Water Studies Centre

Bayesian decision networks

Going beyond expert elicitation for parameterisation and evaluation of ecological endpoints

Carmel A. Pollino and Barry T. Hart

Water Studies Centre, Monash University

Water Studies Centre

Bayesian decision networks

Use in Ecological Risk Assessments and NRM

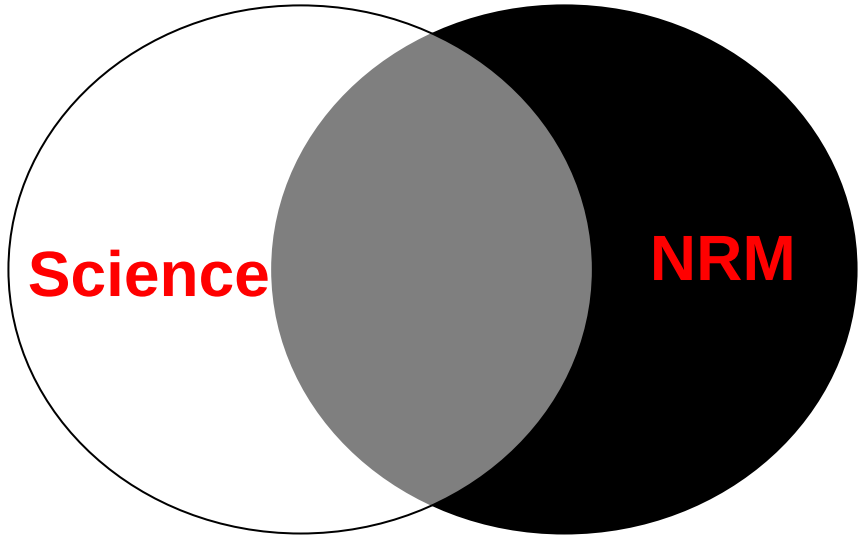
Carmel A. Pollino and Barry T. Hart

Water Studies Centre, Monash University

Models, ERA & NRM

- In ERA & NRM, we need models that:
  - Represent complex systems (i.e. multiple interacting variables)
  - Incorporate knowledge and data
  - Inform decision making
  - Promote adaptive management
  - Scientifically robust
- Role of models
  - Predictive
  - Exploratory: Key knowledge and data gaps

Models: Science & NRM



Scientific Robustness

Versus

Utility in NRM / Decision-making

Ideally models: meet both needs

Bayesian Models

- Model complex systems
- Formal integration of different sources of evidence
  - Subjective & Quantitative
  - Across disciplines
- Guide data collection
  - Targeted to benefit the understanding (and management) of a system
  - Address uncertainties
- Models iteratively updated - adaptive management

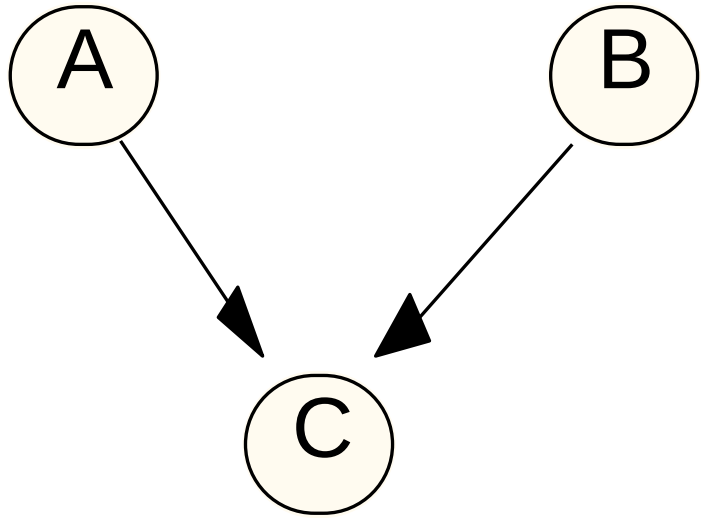
Bayes' Theorem

$$P(B \mid A) = \frac{P(A \mid B) \cdot P(B)}{P(A)}$$

Rev. Thomas Bayes
(1702-1761)

What is a Bayesian Network?

- Two components
  - Structure
  - Probabilities
- Links between variables represent causal relationships (as with a conceptual model)



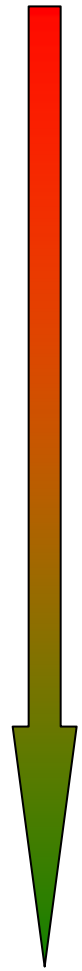
- Probabilistic relationships are used to describe the strengths between variables
- Inputs: expert opinion (technical / non-technical), literature, monitoring / research data, other models

Are BNs scientifically robust?

Can BNs meet the needs of NRM?

BN Models: Science & NRM

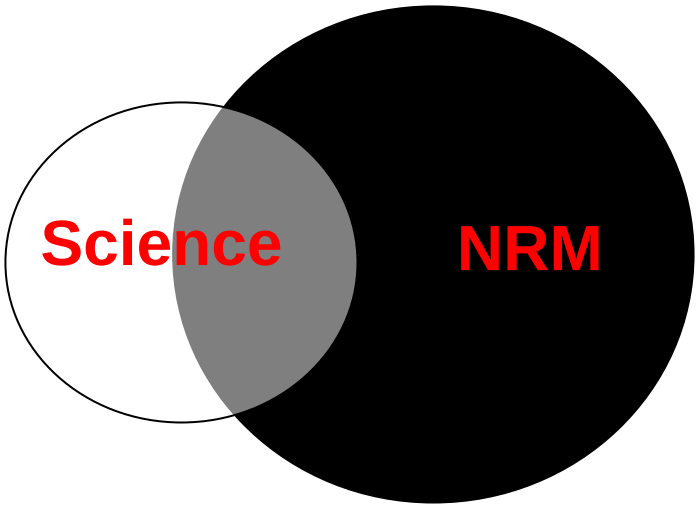
Criteria	BNs
Dynamic systems (loops)	Poor
Continuous distributions	Poor
Imprecise Probabilities*	Poor
Transparency	Poor / Okay
Multiple hazards/risks	Okay
Communication tool	Okay
Integration tool**	Okay
Adaptive Management	Okay
Scenario analysis	Okay



*** Exact inference only in BNs**

**** Across disciplines & merge subjective and quantitative info**

BN Models: Science & NRM



Scientific Robustness

Versus

Utility in NRM / Decision-making

BN models: meet many needs of NRM, scientific robustness still catching up

BNs – some examples

- Flexible and adaptive modelling tool
- Excellent communication tool
- No single method or purpose for building models
- Let me show you….

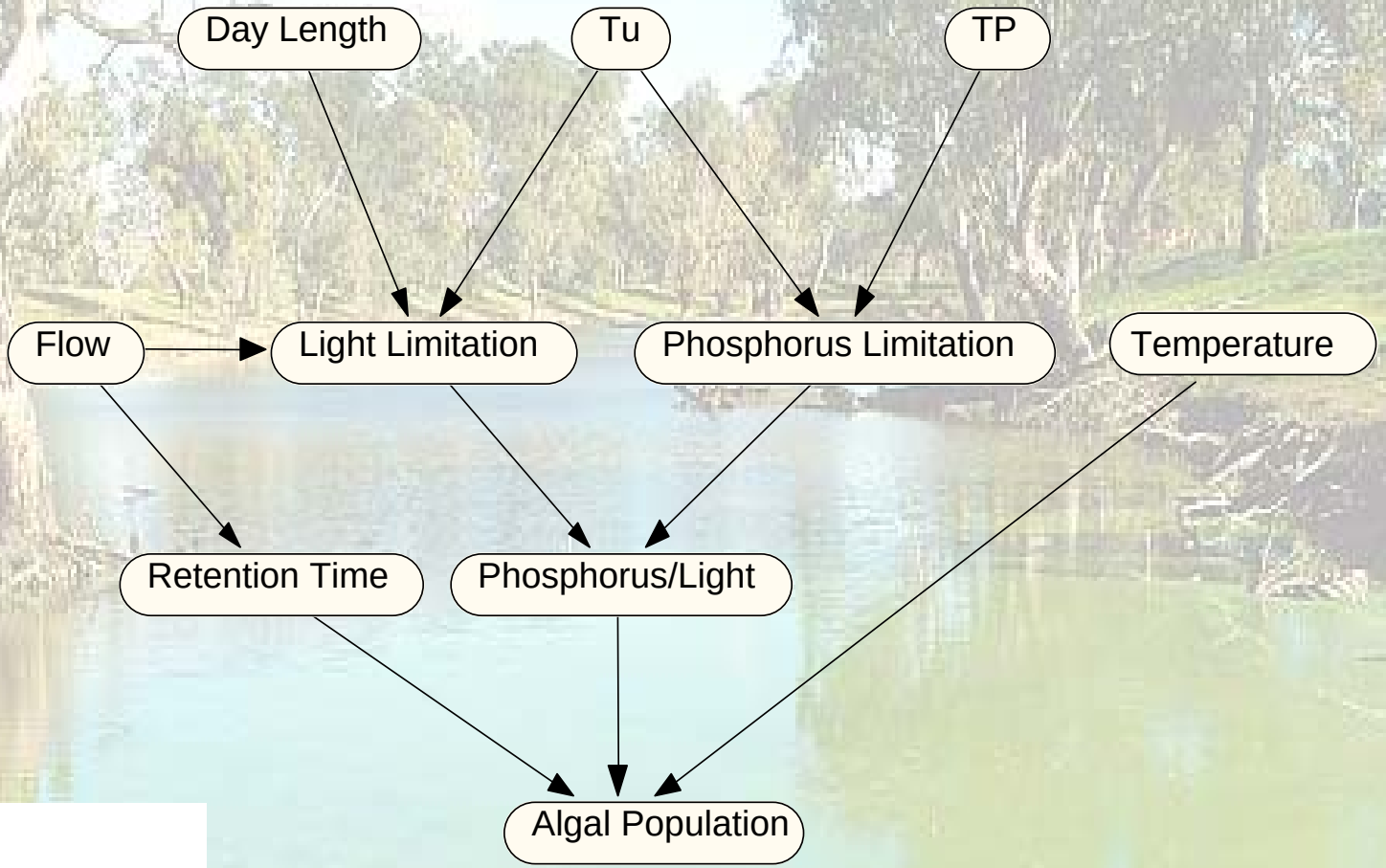
Conceptual models ⇒ Quantitative Models

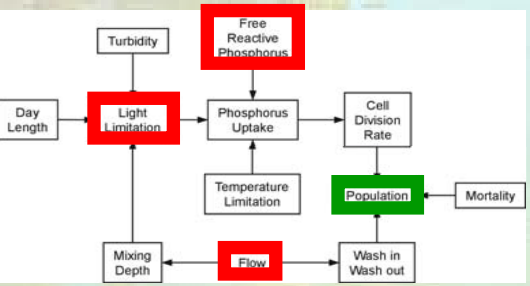
Case Study example:

Blue Green algal booms (*Anabaena*) in Burke Weir

- Data-driven model

Bayesian Networks (BNs)





Purpose: Predicting & managing blooms

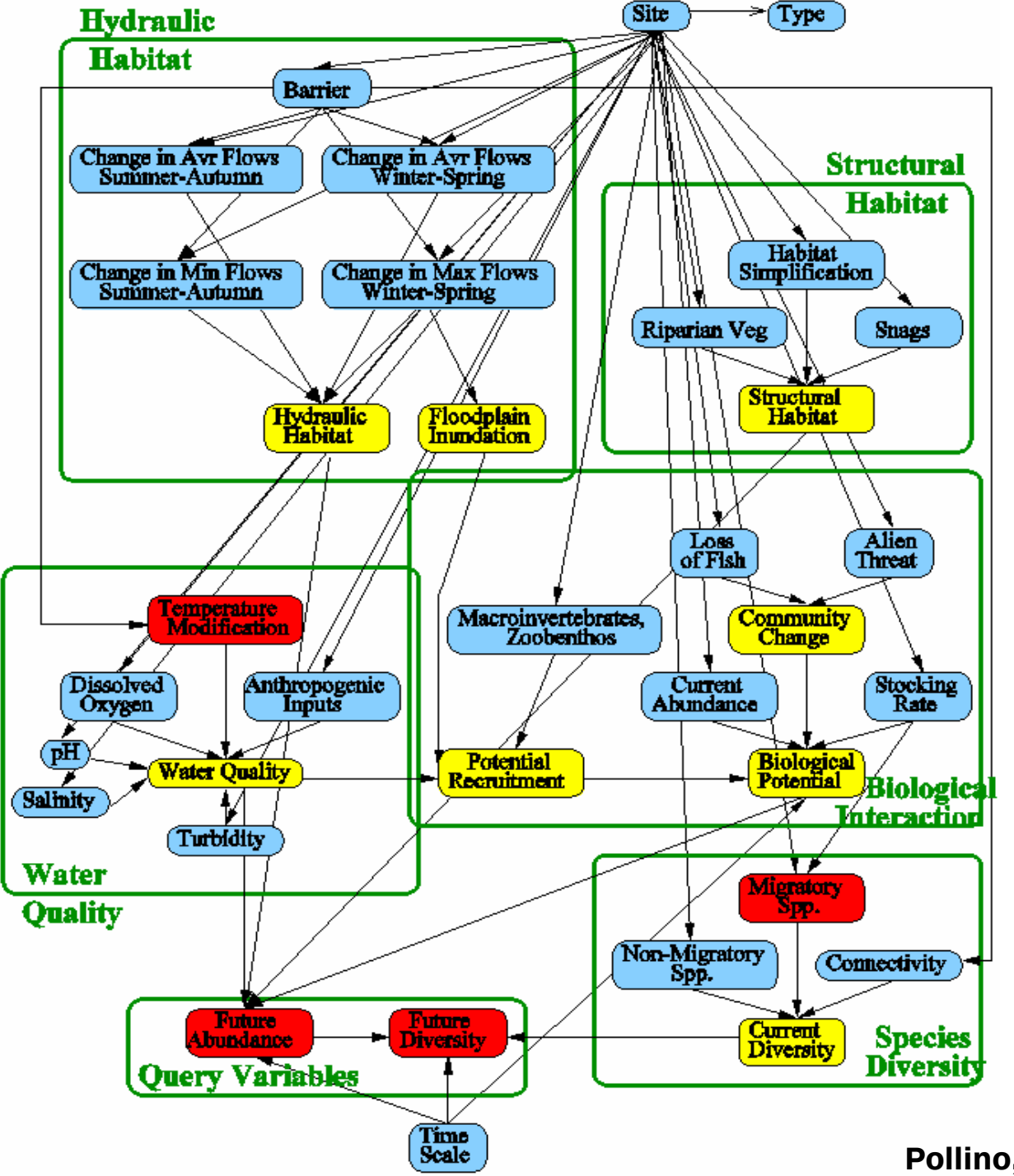
Webb & Pollino

Model sensitivity ⇒ Ranking / prioritising risks

Case Study example:

Native fish in the Goulburn Catchment

- Data and expert-driven



Fish Network

-5 sub-networks

Water Quality

Flow

Structural Habitat

Biological Interactions

-2 query nodes

Fish Abundance

Fish Diversity

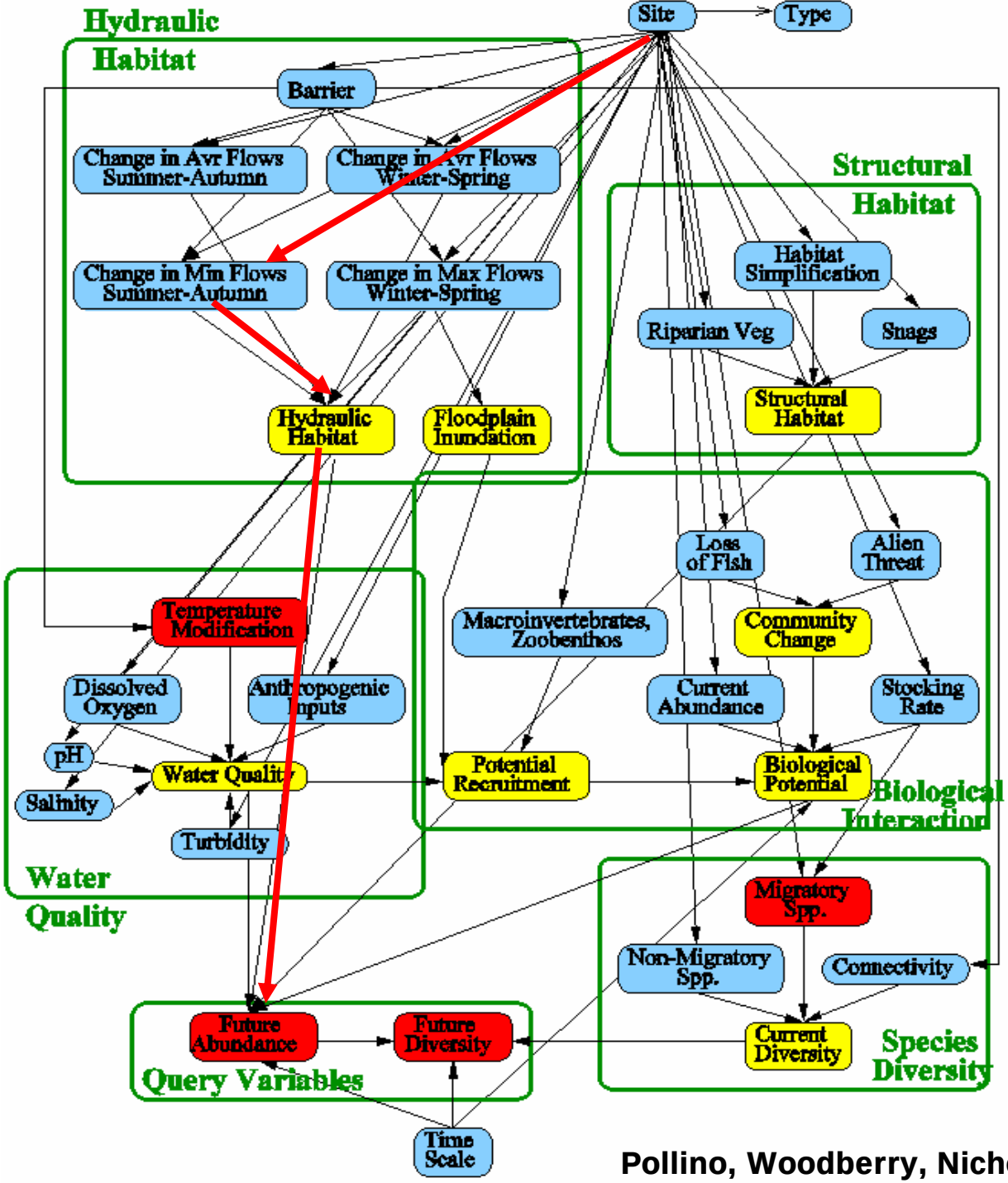
-23 sites

6 reaches

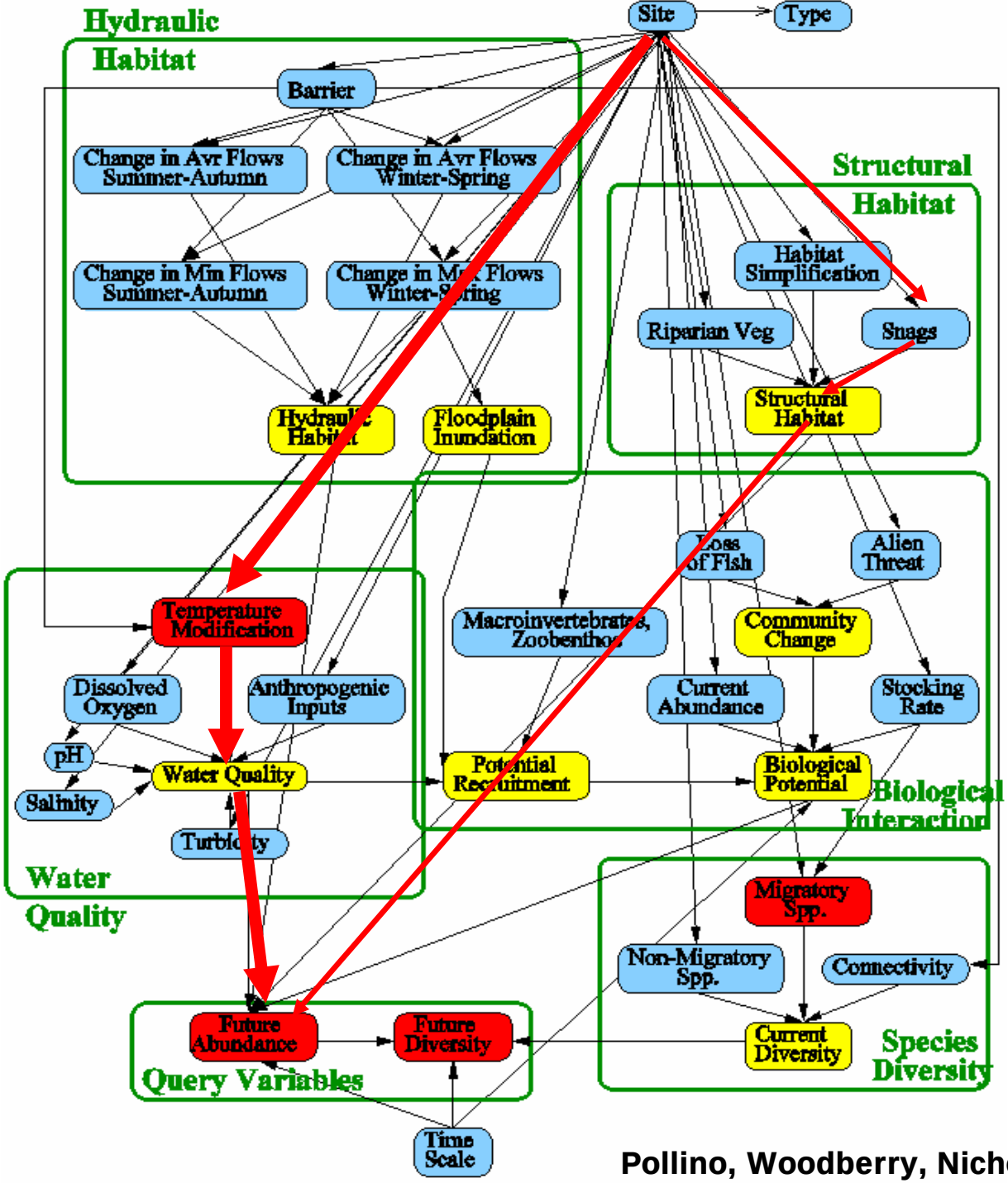
-2 temporal scales

1 and 5 year changes

Pollino, Woodberry, Nicholson, Korb, Hart



Pollino, Woodberry, Nicholson, Korb, Hart



Pollino, Woodberry, Nicholson, Korb, Hart

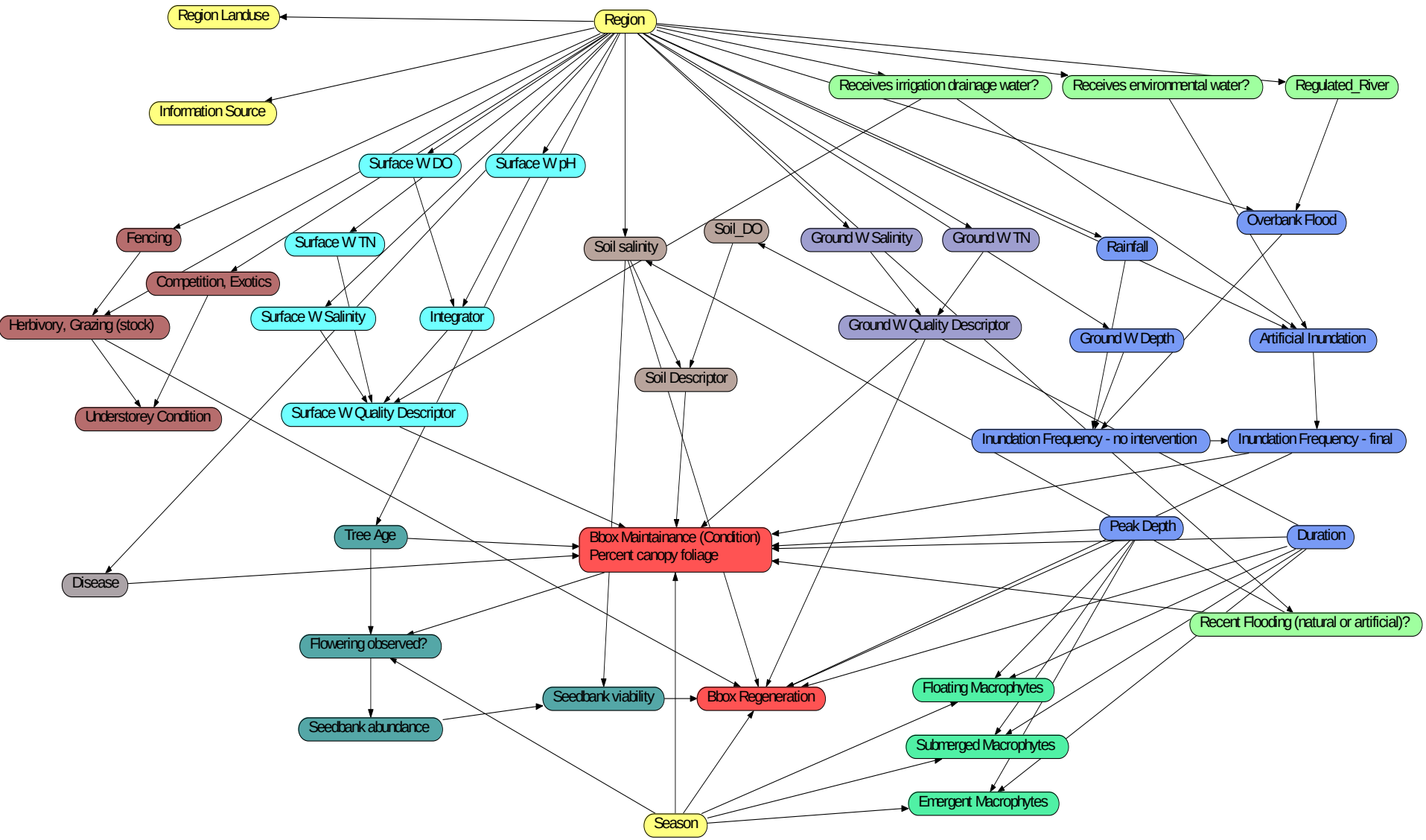
Complex Models ⇒ Simple Models

Case Study example:

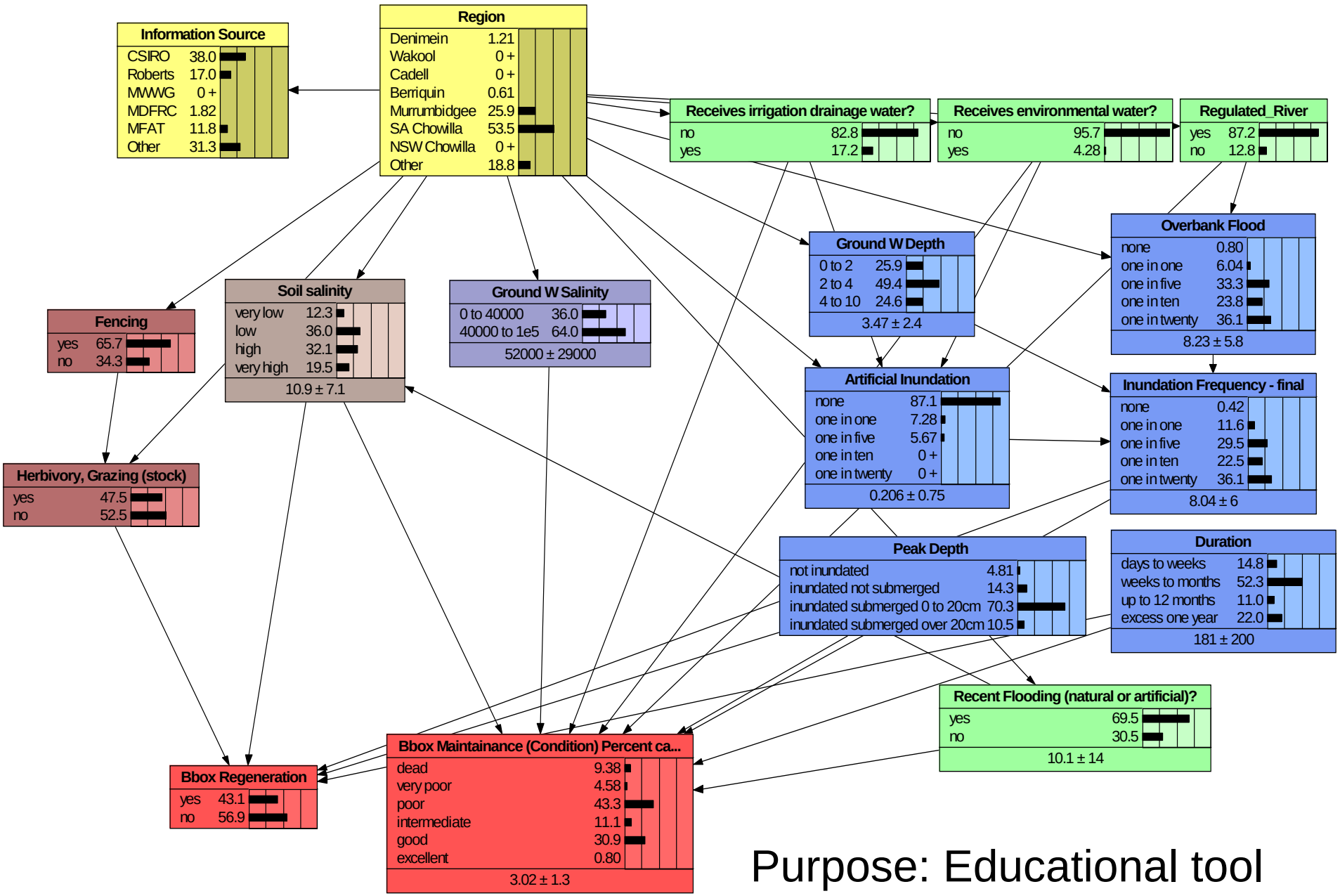
Black box *(Eucalyptus largiflorens*) depressions on the Murray floodplain

- Data and expert-driven

Black box Network (complex)



Black box Network (simple)



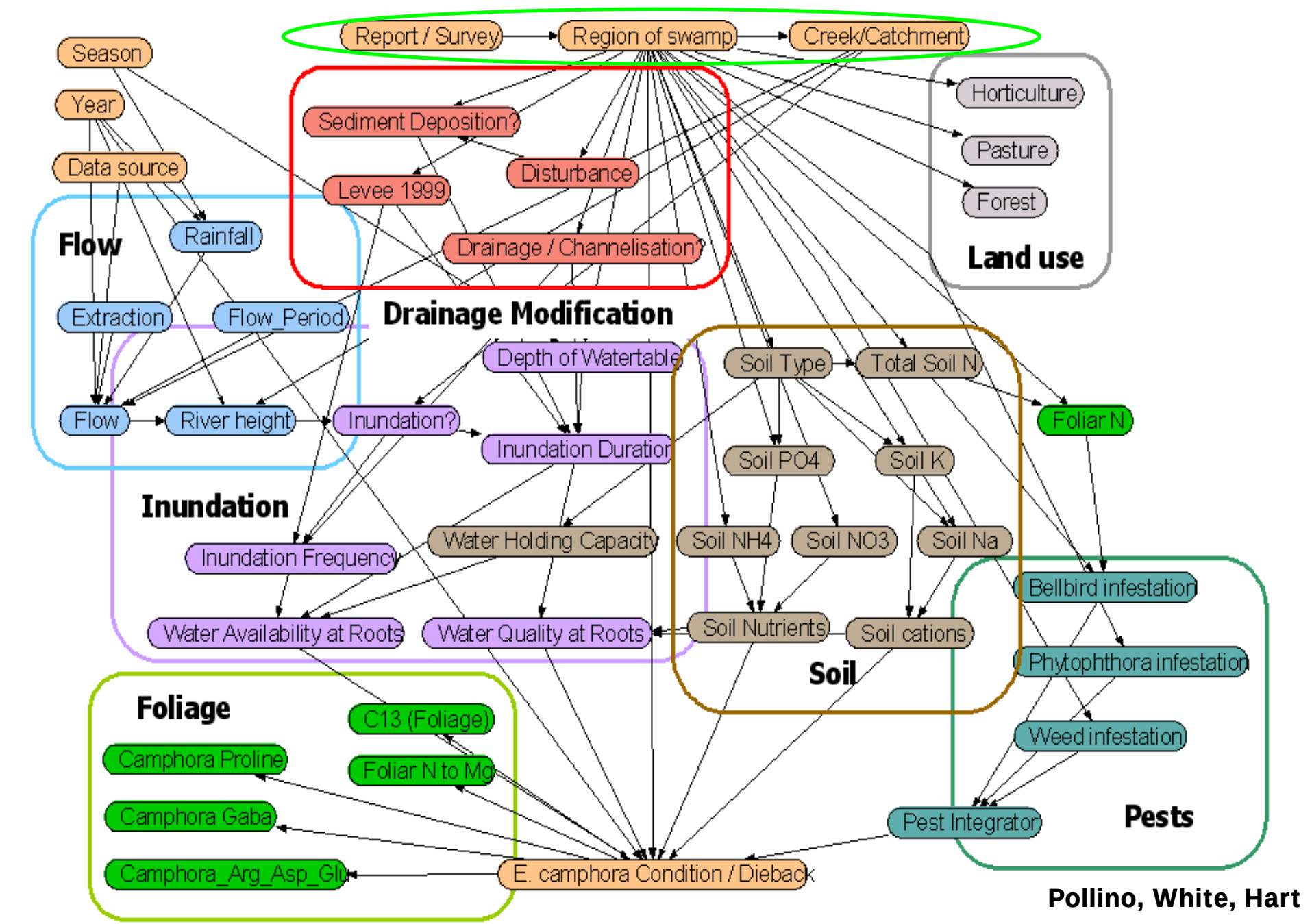
Purpose: Educational tool

Multiple Hypotheses / Models ⇒ Single framework

Case Study example:

Eucalyptus camphora in the Yellingbo Nature Conservation Reserve

- Data and expert-driven



Purpose: Exploratory (conflict, gaps & future directions)

Important variables*

Uni of Melb assessment	Consultant assessment	Integrated model
Soil NO_3	Soil cations	Pests
Pests	Inundation	Soil NO_3 & PO_4
Soil cations	Water quality	Soil type
Soil type	Drainage, channelisation	Watertable depth
Soil PO_4	Pests	Soil cations

* Sensitivity Analysis

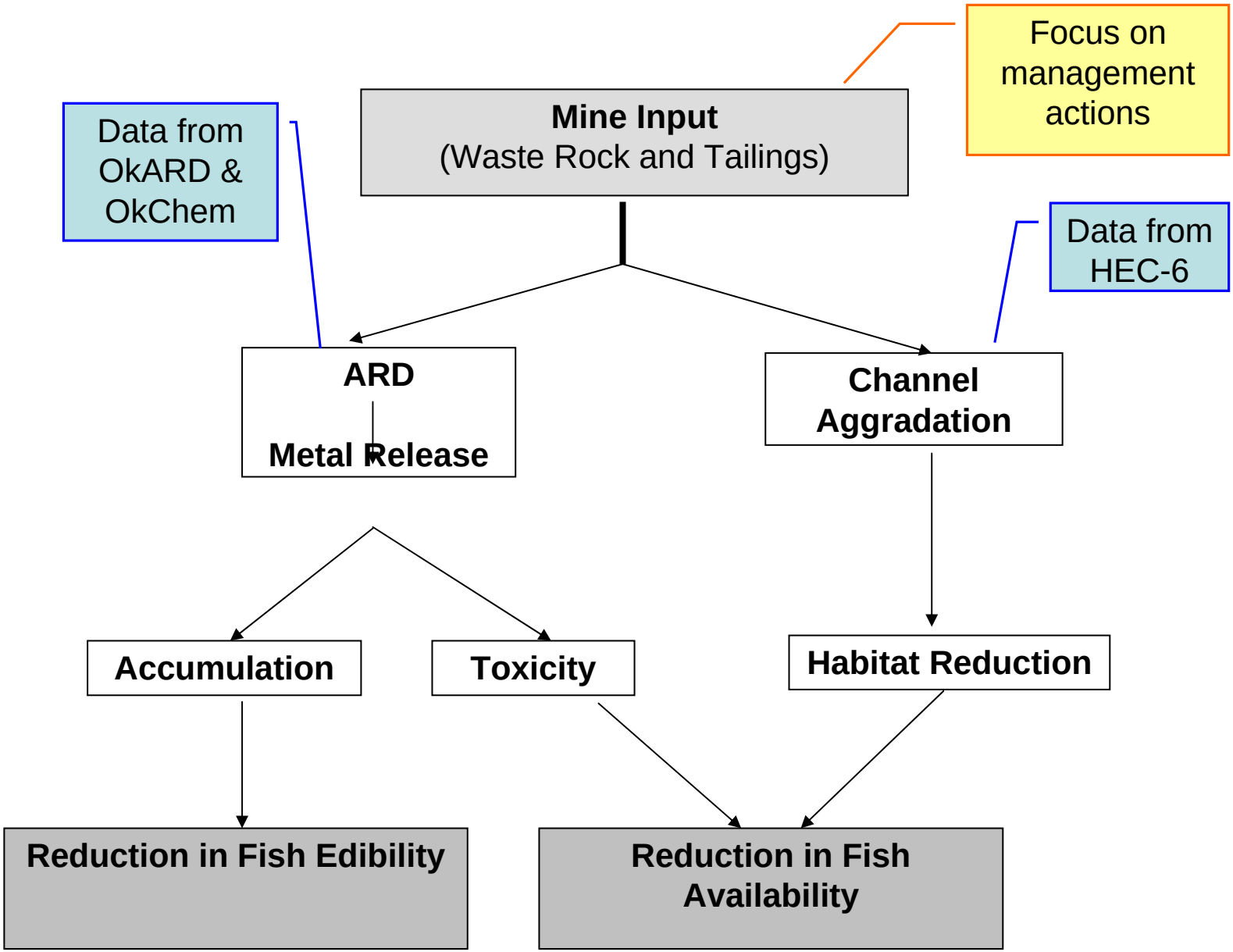
Risk Assessment ⇒ Prediction & Scenario Analysis

Case Study example:

Mine operation scenarios

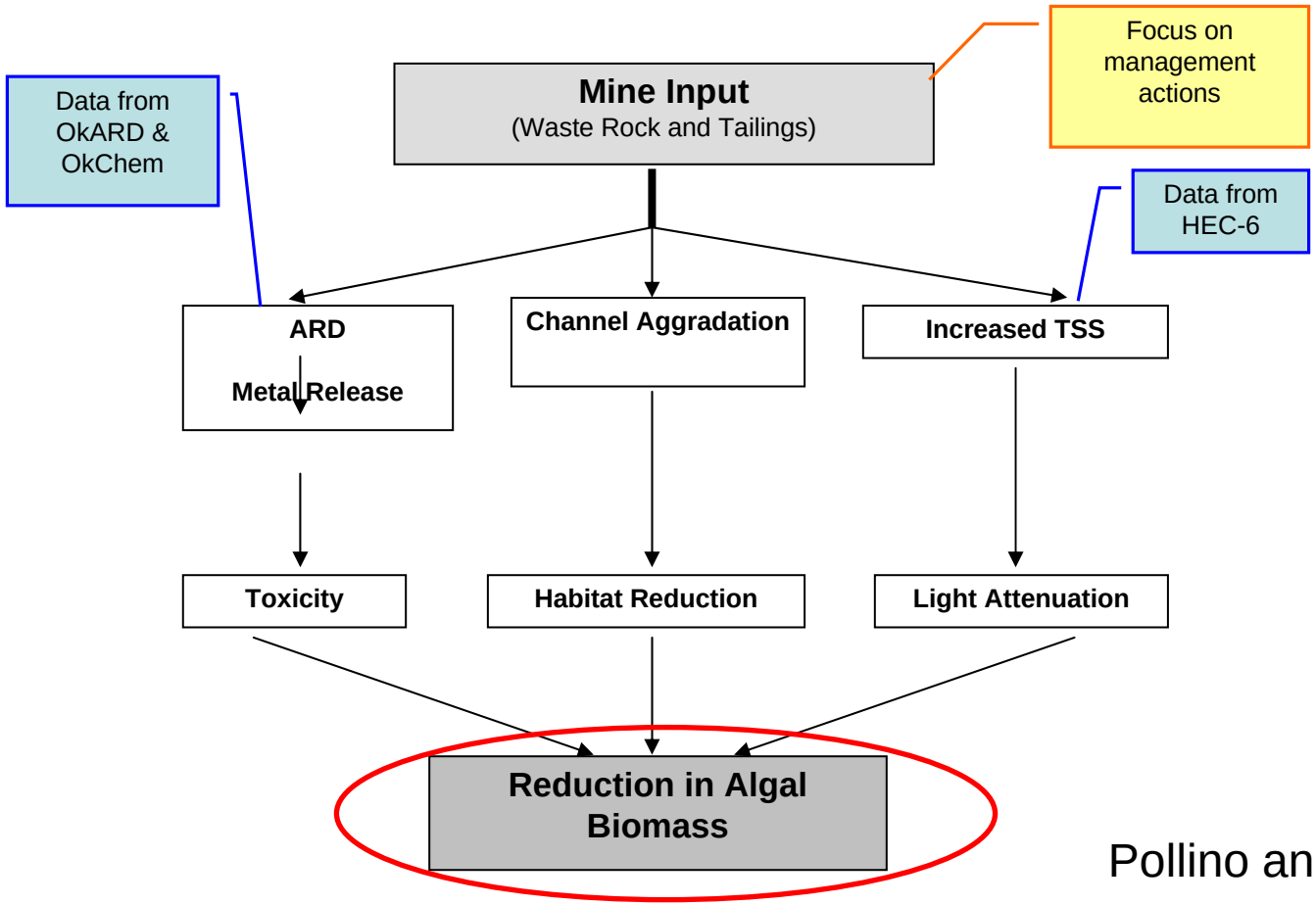
- Data and expert-driven

Lots of data


Focus on management actions
Mine Input
(Waste Rock and Tailings)
Data from OkARD & OkChem
Data from HEC-6
ARD
Metal Release
Channel Aggradation
Accumulation
Toxicity
Habitat Reduction
Reduction in Fish Edibility
Reduction in Fish Availability

Little data

Expert elicitation & targeted research / monitoring



Pollino and Hart

Acknowledgements

- Angus Webb
- Andrea White
- Ann Nicholson
- Owen Woodberry
- Kevin Korb