Contributions of Environmental Flows Science to River Conservation and Restoration

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Australia
750 delegates from over 50 countries produced:

Brisbane Declaration 2007 http://www.watercentre.org/news/declaration

• A new definition of e-flows
• 7 e-flow principles
• 9-point Global Action Agenda to protect rivers globally by maintaining or restoring environmental flows
Environmental Flows – a new definition

Environmental flows describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend upon these systems.

Brisbane Declaration 2007
International Environmental Flows Conference, Brisbane, September 2007
750 delegates from over 50 countries
Brisbane Declaration 2007

• Freshwater and estuarine ecosystems have evolved with, and depend upon, naturally variable flows of high-quality fresh water

• Flow alteration imperils freshwater and estuarine ecosystems

Flaming Gorge Dam 1963
Brisbane Declaration 2007

- Greater attention to environmental flows must be exercised when attempting to manage floods, water supplies, hydropower generation, navigation and recreation.

- Scientifically credible e-flow methodologies must quantify the variable – not just minimum – flows needed for each water body by explicitly linking environmental flows to specific ecological functions and social values.
Scientifically credible e-flow methodologies

70% of global methods are based on:

- hydrological rules, e.g. % of historical flow
- hydraulic analysis, e.g. wetted perimeter
- habitat modelling, e.g. PHABSIM (IFIM)

Valuable contributions to habitat protection and restoration
Significant new advances in habitat modelling, e.g. SEFA
SEFA: System for Environmental Flow Analysis
Tom Payne, Bob Milhous, Ian Jowett
http://sefa.co.nz/

SEFA contains:
- one and two dimensional habitat analysis
- habitat suitability criteria (e.g. fish)
- water temperature, dissolved oxygen modeling
- sediment analysis (deposition, flushing flows)
- riparian inundation modeling
- time series analysis of flows & aquatic habitat
Aquatic biodiversity and natural flow regimes

Principle 1
Life history patterns
- spawning
- recruitment

Principle 2
Natural regime discourages invasions

Principle 3
Lateral connectivity
Longitudinal connectivity

Principle 4
Discharge
- spates
- variability
- reproductive triggers
- seasonality
- predictability
- stable baseflows
- drought

Channel form and habitat

Life history

Bunn & Arthington (2002)

- E-flows for riverine ecosystem from source to terminal waterbody, including:
  - channel & habitat
  - algae
  - aquatic vegetation
  - invertebrates & fish
  - riparian vegetation
  - floodplain processes
  - fisheries

Arthington et al. (1992)
Mapping ecological components to natural hydrograph

Building Block Methodology – BBM
Sth Africa - King & Louw (1998)

Expert/Scientific Panels, FLOWS,
Flow Events Method - Australia

CAMS (Catchment Abstraction Management Strategies) UK

Holistic-ecosystem applications:

* River conservation
* River restoration

Speed et al. (2011)
River Conservation

- Maintain flow regime as near to natural as possible
- Identify unacceptable thresholds of ecological change

River Restoration

- Restore flow regime towards natural pattern
- Identify ecological end points that can be achieved by flow restoration given constraints
Identifying unacceptable levels of ecological change

Two frameworks: DRIFT ELOHA
DRIFT – Downstream Response to Imposed Flow Transformation

Lesotho Highlands Water Project

Objectives:
- Export water to SA
- Hydro-electricity in Lesotho

Multi Phase project
- 6 Dams
- Delivery & transfer tunnels
- Infrastructure

Define scenarios of e-flows
- rivers with proposed or existing water infrastructure
DRIFT Framework

Describe Aquatic Ecosystem & Hydrological relationships

Develop models to predict flow related changes

Identify possible future flow scenarios

Predict & rate biophysical consequences

Calculate compensation & mitigation

Output to decision maker

Describe river use, health profiles & ID PAR

Develop predictive capacity for social impacts

Describe social consequences

King et al. (2003)
DRIFT Fish: Predicting impacts of flow regime change on fish

e.g. Maloti Minnow
*Pseudobarbus quathlambae*

Arthington *et al.* (2003)
**DRIFT outputs**

- Combined Integrity Score vs flow left in river
- E-flow options tested against development scenarios
- Social & financial implications of development scenarios
- Integrated Basin Flow Management (IBFM)
  
**Graph:**
- Present River State = Near natural
- Total flow left in river, % MAR
- Integrity Score
- Flow left in river vs Integrity Score
- Different stages of modification:
  - Near natural
  - Moderately modified
  - Significantly modified
  - Highly significantly modified

**Table:**

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DRIFT applications - Africa, SE Asia, South America

Lesotho Highlands Water Project, 17 river systems & Lake Sibaya (South Africa)
Lower Zambezi River & Delta (Mozambique)
Mzingwane River (Zimbabwe)
Okavango Basin (Angola, Namibia, Botswana)  
Neelum-Jhelum Basin, Poonch River (Pakistan)
Lower Mekong River (SE Asia)

DRIFT recognised as a good practice E-Flows methodology by:
World Bank, ADB, IFC, IUCN, OKACOM, and the South African, Tanzanian and Pakistan governments

King & Brown (2010)
Project → basin-scale → regional e-flow assessment

**DRIFT** - single dam to basin scale e-flows

E-flows for river reaches based on expert prediction of ecological responses to flow alteration

King & Brown (2010)

**ELOHA** - Ecological Limits of Hydrologic Alteration

Regional-scale, multi-basin e-flows e.g. bioregion, province

E-flow ‘standards’ for many rivers based on analysis of existing or new ecological data, along gradients of flow alteration

Arthington *et al.* (2006); Poff *et al.* (2010)
Classification of regional flow regimes into different types
E-flows for each river type

1. Classification based on reference stream flow data
Plots of ecological condition along flow alteration gradients for each flow metric / river type.

Sustainable level of flow change

Unsustainable level of flow change
Flow-ecology relationships: Arthington et al. (2012)

-ve
Riparian species richness vs constancy and predictability

Inter-annual variability and predictability

Seasonal timing

Flood magnitude

-ve
Basal area late successional riparian species, No. regenerating species per ha vs CV daily flows

-dispersion
Total species richness, species per ha, Basal area late succession riparian species, No. regenerating species per ha vs CV daily flows

+ve
Density alien fish species vs no. zero flow days

Zero and low flow duration

Flood duration

-ve
Species richness density vs median daily flow, 10-year ARI

-ve
Aquatic plant cover vs high spell duration

Mixed response
Fish species richness vs change in CV daily flows

+ve
Density alien fish species vs no. zero flow days

-ve
Aquatic plant cover vs flow to mobilise substrates, +ve response aquatic plant cover vs change in low spell
ELOHA - Ecological Limits of Hydrologic Alteration
Poff, Richter, Arthington, Bunn et al. (2010)

**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
- Flow Alteration-Ecological Response Relationships by River Type

**SOCIAL PROCESS**

**Implementation**
- Environmental Flow Standards
- Acceptable Ecological Conditions

**Adaptive Adjustments**
- Societal Values and Management Needs
ELOHA applications to e-flows at regional scale

- 6 US states and 3 interstate river basins

A practical guide to environmental flows for policy and planning
Kendy et al. (2012) [www.conservationgateway.org](http://www.conservationgateway.org)

- Mexico
- Colombia
- China
- European Union
- Australia
  - northern rivers
  - SE Queensland
  - Murray-Darling Basin
Murray-Darling Basin

>1 million km$^2$, 4 states and ACT

>77,000 km of rivers, creeks and watercourses, 30,000 wetlands

Inflows 31,600 (6,700 -117,900) GL / year

Water use audit 1995, water take capped


$AUD 9 billion for e-water purchases and improvements in water infrastructure (20% reduction in consumptive use)

Geosciences Australia & MDBA (2008)
Basin-scale classification & mapping of ecological assets

Bunn et al. (2014)


Distribution of 14 riverine classes across the M-DB - large lowland rivers to small headwater streams

Distribution of floodplain, wetland & lake classes across the M-DB
Flow-ecology response models for different components of the flow regime - IPCC terminology (Mastrandrea et al. 2010)

Artificially stable high flows in summer are likely to reduce the spawning and recruitment success for native fish (*medium to high confidence*).

Reversed seasonality of flows is likely to reduce recruitment of riparian trees and increase the risk of blackwater (low oxygen) events in-channel, if flood flows inundate floodplains rich in organic matter during summer (*high confidence*).
ELOHA Innovations

New approaches to:

Constructing hydrologic time series, flow regime & waterbody classification
(Kennard et al. 2010; Olden et al. 2011; Mackay et al. 2014; Bunn et al. 2014)

Modelling ecological roles of flow & effects of flow alteration

Stakeholder engagement, inclusion of indigenous values & needs
(Finn & Jackson 2011)

Monitoring e-flow outcomes, identification of knowledge gaps, R&D priorities
ELOHA enables river managers to:

• deliver e-flows for rivers of distinctive flow regime type

• minimise ecological impacts at most sensitive, high value waterbodies

• prioritize river segments for flow regime restoration at basin and regional scale

• envisage / predict how rivers may change under different water infrastructure / management / climate scenarios

Abel et al. (2007)
Looking to the future

• Climates, flow regimes and freshwater ecosystems will change

• E-flows are a vital tool for adaptation to climate & environmental change

• E-flows science must generate deeper ecological understanding to inform river flow management in changing environments

• Monitoring e-flow outcomes is essential to inform the e-flow scientists and managers of the future

Ecological states under shifting hydrological & geomorphic regimes

Auerbach et al. (2009)
Further light reading

University of California Press

Inbooks.com
www.inbooks.com.au

Amazon.com

eBay