Assessing the likely ecological effects of environmental flows: Systematic evaluation of ecological literature to support causal inference

Susan Nichols & Renee Brawata
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University of Canberra
The case for causal criteria analysis

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Richard Norris, Angus Webb, Mike Stewardson
What is systematic causal assessment?

Systematic review of scientific literature on specific topic

Eco Evidence framework - adapted from epidemiology (causal criteria approach) but developed specifically for environmental sciences

Standardized method & algorithm for combining scientific evidence to assess level of support for, or against, cause-effect hypotheses

Supporting software – Eco Evidence

- Evidence database (online)
- Analysis software (desktop)

Don’t we use the literature already? Anecdotal evidence may suggest we don’t use it well

- Who has ever searched for that one reference to support a statement?
- Have you ever read only the article’s abstract?
- Do you accept the result without really assessing the quality of the study?
- Do you read the paper without recording key findings?
Our motivation for Eco Evidence

- To facilitate adoption of evidence-based practice that could make better use of scientific literature
- To develop a logical framework to combine & evaluate multiple lines of scientific evidence
- To develop a standardized causal criteria approach to provide transparency & strengthen confidence in conclusions
- Database to store & reuse evidence items
- Efficient & effective use of research literature
What can it be used for?

• When more evidence is required to confidently infer causality
• Augment results from local field studies to assess general applicability, or transferability of results
• To support evidence-based practice in environmental management
• Assess likely environmental effects of a proposed development or restoration activity
• Identifying most likely cause/s of an observed environmental impact
…what else can it be used for?

• To complement environmental risk assessments
• To provide quality assurance & a reusable resource for any literature review undertaken by consultants to environmental management organizations
• To present evidence in a transparent & defensible format suitable for use in legal cases or administrative action over environmental impacts
• To focus a literature review of specific topics to be published as a succinct & defensible review paper
Why do we need it?

Legal challenges are becoming more frequent

- Defensible, repeatable, transparent, evidence-based approach to support decision-making

Managers required to use ‘best available science’ to conduct ‘evidence-based’ decision making

- Effectiveness – e.g. restorations that are likely to work, effective environmental flows, etc.

Murray-Darling Basin Plan will return water to rivers specifically for environmental purposes

- such investment can be controversial if the ecological benefits are poorly understood

Demonstrating cause–effect relationships in natural systems is challenging
The challenge of demonstrating cause–effect

- Difficulties with natural variability
- Performing suitably scaled experiments
- Lack of true replication & randomization
- Presence of confounding influences
- Before After Control Impact - powerful designs
- But what if elements are missing? e.g. no ‘before’ period, lack of control
- Cannot fix the problem with a ‘better’ study design if we cannot replace the missing information
- All this = uncertainty in inferring a causal link
- What can we do?
Epidemiologists faced similar challenges

Causal Criteria defined in US Surgeon General’s report on health effects of smoking (USDHEW 1964)
- Consistency of Association
- Strength of Association
- Specificity of Association
- Temporal Relationship
- Coherence
Epidemiology faced similar challenges

Causal Criteria defined in US Surgeon General’s report on health effects of smoking (USDHEW 1964)

- Consistency of Association
- Strength of Association
- Specificity of Association
- Temporal Relationship
- Coherence
- Biological gradient (dose–response)
- Biological plausibility
- Experiment
- Analogy
Problem-Focused Analysis Framework

1. Document the nature of the problem & draft the question (hypothesis) under investigation
2. Identify the context in which the question will be asked
3. Develop a conceptual model & clarify the question
4. Decide on the relevant causal agents & potential effects
5. Search and review literature, and extract evidence
6. Revise conceptual model & previous steps if necessary

7. Catalogue & weight the evidence
8. Assess the level of support for the hypothesis & make a judgement

Revise hypothesis if needed i.e. in light of inconsistent evidence

document revisions to all steps

Publications & more in press


IDENTIFICATION OF THE PROBLEM
Assessment of site specific information on stressor(s) & environment;
    Determine contaminant pathways if applicable; and
    Determine the time-frame that over which the problem operates

ANALYSE information
    (both spatial and temporal)

ASSESS EXTENT (Field assessment: eg. bioassays, monitoring surveys etc)

ASSESS EFFECTS
    (eg. Chemical concentrations, spatial and temporal distribution)

RISK CHARACTERISATION
    (Comparison of the Effects with the Extent, eg using a GIS framework)

RISK MANAGEMENT & REDUCTION
    (Manage inputs and/or modify management practice)

MONITORING
    (Use early warning or rapid assessment indicators/ GIS based approach)

ADAPTIVE MANAGEMENT LOOP
Adaptive management cycle

Periodically review overall management program

Report findings and recommendations of evaluation

Evaluate management effectiveness

Adjust management actions and arrangements to enhance effectiveness

Implement strategies and actions to achieve objectives

Establish monitoring programs for selected performance indicators

Develop management strategies and actions

Define key desired outcomes

Identify performance indicators

Determine management objectives

From Jones (2005).
## Causal Criteria in Eco Evidence

<table>
<thead>
<tr>
<th>Causal criterion</th>
<th>Description &amp; basis for selection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plausibility</strong></td>
<td>Plausible mechanism (e.g., biochemical reaction) that could explain the relationship between causal agent &amp; potential effect - conceptual model</td>
</tr>
<tr>
<td><strong>Evidence of response</strong></td>
<td>Study reports an association between causal agent &amp; potential effect e.g. statistically significant</td>
</tr>
<tr>
<td><strong>Consistency of association</strong></td>
<td>Association between causal agent &amp; potential effect is in the form of a “dose–response” relation</td>
</tr>
<tr>
<td><strong>Evidence of stressor in biota</strong></td>
<td>This would include evidence of a chemical residue within an organism of interest</td>
</tr>
<tr>
<td><strong>Agreement among hypotheses</strong></td>
<td>When results for individual cause–effect hypotheses are considered collectively, do they support or refute the question</td>
</tr>
</tbody>
</table>
Weighting evidence
Studies that account better for environmental variability or error should carry more weight in the analysis - improves inferential power

<table>
<thead>
<tr>
<th>Study Design</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>After impact</td>
<td>1</td>
</tr>
<tr>
<td>Before-after or Control-impact</td>
<td>2</td>
</tr>
<tr>
<td>Gradient designs</td>
<td>3</td>
</tr>
<tr>
<td>BACI &amp; derivatives</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gradient design Replication</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td># Sampling units</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>&gt;5</td>
<td>6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factorial design Replication</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td># Impact sampling units</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>&gt;2</td>
<td>3</td>
</tr>
<tr>
<td># Control sampling units</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>&gt;1</td>
<td>3</td>
</tr>
</tbody>
</table>

Design weight + Replication weight = Evidence Weight for each evidence item
Assessing support: combine across the criteria

<table>
<thead>
<tr>
<th>Evidence of Response</th>
<th>Dose-Response</th>
<th>Consistency of Association</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 20</td>
<td>≥ 20</td>
<td>&lt; 20</td>
<td>Support for hypothesis</td>
</tr>
<tr>
<td>≥ 20</td>
<td>&lt; 20</td>
<td>&lt; 20</td>
<td>Support for hypothesis</td>
</tr>
<tr>
<td>&lt; 20</td>
<td>&lt; 20</td>
<td>&lt; 20</td>
<td>Insufficient evidence</td>
</tr>
<tr>
<td>≥ 20</td>
<td>≥ 20</td>
<td>≥ 20</td>
<td>Inconsistent evidence</td>
</tr>
<tr>
<td>≥ 20</td>
<td>&lt; 20</td>
<td>≥ 20</td>
<td>Inconsistent evidence</td>
</tr>
<tr>
<td>&lt; 20</td>
<td>&lt; 20</td>
<td>≥ 20</td>
<td>Support for alternate hypothesis</td>
</tr>
</tbody>
</table>
Eco Evidence Analyser

Eco Evidence Analysis Software provides a systematic framework for the evaluation of evidence for environmental cause-effect relationships. The various steps can be grouped into 3 broad tasks:

1. **Formulate the problem**
   - Describe the problem of interest and formulate the question to be assessed
   - Define the context of the question
   - Develop a conceptual model of the potential causes and effects
   - Identify the potential causes-effect linkages that will be investigated

2. **Search and review the literature**
   - Describe the search strategy you used for the literature review
   - Summarise each of the citations consulted
   - Analyse the evidence from each citation to assess its relevance

3. **Weight the evidence and judge causation**
   - Weight the evidence according to the study design and sampling units
   - View the generated analysis report

Overview

1. Formulate question
2. Define the context
3. Describe conceptual model
4. Identify cause-effect linkages
5. Conduct literature review
6. Consider revisions
7. Weight the evidence
8. Draw conclusions
Online database for recording & retrieving studies & metadata concerning associations between a cause (X) & an effect (Y)
Effects of inundation on wetland plants – Wallis
Effectiveness of artificial fish habitat

Ebner, Lintemans, Nichols
Effects of flooding on river ecology

— Harrison, Nichols
Sediment effects on aquatic invertebrates
— Harrison & Nichols
Effects of overbank flows on floodplain vegetation
– Webb
More Case Studies

- Effects of seasonal flow inversion on riparian vegetation – Greet
- Effects of Groundwater abstraction of stream flow – Barlow, Nichols
- Effects of flow regulation on floodplain geomorphology – Grove
CRN Project: Using an evidence-based approach in the optimization of water allocation decisions

University of Canberra
Sue Nichols
Sue Powell
Renee Brawata
Brenda Dyack
Mike Peat (PhD student)

University of Melbourne
Angus Webb
Mike Stewardson (ARC Linkage)

Charles Sturt University
Wayne Roberson
eWater
Geoff Adams

Candidate Ecological responses

ecology/flow hypothesis

Eco Evidence (systematic evaluation of existing literature)

Accepted hypothesis

Expert elicitation → Eco Evidence → Empirical data analysis

analysis relevant to hydrology/hydraulics

Ecological Response Functions

$ valuation alternative values

ERF model coding

Source river model (including existing river management & extractive use modelling)

Optimisation tools

Ecological values

Extractive use values

Social values
Ecological responses to flow

- Terrestrial vegetation
- Fish
- Macroinvertebrates

video
http://www.youtube.com/watch?v=nZisNoKE2A8&list=FLQghHAP1bgaxrmftUnkYOug
Application of Eco Evidence to explore ecological response to flow:

A Case Study from the Cotter River, ACT

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University of Canberra
Steps of the Eco Evidence framework:

- **Describe** the problem
- **Define** the context
- **Develop** a conceptual model identifying cause & effect linkages
- **Search** the literature
- **Select** relevant citations
- **Systematically** enter into database
- **Weigh** the evidence
- **Write** up the findings using generated report
Describe the problem

Identify a broad area of interest:
Can we use existing literature to help make predictions about the response of macroinvertebrates to extreme flow events in rivers like the Cotter River?

- Climate change – predicted increase in extreme events
- Human impacts – need to provide environmental water
- Macroinvertebrates used as indicator of eflow success
Define the context

The Cotter River

- Regulated river (Three reservoirs; Corin, Bendora & Cotter Dams)
- Upland ecosystem – 1760m to approx. 400m elevation
- Temperate zone of Australia
- Perennial river – maintains flow even when not raining because of groundwater
- Mostly natural land use (88% of catchment within Namadgi NP)
- Catchment area of 482km² & river is 74km
- Cobble dominated substrate
Can be general to begin with, but needs to be specific enough to inform the construction of a conceptual model….

Does the timing & magnitude of extreme flow events alter macroinvertebrate communities in rivers like the Cotter River, ACT?

Quantify cause & effect terms
Develop a conceptual model - HF

**Cause**

Flow magnitude (volume/velocity)
(3 x magnitude median baseflow)
*Baseflow is flow supported by groundwater*

**Linkages (processes)**
Riparian - adults → Physical removal of habitat and taxa → Substrate stability

**Effect**
Measurement of changes in communities:
- Taxon diversity and richness
- Total abundance
- Assemblage structure (relative abundance)

**Extreme Flow Event**

**Time between events**
(frequency consecutive HF vs. one-off)
Develop a conceptual model - LF

**Cause**

- Flow magnitude (volume/velocity) (magnitude 90\%tile or lower)
  - Flow is at that level or >90\% of the time

**Linkages (processes)**

- Riparian – adults and temperature
- Eflows – flow maintenance

**Duration of low flow and time between events**
- (no. of days CTF and frequency)
- Change in water quality, increases in temperature and algae

**Effect**

- Measurement of changes in communities:
  - Taxon diversity and richness
  - Total abundance
  - Assemblage structure (relative abundance)
Selecting relevant citations

Using Context and Conceptual model to focus literature search:

• Perennial rivers only (ground water sourced, flowing), not ephemeral/intermittent streams or still water bodies (e.g. lakes) because of risk of naturally adapted biota to dry/flushing periods

• Only included extreme flow events

• Reduced confounding from urban streams because of pollution, flooding after bushfires or drying/flooding after insecticide, but studies in grasslands & minimal impact agriculture were used

• Included stone/substrate movement & acidification (flood/drought-induced only, not all) as an important mechanism of the impact on macroinvertebrates
Literature Search Strategies

Documenting the process

• Recorded search strategies, including search engines and search terms used.


• Used all relevant media types available: journal papers, books, reports, conference proceedings.

• Summarised the findings:

  We collected 193 references including 27 review papers (reference lists used only)

Justification, repeatability and transparency
The Eco Evidence online database

Step by step through software component 1

Overview

Eco Evidence is a product for analysing scientific evidence and assessing its strength and quality. It comprises:

- an online database for recording and retrieving studies and metadata concerning associations between a cause (X) and an effect (Y); and
- analysis software that provides a mechanism to evaluate the strength of evidence supporting a causal link between X and Y, strengthening inferential ability.

Obtaining access

All registered users of the eWater CRC Toolkit have read-only permissions in Eco Evidence. Additionally, insert/edit permissions are granted to appropriate and interested users.

Please contact the developers and request insert/edit access.

Contact us

eWater CRC researchers from the University of Canberra and The University of Melbourne have been involved in the development of the Eco Evidence product. Development has also been in collaboration with members of the US EPA.

For more information, contact the developers.
Systematically entering a citation

New citation

Title *
Post-Flood Recovery of a Macroinvertebrate Community in a Regulated River: Resilience of an Anthropogenically Altered Ecosystem

Similar citations
Citation detail
No citations exist

Check
Preservation of biodiversity depends on restoring the full range of historic environmental variation to which organisms have evolved, including natural disturbances. Lotic ecosystems have been fragmented by dams causing a reduction in natural levels of environmental variation. This presents a challenge to scientists who study diversity during restoration.

Keywords: floods, macroinvertebrate diversity, stream regulation, stream restoration, temperature restoration.
## Identifying cause and effect linkages

<table>
<thead>
<tr>
<th>Trajectory</th>
<th>Available terms</th>
<th>Selected term/definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cause</strong></td>
<td></td>
<td>surface water (volume)</td>
</tr>
<tr>
<td>No trajectory</td>
<td>surface</td>
<td>Volume of a surface water body</td>
</tr>
<tr>
<td>Change</td>
<td>surface water, surface water (area), surface water (depth), surface water</td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>(frequency), surface water (seasonality), surface water (velocity), surface</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td>water (volume)</td>
<td></td>
</tr>
<tr>
<td>No change</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Detailed cause</strong></td>
<td>Two floods, largest flows in 32 years since dam. First flood in July 1983 with</td>
<td>HF lasting 1.5 months, the second flood in July 1984 with HF lasting 4.5 months.</td>
</tr>
<tr>
<td><strong>Effect</strong></td>
<td>invertebrates, invertebrates (behaviour), invertebrates (competition),</td>
<td>invertebrates (diversity)</td>
</tr>
<tr>
<td>No trajectory</td>
<td>invertebrates (condition), invertebrates (deformities), invertebrates (disease),</td>
<td>The number of invertebrate taxa in an area and also their relative abundance</td>
</tr>
<tr>
<td>Change</td>
<td>invertebrates (dispersal), invertebrates (diversity), invertebrates (exotic</td>
<td></td>
</tr>
<tr>
<td>Increase</td>
<td>invasion), invertebrates (growth)</td>
<td></td>
</tr>
<tr>
<td>Decrease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No change</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Detailed effect</strong></td>
<td>Invertebrate richness declined after the first flood at the regulated site,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>compared to unregulated and natural temperature sites. Invertebrate community</td>
<td></td>
</tr>
<tr>
<td></td>
<td>was more resilient to second disturbance. After ten years returned to pre-flood</td>
<td></td>
</tr>
<tr>
<td></td>
<td>levels but never reached richness estimates of other two sites</td>
<td></td>
</tr>
</tbody>
</table>

### Study design

<table>
<thead>
<tr>
<th>Study design</th>
<th>MBACI/MBARI</th>
</tr>
</thead>
<tbody>
<tr>
<td># sampling units - impacted</td>
<td>2</td>
</tr>
<tr>
<td># sampling units - control/reference</td>
<td>1</td>
</tr>
</tbody>
</table>
↑ surface water (volume) → ↓ invertebrates (diversity)

Russell B. Rader, Neal J. Voelz and James V. Ward (2008)

*Post-Flood Recovery of a Macroinvertebrate Community in a Regulated River: Resilience of an Anthropogenically Altered Ecosystem*

<table>
<thead>
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<tr>
<td>Cause</td>
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<td><em>Volume of a surface water body</em></td>
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</tr>
<tr>
<td>Effect</td>
<td>Decrease</td>
</tr>
<tr>
<td></td>
<td><em>invertebrates (diversity)</em></td>
</tr>
<tr>
<td></td>
<td><em>The number of invertebrate taxa in an area and also their relative abundance</em></td>
</tr>
<tr>
<td>Detailed effect</td>
<td>Invertebrate richness declined after the first flood at the regulated site, compared to unregulated and natural temperature sites. Invertebrate community was more resilient to second disturbance. After ten years returned to pre-flood levels but never reached richness estimates of other two sites.</td>
</tr>
</tbody>
</table>
Weighting the evidence

Step by step through software component 2

Refining & defining the questions for analysis….

**High Flow**

1. Do extreme high flows over consecutive years (or closer) change macroinvertebrate assemblages?

2. Do extreme high flows following a period of extreme low flow change macroinvertebrate assemblages?

**Low Flow**

1. Does the frequency of extreme low flows over consecutive years (or closer) change macroinvertebrate assemblages?

2. Do extended extreme low flows (duration of >1 week CTF) change macroinvertebrate assemblages?

**Question too broad – inconclusive results**

**Question too narrow – little evidence**
Using Eco Analyser – first steps (1-3)

Problem
Document the nature of the problem you are investigating.
We are interested in whether or not we can make some predictions about the response of macroinvertebrate abundance, diversity and richness to extreme high flow (flood) and low flow (drought) events. The context is examining the potential impacts of climate change (which indicates that there will be an increasing magnitude and frequency of extreme EF events and increasing duration of LF in response to warmer conditions) in the Cotter River, a perennial, upland river system in temperate southeastern Australia. So, can we use existing literature to help make predictions about the response of macroinvertebrate populations in the Cotter River to extreme flow events?

Question
Draft your Eco Evidence question.
Q. Does the timing and magnitude of extreme flow events alter macroinvertebrate communities in the Cotter River, ACT?
Sub-Q: Do extended extreme low flows (duration of >1 week CFI) change macroinvertebrate assemblages?

Define the context
Document the type of environment under investigation and set the context and boundaries for the question.
Regulated river (Three reservoirs: Corin, Bndora and Cotter Dams)
Upland ecosystem – 1260m
Temperate zone – NSW
Perennial river
Mostly natural land use (88% of catchment within Namadgi NP)
Granitic dominated geology
Catchment area of 487km² and river is 74km in length

Looked at literature from perennial rivers only (ground water sourced, flowing), not ephemeral, intermittent or non-perennial or other water bodies due to risk of naturally adapted biota to dry/flushing periods.
Did not include base flow response, only flow “extremes” or “out of the norm”.
Did not include urban streams due to pollution as a confounding variable, grasslands and minimal agriculture ok.
Did not include flooding after burns or drying/flooding after insecticide
Did include stream/substrate movement references and acidification (drought-induced only, not all) as an important mechanism of the impact on macroinvertebrates

Conceptual model
Develop a conceptual model of the relationships in question. List the potential causes and effects.

Include image file
Identify cause and effects (Step 4)

Load terms from data source

Choose data source: Eco Evidence database

Terms
Terms for use when creating model linkages (i.e. the causes and effects)

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>agriculture</td>
<td>Land use involving the cultivation of animals, plants, fungi and other life forms for food, fiber, and other products used to sustain life</td>
<td>Eco Evidence database</td>
</tr>
<tr>
<td>algae</td>
<td>Unicellular to multicellular, non-vascular, autotrophic</td>
<td>Eco Evidence database</td>
</tr>
</tbody>
</table>

Add | Remove

Linkages
A link is a pair of cause and effect terms, along with their trajectories, which are used to describe a hypothesis under investigation. Use the ‘Add’ button to create linkages.

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>surface water → Δ invertebrates (assemblage)</td>
<td>Does a decrease in surface water volume (90th percentile) lead to a change in macroinvertebrate assemblages</td>
</tr>
</tbody>
</table>

Add | Cause term | Trajectory | Effect term | Trajectory | Description |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>surface water</td>
<td>Decrease</td>
<td>Δ invertebrates (assemblage)</td>
<td>Change</td>
<td>Does a decrease in surface water volume (90th percentile) lead to a change in macroinvertebrate assemblages</td>
<td></td>
</tr>
</tbody>
</table>
Conduct a literature review (Step 5)

Overview
1. Formulate question
2. Define the context
3. Describe conceptual model
4. Identify cause-effect linkages
5. Conduct literature review
6. Consider revisions
7. Weight the evidence
8. Draw conclusions

Conduct literature review

Search strategy
Document the search strategy used for undertaking the literature search and review.

I searched Google Scholar, Scopus and Web of Knowledge for the search terms 'supra-seasonal', 'invertebrates', 'extreme', 'drought', 'food', 'high flow', 'low flow', removing literature that did not fit within the given boundaries/context of the question given in steps 1-3.
We collected 198 references including 27 review papers (from which reference lists were used to search further literature).

Search a data source
Search for evidence about one or more linkages from one or more configured data sources. The evidence and citations will be added to your project once the search is complete.

Citations

<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
<th>Year</th>
<th># Evidence</th>
<th># Analysed</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>More for less: a study of environmental flows during drought in two Australian rivers</td>
<td>White, M.L., Nicholls, S.J., Robinson, W.A., Norris, R.H.</td>
<td>2012</td>
<td>1</td>
<td>0</td>
<td>Freshwater Biology</td>
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<tr>
<td>Effects of floods on epilithon and benthic macroinvertebrate populations in an unstable New Zealand river</td>
<td>Senequeur, G. J. and Winterburn, M. J.</td>
<td>1989</td>
<td>1</td>
<td>0</td>
<td>Hydrobiology</td>
</tr>
<tr>
<td>Destruction and re-establishment of stream fish and invertebrates affected by drought</td>
<td>R. Walton Lainzmore, William F. Clevlers</td>
<td>1959</td>
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<td>1</td>
<td>Transactions of the American Fisheries Society</td>
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<tr>
<td>The ecology of a small chalk stream and its responses to drying during drought conditions</td>
<td>M. Leslie and J.A.B. Bass</td>
<td>1981</td>
<td>1</td>
<td>0</td>
<td>Archive for Hydrobiology</td>
</tr>
</tbody>
</table>

Description of study design below
Consider Revisions (Step 6)

1. Document the nature of the problem & draft the question (hypothesis) under investigation
2. Identify the context in which the question will be asked
3. Develop a conceptual model & clarify the question
4. Decide on the relevant causal agents & potential effects
5. Search and review literature, and extract evidence
6. Revise conceptual model & previous steps if necessary
7. Catalogue & weight the evidence
8. Assess the level of support for the hypothesis & make a judgement

- Is my question still relevant? Too broad?
- Was my literature search too narrow? Did I miss something?
- Are my conceptual models/linkages still representative of what I am interested in?
Weight the evidence (Step 7)

For and against the hypothesis

<table>
<thead>
<tr>
<th>Linkage</th>
<th>Conclusion</th>
<th>Response</th>
<th>Dose-response</th>
<th>Consistency</th>
<th># Evidence items</th>
<th># Cause in biota</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ surface water → Δ invertebrates (assemblage)</td>
<td>Support for hypothesis</td>
<td>High (101)</td>
<td>No evidence (0)</td>
<td>High (14)</td>
<td>25</td>
<td>0</td>
</tr>
</tbody>
</table>

Weightings

The evidence weightings and thresholds used to determine combined evidence outcomes can be adjusted here.

<table>
<thead>
<tr>
<th>Study design weights</th>
<th>Control location weights</th>
<th>Impact location weights</th>
<th>Gradient design location weights</th>
<th>Response thresholds</th>
<th>Consistency thresholds</th>
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</thead>
<tbody>
<tr>
<td>Add</td>
<td>Name</td>
<td>Weight</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Remove</td>
<td>BACI or BARI MBACI or Beyond MBACI</td>
<td>4</td>
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<td></td>
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<tr>
<td></td>
<td>Before v. after (no reference/control)</td>
<td>2</td>
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<tr>
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<td>Reference/control vs. impact (no before)</td>
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<tr>
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<td>After impact only</td>
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</tbody>
</table>

Please detail any modifications made to the default weightings and explain why they needed to be changed. This documentation is important to maintain the transparency of the process.

No modifications made.

We asked the question for the same cause but evaluated different effects (e.g. taxon diversity/richness)
• Write up findings using succinct, generated report.
• Report can be used as the basis of a review paper.
• Make new hypotheses - Why did macroinvertebrate assemblages not change in some studies?
Management of extreme flow impacts: mechanisms for recovery

**Cause**
Retaining riparian vegetation:

**Processes**

High Flow
- Provides support / refuge for adults to recolonise after the flood/drought

Low Flow
- Provides leaf litter for shedders in LF conditions (maintains assemblage)
- Thermal regulation (reduces water temperatures)
- Assists in maintenance of pools from which populations may recover

**Effect**
Maintenance of macroinvertebrate assemblage, taxon richness and/or diversity?
Conclusion

- Study is a series of questions surrounding effects of extreme flow events - will be written up as a review paper
- Evidence used to establish support for example hypothesis
- Evaluate further questions on the influence of riparian vegetation on reducing impacts of extreme flow events
- Next part of the project aims to see if we can quantify these processes using extensive datasets and literature
- Transparency of output report - easy to evaluate
- Efficient - once evidence items are in the database can be re-analysed
- Identifies research gaps & priority areas for field studies where little evidence exists