Introduction to Stressor Identification & CADDIS [Causal Analysis/Diagnosis Decision Information System]
Why Stressor Identification?

- Many states and several tribes use biological assessments to identify whether streams and small rivers are impaired.

- In many cases, causes of impairment are unknown.

<table>
<thead>
<tr>
<th>General Impairment Name</th>
<th>Causes of Impairment Reported</th>
<th>Percent of Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERCURY</td>
<td>8555</td>
<td>13.45</td>
</tr>
<tr>
<td>PATHOGENS</td>
<td>8526</td>
<td>13.41</td>
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<tr>
<td>SEDIMENT</td>
<td>6689</td>
<td>10.52</td>
</tr>
<tr>
<td>METALS (OTHER THAN MERCURY)</td>
<td>6389</td>
<td>10.05</td>
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<tr>
<td>NUTRIENTS</td>
<td>5654</td>
<td>8.89</td>
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<tr>
<td>OXYGEN DEPLETION</td>
<td>4568</td>
<td>7.18</td>
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<tr>
<td>PH</td>
<td>3389</td>
<td>5.33</td>
</tr>
<tr>
<td>CAUSE UNKNOWN - BIOLOGICAL INTEGRITY</td>
<td>2866</td>
<td>4.51</td>
</tr>
<tr>
<td>TEMPERATURE</td>
<td>2854</td>
<td>4.49</td>
</tr>
<tr>
<td>HABITAT ALTERATION</td>
<td>2220</td>
<td>3.49</td>
</tr>
<tr>
<td>PCBS</td>
<td>2081</td>
<td>3.27</td>
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<tr>
<td>TURBIDITY</td>
<td>2050</td>
<td>3.22</td>
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<tr>
<td>CAUSE UNKNOWN</td>
<td>1356</td>
<td>2.13</td>
</tr>
<tr>
<td>PESTICIDES</td>
<td>1322</td>
<td>2.08</td>
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<tr>
<td>SALINITY/TDS/CHLORIDES</td>
<td>996</td>
<td>1.57</td>
</tr>
<tr>
<td>FLOW ALTERATION</td>
<td>591</td>
<td>.93</td>
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<tr>
<td>ALGAL GROWTH</td>
<td>510</td>
<td>.80</td>
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<tr>
<td>AMMONIA</td>
<td>415</td>
<td>.65</td>
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<tr>
<td>OTHER TOXIC ORGANICS</td>
<td>339</td>
<td>.53</td>
</tr>
<tr>
<td>TOTAL TOXICITY</td>
<td>292</td>
<td>.46</td>
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<tr>
<td>DIOXINS</td>
<td>290</td>
<td>.46</td>
</tr>
<tr>
<td>TOXIC INORGANICS</td>
<td>270</td>
<td>.42</td>
</tr>
<tr>
<td>FISH CONSUMPTION ADVISORY</td>
<td>260</td>
<td>.40</td>
</tr>
</tbody>
</table>
CADDIS is based on a formal method

SI Guidance

http://www.epa.gov/caddis

2000

2005, 2007...2010
Why use a formal method?

- To convince stakeholders
- To increase confidence that remedial or restoration efforts can improve biological condition
- To identify causal relationships that are not immediately apparent
- To prevent biases and other lapses of logic

“Science is a way of trying not to fool yourself. The first principle is that you must not fool yourself – and you are the easiest person to fool.” [Feynman 1964]
Causation is one of the most difficult & controversial concepts in philosophy

- Only one reliable method for establishing causation: \textit{randomized, replicated, controlled} experiment

- Unfortunately, this approach is not usually available...
Causation is one of the most difficult & controversial concepts in philosophy

David Hume
- We experience causality as associations between events

John Stuart Mill
- Manipulation of cause results in change in effect

Karl Pearson
- Need to quantify probability of association

Ronald Fisher
- Controlled experiments with replication and randomization

Austin Bradford Hill
- Causality based on strength of evidence
General vs. Specific causation

• General –
  • Does C cause E?
  – Does smoking cause lung cancer?

• Specific Cause –
  • Did C cause E?
  – Did smoking cause lung cancer in Ronald Fisher?
General vs. Specific causation

• General – *Does C cause E?*
  – Does increased water temperature reduce bull trout abundance in rivers?

• Specific Cause – *Did C cause E?*
  – Did increased water temperature reduce bull trout abundance in *the Touchet River, Washington*?
# Defining a Cause

<table>
<thead>
<tr>
<th>Type of Causation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent</td>
<td>Deoxygenated water causes dead fish</td>
</tr>
<tr>
<td>Event</td>
<td>Exposure to deoxygenated water causes fish to die</td>
</tr>
<tr>
<td>Process</td>
<td>Exposure to deoxygenated water asphixates fish that die</td>
</tr>
</tbody>
</table>
### Causal Characteristics

<table>
<thead>
<tr>
<th>Time order</th>
<th>The cause precedes the effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-occurrence</td>
<td>The cause co-occurs with the unaffected entity in space and time</td>
</tr>
<tr>
<td>Preceding causation</td>
<td>Each causal relationship is a result of a larger web of cause and effect relationships</td>
</tr>
<tr>
<td>Sufficiency</td>
<td>The intensity, frequency, and duration of the cause are adequate and the entity is susceptible to produce the type and magnitude of the effect</td>
</tr>
<tr>
<td>Physical interaction</td>
<td>The cause physically interacts with the entity in a way that induces the effect</td>
</tr>
<tr>
<td>Alteration</td>
<td>The entity is changed by the interaction with the cause.</td>
</tr>
</tbody>
</table>
Our Causal Strategy: Pragmatic

- Identify alternative candidate causes
- Logically eliminate when you can
- Diagnose when you can
- Use strength of evidence for remaining
- Identify most likely cause

Do not claim proof of causation

Use consistent process

Document evidence & inferences

This is abductive inference (C.S. Pierce): reasoning to the best solution, given a set of data (observations, facts, etc.) and a set of alternative solutions.
CADDIS: Helping Scientists Identify the Causes of Biological Impairments

Thousands of water bodies in the United States are listed by states as biologically impaired. For many of these, the cause of the impairment is reported as "unknown". Before the TMDL process can be used to formulate an appropriate management action, the cause of the biological impairment must be determined. Defensible causal analyses require knowledge of the mechanisms, symptoms, and stressor-response relationships for various specific stressors as well as the ability to use that knowledge to draw appropriate conclusions.

CADDIS is an online application that helps scientists and engineers in the Regions, States and Tribes find, access, organize, use and share information to conduct causal evaluations in aquatic systems. It is based on the U.S. Environmental Protection Agency Stressor Identification process which is a formal method for identifying causes of impairments in aquatic systems. Current features of this site include:

- The Step-by-Step Guide to conducting a causal analysis,
- Example worksheets,
- Introductory material on several commonly encountered candidate causes,
- A conceptual model library, and an interactive conceptual model for phosphorus,
- Advice on how to use specific data analysis methods, general advice on data handling and analysis in a causal assessment, and downloadable data analysis tools,
- Information sources including related links, glossary and acronyms list, databases of stressor-response relationships, and...
CADDIS

Causal Analysis/Diagnosis Decision Information System

www.epa.gov/caddis
The bad news...

- You can’t just push a button on CADDIS to determine the cause of impairment
- You will need data
The good news...

• CADDIS walks you through steps to help you:
  – Identify probable causes
  – Communicate conclusions to others

• CADDIS provides tools & information

• States have used this method to:
  – Direct management action
  – Justify resources for data collection
Common Assessment Process

Initiator

Planning

Analysis

Synthesis

Decision/Action

Problem Resolution
Initiator

Planning

Analysis

Synthesis

Decision/Action

Problem Resolution

Biological impairment

Identify the probable causes

Remove or reduce the cause
CADDIS Stressor Identification Process

**Initiator**
- Detect or Suspect Biological Impairment

**Planning**

**Analysis**

**Synthesis**

**Decision/Action**
- Identify and Apportion Sources
- Management Action:
  - Eliminate or Control Sources, Monitor Results
- Biological Condition Restored or Protected

**Problem Resolution**
CADDIS Stressor Identification Process

Initiator

Planning

- Define the Case
- List Candidate Causes

Analysis

- Evaluate Data from the Case
- Evaluate Data from Elsewhere

Synthesis

- Identify Probable Cause

Decision/Action

- Identify and Apportion Sources
- Management Action: Eliminate or Control Sources, Monitor Results

Problem Resolution

- Biological Condition Restored or Protected

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Common Assessment Process

- Initiator

  - Planning
    - Define the Case
    - List Candidate Causes
  
  - Analysis
    - Evaluate Data from the Case
    - Evaluate Data from Elsewhere
  
  - Synthesis
    - Identify Probable Cause

- Decision/Action

- Problem Resolution
The causal analysis framework

- Detect or Suspect Biological Impairment

**Stressor Identification**
- Define the Case
- List Candidate Causes
- Evaluate Data from the Case
- Evaluate Data from Elsewhere
- Identify Probable Cause

**Decision-maker and Stakeholder Involvement**

**As Necessary: Acquire Data and Iterate Process**

- Identify and Apportion Sources
- Management Action: Eliminate or Control Sources, Monitor Results
- Biological Condition Restored or Protected
Detect or suspect biological impairment

Stressor Identification

- Define the Case
- List Candidate Causes
- Evaluate Data from the Case
- Evaluate Data from Elsewhere
- Identify Probable Cause
- Identify and Apportion Sources

As Necessary: Acquire Data and Iterate Process

Decision-maker and Stakeholder Involvement

Management Action:
- Eliminate or Control Sources, Monitor Results
- Biological Condition Restored or Protected

- Fish kills
- Organismal anomalies
- Changes in community structure
- Low biotic index values
Detect or Suspect Biological Impairment

**Step 1: Define the Case**

- List Candidate Causes
- Evaluate Data from the Case
- Evaluate Data from Elsewhere
- Identify Probable Cause

**Stressor Identification**

- As Necessary: Acquire Data and Iterate Process

**Decision-maker and Stakeholder Involvement**

- What specific biological effects are observed?
- Where are they occurring?
- Where are comparable reference sites?

**Management Action:**

- Identify and Apportion Sources
- Eliminate or Control Sources, Monitor Results
- Biological Condition Restored or Protected
Detect or Suspect Biological Impairment

Stressor Identification

Define the Case

Step 2: List Candidate Causes

• Make a map
• Gather information on potential sources, stressors, and exposures
• Develop a conceptual model
• Engage stakeholders

Decision-maker and Stakeholder Involvement

Evaluate Data from the Case

Evaluate Data from Elsewhere

Identify Probable Cause

As Necessary: Acquire Data and Iterate Process

Identify and Apportion Sources

Management Action:
Eliminate or Control Sources, Monitor Results

Biological Condition Restored or Protected
Detect or Suspect Biological Impairment

Stressor Identification
- Define the Case
- List Candidate Causes

Step 3: Evaluate Data from the Case
- Evaluate Data from Elsewhere
- Identify Probable Cause

Identify and Apportion Sources
Management Action:
- Eliminate or Control Sources, Monitor Results
- Biological Condition Restored or Protected

EVIDENCE FROM THE CASE
- Observations
- Manipulations

Decision-maker and Stakeholder Involvement
Detect or Suspect Biological Impairment

Define the Case

List Candidate Causes

Evaluate Data from the Case

Step 4: Evaluate Data from Elsewhere

• Observations
• Manipulations
• General Knowledge

Identify Probable Cause

Identify and Apportion Sources

Management Action:
Eliminate or Control Sources, Monitor Results

Biological Condition Restored or Protected

Acquire Data and Iterative Process

EVIDENCE FROM ELSEWHERE

As Necessary: Acquire Data and Stakeholder Involvement

Decision-maker and Stakeholder Involvement

Stressor Identification
Step 5: Identify Probable Cause

- Identify and Apportion Sources
- Management Action: Eliminate or Control Sources, Monitor Results
- Biological Condition Restored or Protected

Identify Probable Cause

- Eliminate if you can
- Diagnose if you can
- Evaluate strength of evidence for each cause
  - Weight evidence
  - Weigh body of evidence
- Build the case by synthesizing evidence among causes
Detect or Suspect Biological Impairment

**Stressor Identification**
- Define the Case
- List Candidate Causes
- Evaluate Data from the Case
- Evaluate Data from Elsewhere
- Identify Probable Cause

**Decision-maker and Stakeholder Involvement**

**As Necessary:**
- Acquire Data and Evaluate Data from the Case
- Iterate Process

**Identify and Apportion Sources**

**Management Action:**
- Eliminate or Control Sources, Monitor Results

**Biological Condition Restored or Protected**

Causal analysis is one step in management process...
- After causes identified, sources & management actions must be identified
- Biological monitoring verifies that actions are effective
Analysis from Effect to Cause

Problem Detection
Condition Assessment

Problem Resolution
Causal Assessments

Environmental Epidemiology

Outcome Assessment

Environmental Management

Predictive Assessments

Analysis from Cause to Effect
RECAP

• Causal relationships can be expressed as agent, event, or process causation.
• There is a distinction between general and specific causation.
• Many environmental assessments deal with specific causation rather than generating new scientific knowledge and therefore have different inferential standards.
• The U.S. EPA process for causal assessment is based on a foundation of scientific philosophy and practical experience.