Using the ELOHA Framework to develop flow-ecology relationships at regional scale

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SCIENTIFIC PROCESS

Step 1. Hydrologic Foundation
- Baseline Hydrographs
- Hydrologic Model and Stream Gauges
- Developed Hydrographs

Step 2. Stream Classification
- Stream Hydrologic Classification
- Geomorphic Stratification

Step 3. Flow Alteration
- Degree of Hydrologic Alteration
- Hydrologic Alteration by River Type

Step 4. Flow-Ecology Relationships
- Flow - Ecology Hypotheses
- Ecological Data and Indices

SOCIAL PROCESS

Implementation
- Environmental Flow Standards
- Acceptable Ecological Conditions

Adaptive Adjustments
- Societal Values and Management Needs

ELOHA – Ecological Limits of Hydrologic Alteration - Poff et al. 2010
Rivers of a chosen region can be grouped into distinctive flow regime classes on the basis of ecologically relevant flow metrics - measures of magnitude, seasonal timing, frequency, duration and variability of particular flows.

**Ecological characteristics of rivers** within each flow regime class will be relatively similar compared to those of other classes. Therefore class members may be managed in similar ways in terms of environmental flows.

Increasing degrees of flow regime change will have increasing impacts on **ecological response variables**: these relationships may take different forms – e.g. linear, threshold

Rivers within each flow regime class that are ‘regulated’ (or supplemented) in the same way by dams or other infrastructure will show similar ecological responses to flow regime change.
Borumba Dam, Yabba Ck
42,600 ML, first completed 1964

Six Mile Creek Dam, 9,300 ML
1964

Baroon Pocket Dam, Obi Obi Ck, 61,000 ML
1989

Wivenhoe Dam

Moogerah Dam, Reynolds Ck
92,500 ML, 1961

Hinze Dam
Nerang River

Maroon Dam, Burnett Ck, 38,400 ML, 1974

Dams and weirs store ~ 38% MAR
Storage capacity 730 - 1,150,000 ML
Most built in 1970-80s
Mostly urban and irrigation supplies
Extensive unsupplemented extraction

SE Qld Study Area
Classification of pre-development (unregulated) flow regimes

Ordination (SSHMDS) of 88 sites and flow classes based on IQQM data and 35 ecologically relevant hydrologic metrics

Reference Flow Regime Classification
6 classes of pre-development flow regimes
1 = 26 nodes from all major rivers
2 = 17 nodes from Mary, Brisbane and Logan-Albert - dry
3 = 5 nodes from Logan-Albert, lower Mary River, Teewah Creek
4 = 17 nodes from Mary and Brisbane
5 = 18 nodes from Mary, Maroochy, Brisbane, Maroochy, Gold Coast
6 = 5 nodes from 5 catchments, 3 rising in Maleny plateau – wet

Distinguishing flow metrics

Discharge magnitude, especially low flow variables:
Mean annual 1dayMin, MA1dayMax, Median March, September
Median Annual Max

Discharge variability:
CV (coefficient of variation) daily flow
Mean number of zero flow days per year
Low flow spell duration
Field Methods - Riparian Vegetation

• Minimum 3 randomly located transects within 100 m stream section running perpendicular to the river.

• Upper boundary determined by bankfull level or 50 m distance from the water’s edge

• Recording:
  • ID all trees, shrubs, ferns, reeds and sedges within a 5 meter wide band.
  • Distance along transect recorded
  • height, health, DBH, vines

Over 15 500 individual trees and shrubs were identified
191 trees and shrub species, 43 vine species, 23% alien individuals
Field Methods - Aquatic Vegetation

• In-stream & bank vegetation recorded at quadrat, transect and site scale

• Water quality and habitat variables measured or estimated

74 aquatic species identified, mostly submerged, 27% alien taxa
Field Methods - Fish

- Multiple pass electrofishing and block seine in pool- riffle-run habitats
- Fish identified, counted, measured, and returned or kept for further analysis (diet, reproductive status)
- In-stream and bank habitat structure assessed

35 fish species identified, 5 alien species - 3.7% alien individuals

Fish images: Pusey et al. 2004
Ecological characteristics of rivers within each Reference flow regime class will be relatively similar compared to those of other classes.

We compared many ecological metrics for each ecological assemblage across flow regime classes.

• Riparian vegetation species richness varied along the Reference flow class climatic and hydrological gradient. Species richness was higher in wetter catchments.

• Aquatic vegetation species richness varied along a gradient in channel morphology (bank full width : bank full depth) and the climatic gradient underlying Historic flow classes.

• Fish assemblages in Reference flow classes differed in species richness, non-migratory species richness, total fish density, native species density, non-migratory density and alien density.

Given these differences in ecological metrics across flow regime classes, we searched for ecological relationships with flow variability gradients across the SEQ region.
Responses of riparian trees and shrubs to flow variability (all unregulated sites across SE QLD)

CV daily flow in Dry Season (October - March)

-ve relationship with:

- Total species richness
- No. species per m²
- No. native species per ha
- No. late succession spp per ha
- Basal area of late succession spp per ha
- No. of regenerating native species per ha

Total species richness lowest at intermediate levels of CV annual flow
Responses of aquatic vegetation to flow variation
(all regulated and unregulated sites across SE QLD)

Percentage of days in 12 months prior to sampling where discharge (Q) was above the threshold required to mobilise the median substrate particle size (D50)

-ve relationship with:
- Total in-stream vegetation cover
- Emergent cover
- Total in-stream vegetation density
- Emergent vegetation density
- Total plant density –ve with number of high flow spells (>75th percentile)

+ve relationship between total in-stream vegetation cover and log of Q_D50MOVE. Total cover higher where likelihood of D50 being mobilised is low.
Responses of fish to flow variation
(all regulated and unregulated sites across SE QLD)

Total species richness (SPR):
+ve relationship with
• Constancy and Predictability of monthly flows (15 years before sampling)

SPR lowest at intermediate levels of CV daily flow (4 years before), and high spell number (15 years before)

Density of alien fish per 450 m² reach surface area:
+ve relationship with
Number of zero flow days (4 years before sampling)

Species richness vs total density:
-ve relationship with
• Mean daily flow (4 years before sampling)
• 10-year ARI flood (15 years before sampling)
Rivers within each flow regime class that are ‘regulated’ (or supplemented) in the same way by dams or other infrastructure will show similar ecological responses to flow regime change.

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Baroon Pocket Dam
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Dams and weirs store ~ 38% MAR
Storage capacity 730 - 1,150,000 ML
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165,000 ML, first completed 1989
Heat map showing magnitude and direction of change in flow metrics: Gauge (Historic) vs IQQM (Reference)

Every dam has changed the downstream flow regime in a different way.

Flow metrics increased, decreased or remain relatively unchanged.
The release of water from dams during normally dry months has reduced the duration of low flow spells at downstream sites.

In these wetter conditions, aquatic plants have markedly increased in cover.
The storage of high flows in dams has reduced the duration of high flow spells at downstream sites.

In these less disturbed conditions, aquatic plants have increased in cover.
% change in non-migratory fish species richness vs % change in CV daily discharge

Warning level of ecological change from zero (class 1)

Unacceptable level of ecological change from zero (class 2)

Acceptable level of ecological change from zero

Unacceptable level of ecological change from zero (class 2)

Warning level of ecological change from zero (class 1)
Summary of flow-ecology relationships

- Quadratic Species richness vs interannual CV
- +ve linear Species richness vs constancy and predictability
- -ve linear Total species richness, species per ha, basal area late successional species, no regenerating species per ha vs CV daily flows dry season
- Seasonal timing
  - Flood magnitude
    - -ve linear Species rich/density vs median daily flow, 10-year ARI
    - +ve Aquatic plant cover vs high spell duration
  - Zero and low flow duration
    - +ve density alien fish species vs no. zero flow days
    - Mixed response Species richness vs change in CV daily flows
    - +ve Aquatic plant cover vs flow to mobilise substrates, +ve response Aquatic plant cover vs change in low spell duration
SUMMARY OF ELOHA TESTS

Rivers of a chosen region can be grouped into distinctive flow regime classes on the basis of ecologically relevant flow metrics - measures of magnitude, seasonal timing, frequency, duration and variability of particular flows. **YES**

Ecological characteristics of rivers within each flow regime class will be relatively similar compared to those of other classes. **YES**

Increasing degrees of flow regime change will have increasing impacts on ecological response variables: these relationships may take different forms – e.g. linear, threshold. **YES**

Rivers within each flow regime class that are ‘regulated’ (or supplemented) in the same way by dams or other infrastructure will show similar ecological responses to flow regime change.

**COULD NOT TEST DUE TO LACK OF REPLICATION**