Impacts of Dams in SE Queensland:
A Test of the ELOHA framework for setting environmental flow rules in rivers

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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
- Flow Alteration-Ecological Response Relationships by River Type

SOCIAL PROCESS
- Implementation
- Environmental Flow Standards
- Acceptable Ecological Conditions
- Societal Values and Management Needs

Adaptive Adjustments
SE QLD Drought

- water shortages
- water restrictions
- new supplies
  - groundwater
  - desalination
  - recycling
  - conservation
  - new storages?
Study Area

Baroon Pocket Dam on Obi Obi Ck
Six Mile Creek Dam
Borumba Dam on Yabba Ck
Moogerah Dam on Reynolds Ck
Hinze Dam on Nerang River
Maroon Dam on Burnett Ck

South-east Queensland
Ordination (SSHMDS) of sites based on modelled pre-development flow regime (35 metrics)

6 classes of pre-development flow regimes

1 = 26 nodes from all major rivers
2 = 17 nodes Mary, Brisbane, Logan-Albert
3 = 5 nodes Logan-Albert, lower Mary River, Teewah Creek
4 = 17 nodes Mary and Brisbane rivers
5 = 18 nodes Mary, Maroochy, Brisbane, Maroochy, Gold Coast
6 = 5 nodes from 5 catchments, 3 rising in Maleny plateau

Low to high discharge gradient
SE Queensland dams (9,300 - 165,000 ML storage)

Borumba

Wivenhoe

Hinze

Photos: seqwater.com.au
Flow class 1 = 2 samples (Six-Mile, Obi Obi)
Flow class 2 = 3 samples (Yabba, Burnett, Reynolds)
Flow class 4 = Brisbane River studied previously)
Flow class 5 = 1 sample (Nerang River)

Gower Metric = multivariate measure of dissimilarity in flow regime based on 35 flow variables
0 = similar, 1 = dissimilar
Heat map showing magnitude of change in flow metrics - Gauge (Historic) vs IQQM (Reference)

\[ \frac{(\text{Gauge} - \text{IQQM}) \times 100}{\text{IQQM}} \]

Legend

Red, orange & yellow represent decreases in metric values relative to IQQM

Light blue, blue & dark blue represent increases in metric values relative to IQQM

White represents change of -5% to +5%.
Referential field study design

Gower Metric - multivariate metric of degree of flow regulation

Class 1 = 2 samples (Six-Mile, Obi Obi), Class 2 = 3 samples (Yabba, Burnett, Reynolds), Class 4 = Brisbane River, studied previously, Class 5 = 1 sample (Nerang)
Field Methods - Riparian Vegetation

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

• Upper boundary determined by bank full or 50 m distance from the water’s edge

• Same side of the river

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

- In-stream & bank vegetation recorded
- Sampling at quadrat, transect, site scale
- Water quality & habitat variables (e.g. shear stress) determined from conceptual model
Field Methods - Fish
Multiple pass electrofishing & block seine

- Fish sampled at pool-riffle-run sequences
- Fish identified, counted, measured, returned
- Samples kept for condition, diet & reproductive status
- Habitat structure assessed in-stream & along banks

Fish Drawings - Dr Brad Pusey, ARI

Images: Pusey et al. 2004
MDS ordination of riparian vegetation – tree and shrub densities per ha

% of variation in vegetation structure explained:
- Catchment 16.33
- In-stream 5.28
- Flow 14.08
- Interactions
- Total 49.9

Most important flow metrics:
- CV daily flow in Dry season
- Base flow duration
- CV daily flow all year
- LSN – number of days of low flow (<75th percentile)
- LSDur - mean duration of low spells (<75th percentile)
## % biotic variation explained by flow and catchment variables

<table>
<thead>
<tr>
<th>Ecosystem component</th>
<th>% explained</th>
<th>Important flow variables</th>
</tr>
</thead>
</table>
| Riparian vegetation (trees and shrubs) | Flow = 14.08  
Catchment = 16.33  
Total = 49.9 | CV Dry season flows  
BFDur - mean duration bankfull flows  
LSM – low spell number (< 75th percentile)  
LSDur - mean duration of low spells |
| Aquatic vegetation (submerged or total cover) | Flow = 4.1  
Catchment = 23.0  
Total = 42.9 | DAYS_Q_D50 (days of flow that mobilise median substrate particle size)  
D50_HSDur (duration of high flows that mobilise median substrate particle size) |
| Fish (presence-absence, CPUE)  
Seasonal samples anaylsed individually | Flow = 8.97 - 20.34  
Catchment = variable  
Total = 52.9 - 57.4 | Number of zero flow days  
MD Flow - mean daily flow  
CV daily flows  
LSDur - mean duration of low spells (75th percentile)  
Magnitude of 1 yr ARI  
Constancy and Predictability of mean monthly flows |
Responses of riparian trees and shrubs to flow variation (all unregulated sites across SE QLD)

CV daily flow in Dry Season (October - March)

-ve relationship with:

Total species richness
Total density per m²
Density of native species
Density late succession spp
Basal area of late succession spp
Native regeneration density per hectare

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

-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 reg 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)

Alien density:
+ve relationship with
Number of zero flow days (4 years before sampling)

Species density:
-ve relationship with
  • Mean daily flow (4 years before sampling)
  • 10-year ARI flood (15 years before sampling)
Responses of riparian trees/shrubs to flow change
Partial Least Squares reference models

Predicted (PLS model)  
vs observed riparian metrics  
at regulated sites  

Effect of flow regulation  
(O-E/E) x 100  
vs Gower metric
Gradient of change in CV of mean daily flow

CV increase at Yabba, Reynolds and Burnett Cks, class 2

CV decrease at Obi Obi and Six-Mile Creek (class 1)

CV decrease at Nerang R. (class 5)
‘ELOHA Plot’ for non-migratory fish species richness

Hypothetical 20% ELOHA ‘rule’

- Unacceptable level of ecological change from zero (class 2)
- Warning level of ecological change from zero (class 1)
- Acceptable level of ecological change from zero
Summary – differences between flow regime classes and effects of flow regulation

Flow regime classes differ ecologically, but not consistently across riparian vegetation, aquatic vegetation and fish.

Each dam has a unique flow regulation signature, therefore no replication of type and degree of flow regulation within each flow class.

Flow regulation does impact on some metrics of riparian veg, aquatic veg and fish, with both subsidy and depletion effects.

Many of the metrics tested do not show statistically significant differences between regulated and reference sites.

Dams are relatively recent (10-50 years), degree of change in flow from modelled natural is relatively low (max = 0.25 on Gower dissimilarity scale of 0-1).

Possible that ecological metrics are on temporal trajectories of response to flow regime change, but are not fully adjusted to particular flow changes.
Responses to flow variability across the entire study area and data set are apparent in riparian vegetation via the influence of CV daily flows, CV daily flows in dry season, and mean duration bankfull flows. All have a mechanistic explanation.

Responses to flow variability across the entire study area and data set are apparent in aquatic vegetation via mechanistic hydraulic processes that mobilize stream substrates, and destabilize submerged aquatic vegetation.

Responses to flow variability across the entire study area and data set are apparent for fish:
- **Total species richness (SPR)**: +ve relationship with Constancy and Predictability of monthly flows (15 years before sampling)
- **Alien density**: +ve relationship with number of zero flow days (4 years before sampling)
- **Species density**: -ve relationship with mean daily flow (4 years before sampling), and 10-year ARI flood (15 years before sampling)
Summary – gradients of response to flow variability

PLS models of predicted biotic metrics allow effects of other environmental gradients (e.g. climate, catchment characteristics, landuse) to be removed.

No consistent ecological responses to any individual metrics of flow regime change so far.

No consistent responses to Gower metric of flow regime change established for any biotic metric so far.

Flow regime change captured by the Gower metric is multivariate – how can we capture a few individual flow metrics and ecological responses in meaningful ways for management purposes?
## Dimensions of dams
(urban and irrigation storage)

<table>
<thead>
<tr>
<th>Catchment</th>
<th>Location</th>
<th>Storage</th>
<th>Storage Volume (ML)</th>
<th>Year Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mary</td>
<td>Obi Obi Ck</td>
<td>Baroon Pocket Dam</td>
<td>61 000</td>
<td>1989</td>
</tr>
<tr>
<td></td>
<td>Yabba Ck</td>
<td>Borumba Dam</td>
<td>42 600</td>
<td>1964</td>
</tr>
<tr>
<td></td>
<td>Six Mile Ck</td>
<td>Six Mile Creek Dam</td>
<td>9 300</td>
<td>1964</td>
</tr>
<tr>
<td>Brisbane</td>
<td>Reynolds Ck</td>
<td>Moogerah Dam</td>
<td>92 500</td>
<td>1961</td>
</tr>
<tr>
<td>Logan</td>
<td>Burnett Ck</td>
<td>Maroon Dam</td>
<td>38 400</td>
<td>1974</td>
</tr>
<tr>
<td>South Coast</td>
<td>Nerang River</td>
<td>Hinze Dam</td>
<td>165 000</td>
<td>1989</td>
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