Daly River Fish & Flows Project:

Summary of key findings

Michael Douglas (Charles Darwin University)

Mark Kennard (Griffith University)

Brad Pusey (Griffith University)

Sue Jackson (CSIRO)

Julian Olden (University of Washington)

Australian Government
Land & Water Australia

Charles Darwin
UNIVERSITY

Griffith
UNIVERSITY

CSIRO

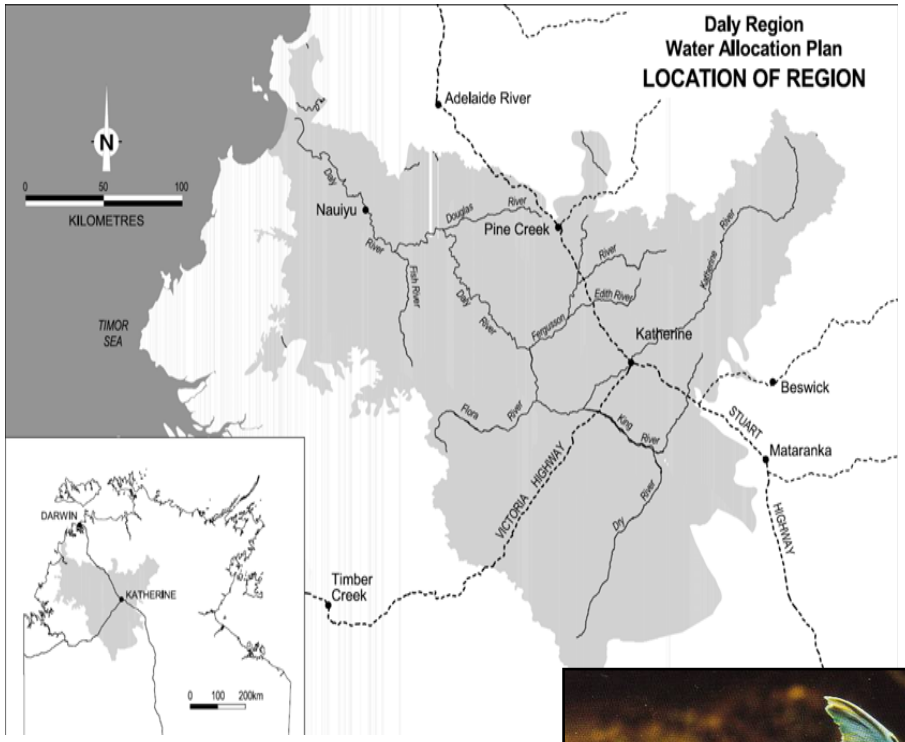
Northern
Territory
Government

TRaCK
Tropical Rivers and
Coastal Knowledge

Outline

- Introduction & Indigenous collaboration (Michael Douglas)
- Biodiversity & Spatial and Temporal Patterns (Brad Pusey)
- Environmental Flows and Risk Assessment (Mark Kennard)
- Summary (Michael Douglas)

Daly River, Northern Territory

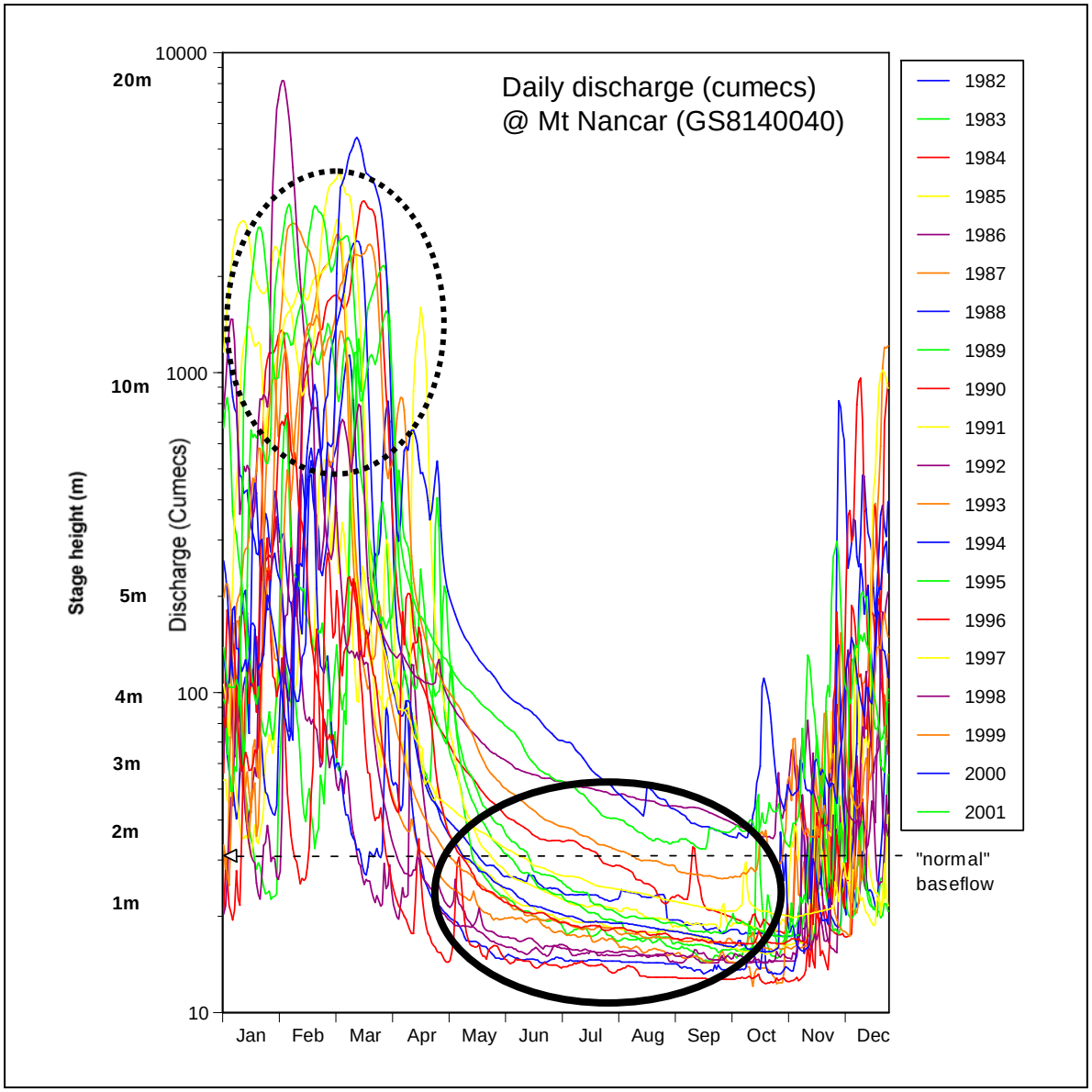


- 20,000 sq KM
- "Iconic" river
  - Tourism
  - Recreational fishing
  - Conservation significance
  - Agriculture





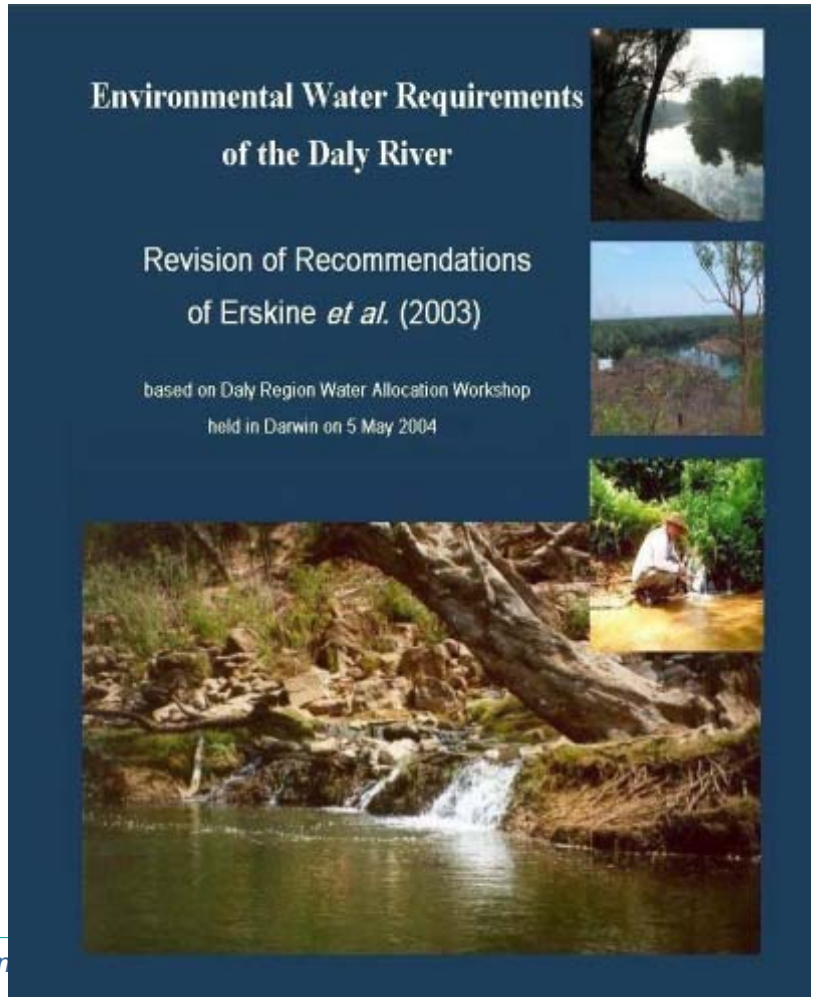
Water Use in the Daly River



- Greatest discharge of all NT rivers
- Highly seasonal
- Interest in abstraction of water for irrigation has focussed on the spring fed dry season
- Some discussion of “flood harvesting” during the wet season
- Current patterns of water abstraction most likely to affect dry season in flow

Environmental flows research in the Daly: past

- Comprehensive studies on:
  - Turtles (Georges et al. 2002)
  - Ribbon weed (Rea et al. 2002)
  - Algae (Townsend et al. 2002)
  - Riparian veg. (O'Grady 2002)
  - Erskine et al (2003, 2004)
- But
  - No work on fish
  - No Indigenous involvement



Aboriginal people and the Daly River

- Aboriginal people
  - Own 30% of catchment
  - Are 30% of population
  - 10 language groups
- *Strong connection with land and the river*
  - Water highly significant
  - Many sacred sites associated with water and river
- Knowledge of aquatic systems
  - Not well documented or recognised
  - Being lost

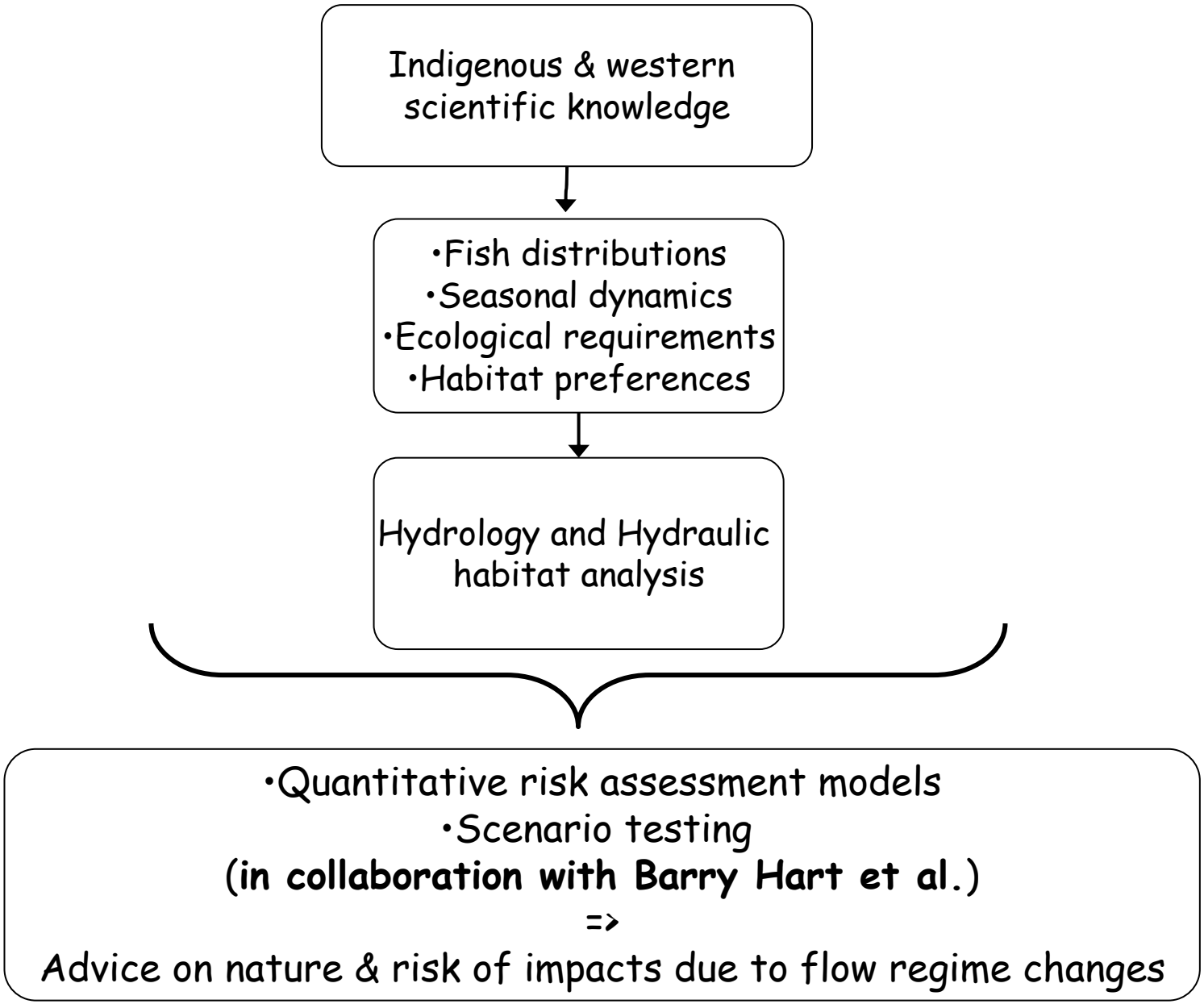
Daly Fish and Flows Project: Aims

1. Collaborate with Aboriginal traditional owners to document:
   - Indigenous knowledge of fish ecology
   - Cultural significance of fish
2. Sample freshwater fish through time and space
3. Quantify drivers of variation in species' distributions and assemblage composition
4. Collate data on habitat requirements and other ecological traits
5. Pilot a risk assessment model for water resource scenario testing
6. Capacity building of researchers and Indigenous collaborators

Project collaborators

- **Funders**
  - Land and Water Australia (2006-9), TRaCK (2008-10)
- **Research team**
  - Michael Douglas, Brad Pusey, Mark Kennard, Sue Jackson, Julian Olden
  - Poncie Kurnoth, Quentin Alsop, Thor Saunders, (DRDPIFR)
  - Helen Larson, Simon Townsend, Steve Tickell, Tony Boland (NRETAS)
  - Wagiman Association, Wardaman Association
  - Barry Hart, Terry Chan (Monash University), Carmel Pollino (ANU)
  - Danielle Warfe, Ian Dixon, Peter Kyne, Eric Valentine (CDU)
- **Steering committee**
  - Bill Harney (Wardaman), Lizzie Sullivan, Mona Liddy (Wagiman)
  - Jim Donaldson (LWA), Stuart Blanch (WWF), Chris Makepeace (AFANT), Ian Lancaster (NRETAS), Gary Higgins (KRTA), Andria Handley (DRDPIFR)

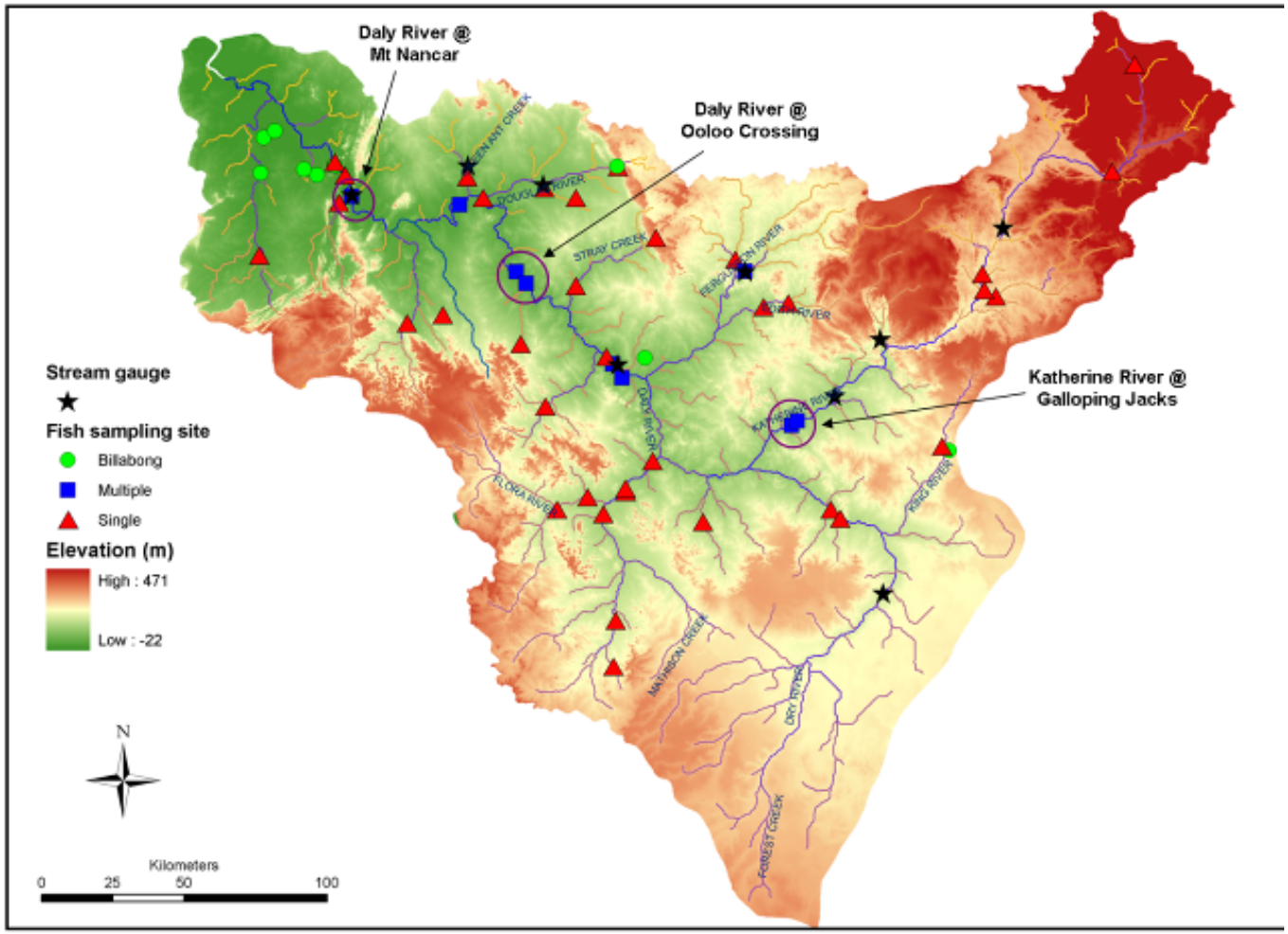
Project design



Sampling sites

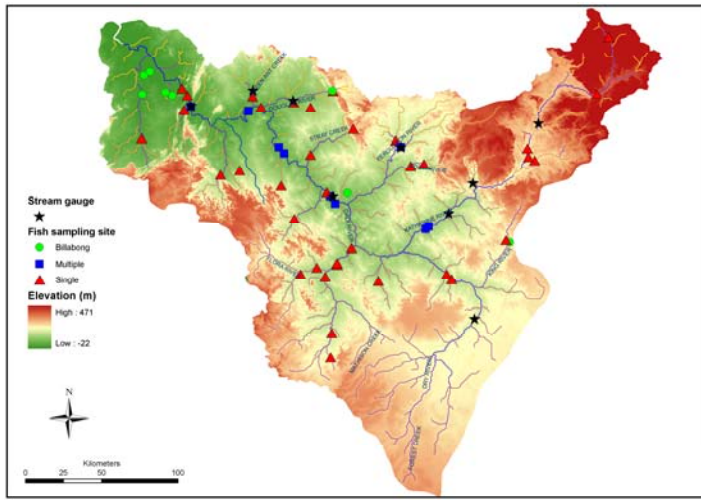
- 55 sites
- Permanent & ephemeral streams, rivers and floodplain billabongs

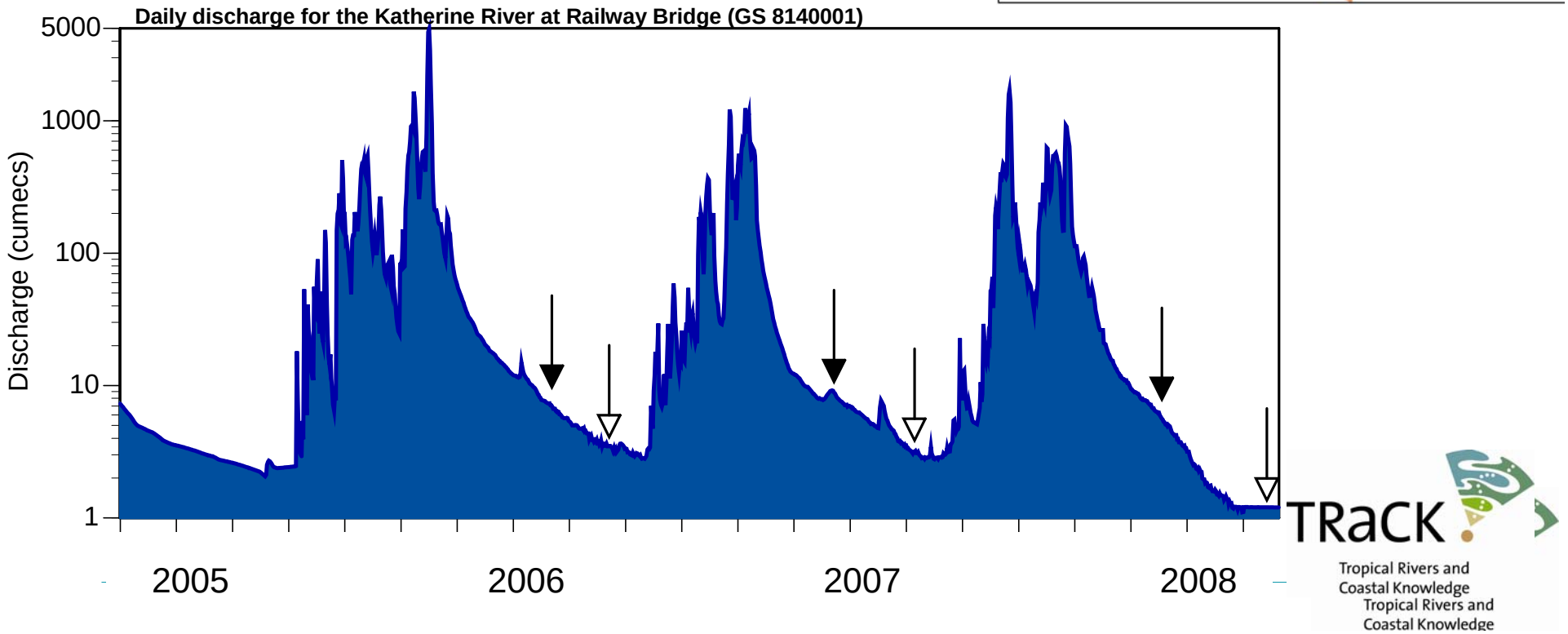
- 8 focal study sites
- Sampled early & late dry
- over 3 years (2006-2008),



Sampling times

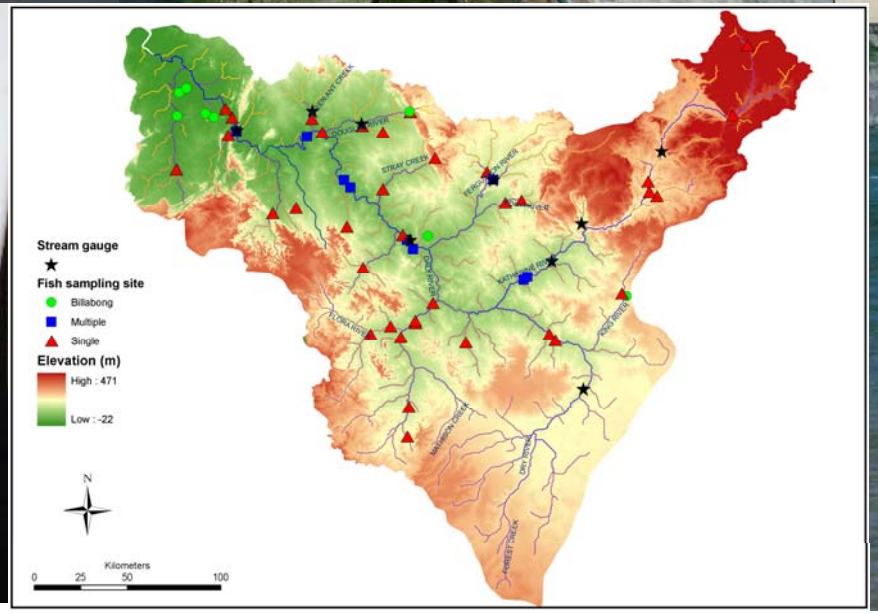
- Sampling encompassed a range of flow conditions
- Sampled seasonally (July and September)
- Sampling is continuing in 2009 & into future…

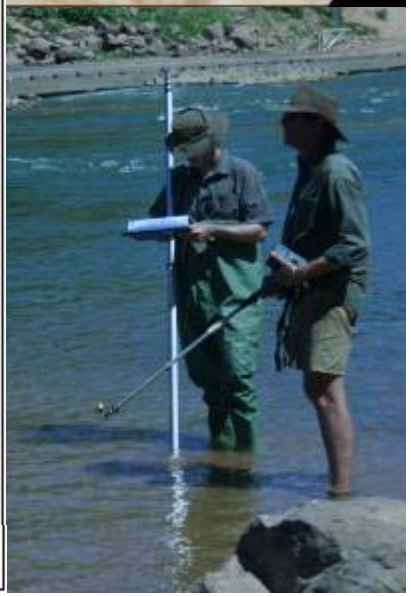




TRaCK
Tropical Rivers and Coastal Knowledge
Tropical Rivers and Coastal Knowledge

Sampling approach





Indigenous knowledge

- Structured surveys and interviews
  - Fish distribution and ecology
  - Use of fish
  - Cultural significance

- New ecological information
  - Distribution
  - Habitat use
  - Ecology (predation)

- Selection of endpoints for models
  - Black Bream

- Increased recognition and appreciation of the value and Indigenous knowledge

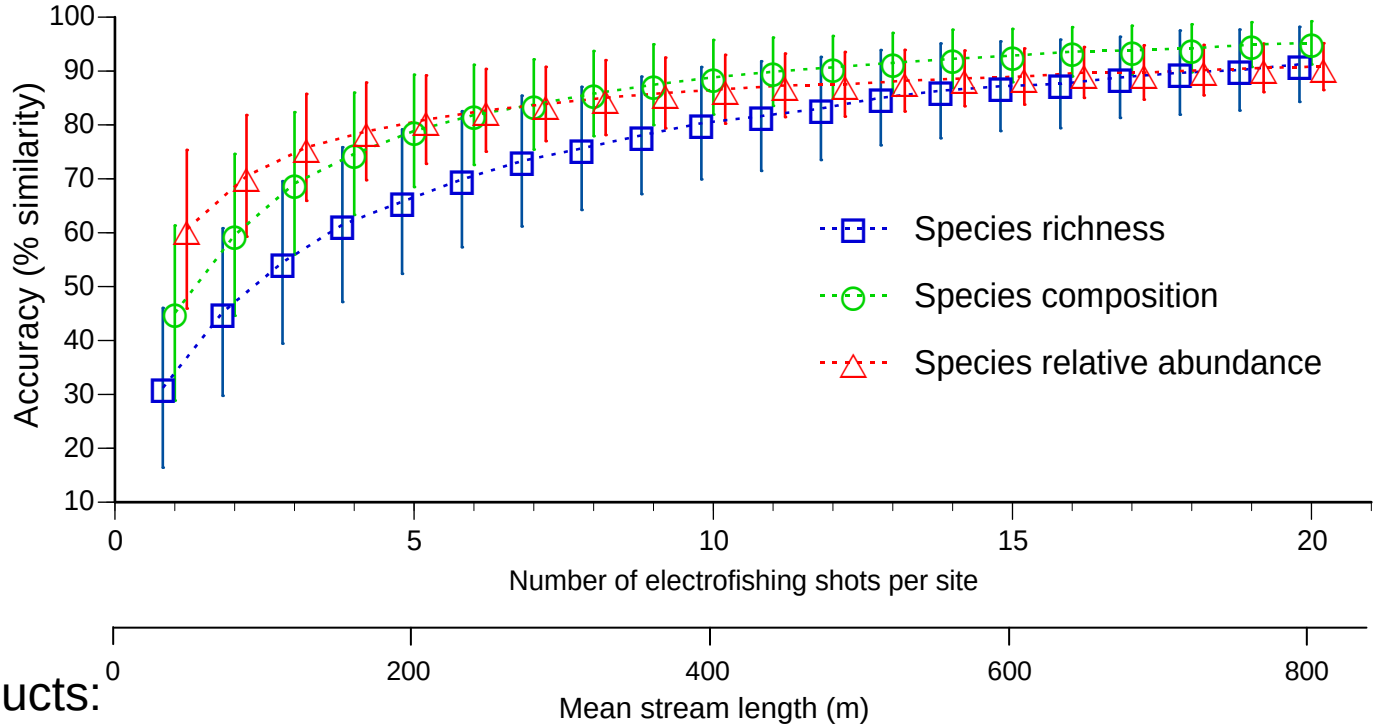
Increased capacity of researchers for doing collaborative research with Aboriginal people

Outline

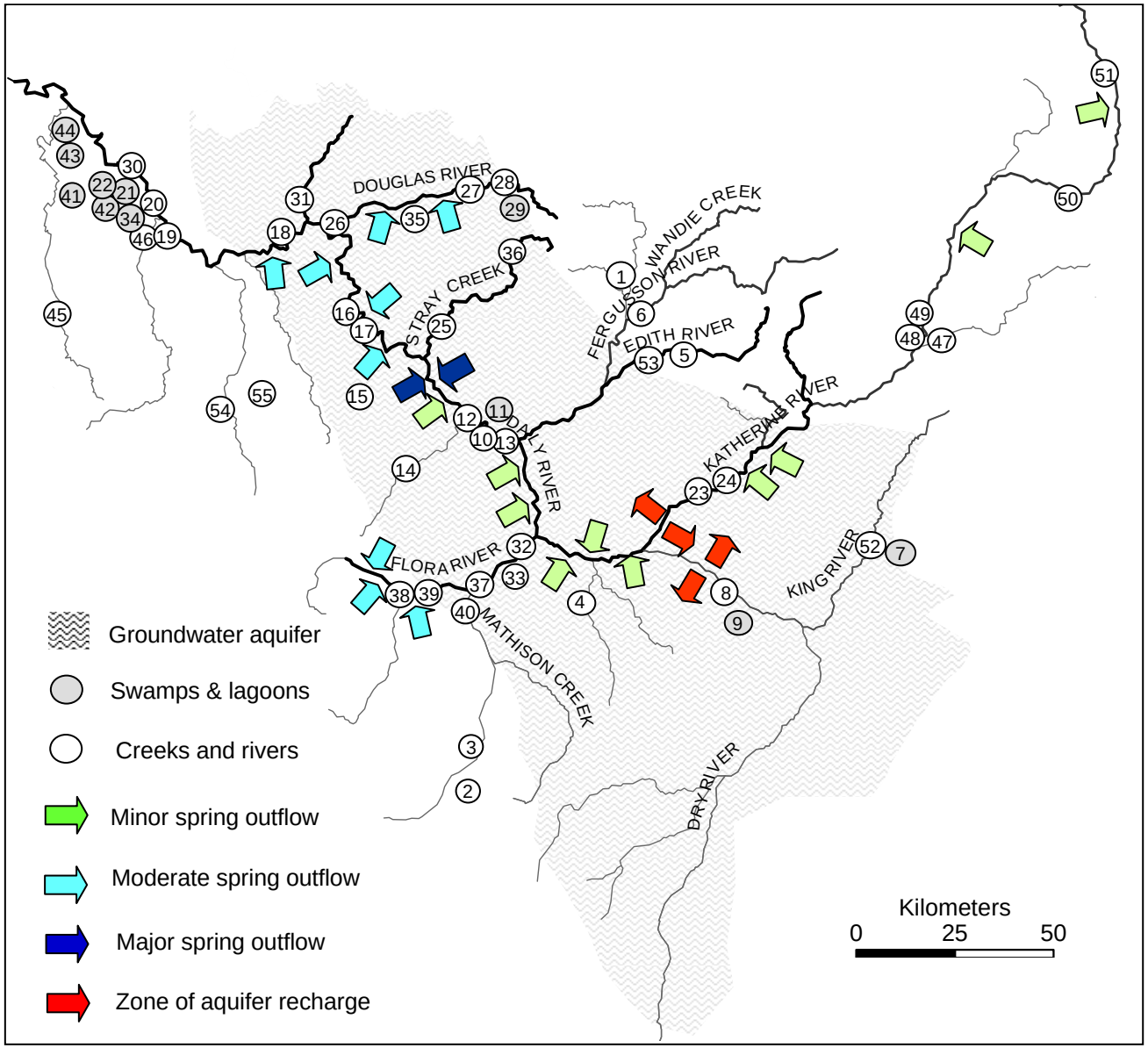
- Introduction & Indigenous collaboration (Michael Douglas)
- Biodiversity & Spatial and Temporal Patterns (Brad Pusey)
- Environmental Flows and Risk Assessment (Mark Kennard)
- Summary (Michael Douglas)

Development & evaluation of fish sampling protocols

- Changes in estimates of fish assemblage attributes with increasing sampling effort



- Products:
  - Data sheets
  - Sampling protocol manual
  - Journal article (in prep.)
- Applications:
  - Framework for the Assessment of River and Wetland Health (tropical-FARWH)
  - Northern Australia Fish Fauna project (NHT)

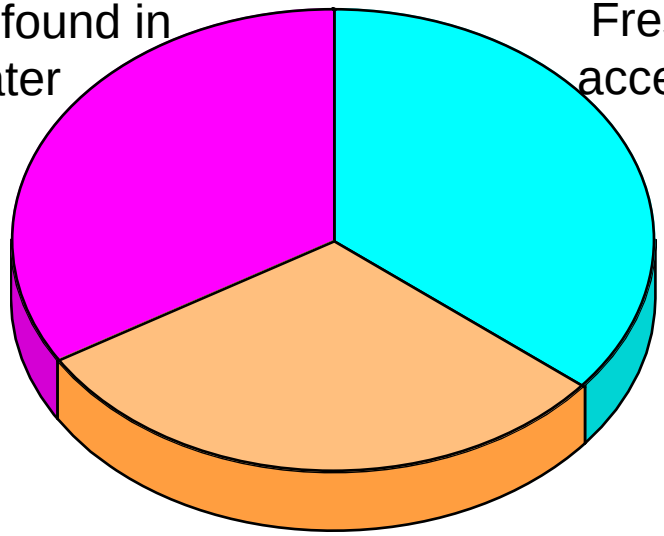

DOUGLAS RIVER
STRAY CREEK
WANDIE CREEK
FERGUSSON RIVER
EDITH RIVER
KATHERINE RIVER
DALY RIVER
FLORA RIVER
MATHISON CREEK
KING RIVER
DRY RIVER
Groundwater aquifer
Swamps & lagoons
Creeks and rivers
Minor spring outflow
Moderate spring outflow
Major spring outflow
Zone of aquifer recharge
Kilometers
0
25
50

Biodiversity

98 species in total recorded from the Daly River

47 by electrofishing in present study

Estuarine species occasionally found in freshwater



Freshwater species requiring access to estuary for breeding

Exclusively freshwater

1 endemic species only (Hypseleotris barrowayi)

3 species previously recorded from catchment not collected by us

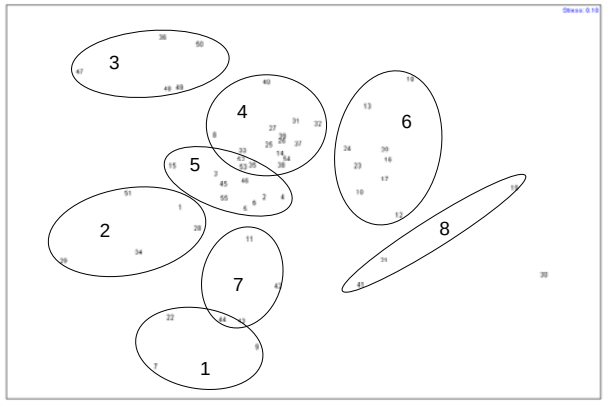
Freshwater fish component not especially diverse cf. other northern rivers

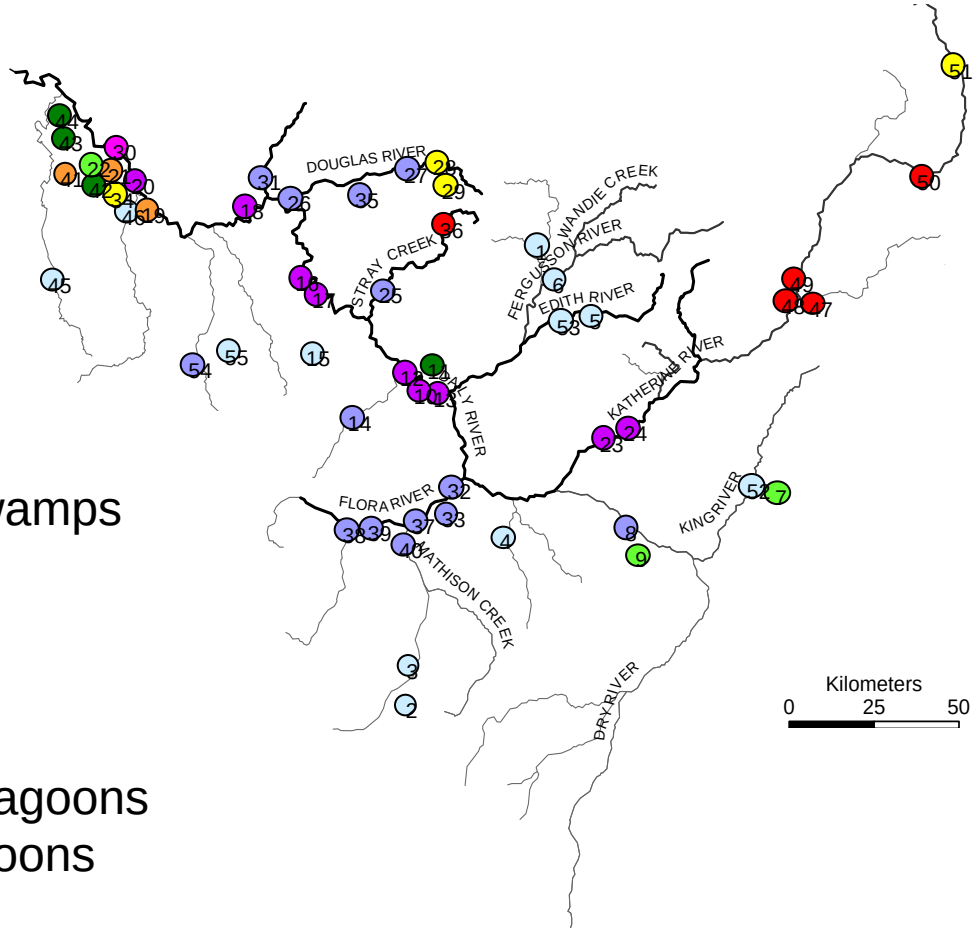
Biodiversity may be higher due to presence of presence of genetically distinct but morphologically conservative “cryptic” species

Subject of ongoing TRaCK research

Analytical approach – spatial variation

- Classification/ ordination of presence/absence data and abundance data (CPUE)
- coupled with Analysis of Similarity (analogous to a multivariate ANOVA) to test strength of distinction between groups (i.e. upstream/downstream of putative barrier and perennial vs intermittent
- BIOENV (analogous to a multivariate correlation) to test for associations between assemblage structure and habitat related variables





1. Small upland lagoons
2. Headwater creeks and swamps
3. Stone country creeks
4. Perennial tributaries
5. Intermittent tributaries
6. Main river channel
7. Large shallow floodplain lagoons
8. Large deep floodplain lagoons

7 key findings relevant to environmental flow management

1. Highly structured fish assemblages determined by position in catchment, distance from river mouth, flow permanence and habitat structure

2. High conservation value taxa comprised of two sets of species with contrasting distributions and levels of threat from water resource development

A. distinct, isolated assemblage present in the high elevation "stone country" of the escarpment comprised of *Hypseleotris barroway, Melanotaenia exquisita* and *Pingalla midgleyi*

High conservation significance but unlikely to be affected by water resource development

B. Freshwater stingray (*Himantura chaophraya*) and sawfish (*Pristis microdon*) present downstream, potentially threatened by reduced dry season flows

3. Unimpeded movement between freshwaters and the river's estuary and between different freshwater parts of the river critical in maintaining healthy fish populations

•High proportional contribution to total richness by estuarine species and species with an estuarine dependence for breeding

•Extensive upstream movement by many species seemingly limited only by flow permanence

Movement very rapid in some species such as barramundi but much slower in others such as freshwater flatfish (*L. triramus*)

Extensive movement within freshwaters associated with reproduction – terapontid grunters and neosilurid catfishes

4. Physical barriers to movement presently limited

Stone country assemblage isolated by series of falls within Nitmiluk National Park (e.g. Katherine Gorge, Centipede Dreaming Gorge) – unlikely to be affected by water resource development

Main river below Katherine with only single barrier – Beebom (Jiboom) Crossing – under current flow regime acts as a filter, slowing down upstream movement for many species. Would be a very effective barrier under a modified flow regime with decreased dry season flows

5. Water depth is a key determinant of assemblage structure in both river and off channe habitats

Deeper reaches contain larger bodied species and larger size classes

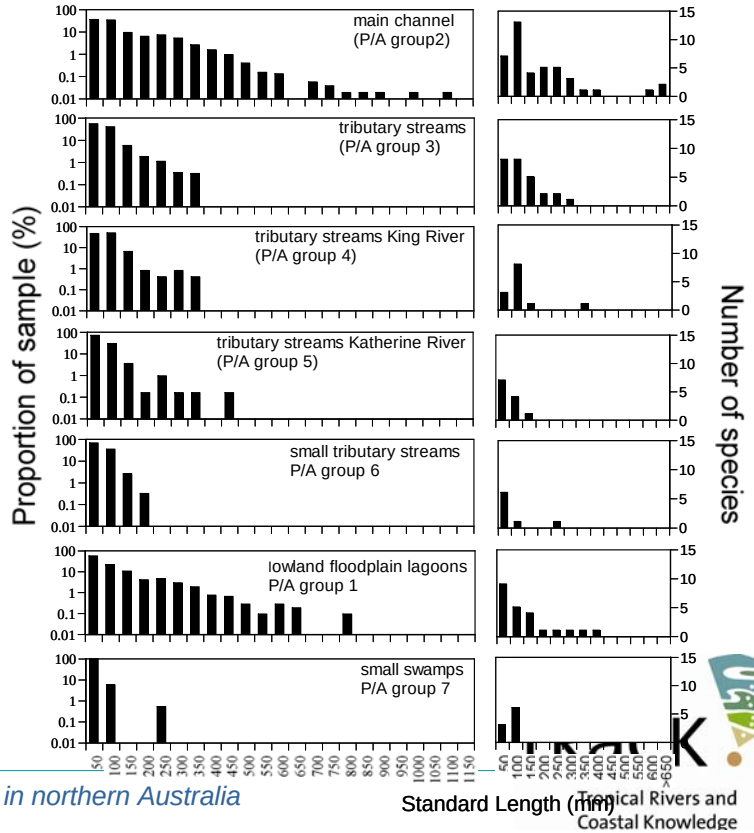
Riffle areas identified as key habitat for many species especially juvenile phases for terapontid grunters (e.g. Sooty grunter *Hephaestus bancrofti*)

6. Flow permanence important in determining assemblage structure

Perenniality/intermittency influence relationships between stream size and assemblage structure

Intermittent streams contain

- Fewer species
- Fewer species of large size
- Fewer individuals of large size
- Fewer predatory species



7. Predation an important process

Many large piscivores

- Stingray (*Himantura chaophraya*)
- Bullshark (*Carcharhinus leucas*)
- Sawfish (*Pristis microdon)*
- Shovel nosed catfish (*Ariopsis midgleyi*)
- Long tom (*Strongylura krefftii*)
- Barramundi (*Lates calcarifer)*
- Freshwater crocodile (*Crocodylus johnstoni*)
- Estuarine crocodile (*Crocodilus porusus*)

Analytical approach – temporal variation

- Examination of population size structure to determine reproductive and migration phenologies
- Univariate ANOVA species richness, abundance, individual species
- Ordination, ANOSIM & BIOENV

Spawning/migration phenologies – 4 guilds

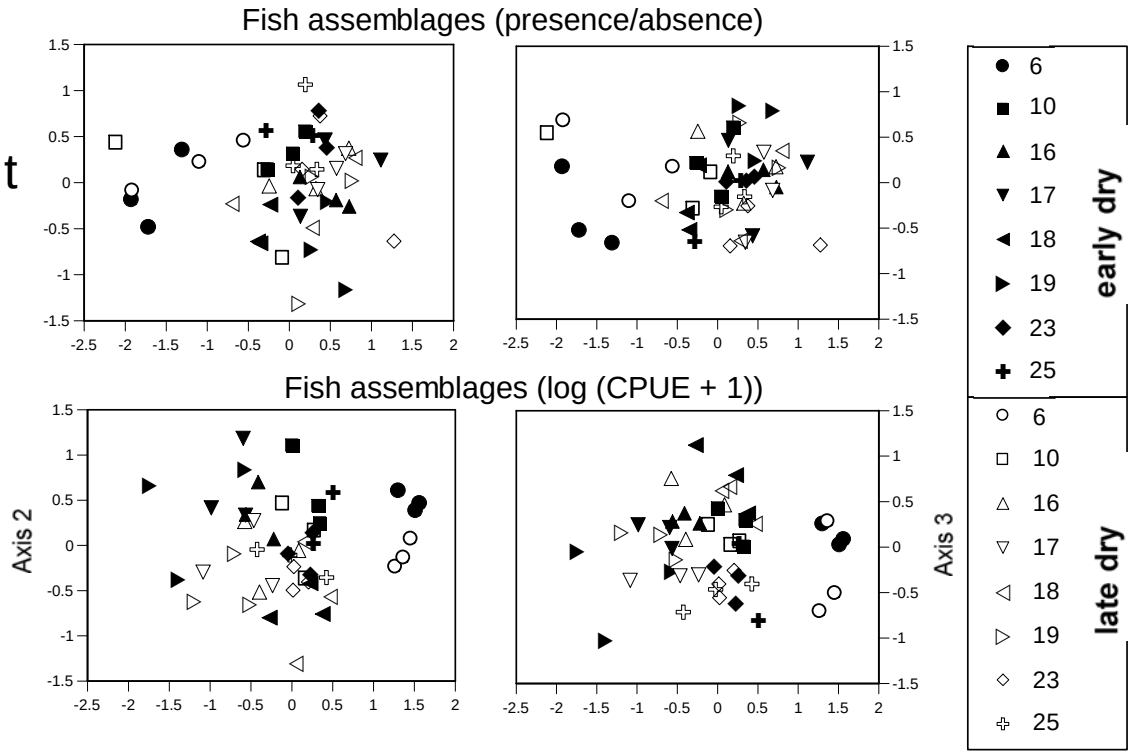
1. Wet season – estuarine: upstream migration of juveniles (e.g. barramundi, freshwater sole, Berney's catfish)

2. Wet season – freshwater: migrating to spawning sites in main river and tributaries, dispersing as flows recede (e.g. black bream, plotosid catfishes)

3. Dry season – freshwater: dispersal during wet season (bony bream, golden goby, mouth almighty, long tom, shovel nosed catfish.

4. Non seasonal – spawning year-round (rainbowfish, strawman)

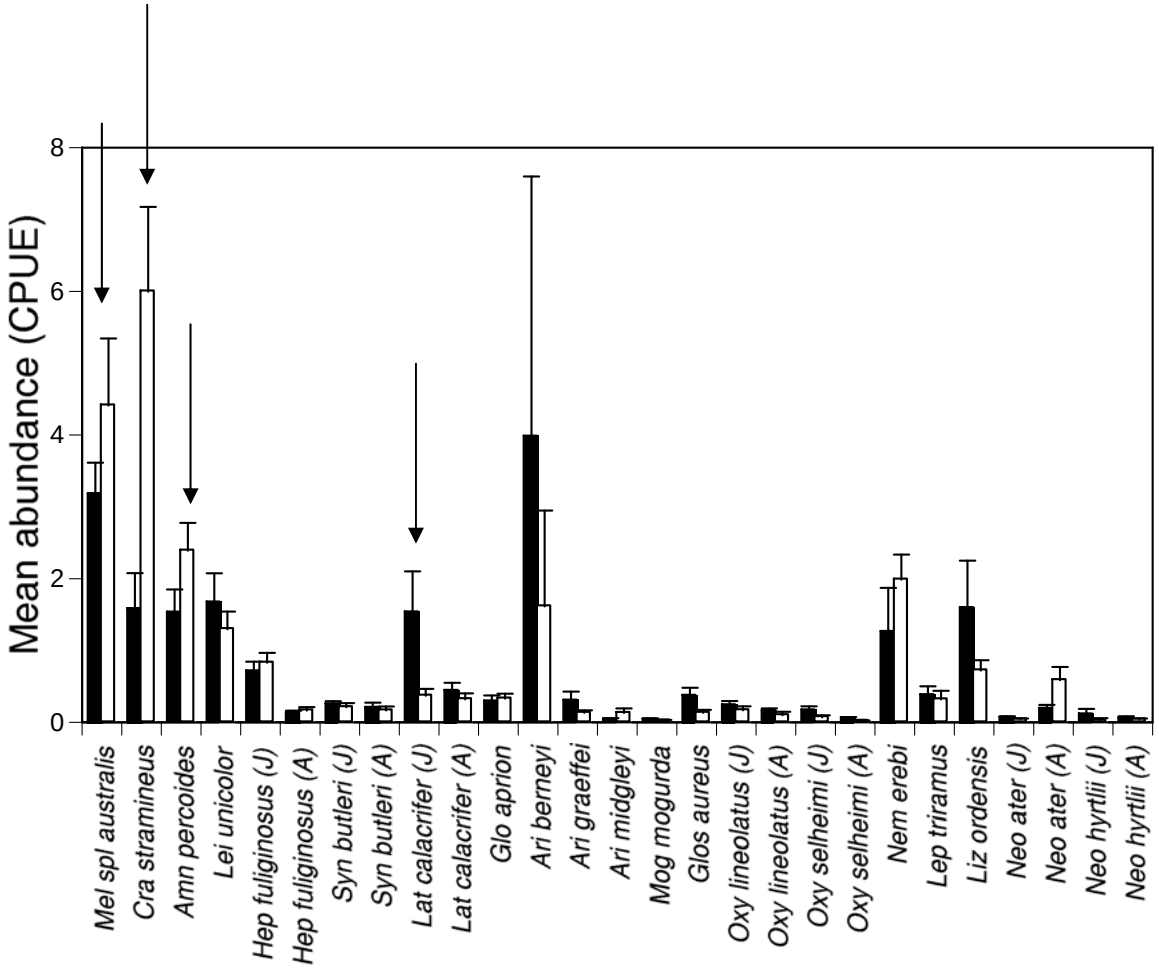
PA
Significant site effect
No significant season effect
No significant year effect



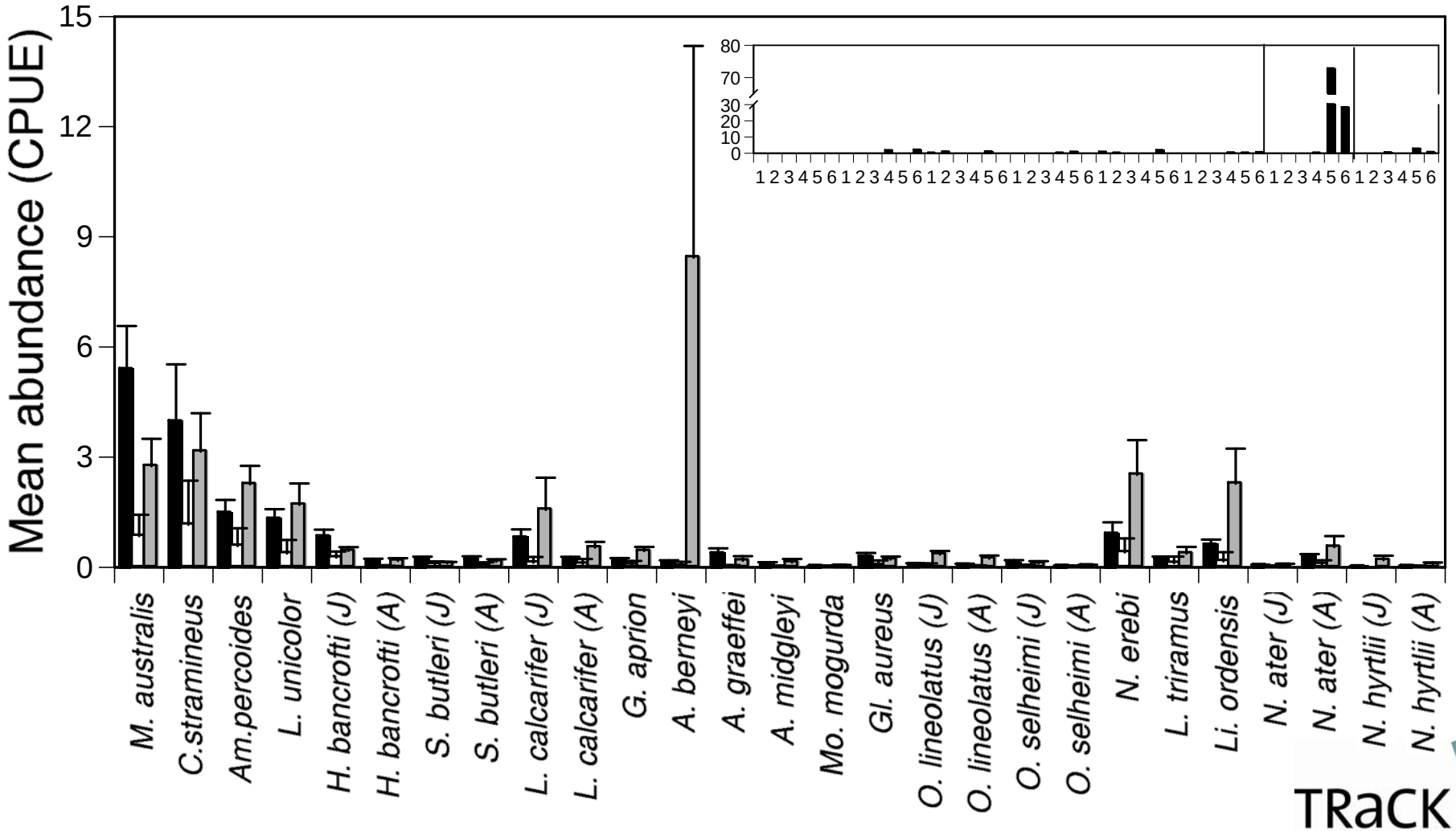
CPUE
Significant site effect
Significant season effect (strongest when nested within site)
No significant year effect but…

BIOENV – Depth, Width, %Cobble correlation = 0.606

Seasonal differences



Between year differences



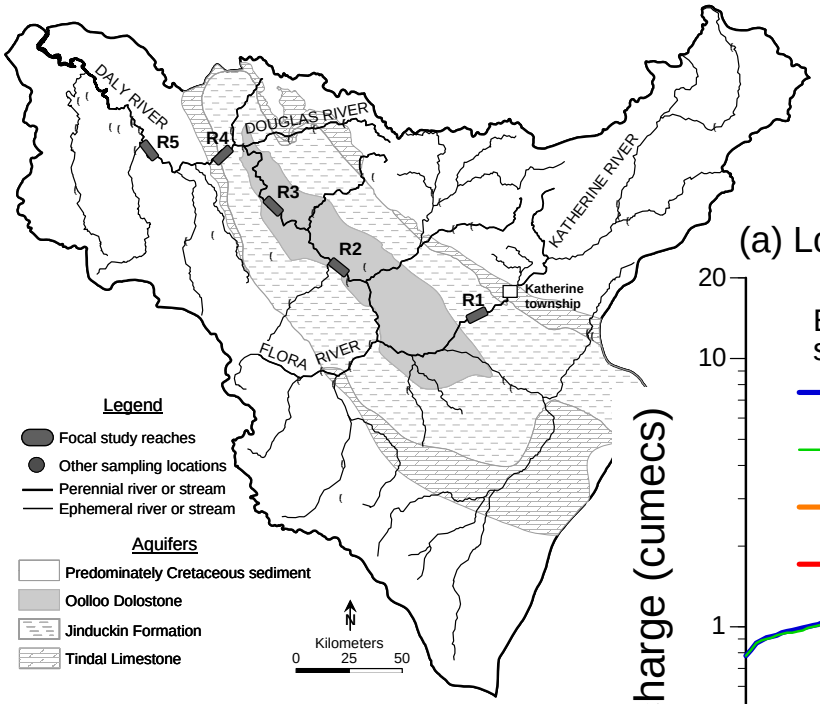
Key findings relevant to environmental flow management

- Seasonal changes in assemblage structure correlated with decreasing depth - abstraction/flow reduction has potential to exacerbate seasonal variation
- Site specific responses – suggests broad spatial approach needed when assessing e flow requirements
- Spatially-consistent species responses limited but included important species such as barramundi – late dry reduction in abundance
- Pronounced between year variation for some species has potential to obscure effects of flow – long term view required.
- Better understanding of flow related drivers of variation needed.

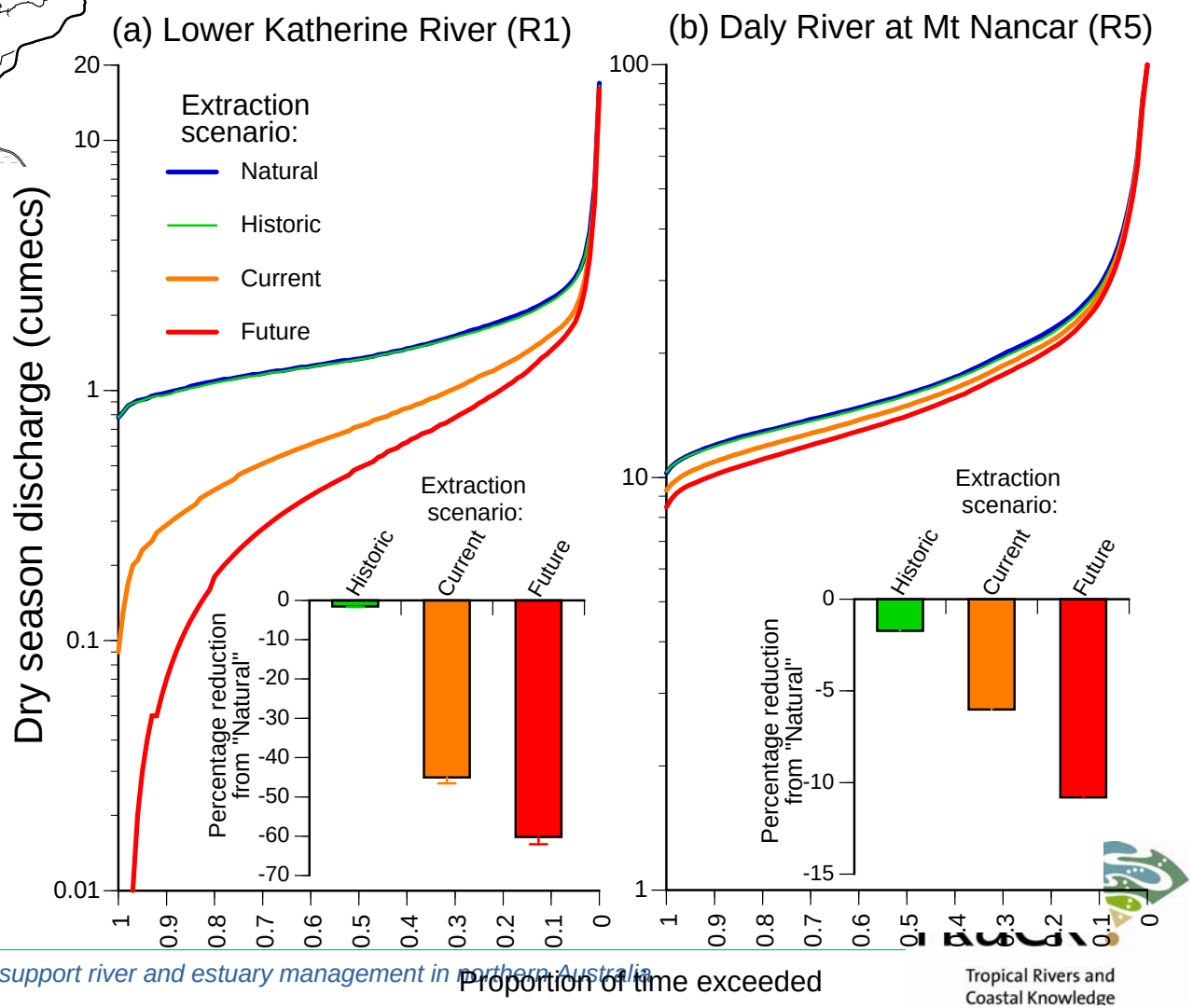
Outline

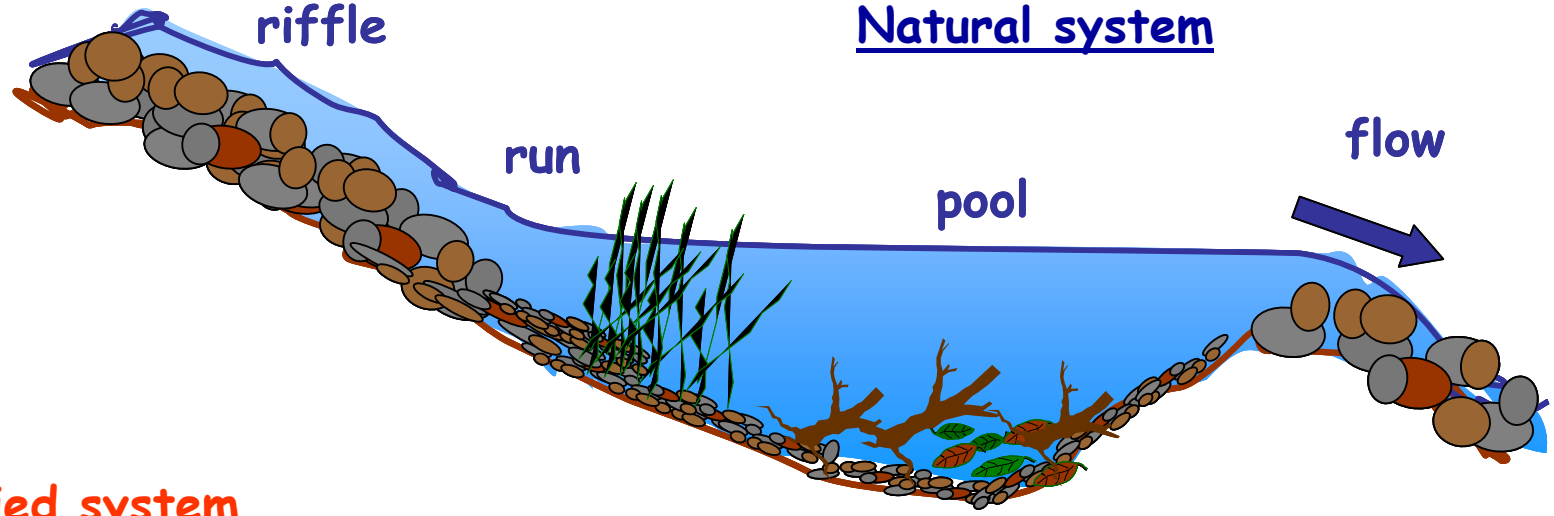
- Introduction & Indigenous collaboration (Michael Douglas)
- Biodiversity & Spatial and Temporal Patterns (Brad Pusey)
- Environmental Flows and Risk Assessment (Mark Kennard)
- Summary (Michael Douglas)

Environmental flow risk assessment



- Modelled flow scenarios:

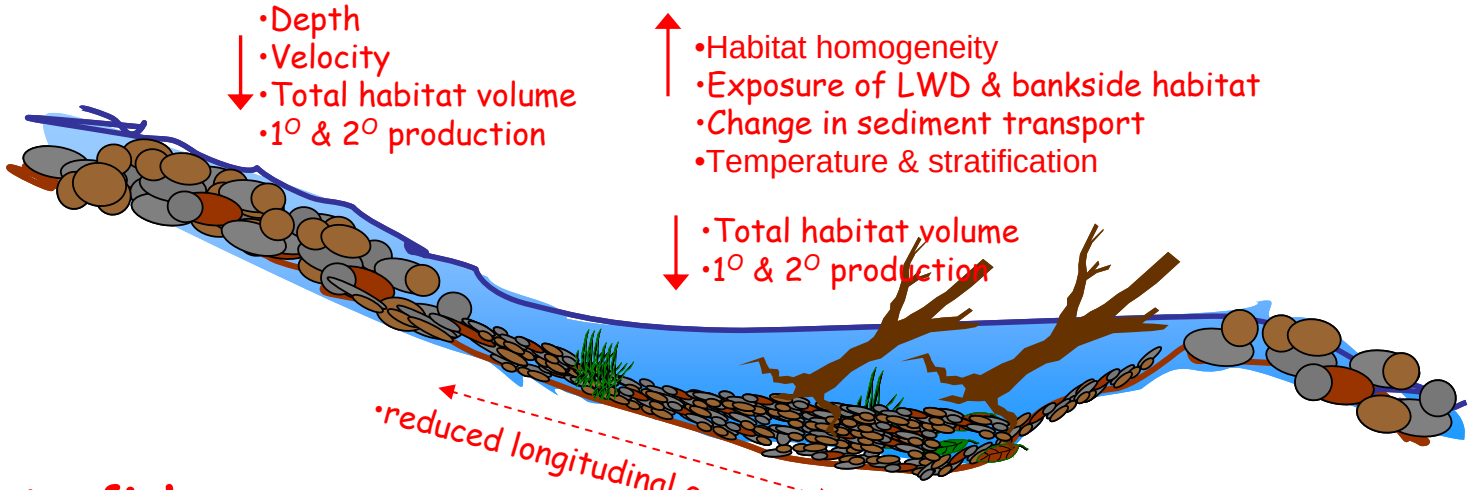




Natural system

Modified system

(water extraction = reduced baseflow magnitude)



Risks to fish

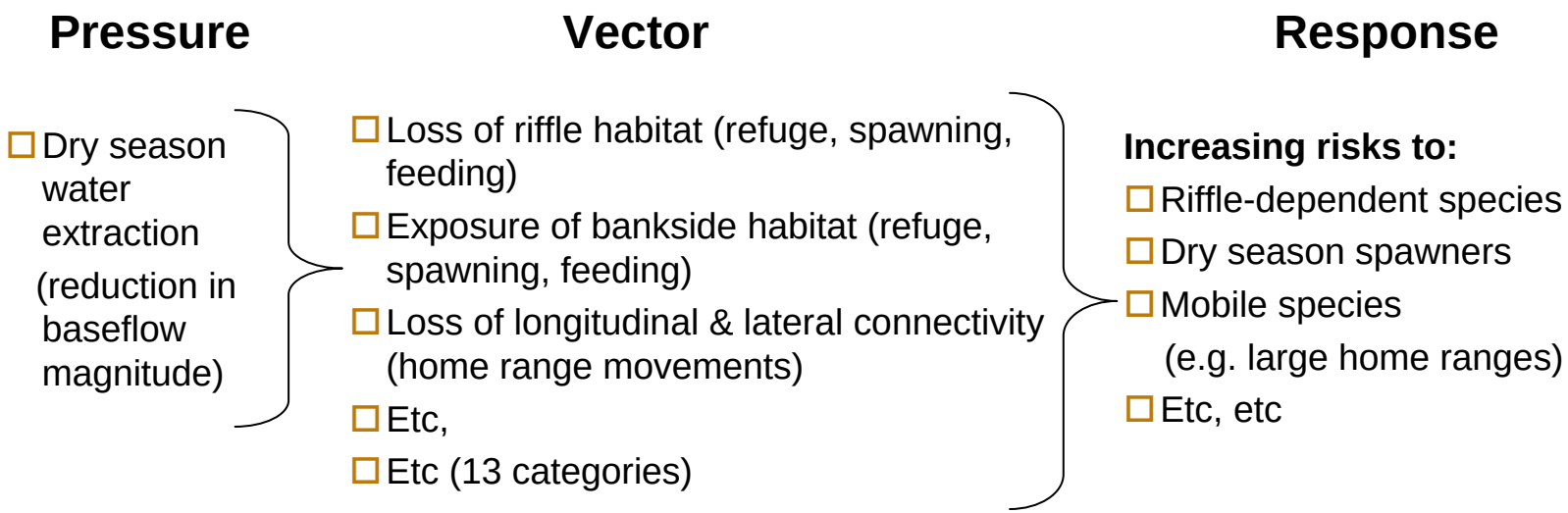
- •Riffle dependent species
- •Food availability
- •Refuge availability
- •Spawning habitat
- •Risk of egg desiccation
- •stranding

•Riffle species constrained to sub-optimal pools

- •Predation
- •Competition
- •disease

- •Food availability
- •Refuge availability
- •Spawning habitat

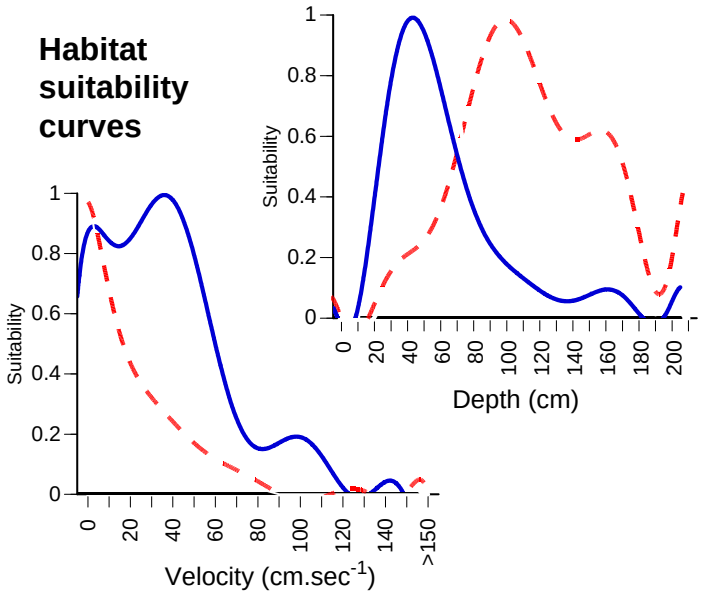
Semi-quantitative Ecological Risk Assessment framework

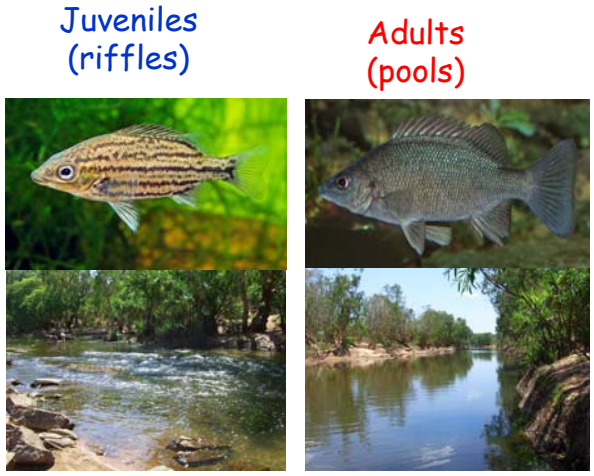


- For each vector, rank the relative risk to each fish species
- 3 risk categories (high, moderate, low)
- 40 species

- Ecological requirements of the fish fauna:

Habitat use





Reproduction

Movement

Feeding

- Relative risks of each fish species to dry season water extraction

- # Quantitative Risk Assessment using Bayesian Belief Networks (BBNs)

  - Explanatory & predictive model
  - Tool for scenario testing
  - Can formally integrate different sources of evidence
    - Subjective & Quantitative
  - Can guide data collection
    - Targeted to benefit the understanding (and management) of a system
    - Address uncertainties
  - Can be iteratively updated - adaptive management

- Quantitative Risk Assessment using Bayesian Belief Networks (BBNs)

- Choice of ecological endpoints:

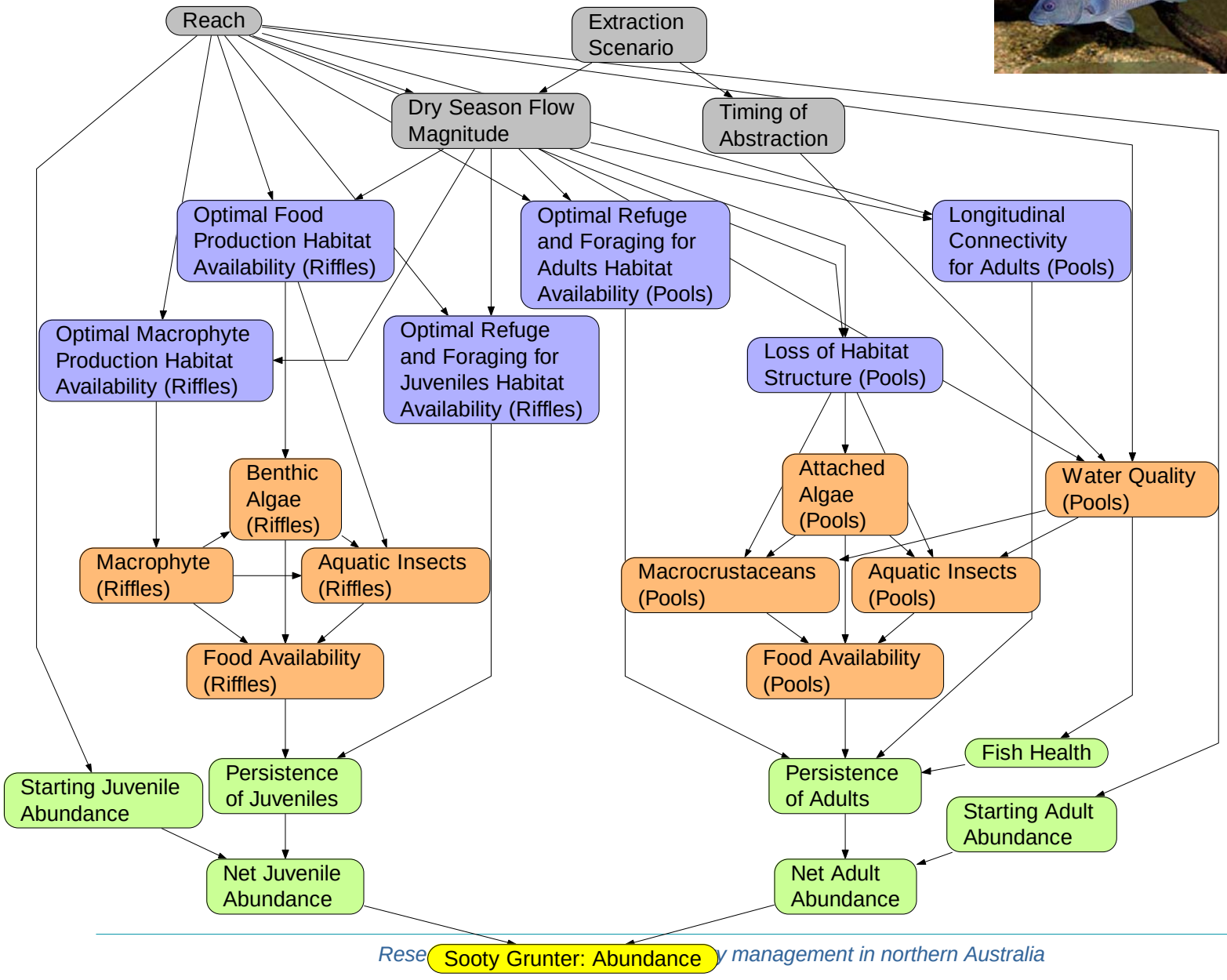
Sooty Grunter (black bream)

- at high risk from water extraction
- culturally & recreationally important
- reasonable ecological knowledge available

Barramundi

- at high risk from water extraction
- culturally, commercially & recreationally important
- good ecological knowledge available
- wet season BBN model available (Bayliss et al)

Model structure



Riparian Inputs

Primary Landuse Impact

Fishing Pressure

Aritificial Barriers

Drivers

Non-Flow-Related Variables

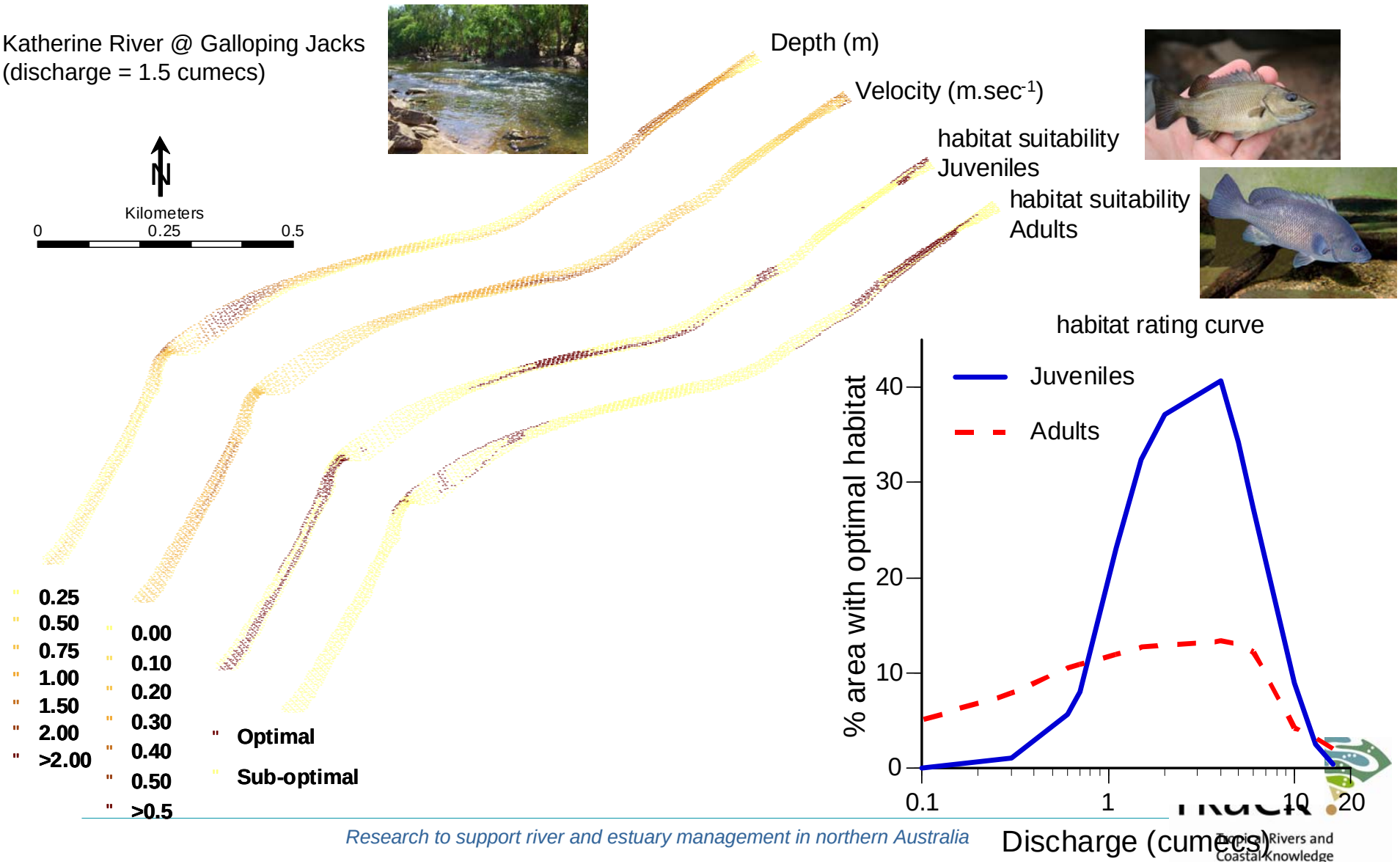
Physical Habitat Variables

Non-Physical Habitat Variables

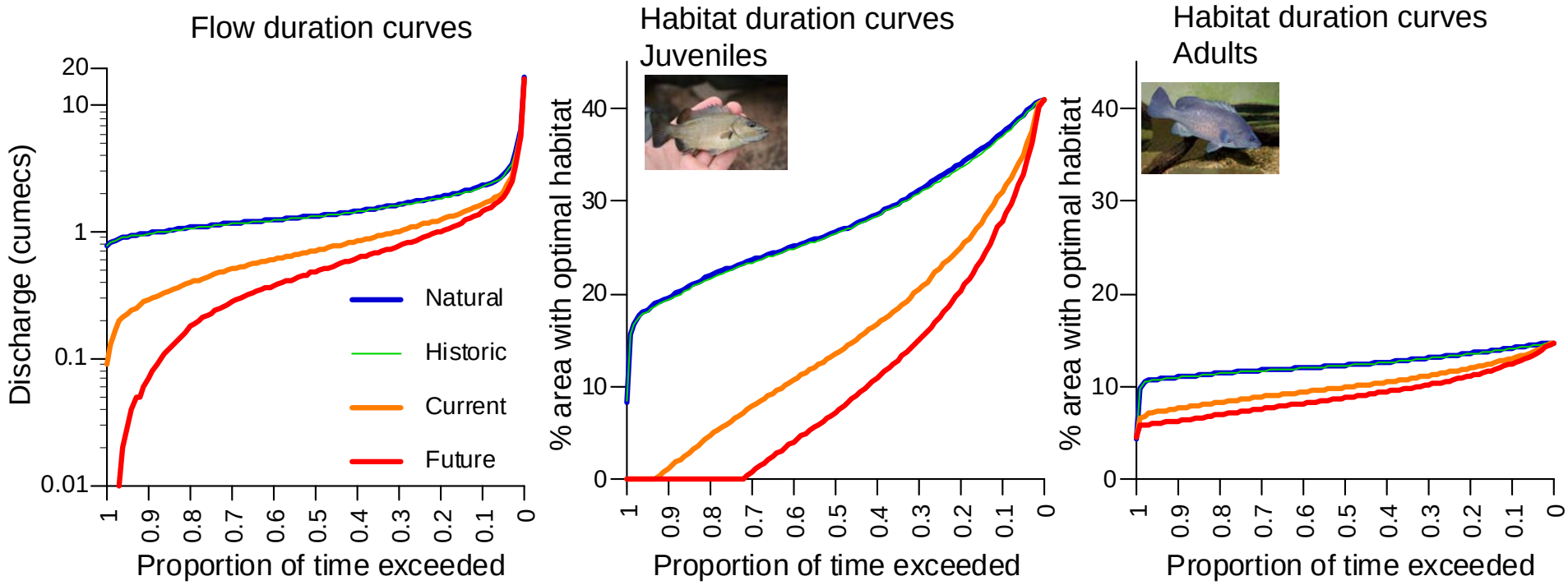
Fish Ecology Variables

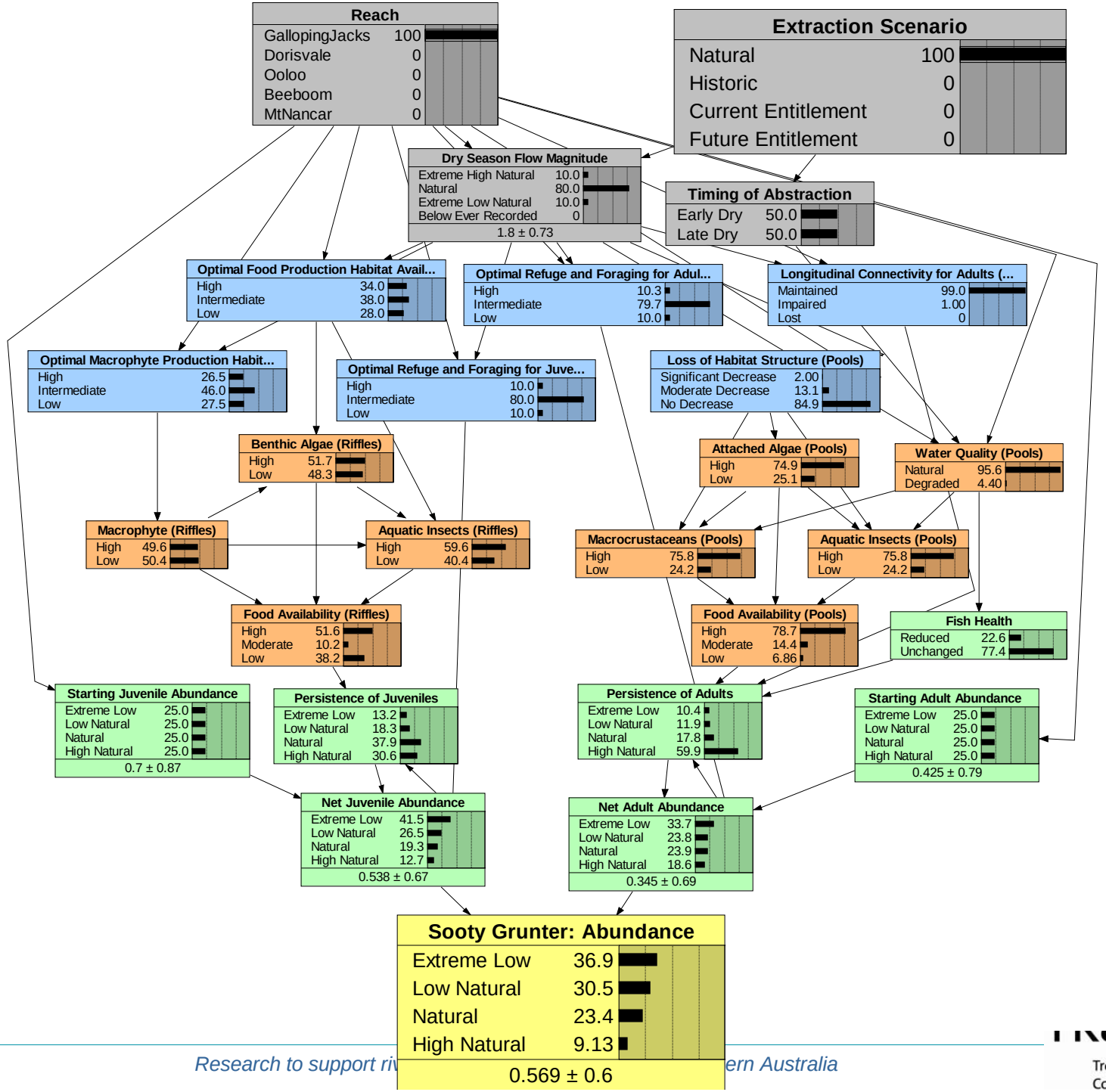
Endpoint

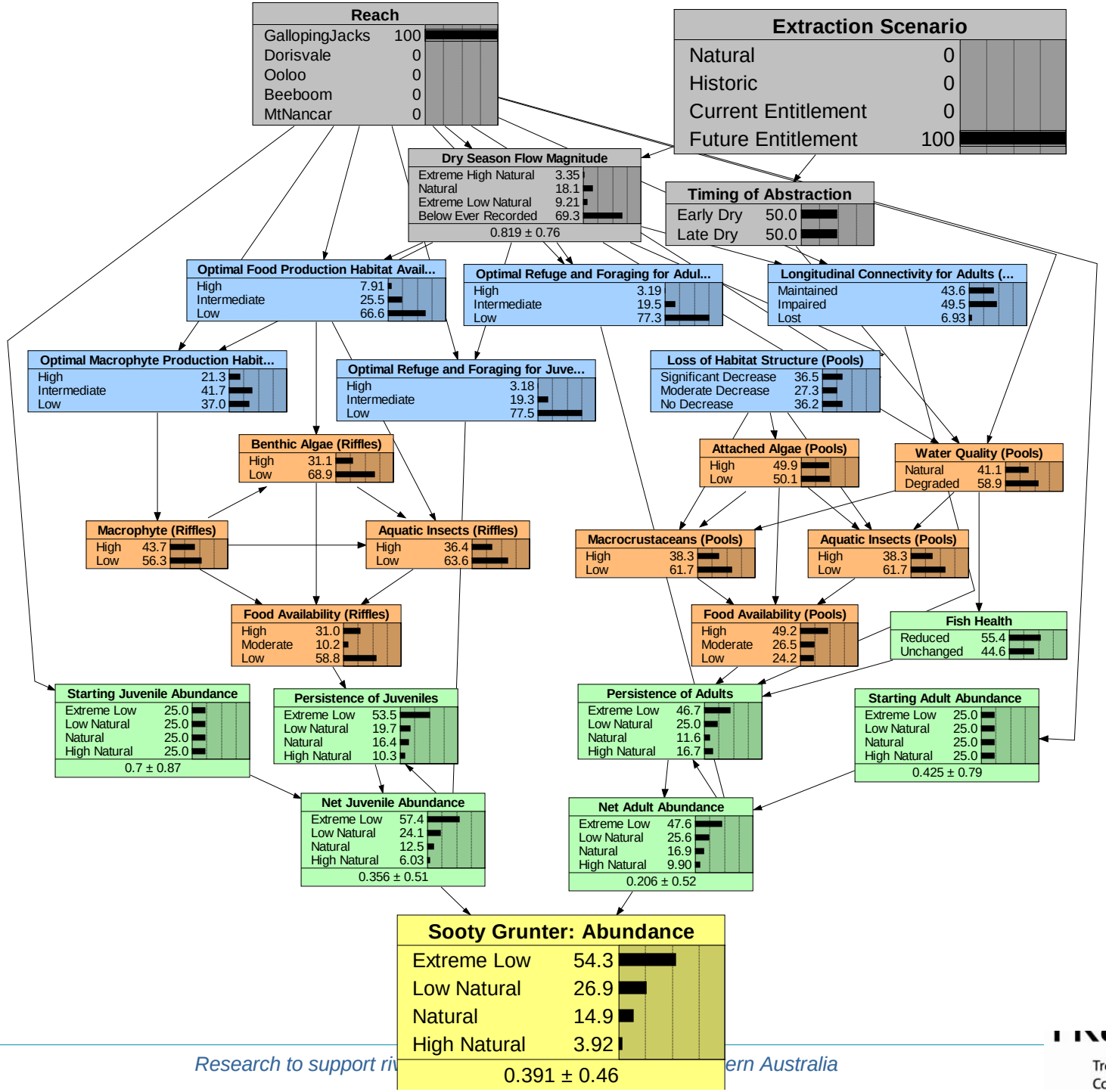
- Used outputs from 2D hydrodynamic habitat model to “populate” some BBN nodes



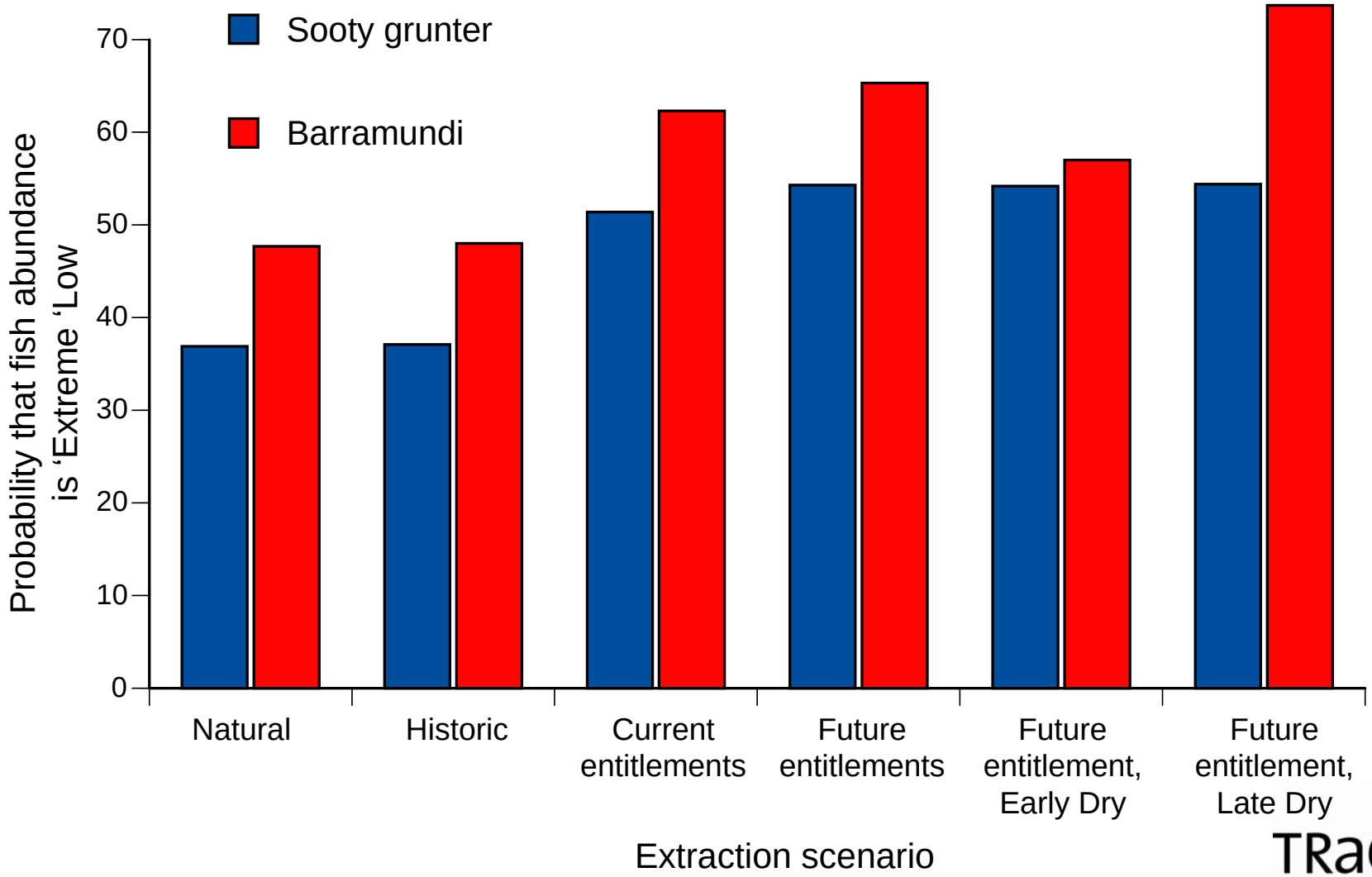
- changes in optimal habitat area under different flow scenarios




Reach
GallopingJacks 100
Dorisvale 0
Ooloo 0
Beeboom 0
MtNancar 0
Extraction Scenario
Natural 100
Historic 0
Current Entitlement 0
Future Entitlement 0
Dry Season Flow Magnitude
Extreme High Natural 10.0
Natural 80.0
Extreme Low Natural 10.0
Below Ever Recorded 0
1.8 ± 0.73
Timing of Abstraction
Early Dry 50.0
Late Dry 50.0
Optimal Food Production Habitat Avail...
High 34.0
Intermediate 38.0
Low 28.0
Optimal Refuge and Foraging for Adul...
High 10.3
Intermediate 79.7
Low 10.0
Longitudinal Connectivity for Adults (...
Maintained 99.0
Impaired 1.00
Lost 0
Optimal Macrophyte Production Habit...
High 26.5
Intermediate 46.0
Low 27.5
Optimal Refuge and Foraging for Juve...
High 10.0
Intermediate 80.0
Low 10.0
Loss of Habitat Structure (Pools)
Significant Decrease 2.00
Moderate Decrease 13.1
No Decrease 84.9
Benthic Algae (Riffles)
High 51.7
Low 48.3
Attached Algae (Pools)
High 74.9
Low 25.1
Water Quality (Pools)
Natural 95.6
Degraded 4.40
Macrophyte (Riffles)
High 49.6
Low 50.4
Aquatic Insects (Riffles)
High 59.6
Low 40.4
Macrocrustaceans (Pools)
High 75.8
Low 24.2
Aquatic Insects (Pools)
High 75.8
Low 24.2
Food Availability (Riffles)
High 51.6
Moderate 10.2
Low 38.2
Food Availability (Pools)
High 78.7
Moderate 14.4
Low 6.86
Fish Health
Reduced 22.6
Unchanged 77.4
Starting Juvenile Abundance
Extreme Low 25.0
Low Natural 25.0
Natural 25.0
High Natural 25.0
0.7 ± 0.87
Persistence of Juveniles
Extreme Low 13.2
Low Natural 18.3
Natural 37.9
High Natural 30.6
Persistence of Adults
Extreme Low 10.4
Low Natural 11.9
Natural 17.8
High Natural 59.9
Starting Adult Abundance
Extreme Low 25.0
Low Natural 25.0
Natural 25.0
High Natural 25.0
0.425 ± 0.79
Net Juvenile Abundance
Extreme Low 41.5
Low Natural 26.5
Natural 19.3
High Natural 12.7
0.538 ± 0.67
Net Adult Abundance
Extreme Low 33.7
Low Natural 23.8
Natural 23.9
High Natural 18.6
0.345 ± 0.69
Sooty Grunter: Abundance
Extreme Low 36.9
Low Natural 30.5
Natural 23.4
High Natural 9.13
0.569 ± 0.6


Reach
GallopingJacks 100
Dorisvale 0
Ooloo 0
Beeboom 0
MtNancar 0
Extraction Scenario
Natural 0
Historic 0
Current Entitlement 0
Future Entitlement 100
Dry Season Flow Magnitude
Extreme High Natural 3.35
Natural 18.1
Extreme Low Natural 9.21
Below Ever Recorded 69.3
0.819 ± 0.76
Timing of Abstraction
Early Dry 50.0
Late Dry 50.0
Optimal Food Production Habitat Avail...
High 7.91
Intermediate 25.5
Low 66.6
Optimal Refuge and Foraging for Adul...
High 3.19
Intermediate 19.5
Low 77.3
Longitudinal Connectivity for Adults (...
Maintained 43.6
Impaired 49.5
Lost 6.93
Optimal Macrophyte Production Habit...
High 21.3
Intermediate 41.7
Low 37.0
Optimal Refuge and Foraging for Juve...
High 3.18
Intermediate 19.3
Low 77.5
Loss of Habitat Structure (Pools)
Significant Decrease 36.5
Moderate Decrease 27.3
No Decrease 36.2
Benthic Algae (Riffles)
High 31.1
Low 68.9
Attached Algae (Pools)
High 49.9
Low 50.1
Water Quality (Pools)
Natural 41.1
Degraded 58.9
Macrophyte (Riffles)
High 43.7
Low 56.3
Aquatic Insects (Riffles)
High 36.4
Low 63.6
Macrocrustaceans (Pools)
High 38.3
Low 61.7
Aquatic Insects (Pools)
High 38.3
Low 61.7
Food Availability (Riffles)
High 31.0
Moderate 10.2
Low 58.8
Food Availability (Pools)
High 49.2
Moderate 26.5
Low 24.2
Fish Health
Reduced 55.4
Unchanged 44.6
Starting Juvenile Abundance
Extreme Low 25.0
Low Natural 25.0
Natural 25.0
High Natural 25.0
0.7 ± 0.87
Persistence of Juveniles
Extreme Low 53.5
Low Natural 19.7
Natural 16.4
High Natural 10.3
Persistence of Adults
Extreme Low 46.7
Low Natural 25.0
Natural 11.6
High Natural 16.7
Starting Adult Abundance
Extreme Low 25.0
Low Natural 25.0
Natural 25.0
High Natural 25.0
0.425 ± 0.79
Net Juvenile Abundance
Extreme Low 57.4
Low Natural 24.1
Natural 12.5
High Natural 6.03
0.356 ± 0.51
Net Adult Abundance
Extreme Low 47.6
Low Natural 25.6
Natural 16.9
High Natural 9.90
0.206 ± 0.52
Sooty Grunter: Abundance
Extreme Low 54.3
Low Natural 26.9
Natural 14.9
High Natural 3.92
0.391 ± 0.46

- # BBN model outputs
  - Probability that fish abundance will be in “Extreme Low” state under each flow scenario



- # Daly River BBNs – the future

  - BBN outputs – can be used to assist water resource planning

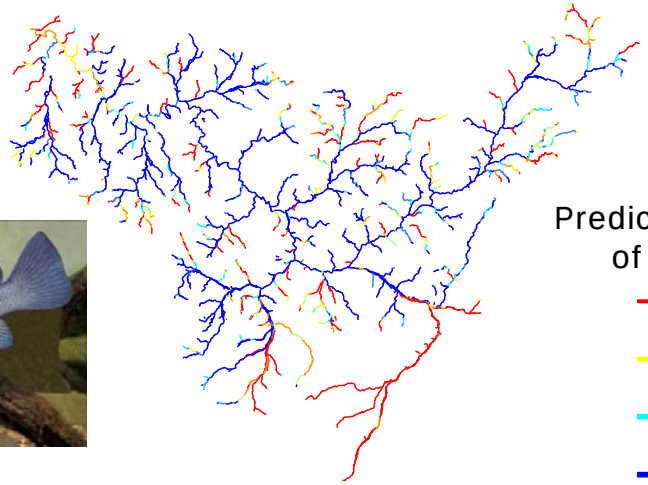
    - **transparent, credible, evidence-based**
      - Can evaluate new scenarios
      - Identify sources of greatest uncertainty (sensitivity analysis)
      - identify knowledge gaps
      - dynamic model, can be periodically updated:

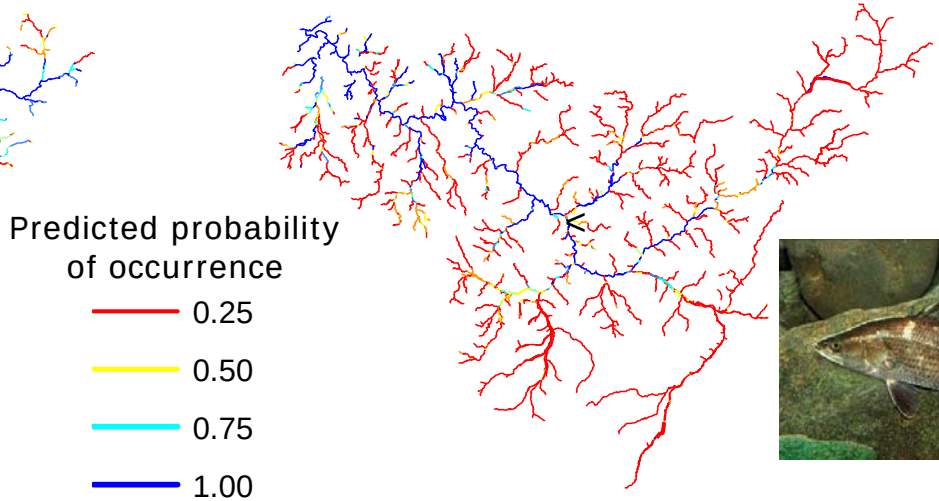
        Collect more data -> Update the model

- What other tools have we developed to assist with catchment planning?

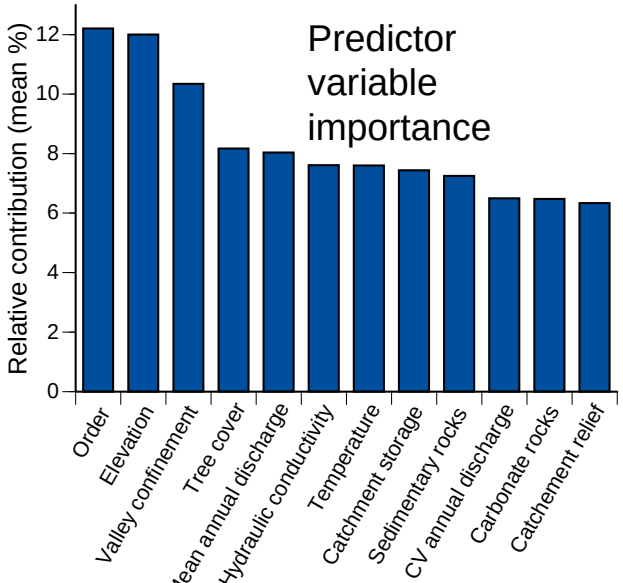
- # Predictive models of fish distributions
  - Species-environment relationships
  - Catchment management & planning
  - River health assessment (tropical-FARWH)

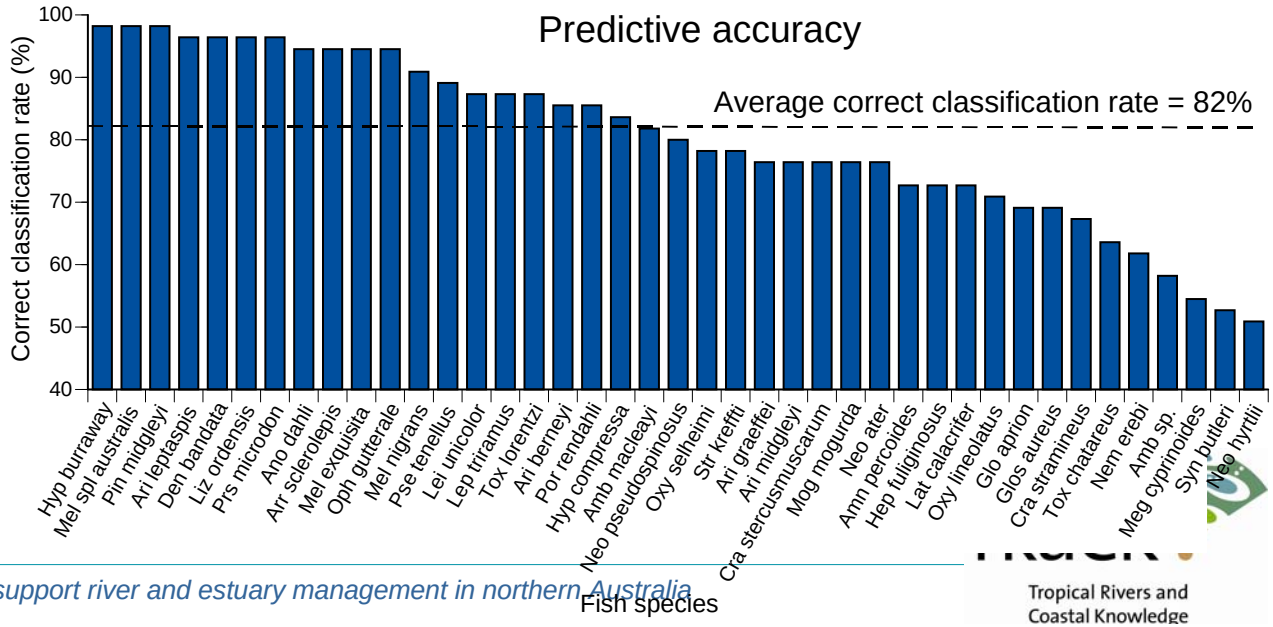
…using multi-response artificial neural network model
(Olden, Kennard, Pusey, et al.)





Predicted probability of occurrence
0.25
0.50
0.75
1.00





Tropical Rivers and Coastal Knowledge

Outline

- Introduction & Indigenous collaboration (Michael Douglas)
- Biodiversity & Spatial and Temporal Patterns (Brad Pusey)
- Environmental Flows and Risk Assessment (Mark Kennard)
- Summary (Michael Douglas)

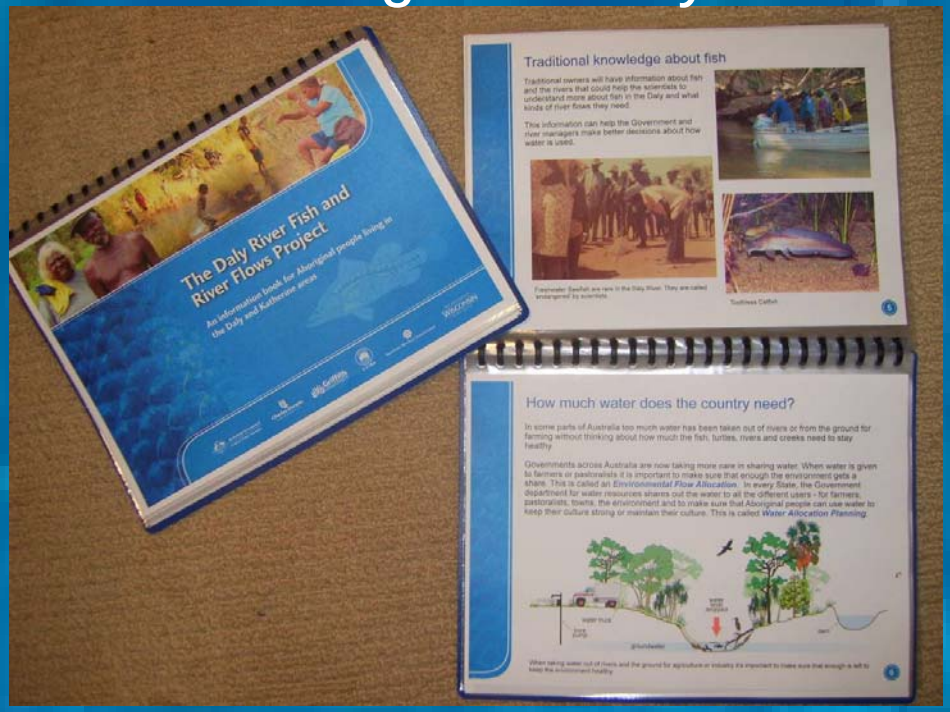
Communication

- Brochures, newsletters
- Plan English story books, poster
- Technical publications
- Talks to advisory committees
- Public meetings, field demonstrations
- Conference & workshop presentations
- Print, TV and radio media

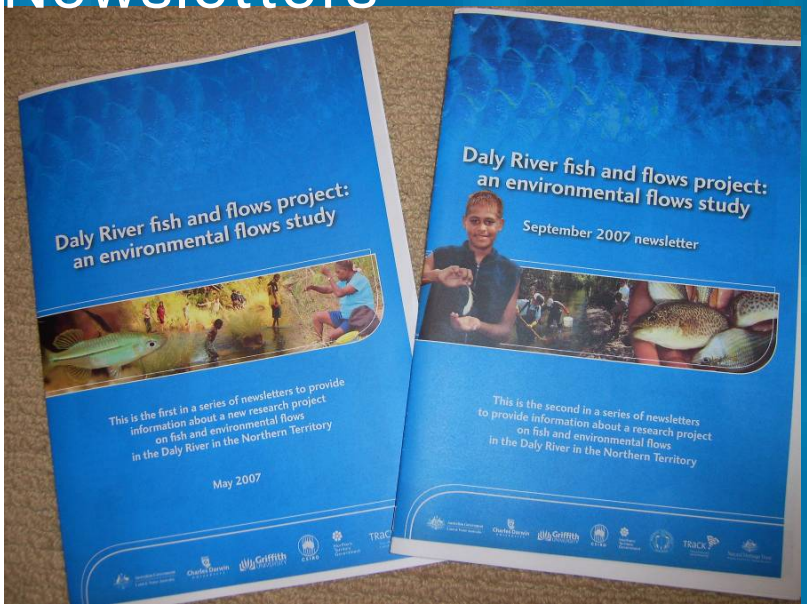
- Indigenous collaboration

- Continuing

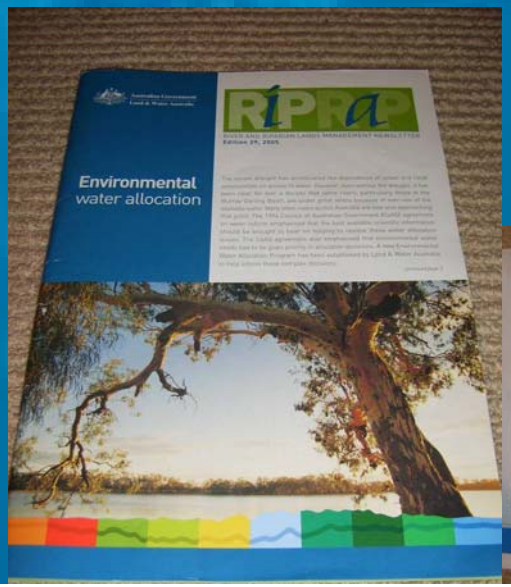
“Plain English story book”

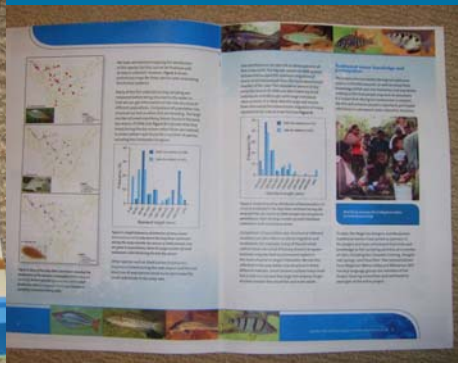


Newsletters



LWA publications





Project outcomes

1. New knowledge about fish, their flow requirements and cultural values
2. Better understanding of risks of impacts due to changes in flow regime
3. Improved scientific basis for water allocation planning and monitoring
4. Enhanced capacity for:
   - Fish research & monitoring in the NT
   - Aboriginal people to participate in research, planning and decision making processes
   - Researchers to collaborate with Aboriginal people
5. Links with other initiatives
   - e.g. TRaCK, Framework for Assessing River and Wetland Health, Conservation Planning
6. Protection of ecological & cultural values in the Daly River for the future

Tropical Rivers and Coastal Knowledge

Acknowledgements

TRaCK brings together leading tropical river researchers and managers from Charles Darwin University, Griffith University, University of Western Australia, CSIRO, James Cook University, Australian National University, Geoscience Australia, Environmental Research Institute of the Supervising Scientist, Australian Institute of Marine Science, North Australia Indigenous Land and Sea Management Alliance, and the Governments of Queensland, Northern Territory and Western Australia.

TRaCK receives major funding for its research through the ustralian Government's Commonwealth Environment Research acilities initiative; the Australian Government's Raising National Water Standards Programme; Land and Water Australia and the Queensland Government's Smart State Innovation Fund

Australian Government
Department of the Environment, Water, Heritage and the Arts
Land & Water Australia
Australian Government Water Fund
Raising National Water Standards

Tropical Rivers and Coastal Knowledge

TRaCK

Tropical Rivers and
Coastal Knowledge

Phone: 08 89 467 444
track@cdu.edu.au
www.track.gov.au