NCCARF National Climate Change Adaptation Research Facility

ACT Government Environment and Sustainable Development

Australian Government National Water Commission

ACTEW WATER

Predicting ecological responses to a changing climate



Fiona Dyer, Paloma Lucena-Moya, Sondoss El-Sawah, Evan Harrison, Trefor Reynoldson, Tony Jakeman, Barry Croke

Hydropredict, Vienna, 2012

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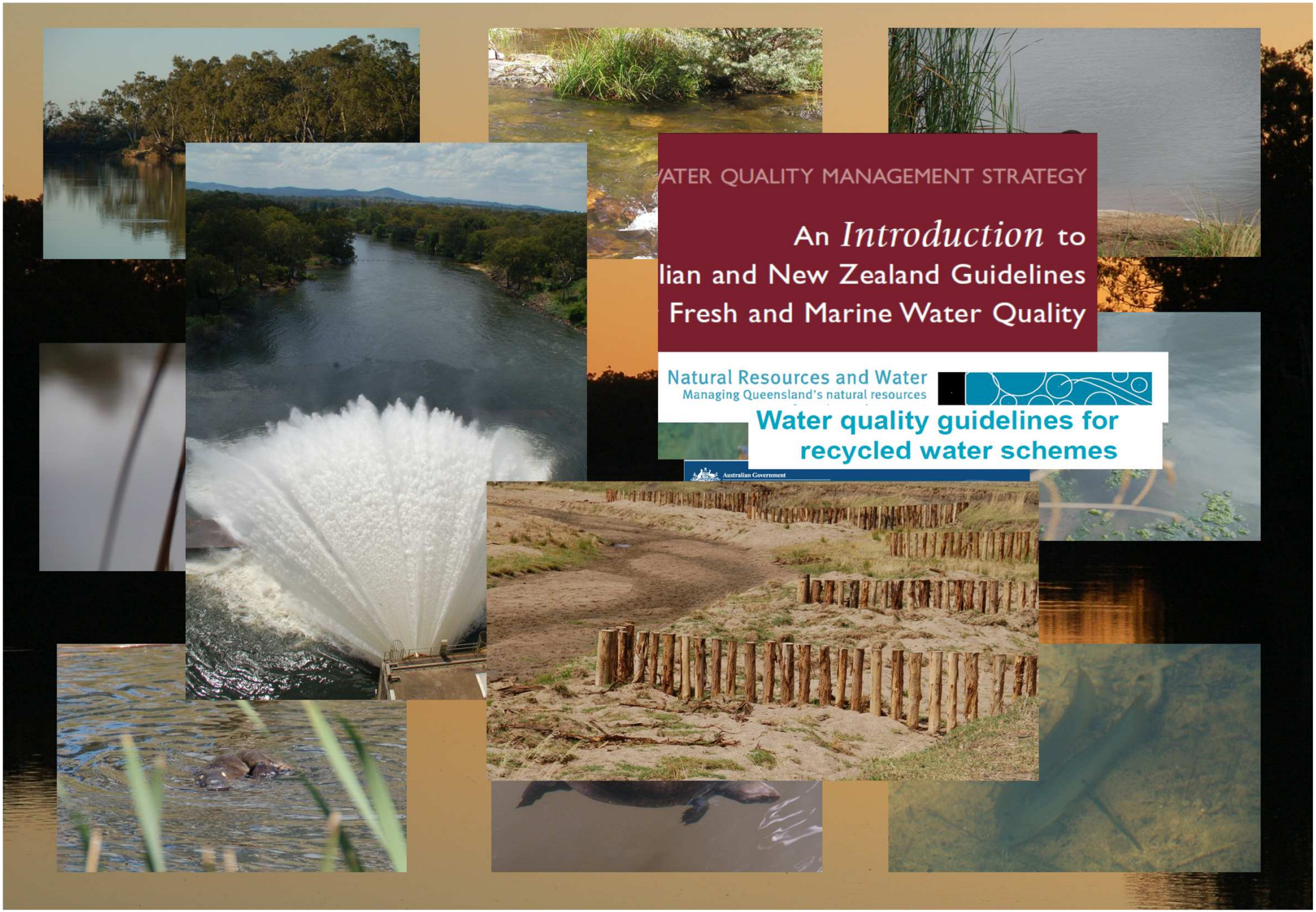
iCAM
Integrated Catchment Assessment and Management Centre

Australian National University


ATER QUALITY MANAGEMENT STRATEGY
An Introduction to
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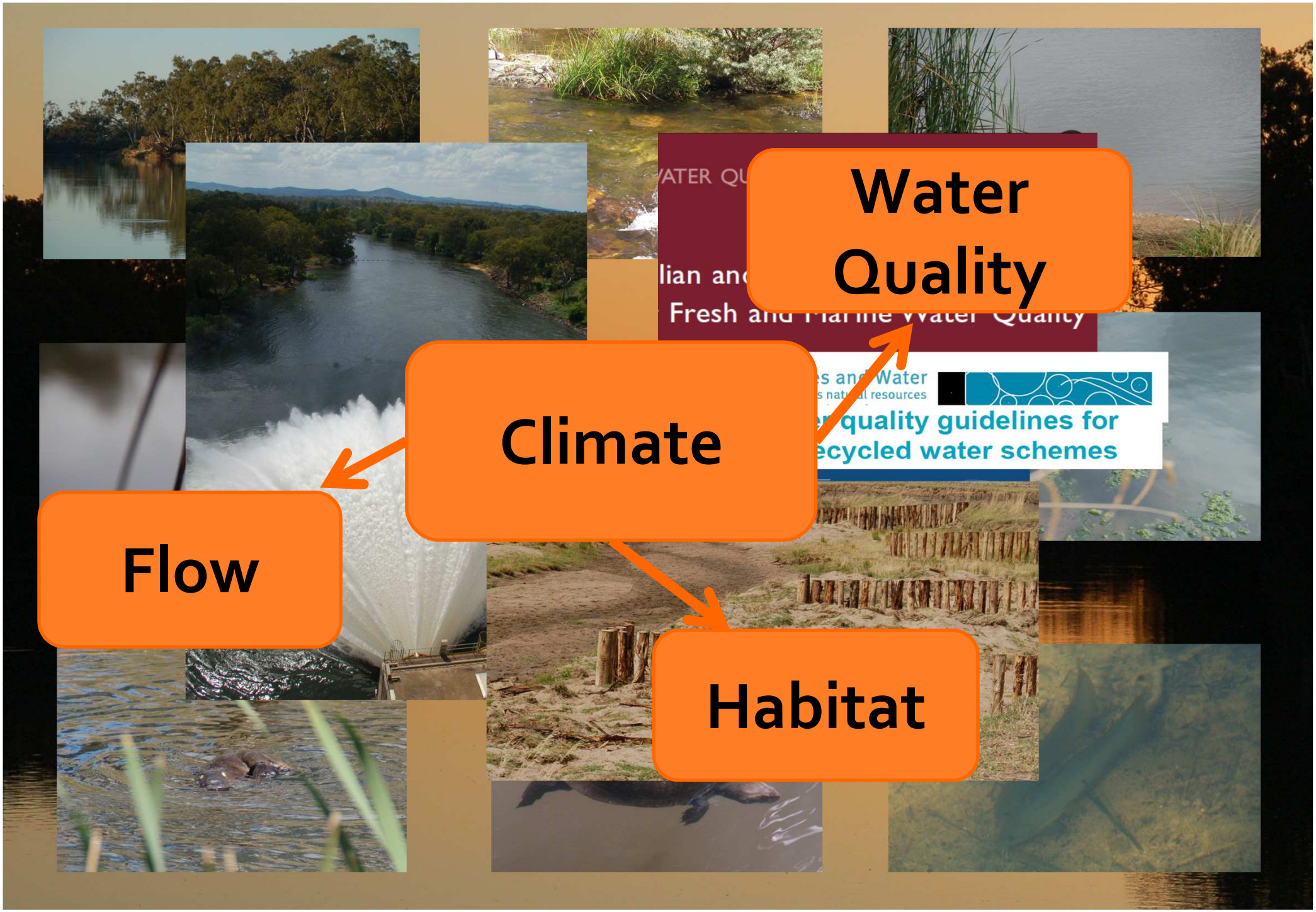
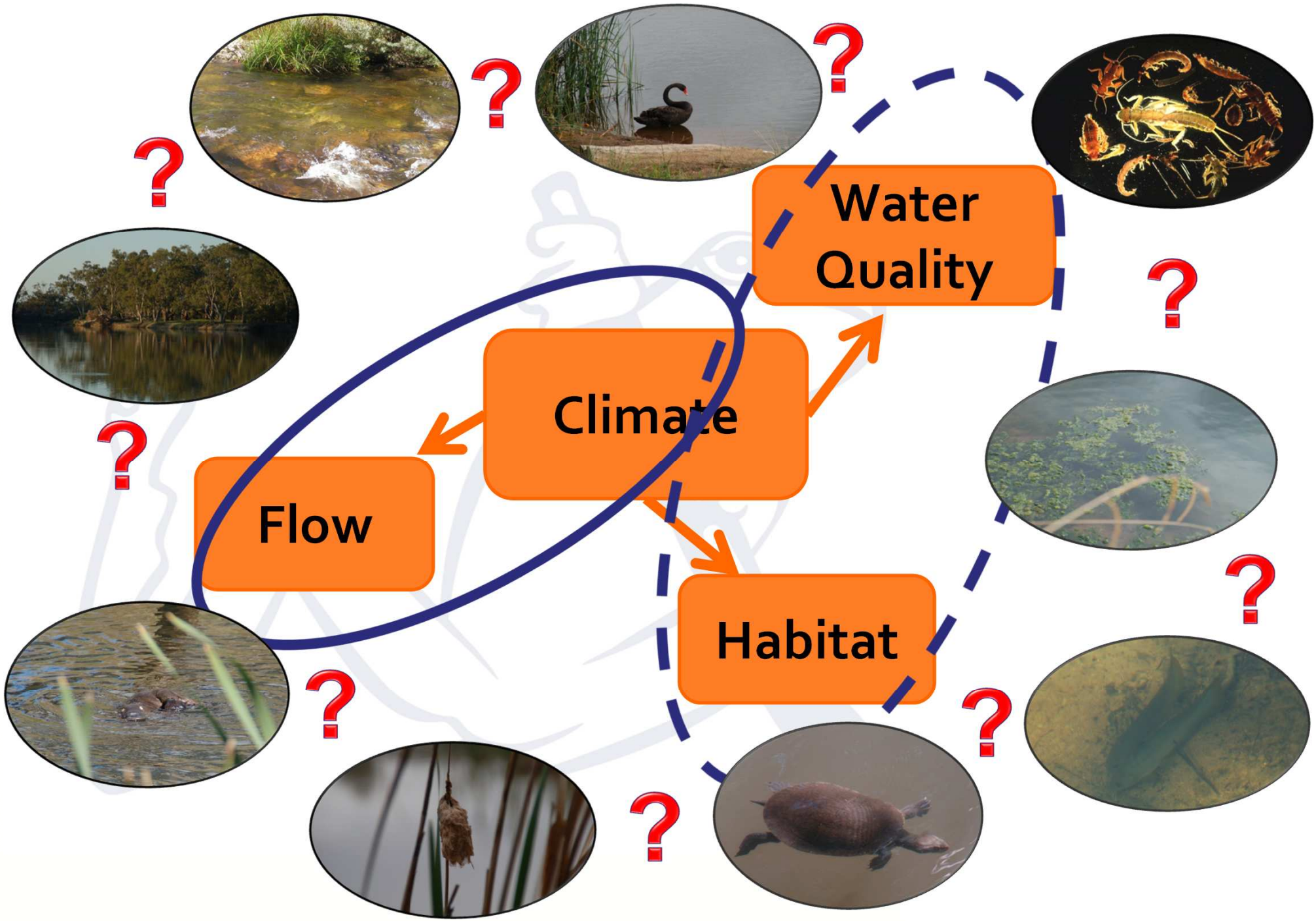
Fresh and Marine Water Quality
Natural Resources and Water
Managing Queensland's natural resources
Water quality guidelines for
recycled water schemes
Australian Government


Water Quality
Climate
Flow
Habitat


Water Quality
Climate
Flow
Habitat

Objectives

- To develop a linked modeling framework:
  - combining hydrological, water quality and ecological response models
  - to predict the response of these complex systems under different climate and adaptation scenarios
- Focus
  - Adverse biological effects
  - Informing adaptation initiatives

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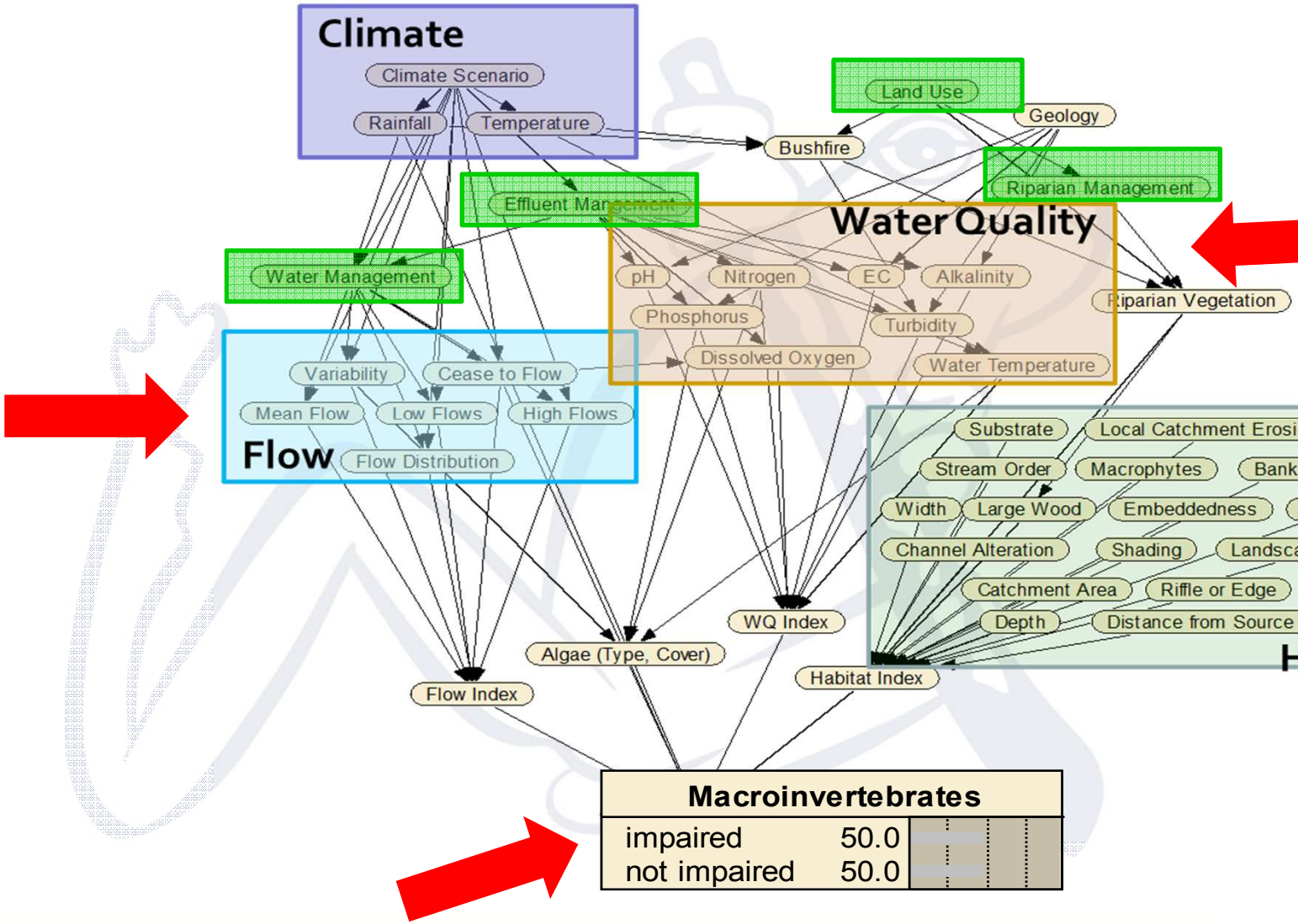
Bayesian meta-modelling approach



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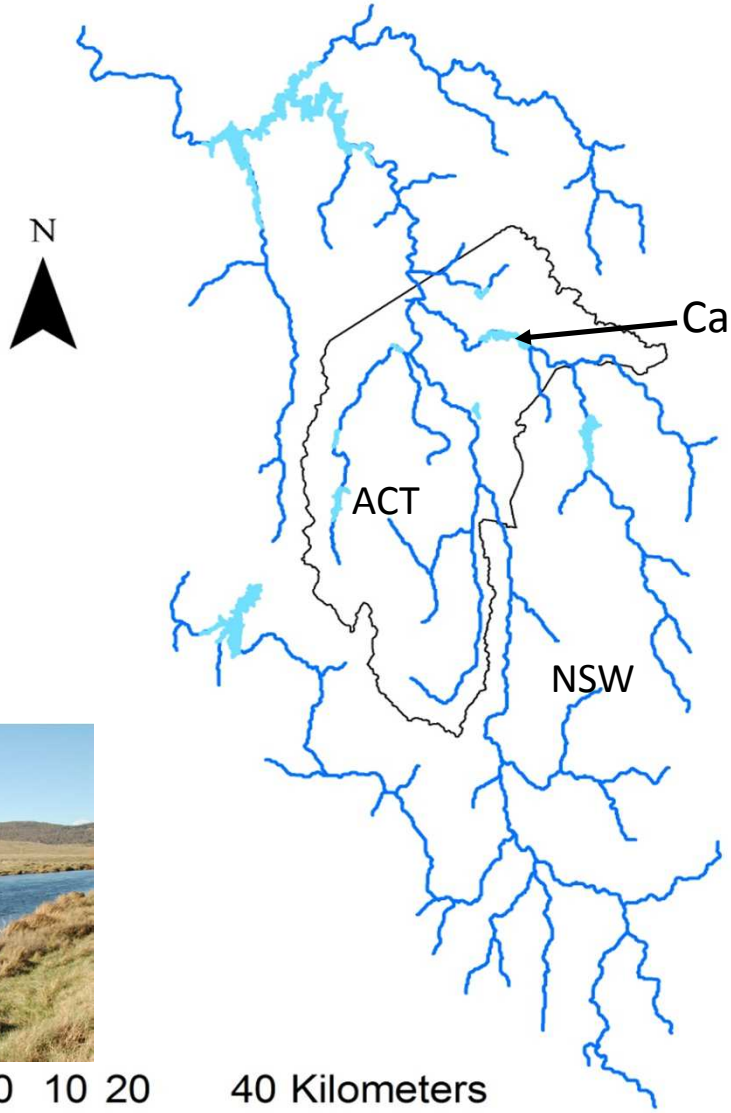
Study Area



Ecological Endpoints

- Macroinvertebrates
  - Indicators of River Health
  - % "Sensitive" taxa (%EPT)
  - Community richness
  - Community structure

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Selecting drivers

- Macroinvertebrate data
  - 320 sites; 20 years
- 128 predictor variables (drivers)
    - Hydrology, climate, landuse, geology, water quality & habitat
- Remove correlated drivers (>0.7)
- Selection methods
  - EPT/Richness: Boosted Regression Trees
  - Community: Multivariate analysis (BEST)

Selecting Drivers

Order based on the importance

- +

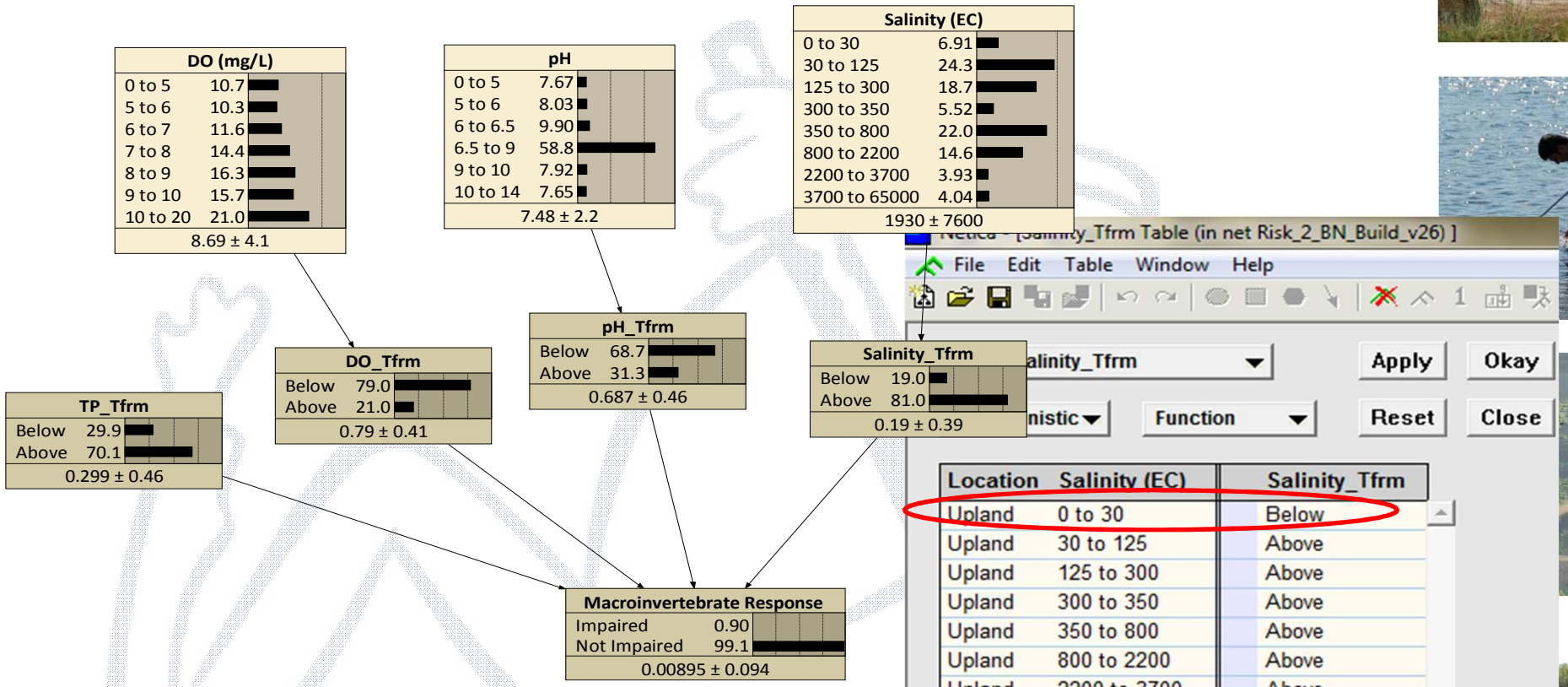
EPT (% explained BRT* model **46.75**)	Relative Importance (%)	**Richness** (% explained BRT* model **36.14**)	Relative Importance (%)	**Whole community**	
CV (year)	10.37 (of 46.75)	Altitude (m)	10.55 (of 36.14)	CV (Month)	
Urban (%)	9.23	Mean flow (year)	7.97	**CV (Year)**	
Days 10th %ile (year)	7.96	pH	7.77	Local Catchment Erosion	ρ= 0.455$^{\#}$ (including these 7 variables)
% Cover of riparian zone < 10m	6.58	% Cover Rip grass, ferns and sedges	7.27	**EC (mS/cm)**	
EC (mS/cm)	6.40	Catchment area	6.75	Volcanic sediment	ρ= 0.510 including 17 variables
CV (90 days)	6.18	**EC (mS/cm)**	6.32	Sandstone	
		Turbidity (NTU)	6.21	**Urban (%)**	

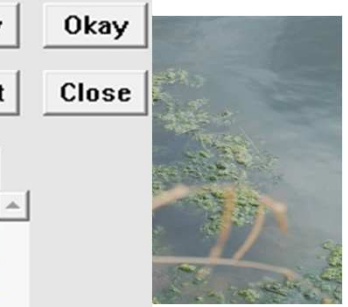
Hydrology | **Water Quality** | **Habitat** | **Land use** | **Geology**

*BRT (Boosted Regression Trees)

$^{\#}$ BEST test (based on rank correlation (Rho, ρ)

Threshold Response?





- Is there a threshold response to those drivers?

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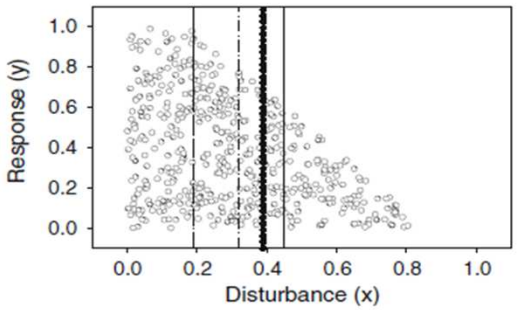

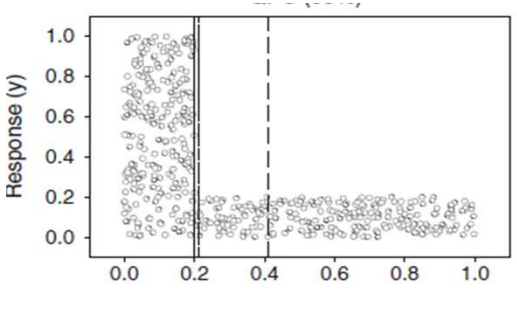

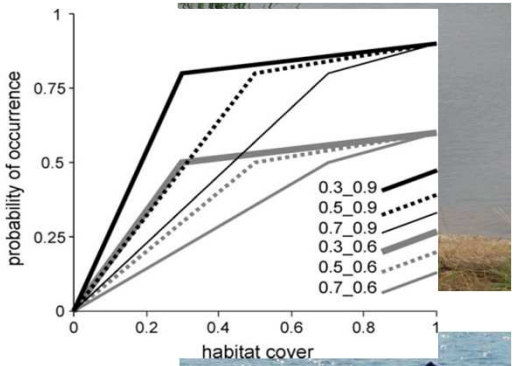

Ecological thresholds: approaches

Environmental Management (2008) 42:821–832
DOI 10.1007/s00267-008-9150-2

Quantitative Identification of Disturbance Thresholds in Support of Aquatic Resource Management

Travis O. Brenden · Lizhu Wang · Zhenming Su

Ecography 32: 1075–1084, 2009
doi: 10.1111/j.1600-0587.2009.05571.x
© 2009 The Authors. Journal compilation © 2009 Ecography
Subject Editor: Thorsten Wiegand. Accepted 7 March 2009

Ecological thresholds: an assessment of methods to identify abrupt changes in species–habitat relationships

J. N. Am. Benthol. Soc., 2010, 29(3):1017–1023
© 2010 by The North American Benthological Society
DOI: 10.1899/09-133.1
Published online: 29 June 2010

Use of ecological thresholds to assess recovery in lotic ecosystems

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Method	Desc
Breakpoint regression (piecewise regression)	Statistical determination if 2 linear) fit data better thar regression
Cumulative frequency distributions	Detects changes in expected combined with analytical differences among distrib acceptable levels of chang
Nonlinear curve fitting	Search methods used to fit a
Nonparametric changepoint analysis	A test for change in varianc dimensional Kolmogorov to calculate empirical con
Quantile regression	Characterization of changes quantile regression trees splines
Recursive partitioning	Predictors can be categorica

Table 1. Papers on ecological thresholds reviewed. Only papers performing statis

Parser	Taxon	Species richness

Table 1. Software for regime shift detection[a]

Program	Methods	Approach	Availability	Authors	URL
Brodgar	Chronological clustering, dynamical factor analysis, min/max autocorrelation factor analysis, etc.	Inferential	Commercial, stand-alone with R interface, Windows	A.F. Zuur [30]	http://www.brodgar.com/brodgar.htm
Caterpillar-SSA	Singular spectrum analysis, structural change detection	Exploratory	Commercial, stand-alone, Windows	N. Golyandina, V. Nekrutkin, A. Zhigljavsky	http://www.gistatgroup.com/cat/index.html
Change-point analyzer	CUSUM charts, bootstrap tests	Inferential	Shareware, stand-alone + Excel add-in, Windows	W. Taylor	http://www.variation.com/cpa
DCPC	Detection of changes using a penalized contrast	Inferential	Freeware, Matlab scripts, multiple OS	M. Lavielle	http://www.math.u-psud.fr/~lavielle/programs
Dimensionality reduction toolbox	Linear (PCA, etc.) and nonlinear dimensionality reduction methods	Exploratory	Freeware, Matlab scripts, multiple OS	L.J.P. van der Maaten [32]	http://www.cs.unimaas.nl/l.vandermaaten/Laurens_van_der_Maaten/Matlab_Toolbox_for_Dimensionality_Reduction.html
Palaeo	Chronological clustering	Exploratory	Freeware, R package, multiple OS	S. Juggins	http://www.staff.ncl.ac.uk/stephen.juggins/analysis.htm
Regime shift detection	Sequential t tests, prewhitening option for autocorrelated data	Inferential	Freeware, Excel add-in, Windows	S.N. Rodionov [42]	http://www.beringclimate.noaa.gov/regimes
STSA:	Dynamical linear models,	Inferential	Commercial, O-matrix	D.D. Thomakos	http://www.omatrix.com/stsa.html

Methods	Description	Comments	Authors
Nonparametric deviance reduction (NDR)	entails splitting a disturbance- response dataset into two groups at points along the ordered disturbance variable gradient and calculating the reduction in the response variable deviance that results from the split. The split that results in the largest reduction in the deviance is the disturbance threshold estimate. **It is inspired by tree-based modeling**; the identified threshold is in fact the first split of a regression tree model.	Percentiles of the threshold's marginal posterior distribution can be used to estimate Bayesian credibility intervals for the threshold. Statistical significance e.g., chi-square test	(Qian et al 2003)
Bayesian change-point (BCP)	**similar to the NDR** approach in that it entails splitting a disturbance-response dataset into two or more groups at points along the ordered disturbance variable gradient; however, **requires explicit specification as the probability** distributions of the groups that result from splitting the original dataset	Statistical significance	(Qian et al 2003, 2004)
Quantile piecewise constant (QPC)	a form of **regression tree** analysis (in this means, similar to **NDR**). The NDR and QPC differ, in how the response variable is split into groups. QPC uses **quantiles to generate regression tree** by recursively partitioning the data series such that each tree node has maximum differences in the 7th quantiles of the response variables.		
Piecewise regression (PR)	**two or more separate regression lines** describing the conditional mean relationship between the disturbance and response variables. The **regression lines are joined** at **unknown points** along the ordered gradient of the disturbance variable ; these points indicate where there are changes in the conditional mean relationship between the disturbance and response variables , i.e. threshold	- can be difficult due to the occurrence of many **local minima** in the objective function surface. - confidence intervals for the estimated threshold can be obtained **by bootstrapping** or through large-sample approximation. - Statistical significance e.g., BIC, permutation hypothesis test	(Toms and Lesperance 2003)
Quantile piecewise linear (QPL)	Blends characteristics of the **QPC** and **PR** approaches. - It is a **regression tree** method that uses **quantiles** to partition groups (like QPC) - partitions the data based on differences in the conditional relationship between the disturbance and response variables at each tree (like PR)	performed well for datasets with conditional mean or upper boundary changes in response variables at the disturbance threshold **most robust threshold identification,** but did **not evaluate uncertainty** (e.g., confidence limits around thresholds, variability, and capture rate of simulated thresholds)	

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Thresholds?

Predictor Variables	Quantile Regression		TITAN	LINKTREE
	Richness	EPT	All community (indicator taxa)	All community
EC	134.2	162.45	72.95	157
CV year	X	2.44	2.3	1.09

- Threshold values comparable
  - Different methods
  - Different end-points

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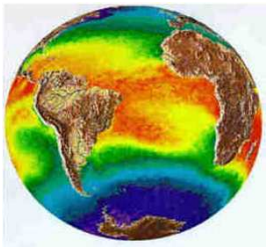
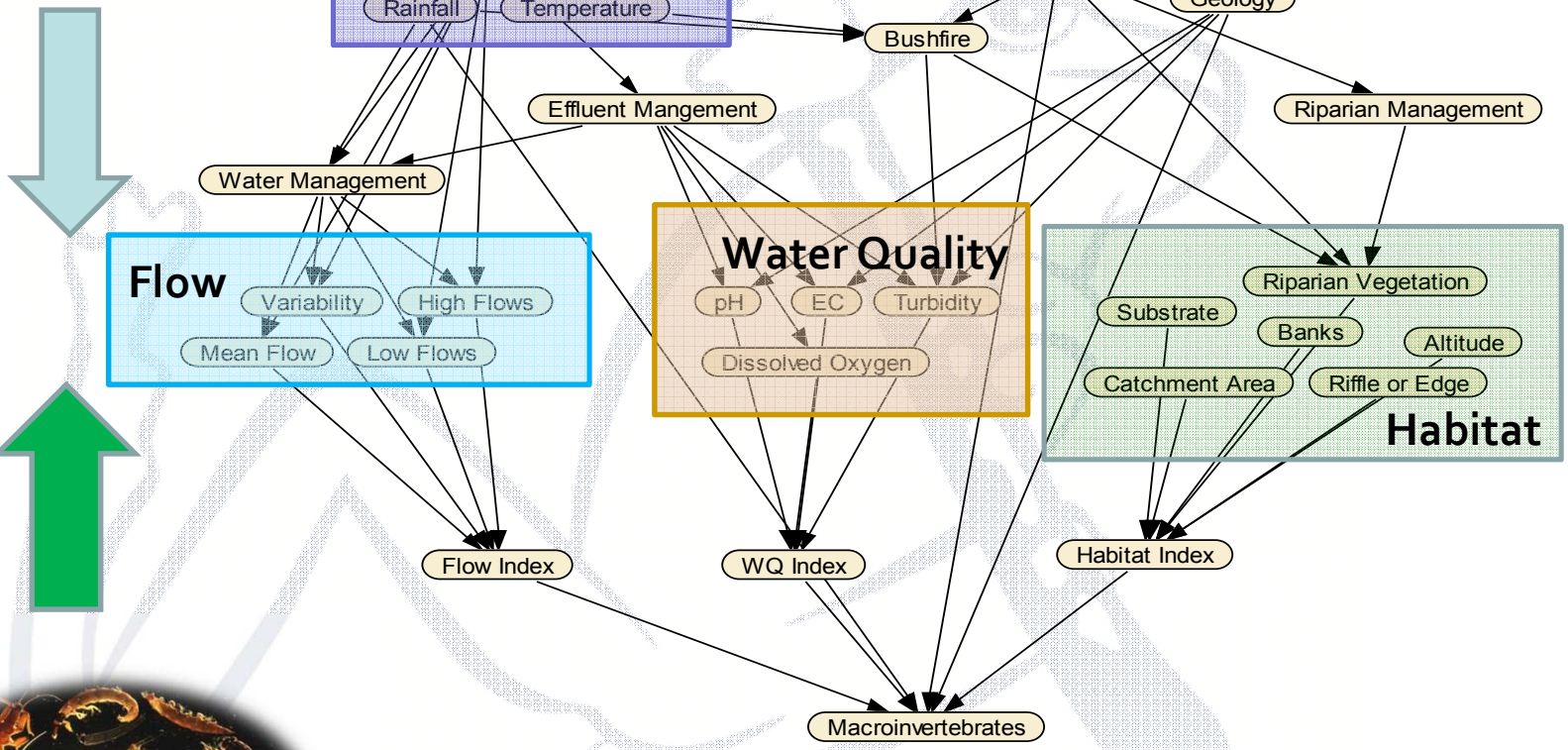
Model Structure





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Conclusions

- Focussing on ecological response
  - Defines model structure
    - Differs depending on definition of ecological response
- Identifying ecological relevant thresholds
  - Different techniques similar thresholds
- Identifies where to invest modelling effort
  - Climate / flow / water quality
  - Uncertainty management

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