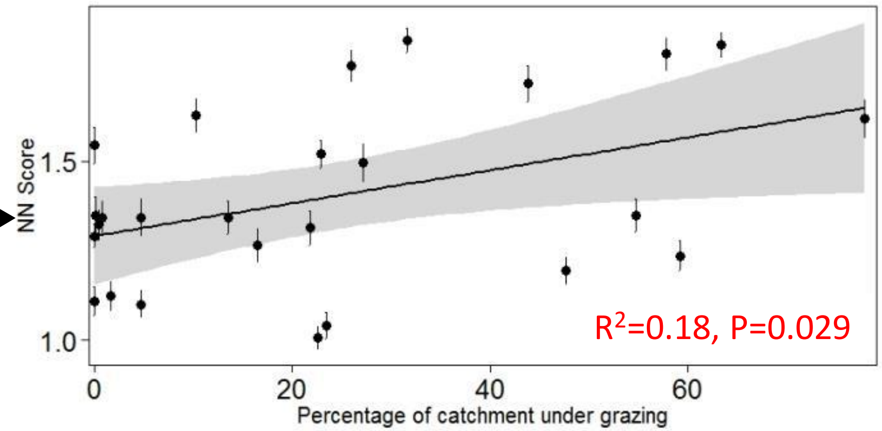
Diagnosis: Grazing Land Use Gradient

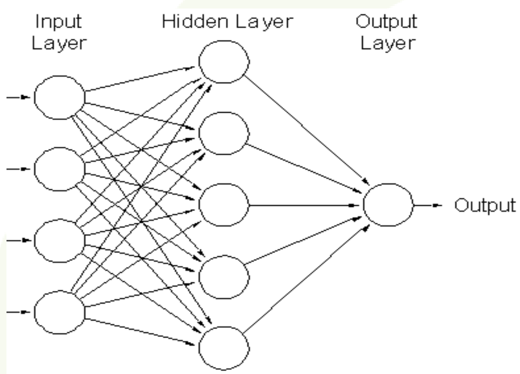


Macroinvertebrate abundance, composition, diversity; Chlorophyll-a

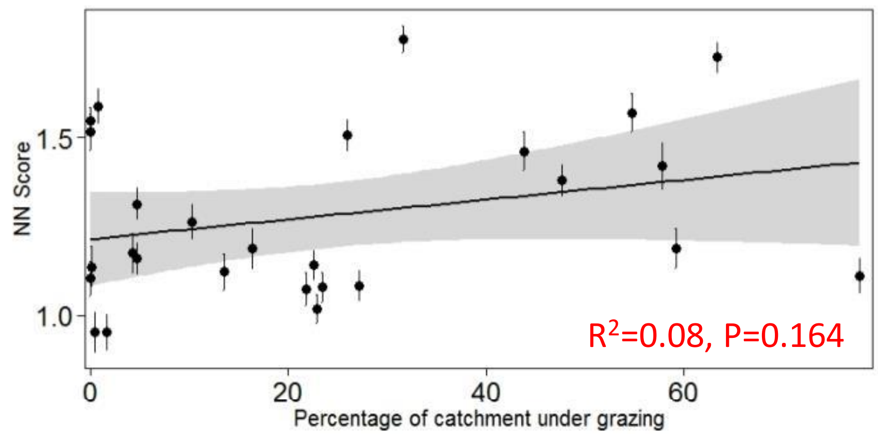


Sediment status

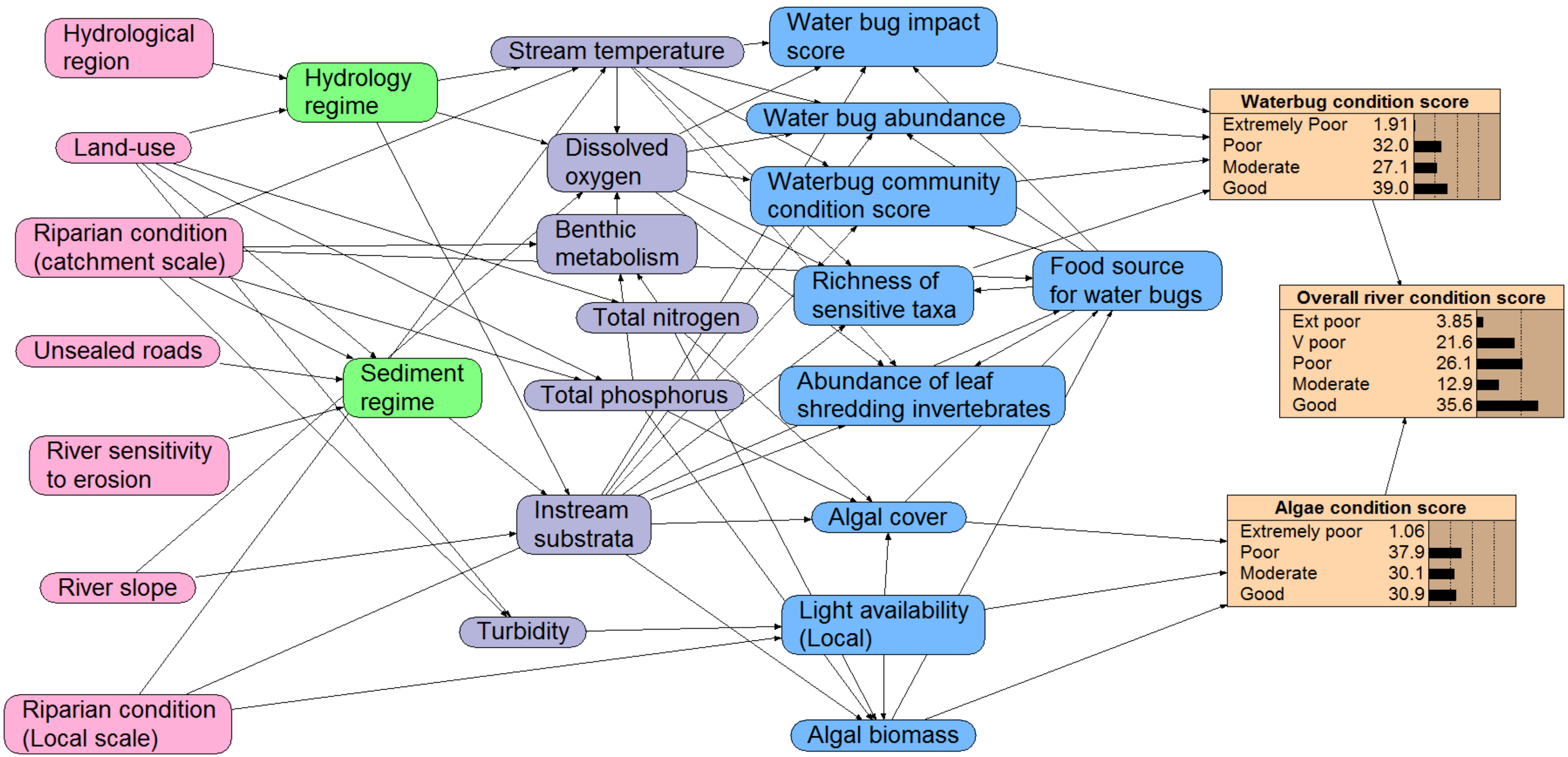




Nutrient status



Phase 3: Bayesian Belief Network



Allan, J.D et al. (2011). *Freshwater Biology* 57:58-73.

Phase 4: Bayesian Belief Network

- Structure ‘easy’, parameterisation difficult:
  - Careful thinking about ‘meaning’ of nodes
  - Careful analysis of evidence to derive credible states and thresholds
  - Needs mix of evidence <u>and</u> ‘expert elicitation’
- Nice way to illustrate how a river works

National Environmental Research Program

LANDSCAPES & POLICY hub

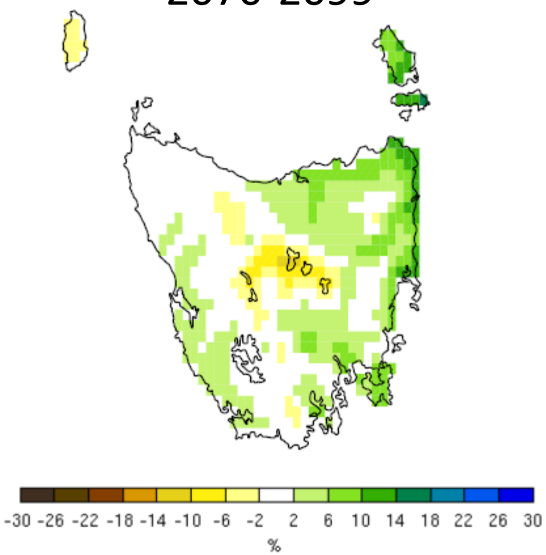
- Interdisciplinary research project
- Tools, techniques, policy options for biodiversity management
- Emphasis on landscape-scale
- 2 study regions: Tasmanian Midlands and Australian Alps

http://www.nerplandscapes.edu.au/

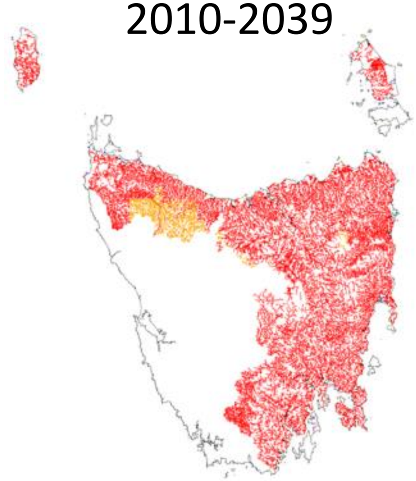
Climate Futures & NCCARF

- Dynamically downscaled (10km²) climate projections
- Stream temperature modelling
- Identified hydrological variables, built BBNs

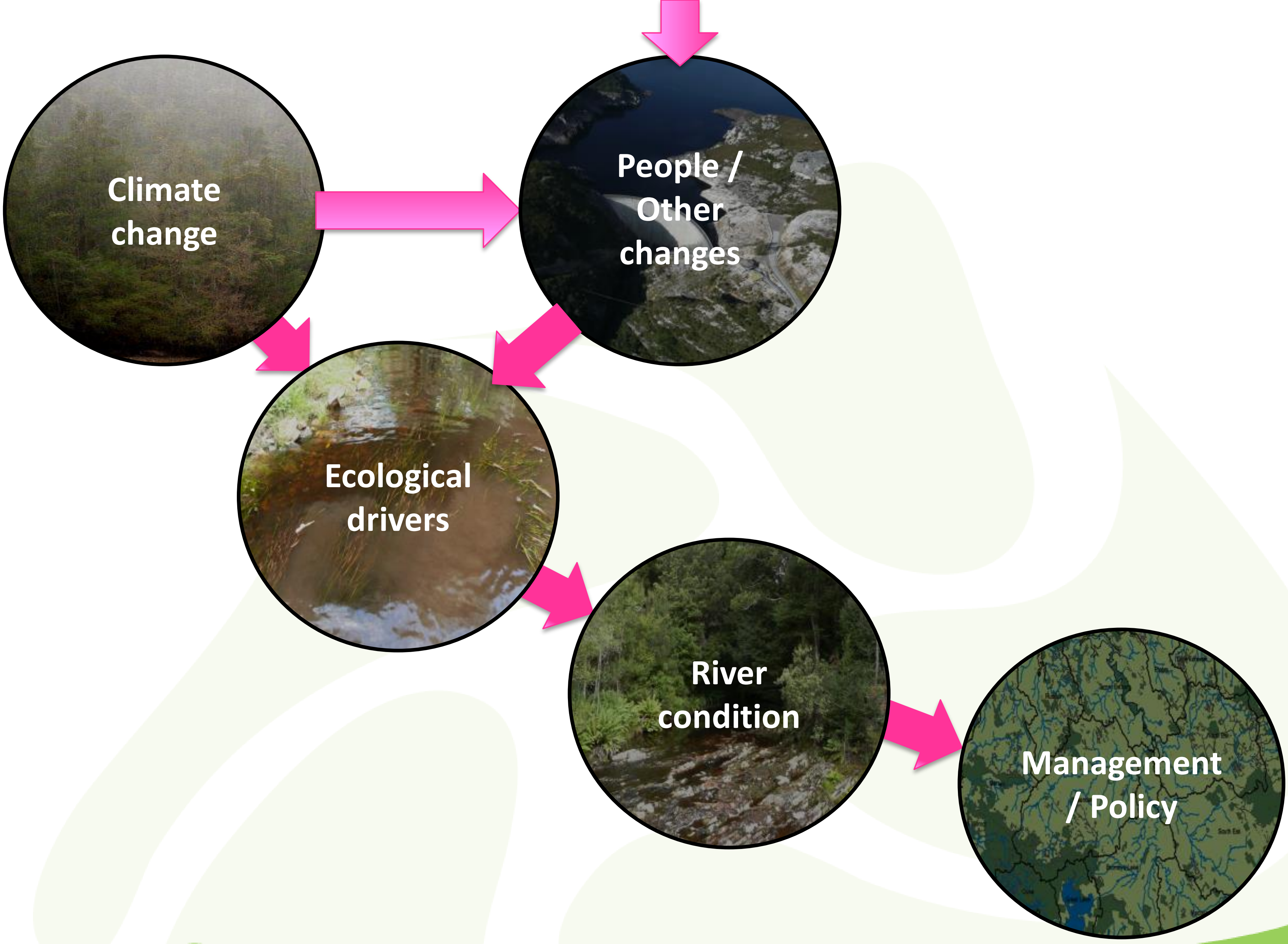
6-model mean % change rainfall 2070-2099



Risk to Bugs - UKMO climate model 2010-2039



Red=Large Risk


Climate change
People / Other changes
Ecological drivers
River condition
Management / Policy

Crazy idea…..

Models

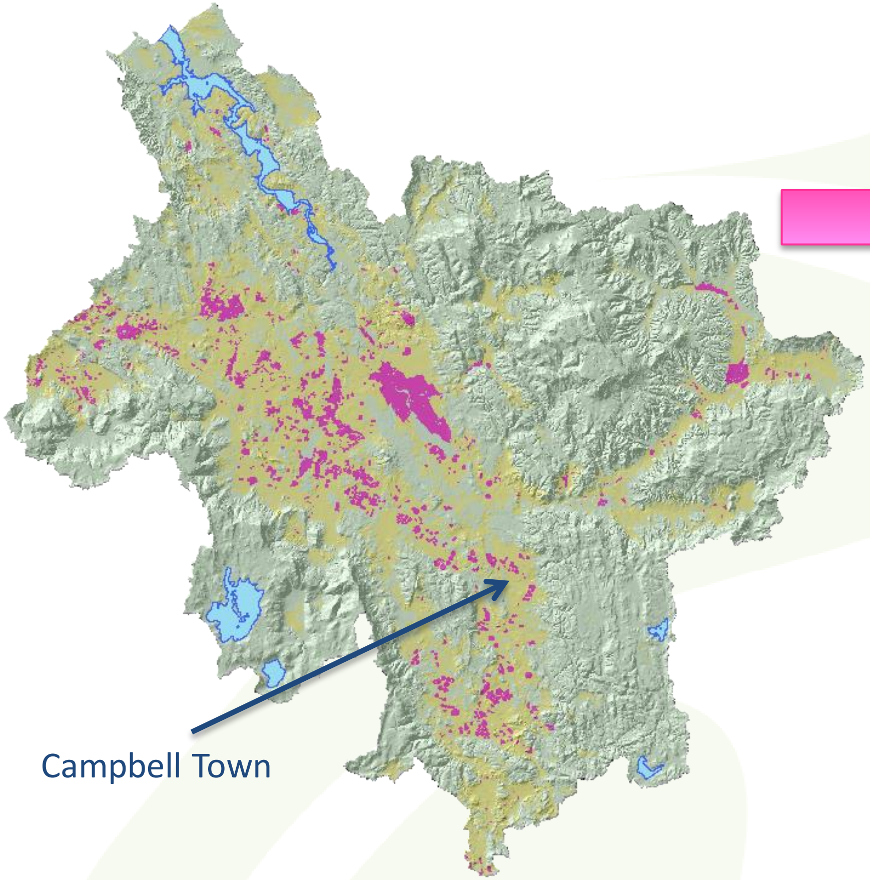
- Hydrological models (DPIPWE)
- Bayes Nets for predicting river condition (NCCARF)
- Selection algorithms for conservation prioritisation (DPIPWE)

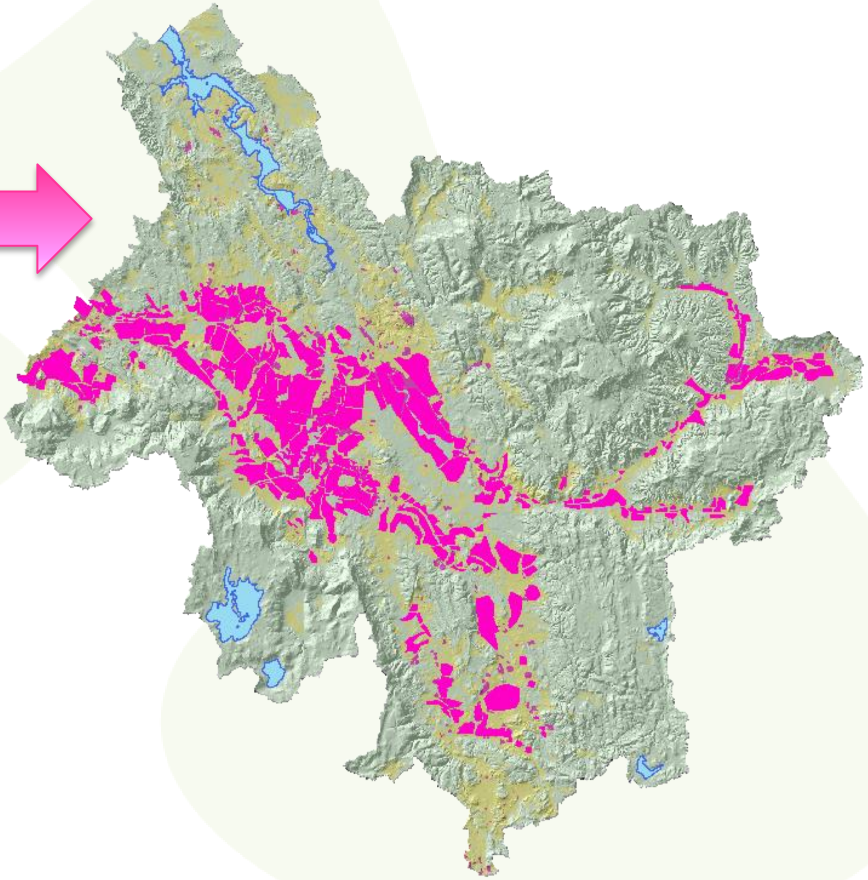
Projections

- Climate (Climate Futures for Tasmania (CFT))
- River temperature (NCCARF & CFT)
- Vegetation cover (LaP & CFT)
- Irrigation development (Tasmania Irrigation & Macquarie Franklin)

Irrigated land 09/10

Projected Irrigation development





Data Sources:
Tasmanian Land Use – Summer 2009/10 DPIPWE
Projected Irrigation development – Macquarie Franklin
Lakes from the LIST, © State of Tasmania

National Environmental Research Program

LANDSCAPES & POLICY hub

Could irrigation development counter the effects of climate change in rivers in the Tasmanian Midlands?

Regina Magierowski, Peter E Davies,
Bryce Graham, Steve Carter and Ted Lefroy

Australian Government
Department of Sustainability, Environment, Water, Population and Communities

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ACE CRC
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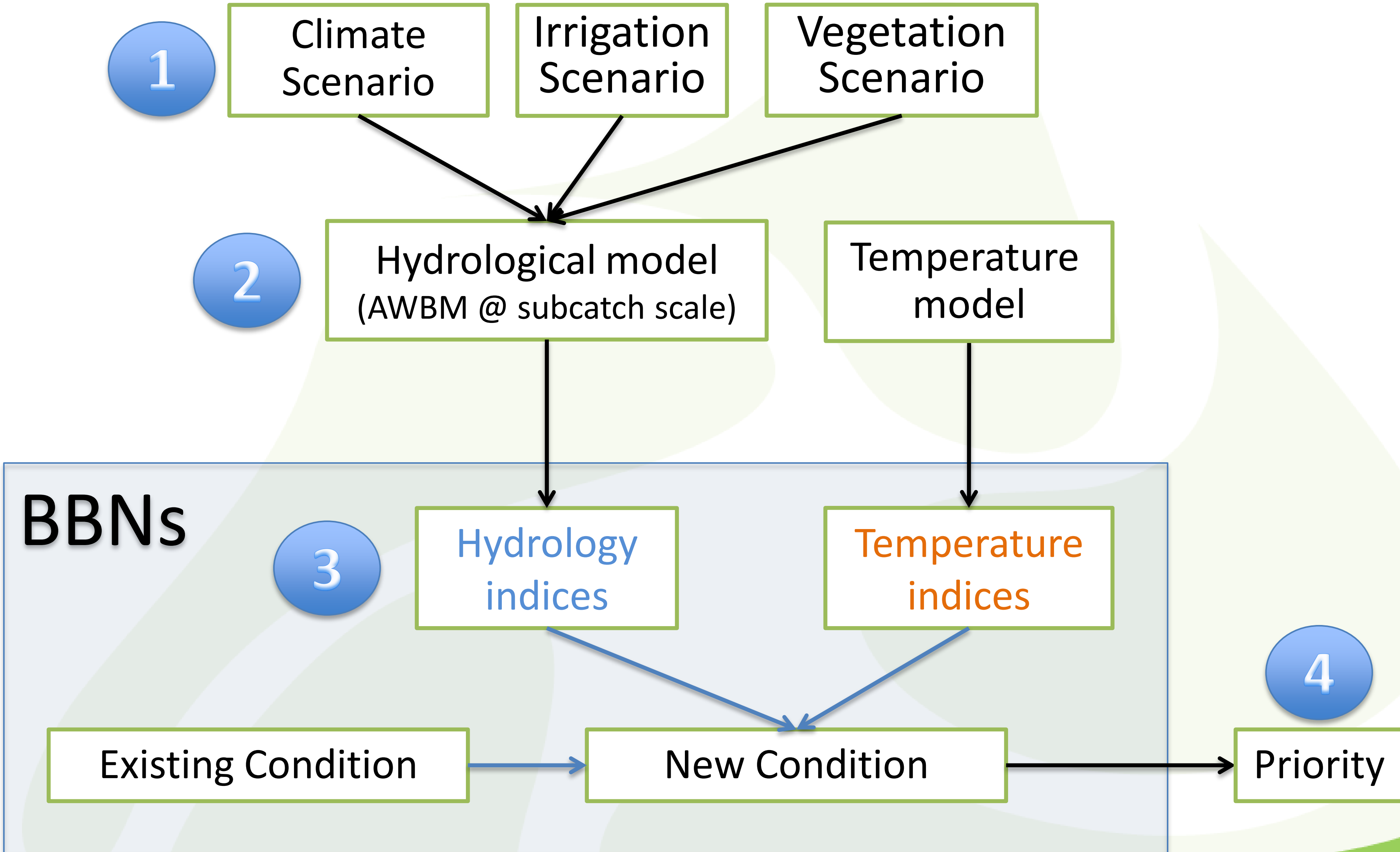
Tasmania
Explore the possibilities

Modelling workflow



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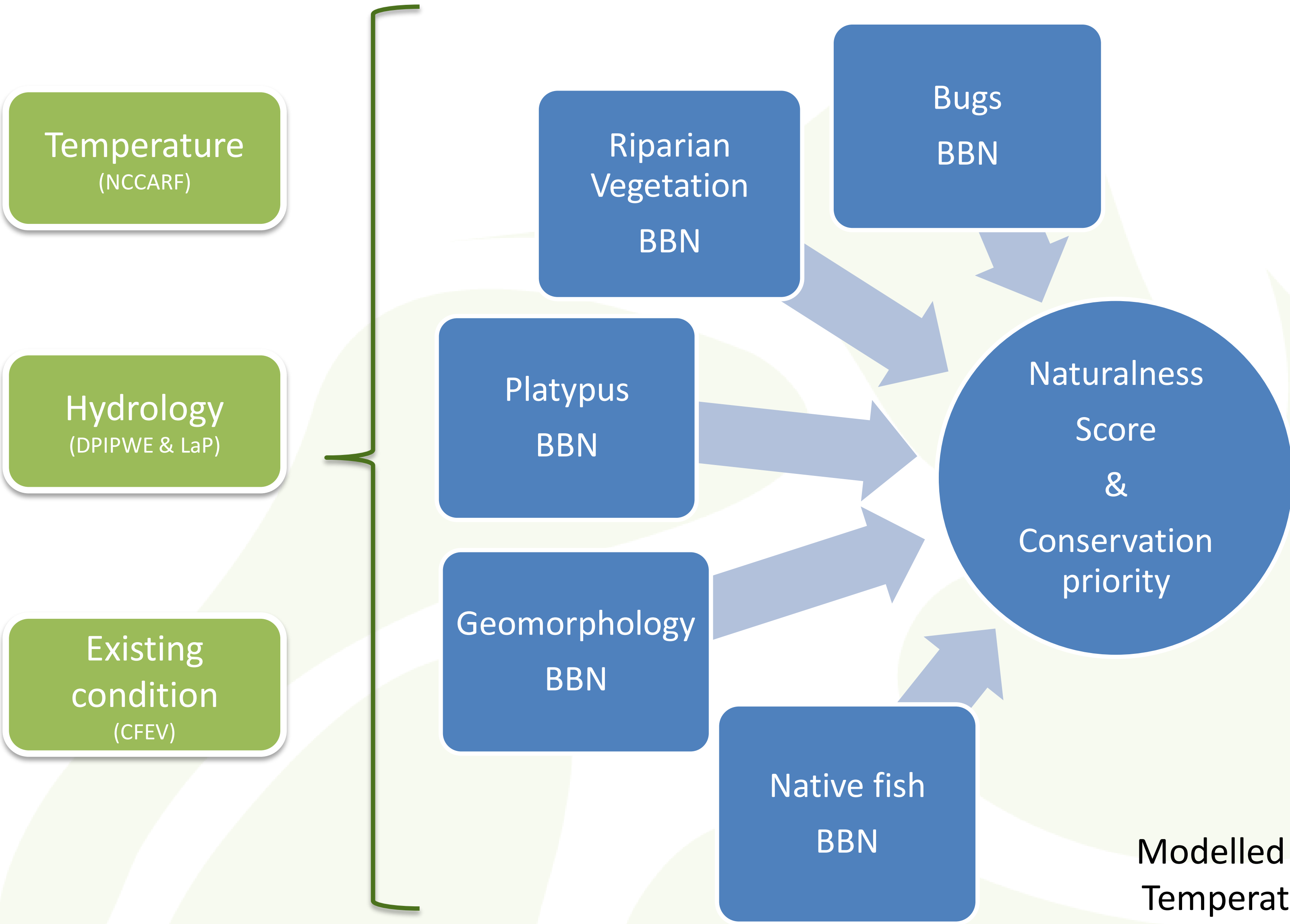
Scenarios

- 2868 river reaches (Sth Esk, Meander, Macquarie)
- 2 climate models (CSIRO (dry) & UKMO (wet))
- 2 time periods (2010-2039 & 2040-2069)

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Natural flows	✓				
Current water management rules		✓	✓	✓	✓
Tasmanian Irrigation			✓	✓	✓
Projected forest cover change				✓	✓
Max'd out Irrigation development					✓

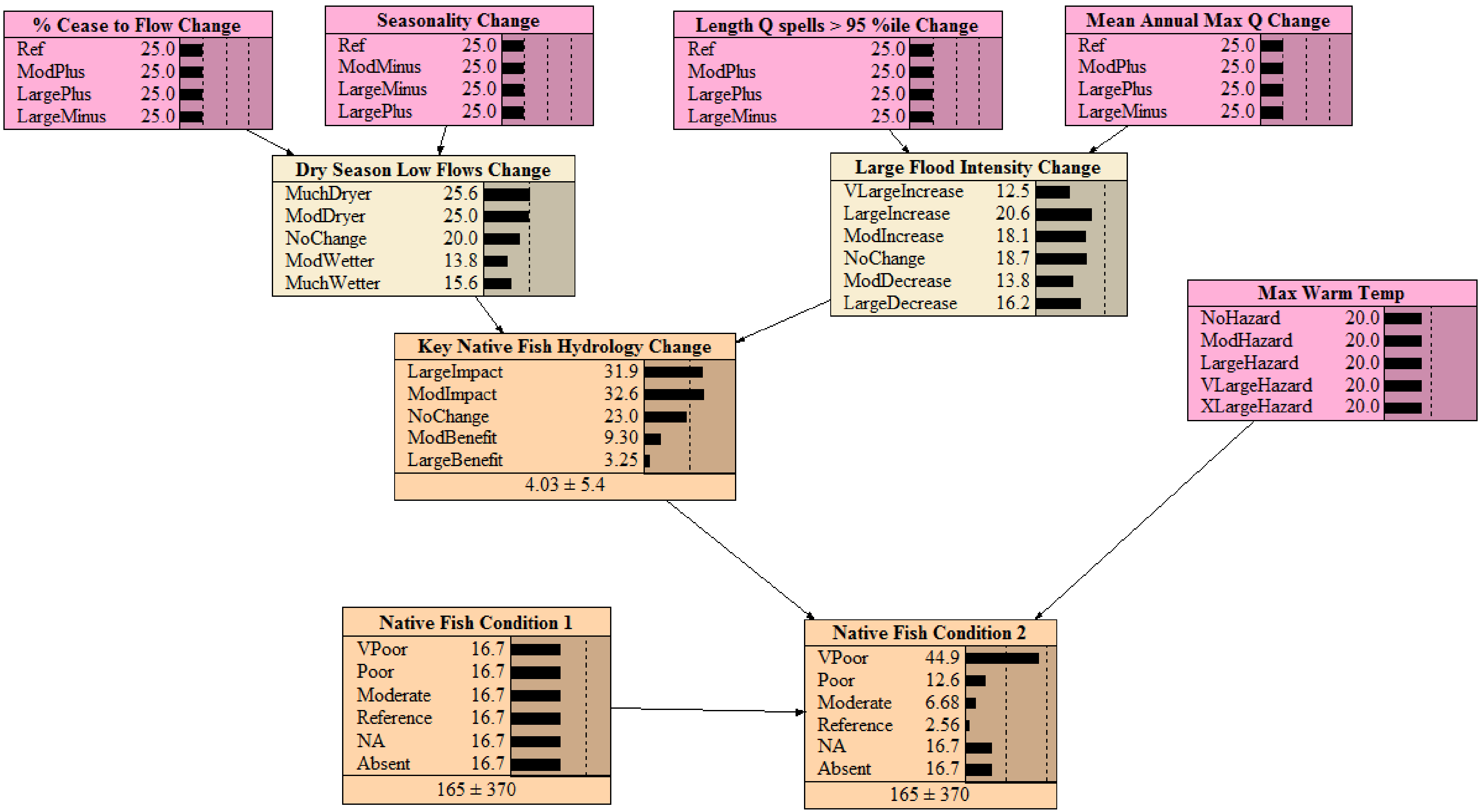
3 & 4

Bayesian Networks



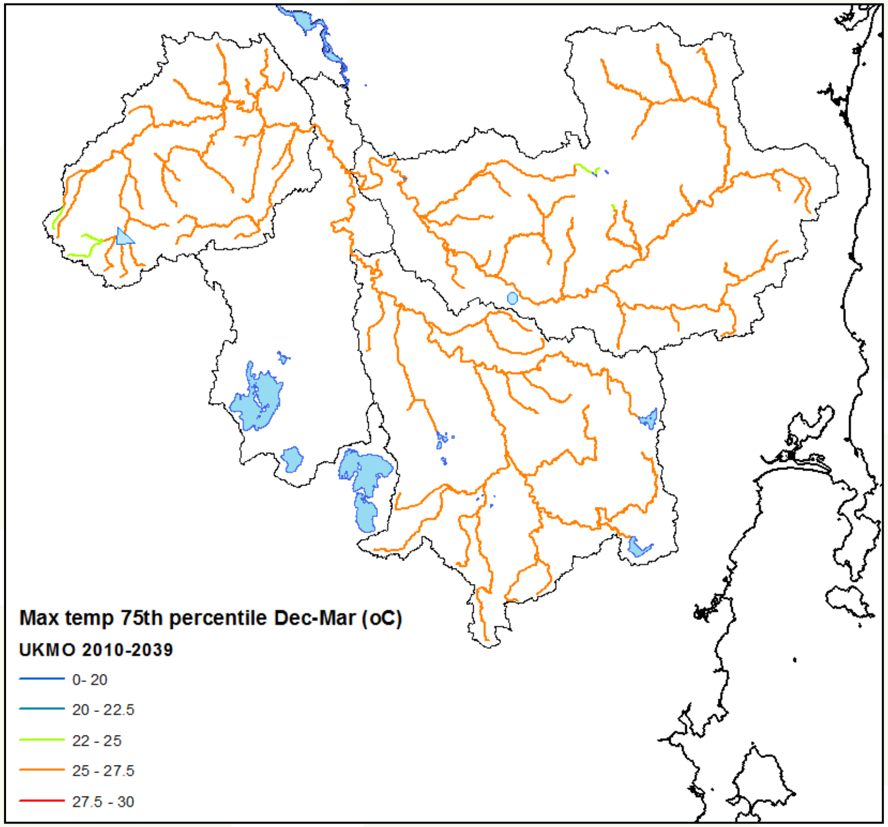
Modelled with/w'out Temperature change

Native fish


% Cease to Flow Change
Ref 25.0
ModPlus 25.0
LargePlus 25.0
LargeMinus 25.0
Seasonality Change
Ref 25.0
ModMinus 25.0
LargeMinus 25.0
LargePlus 25.0
Length Q spells > 95 %ile Change
Ref 25.0
ModPlus 25.0
LargePlus 25.0
LargeMinus 25.0
Mean Annual Max Q Change
Ref 25.0
ModPlus 25.0
LargePlus 25.0
LargeMinus 25.0
Dry Season Low Flows Change
MuchDryer 25.6
ModDryer 25.0
NoChange 20.0
ModWetter 13.8
MuchWetter 15.6
Large Flood Intensity Change
VLargeIncrease 12.5
LargeIncrease 20.6
ModIncrease 18.1
NoChange 18.7
ModDecrease 13.8
LargeDecrease 16.2
Max Warm Temp
NoHazard 20.0
ModHazard 20.0
LargeHazard 20.0
VLargeHazard 20.0
XLargeHazard 20.0
Key Native Fish Hydrology Change
LargeImpact 31.9
ModImpact 32.6
NoChange 23.0
ModBenefit 9.30
LargeBenefit 3.25
4.03 ± 5.4
Native Fish Condition 1
VPoor 16.7
Poor 16.7
Moderate 16.7
Reference 16.7
NA 16.7
Absent 16.7
165 ± 370
Native Fish Condition 2
VPoor 44.9
Poor 12.6
Moderate 6.68
Reference 2.56
NA 16.7
Absent 16.7
165 ± 370

Results - Temperature

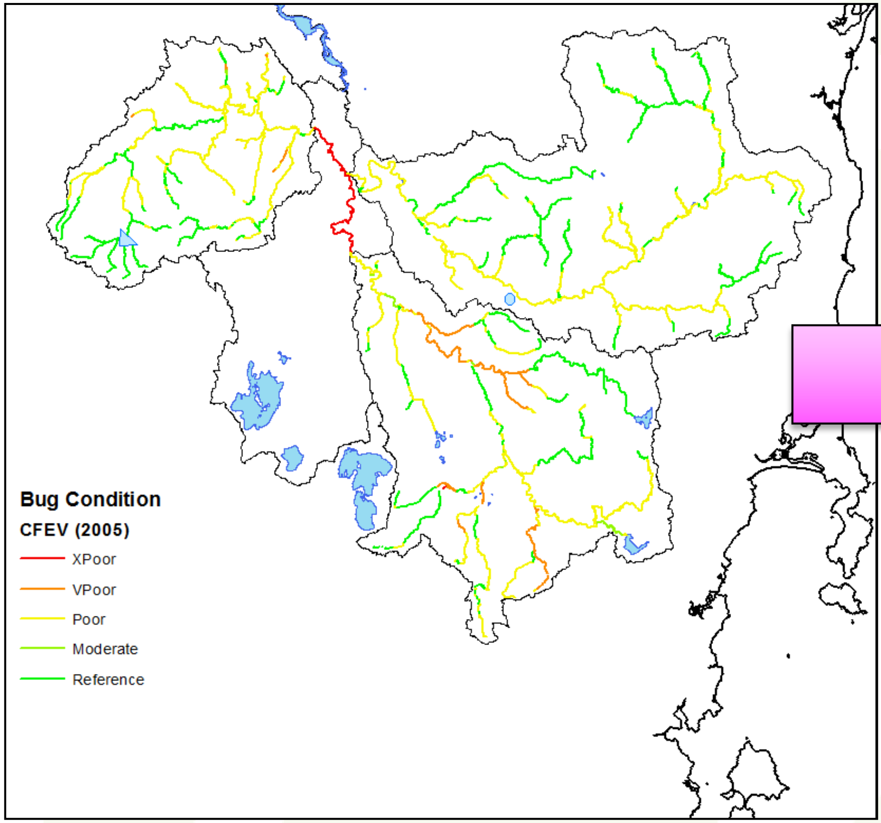
- "MaxWarmTTest" – 75th percentile of max daily temperature for 4 warmest months (December to March)

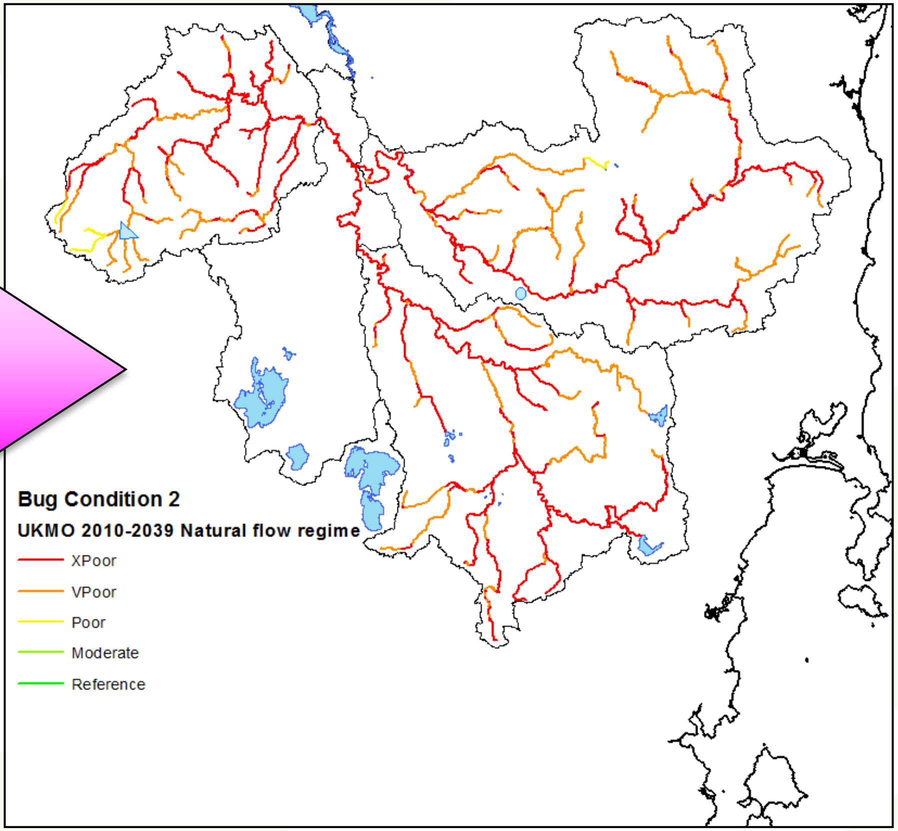


Data Sources:
Temperature data from NCCARF – Barmuta et al. 2013
Base data from the LIST, © State of Tasmania

Results - Temperature

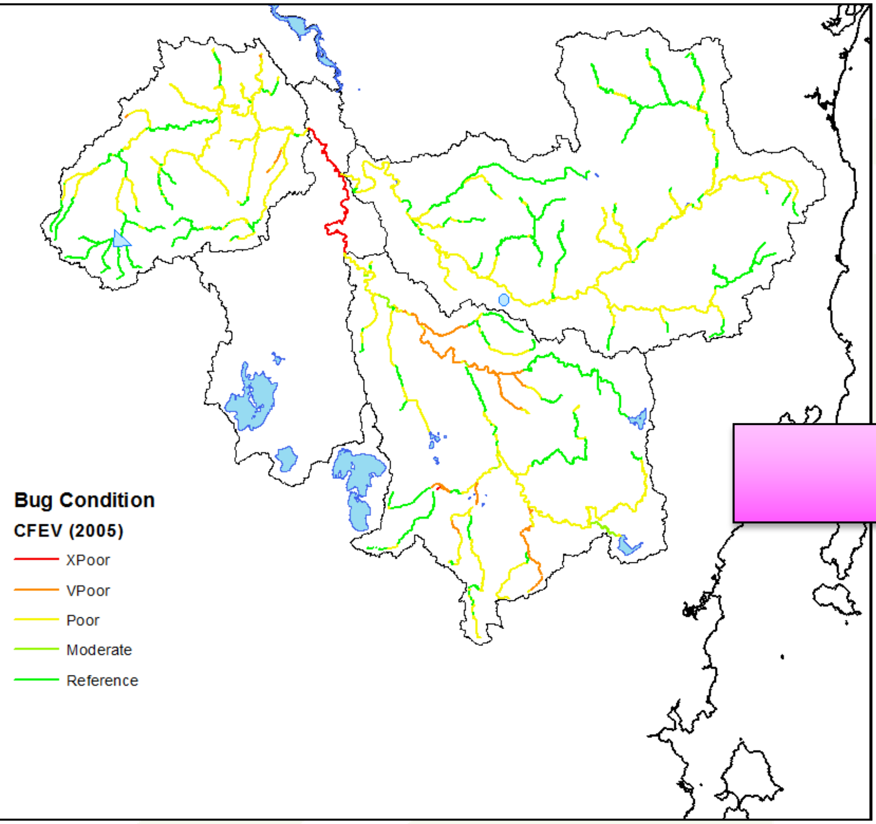
- "MaxWarmTTest" – 75th percentile of max daily temperature for 4 warmest months (December to March)

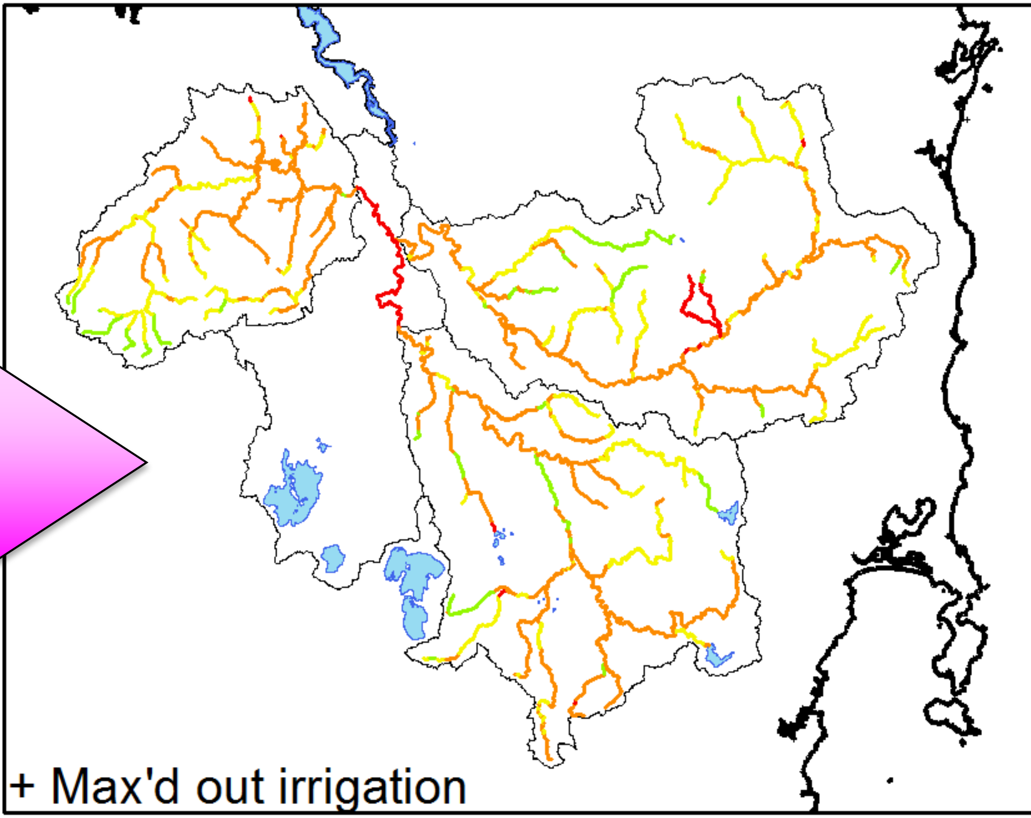




Data Sources:

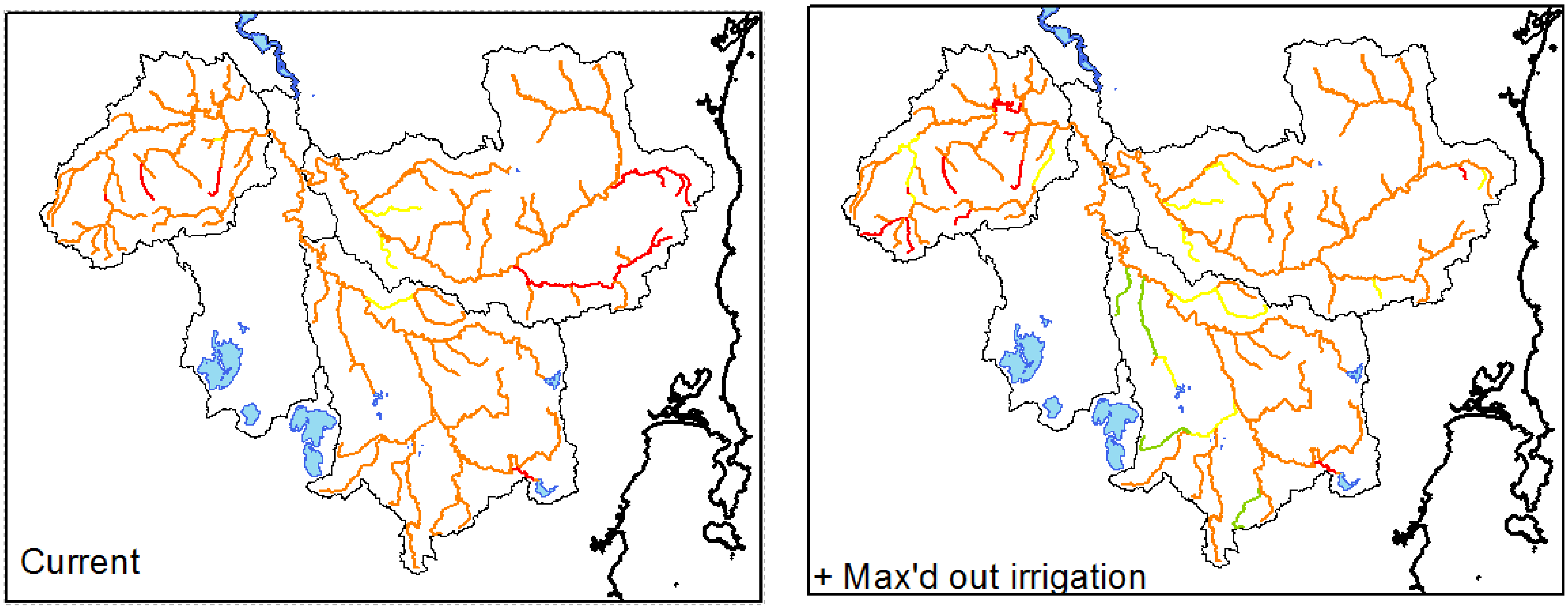
Results – Bug condition





Data Sources:
Base data from the LIST, © State of Tasmania

Results –Hydrological changes that influence riparian veg



- Large benefit
- Mod benefit
- No change
- Mod impact
- Large impact

Flow better: 38%
No change: 15.5%
Flow worse: 46.5%

Data Sources:
Base data from the LIST, © State of Tasmania

Could irrigation development counter the effects of climate change in rivers in the Tasmanian Midlands?

Can only hypothesise about flow (not temperature)

- May be…for some river sections
- BUT only if water releases are well managed

  (see other NCCARF outputs)

- Not sure if this will be sufficient to mitigate against temperature increases or changes in sediment, nutrient loads (from altered land-use).

Summary: Things ecologists might need help with

- Using small datasets to populate probability tables
- Machine learning
- Expert elicitation (but not always the answer to the small dataset problem)
- Handling confounded variables
- Documentation

Alpine bogs BBN
Relative vulnerability to climate change

Coming soon……….