Step 5: Identifying probable causes
Conceptual Bases

Characteristics of Causation

Source of Evidence

Qualities of Evidence

CADDIS

Types of Evidence

Scores

Scored Body of Evidence
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

Management Action:
Eliminate or Control Sources, Monitor Results

Biological Condition Restored or Protected

As Necessary: Acquire Data, and Iterate Process

Decision-maker and Stakeholder Involvement
Quality of the Body of the Evidence

- **Credibility**—The body or evidence is based on relevant and high quality information.

- **Strength**—The body of evidence includes pieces of evidence that are logically compelling or that present quantitatively strong relationships.

- **Diversity**—Many sources of evidence and characteristics of causation are represented in the body of evidence.

- **Coherence**—The body of evidence is internally consistent, consistent with scientific knowledge and theory, and logically explains the facts in the case.
Weighing the evidence for each candidate cause

- Consider the source of information
- Evaluate the quality of the body of evidence
- Summarize the compelling evidence
Evaluate quantity & quality of evidence

- Quality & quantity of data influence scores
- Now evaluate overall quality of evidence
- Lots of consistent evidence reduces quality concerns for any 1 type of evidence
- Poor quality data may be discounted
- Consider study designs, methods, relevance, variability, & other QA issues
Evaluate consistency & credibility

- Prepare summary table of scores
- Do **not** add up scores!
- Evaluate consistency of evidence
- Look for compelling evidence
- If evidence is inconsistent, consider mechanistic explanations
  - e.g., lab data not consistent with field conditions due to differing bioavailability
Summarize compelling evidence

- Make an overall evaluation of strength of evidence for each candidate cause
  - what evidence compels belief that candidate cause induced effect?
  - what evidence strongly casts doubt?

- Consider the principle characteristics of causal relationships
  - these are what you’re trying to show
  - they summarize the 15 types of evidence
There is no magic formula...

All candidate causes must be compared to determine:

– if there is more than 1 probable cause
– the level of confidence in the results
Comparing evidence among causes: best-case scenario

You have compelling evidence for 1 candidate cause; others are weak or refuted...

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<th>TYPE OF EVIDENCE</th>
<th>CANDIDATE CAUSE</th>
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...celebrate, then remediate for Candidate Cause 1
Comparing evidence among causes: more (likely) scenarios

You have uneven evidence across candidate causes...

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- Strong evidence for one candidate cause may be sufficient
- Consider if weakness is due to lack of data
You have unsatisfying evidence across all candidate causes...

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<td>Consistency</td>
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- Reconsider the impairment
- Consider additional candidate causes
- Consider episodic events
- Consider gathering more data
You have insufficient data...

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Consistency: 0 0 0

- Gather data if possible
- Consider other bases for remediation (e.g., BMPs, chemical criteria) and monitor biological responses
- Use professional judgment as last resort
You have evidence suggesting multiple causes...

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- Consider disaggregating indices or metrics
- Combine causes if they share causal pathways, modes of action, sources and routes of exposure, or if they interact
- Remediate dominant cause
- Design remediation to address multiple causes
Combining stressors

• Strategies
  – Combine if they share causal pathways, modes of action, sources & routes of exposure, or if they interact
  – Re-aggregate stressors that have been unnecessarily disaggregated
  – Identify independently acting stressors that cause the same effect
  – Define effects more specifically

• Warnings
  – Avoid combining causes without an underlying model
  – Avoid broad candidate cause definitions
  – Don’t lose independent effects of individual causes
How do I communicate results?

- Make your logic clear
- Present the critical evidence
- Reveal uncertainties
- Fit communication to your audience
- For technical reviewers, include text & tables
- For decision makers, may be helpful to use annotated conceptual model
<table>
<thead>
<tr>
<th>Willimantic case study</th>
<th>Metals</th>
<th>NH₃</th>
<th>Flow</th>
<th>Silt</th>
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<th>Temp</th>
<th>Food</th>
<th>Episodic Mix</th>
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<tr>
<td>Types of Evidence that Use Data from the Case</td>
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<td>Stressor-Response from the Field/Case</td>
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<td><strong>Sufficiency</strong></td>
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What could we have used here? WET test. TIE.
More EPT at MR2 downstream from dam than at MR3.

- **Impoundment**: Increased surface area, low flow, stratification
- **Impervious surfaces**: Retain and transfer heat through storm run-off
- **Lack of tree canopy**: Lack of shading increases exposure to radiant energy

More EPT taxa at FB5 which has similar level of impervious surface.

- **Increased water temperature**: Temperature slightly greater than upstream

Temperatures exceeded benchmarks for effects

- **Thermal stress**

Loss of invertebrates

Temperatures did not change, but EPT increased after removal of illicit source
Sustained exposure

Ammonia levels greater upstream

Episodic exposure

More species were present after rerouting broken effluent pipe and measures of Al, Cr, Pb, and Zn decreased

Cr exceeded benchmarks

Cu and Cd exceeded benchmarks but unimpaired sites also exceeded benchmarks

Al, Fe, Pb, Ni, Zn did not exceed toxic benchmarks

Ammonia did not reach toxic levels

Death or reproductive failure

Loss of Invertebrates Species
What comes after causal analysis?

• If confidence in results is low...
  – plan studies to obtain critical evidence
  – experimental studies most likely to be convincing

• If confidence in results is high...
  – identify sources
  – take action
  – monitor results