Causal Analysis Using Stressor Identification & CADDIS

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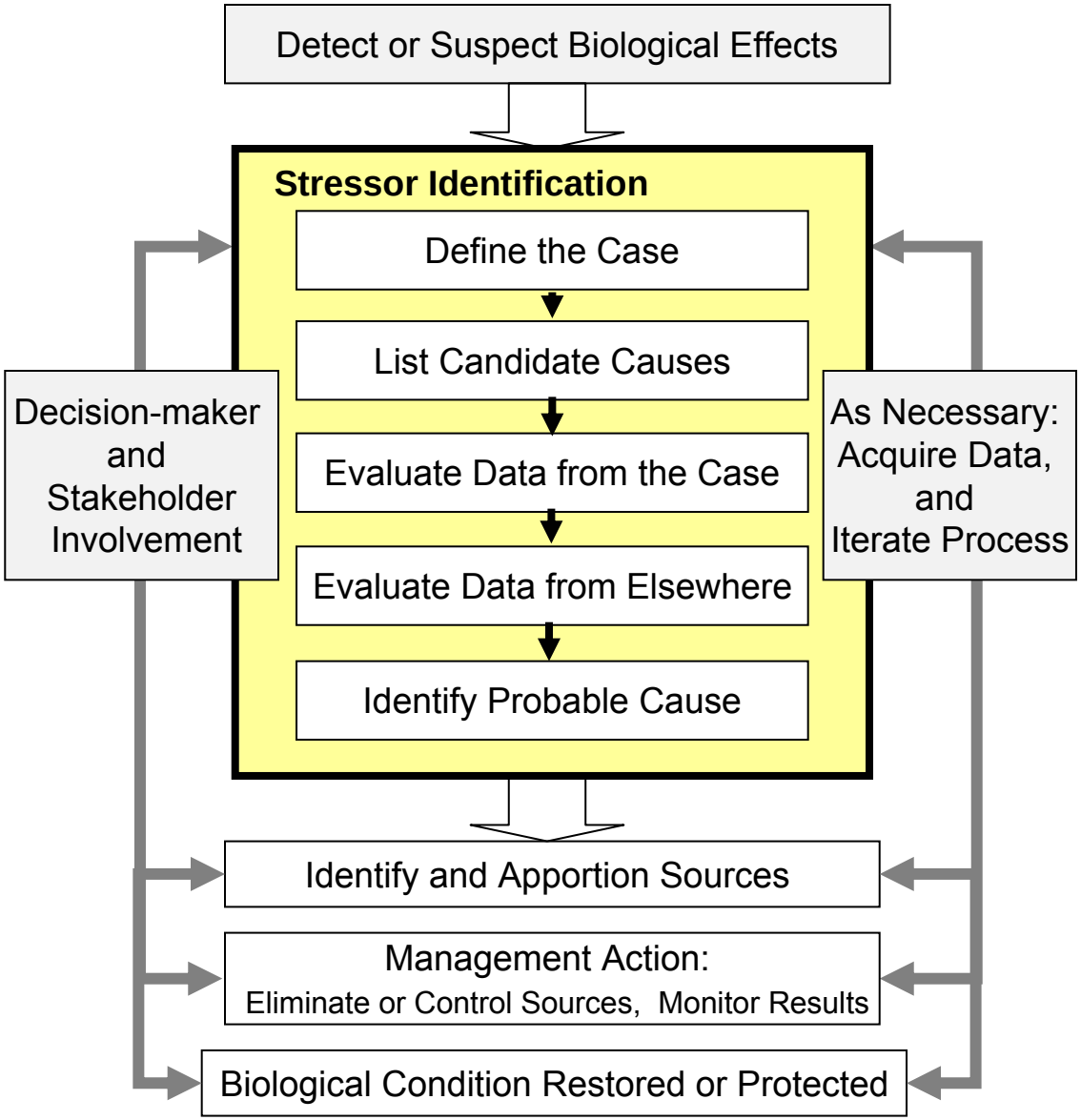
Our Causal Strategy: Stressor Identification

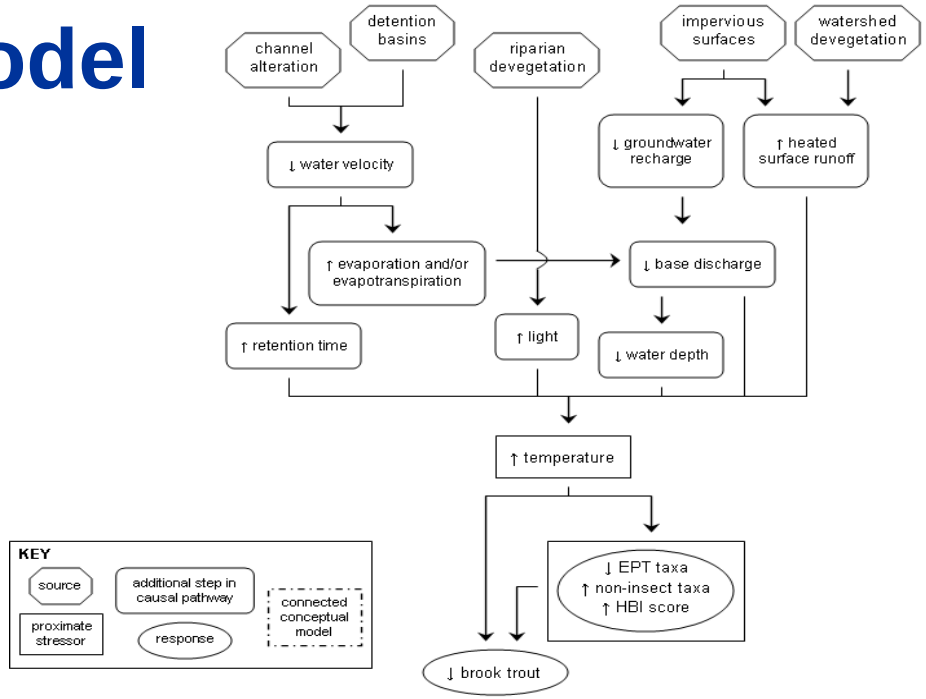


Define the Case

- **Objectives and scope**
  - **Determine cause of failure to meet biocriteria**
  - **Determine whether a source is the cause**
  - **Determine cause of specific effect**
- **Specific Impairment to be analyzed**
- **Location in space and time**

List Candidate Causes

- Make an initial list
- Gather and map information on sources
  Consult stakeholders and experts
- Make conceptual model
- Finalize the list



Causal Analysis is the Hard Part

- Causation is one of the most difficult and controversial concepts in philosophy
- Epidemiologists do not agree on causal inference
- Epidemiologists do not agree that causation can be inferred for specific cases
- No standard formal method
- But errors common without a method

Why do smart people make mistakes?

1. **Theory tenacity:**
   - **We form opinions rapidly based on non-logical processes**
     - **Intuition**
     - **Heuristic biases**
   - **Because we are smart, we can ably defend them.**

Why do smart people make mistakes?

2. **We overweight meaningful chance events:**
   - **Every time I wash my car it _____**

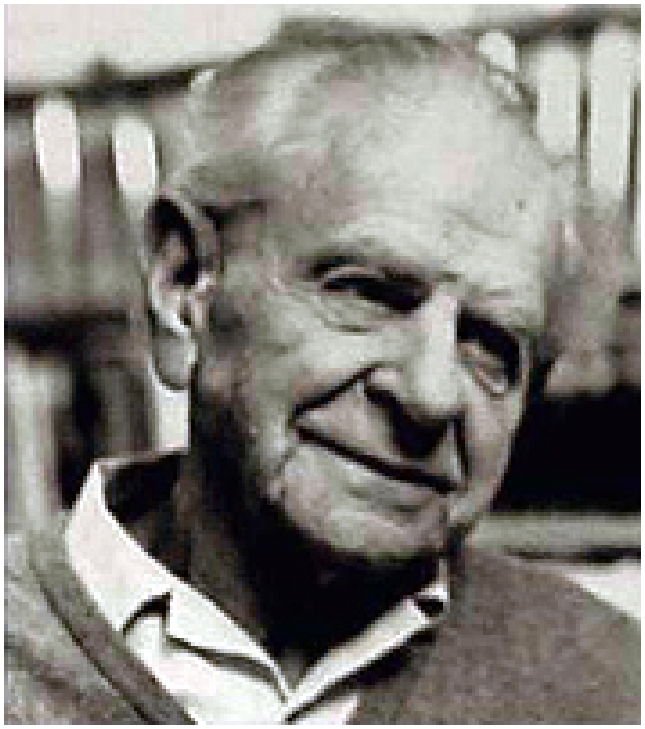
	Wash Car? *Yes*	Wash Car? *No*
Rain? *Yes*		
Rain? *No*		

Disproof

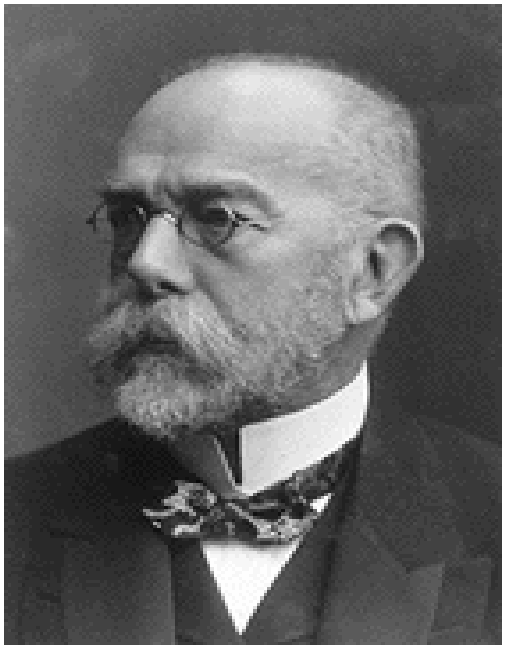
Popperian disproof

- Based on crucial experiment
- Based on observation

- Cannot identify cause
  - No finite list
- But can shorten the list



Diagnostics

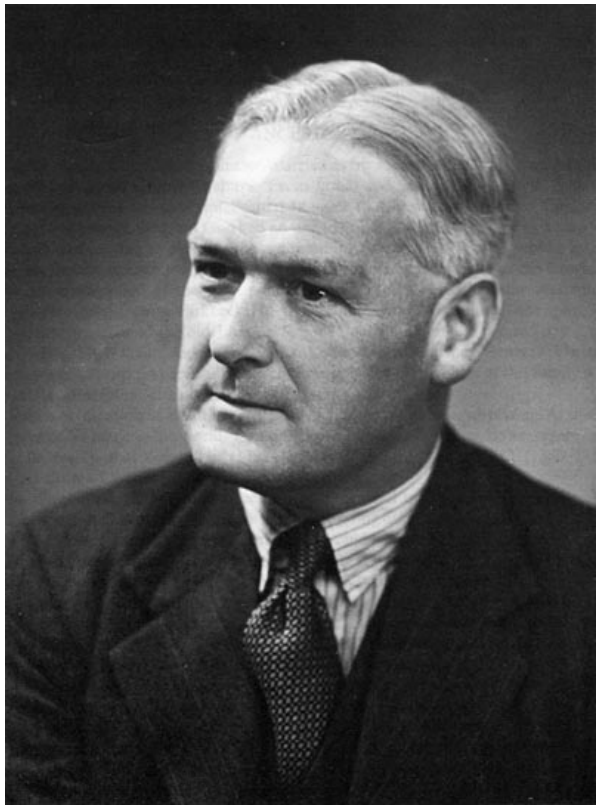


- **Koch's Postulates**

  (single chem. or pathogen)
  - Association of Cause and Effect
  - Isolation of Cause from Effect
  - Experimental Association of Cause and Effect
  - Experimental Isolation of Cause from Effect
- **Can be applied where novel cause**
- **Basis for diagnostic protocols**

Hill's Criteria for Causation

- **Causality based on weight of evidence**
- **By applying criteria to the evidence**
  - **Strength**
  - **Consistency**
  - **Specificity**
  - **Temporality**
  - **Biological Gradient**
  - **Plausibility**
  - **Coherence**
  - **Experiment**
  - **Analogy**



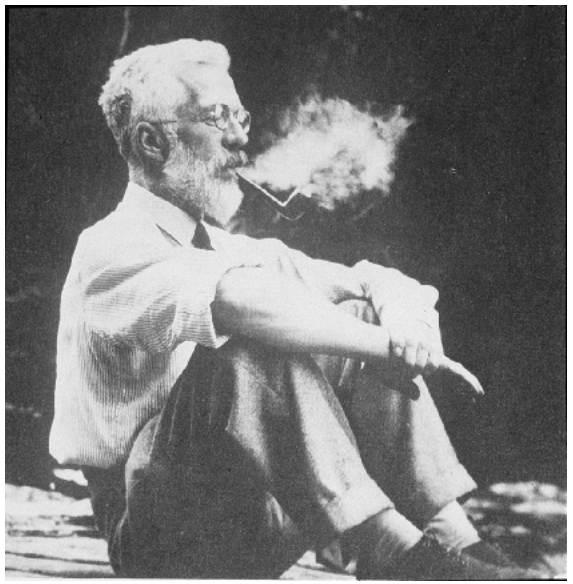
Statistical Methods

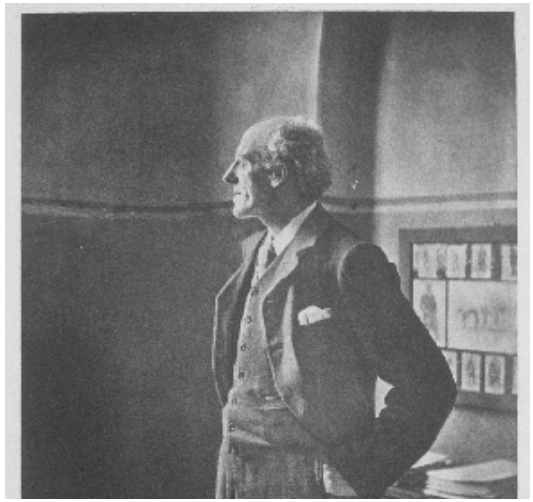
Fisherian Disproof / NHT

- Only for experiments
- Cannot identify cause

Probabilistic Association

- Correlation ≠ Causation
- One type of evidence
- Frequentist
- Bayesian





Inference for Cases

- Abductive Inference -- C.S. Peirce
  - Reasoning to the best solution
    - *D* is a set of data (facts, observations, etc.)
    - *H,* if true, would explain *D*
    - No other hypothesis explains *D* as well as *H* does
    - Then, *H* is probably true
  - A rigorous logic for individual cases

Our Causal Strategy

- **Identify alternative candidate causes**
- **Logically eliminate when you can**
- **Diagnose when you can**
- **Use strength of evidence for the rest**
- **Do not claim proof of causation**
- **Identify the most likely cause**
- **Use a consistent process**
- **Document the evidence and inferences**

We are Concerned with Cases

- Generic Causation
  - Does *C* cause *E* ?
- Case Causation
  - What *C* caused *E* ?
  - Equivalent to autopsies, forensics or cancer clusters

Our Solution

- Hill-like Analysis of the Strength of Evidence
- Types of Evidence, not Criteria
  - None are required
- Redefined and Renamed to reduce Ambiguity
- Three Categories of Evidence
  - Evidence from the Site (9 types)
    - Did *C* cause *E* here?
  - Evidence from Elsewhere (6 types)
    - Does *C* cause *E* in other circumstances?
  - Characteristics of the Body of Evidence (2 types)

Our Solution, 2

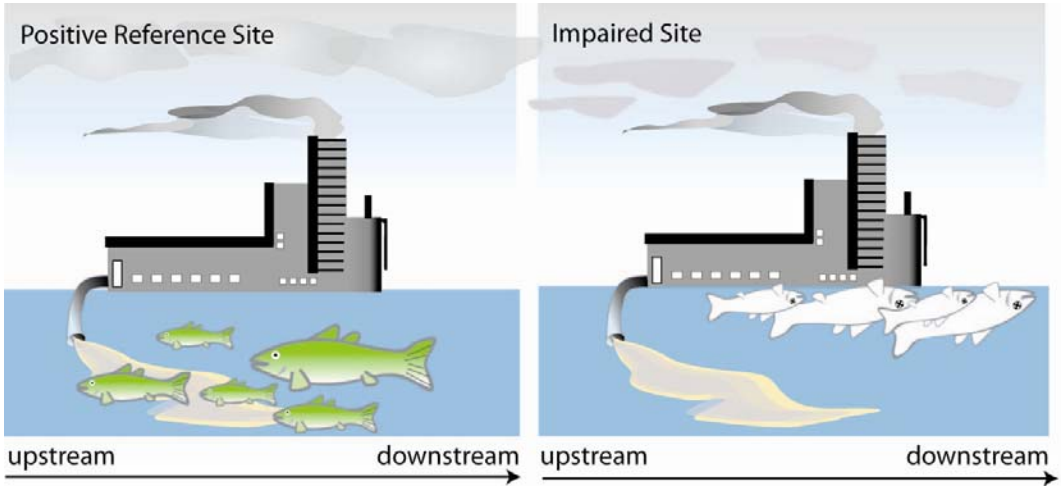
- Adapt Susser's +/- Scoring Approach
- Integrate Diagnostics and Elimination
  - Diagnosis is extreme form of Symptomology
  - Elimination is extreme form of Case-specific Absence of Association
- Iterative and Adaptive Implementation

Types of Evidence that Use Data from the Case

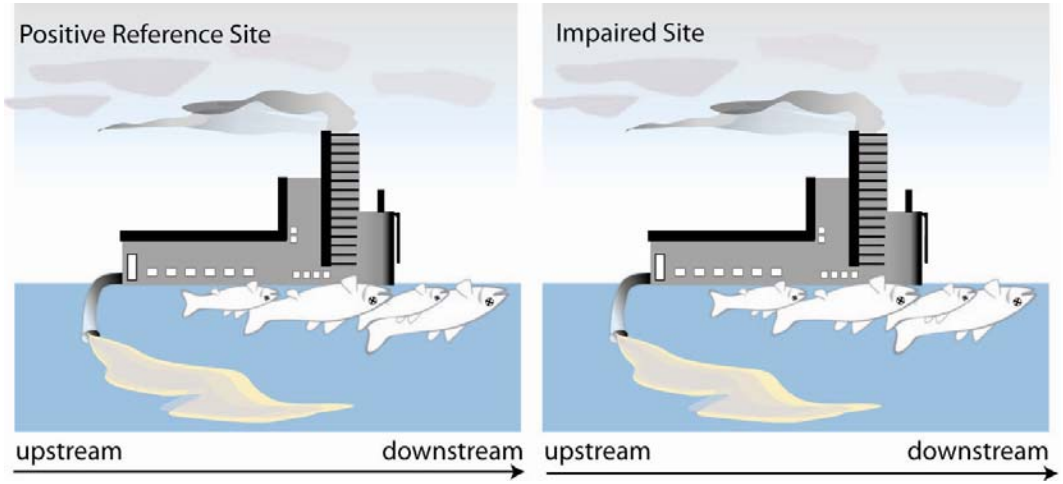
- Spatial/Temporal Co-Occurrence
- Causal Pathway
- Stressor-Response Relationships from the Field
- Evidence of Exposure or Biological Mechanism
- Manipulation of Exposure
- Laboratory Tests of Site Media
- Temporal Sequence
- Verified Predictions
- Symptoms

Spatial/Temporal Co-Occurrence

with positive reference sites



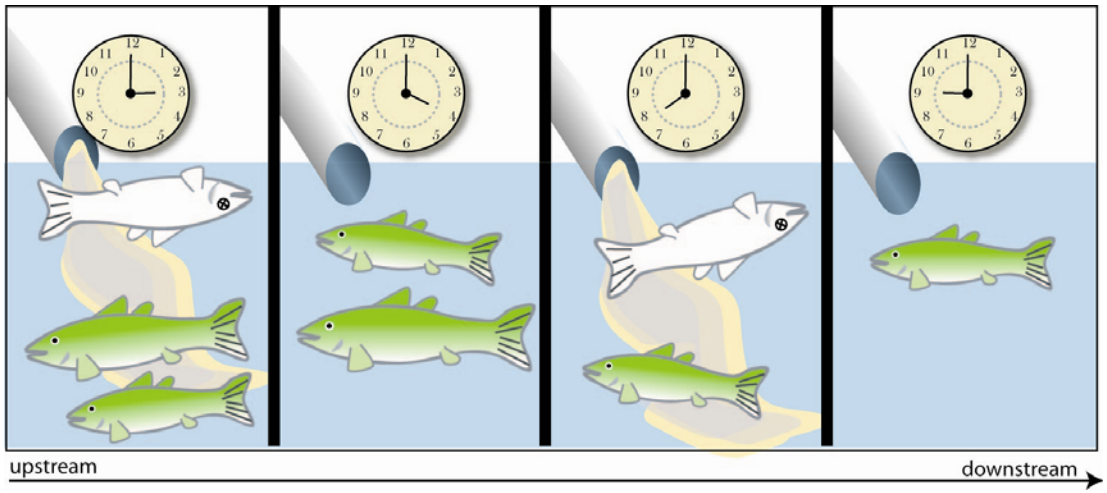
Refutes



Supports

Spatial/Temporal Co-Occurrence

Through Time



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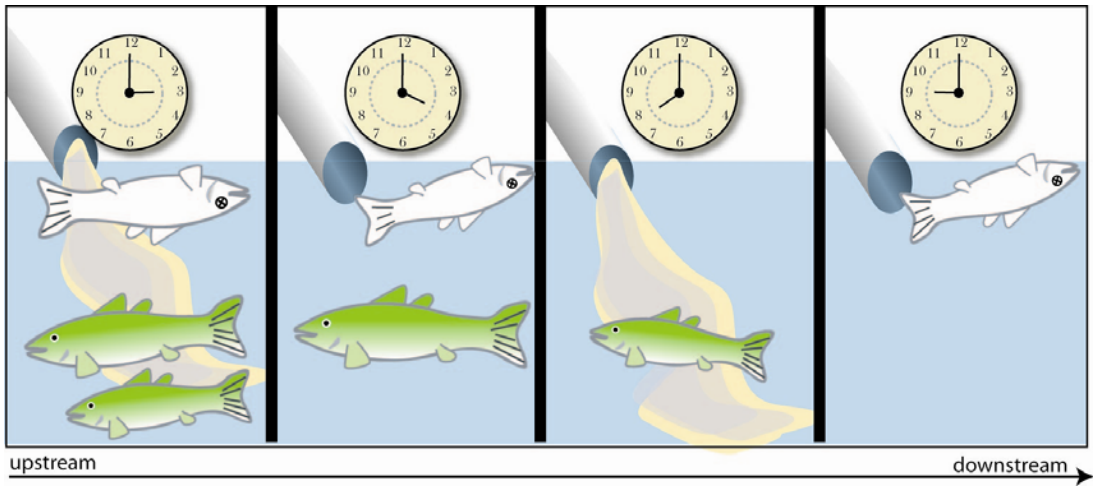
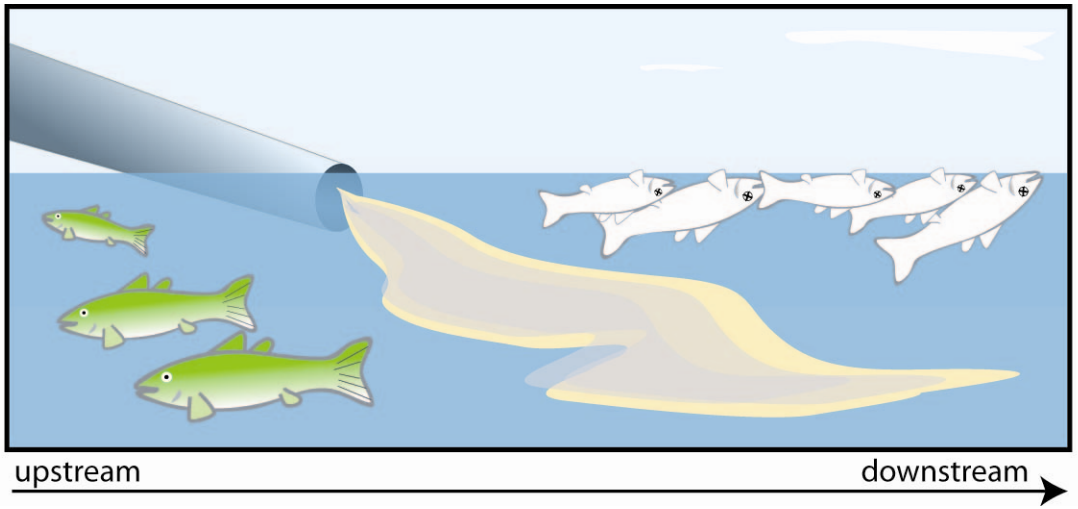


Refutes

Spatial/Temporal Co-Occurrence

Upstream Downstream Comparison



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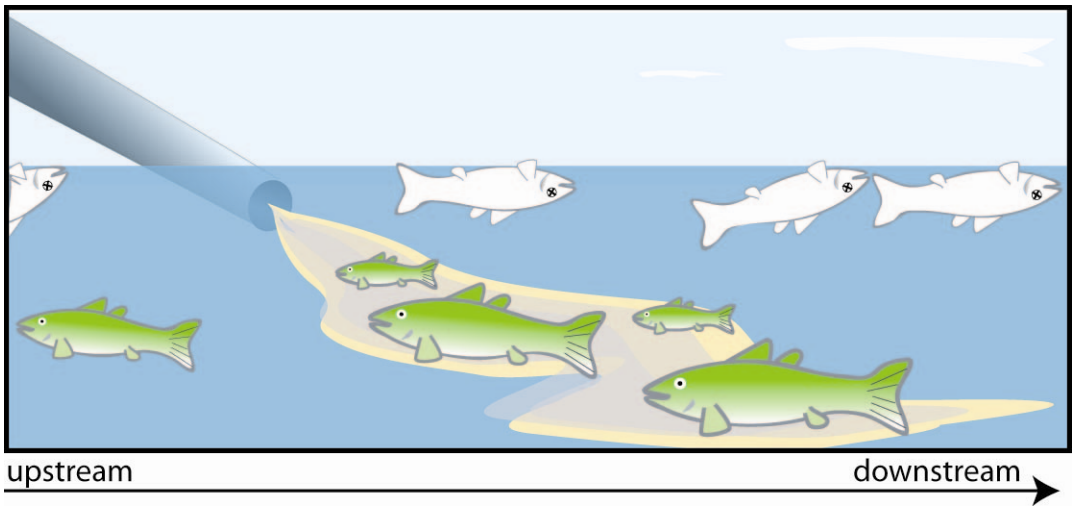
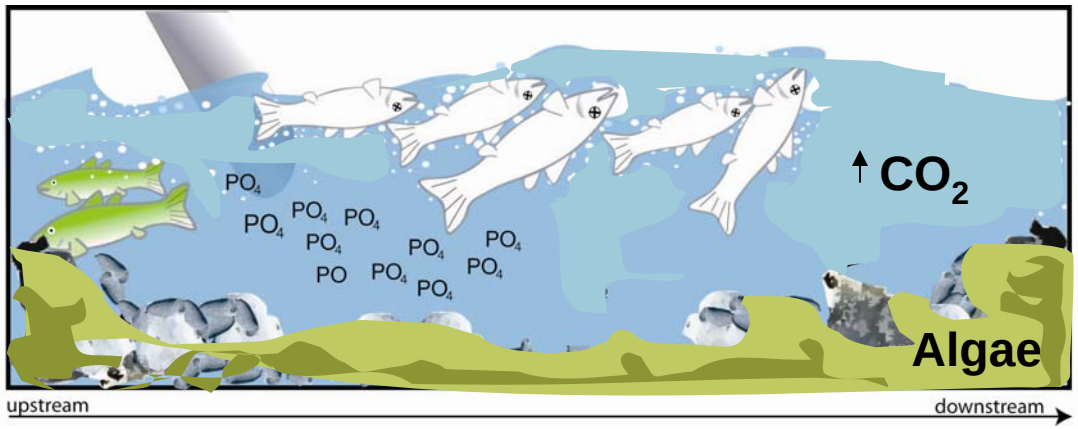


Refutes

Causal Pathway



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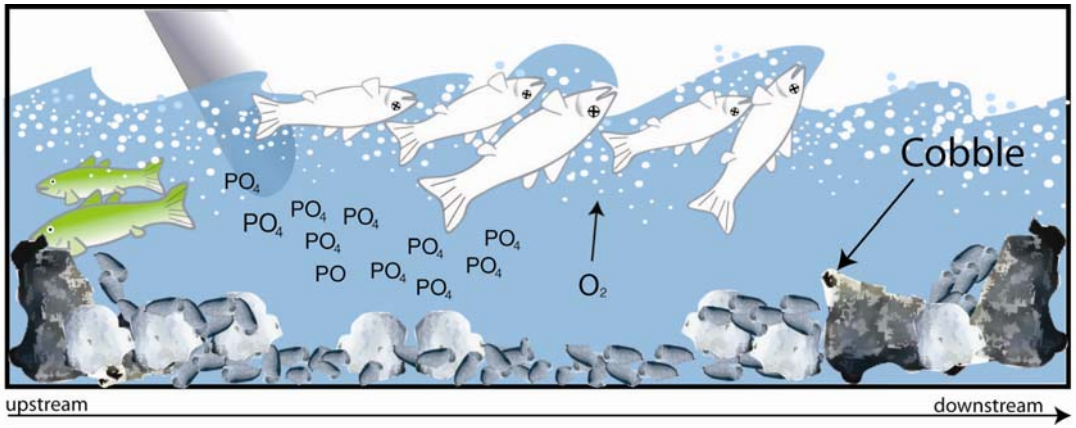
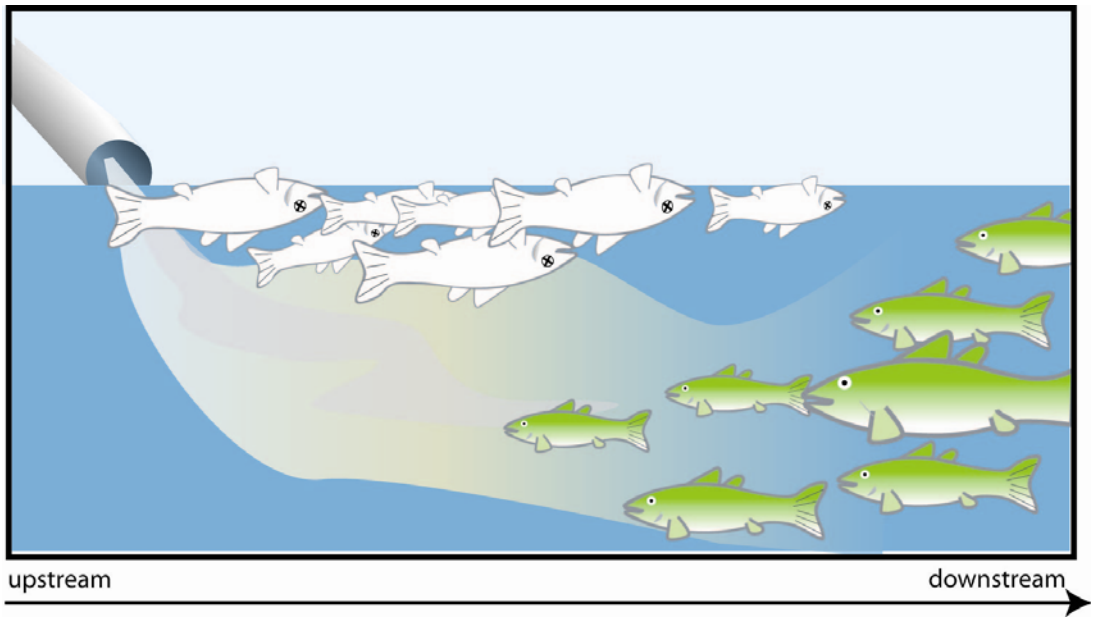


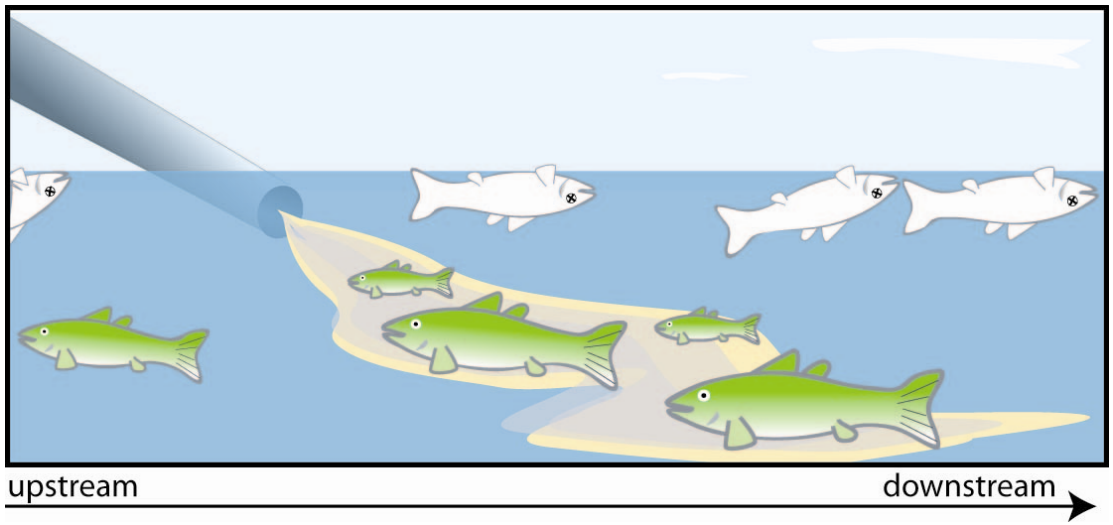
Refutes

Stressor-Response Relationships

from the Field

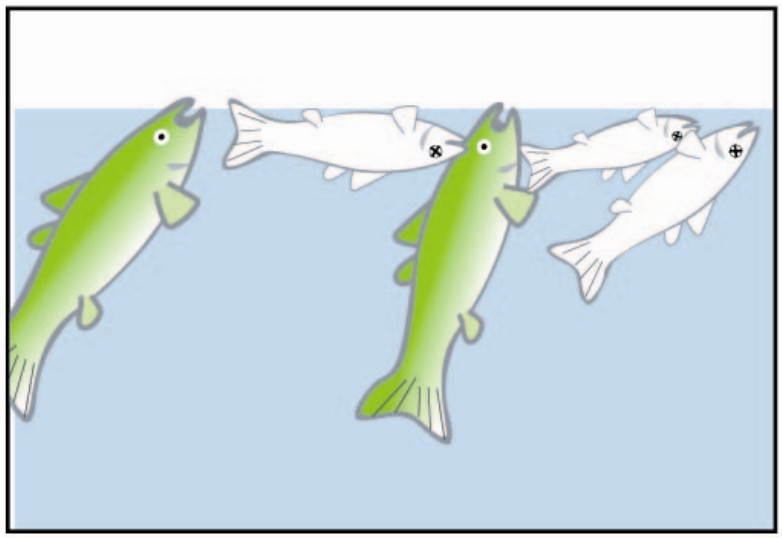


Strengthens



Weakens

Evidence of Exposure or Biological Mechanism



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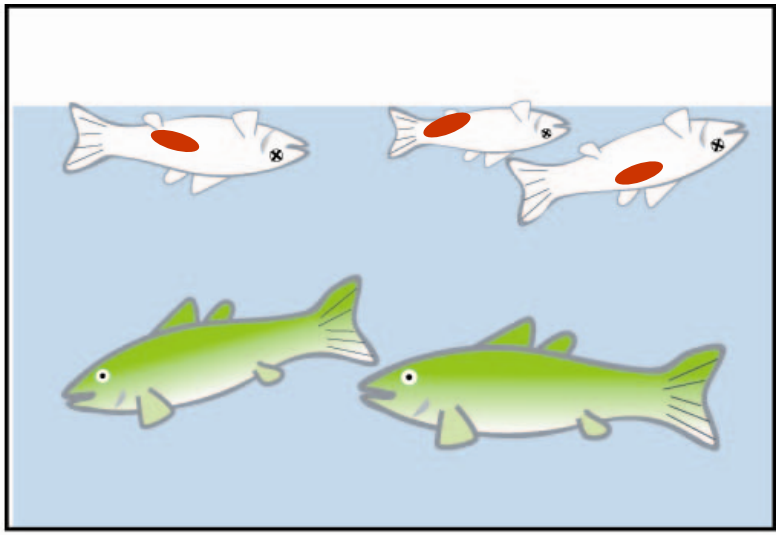
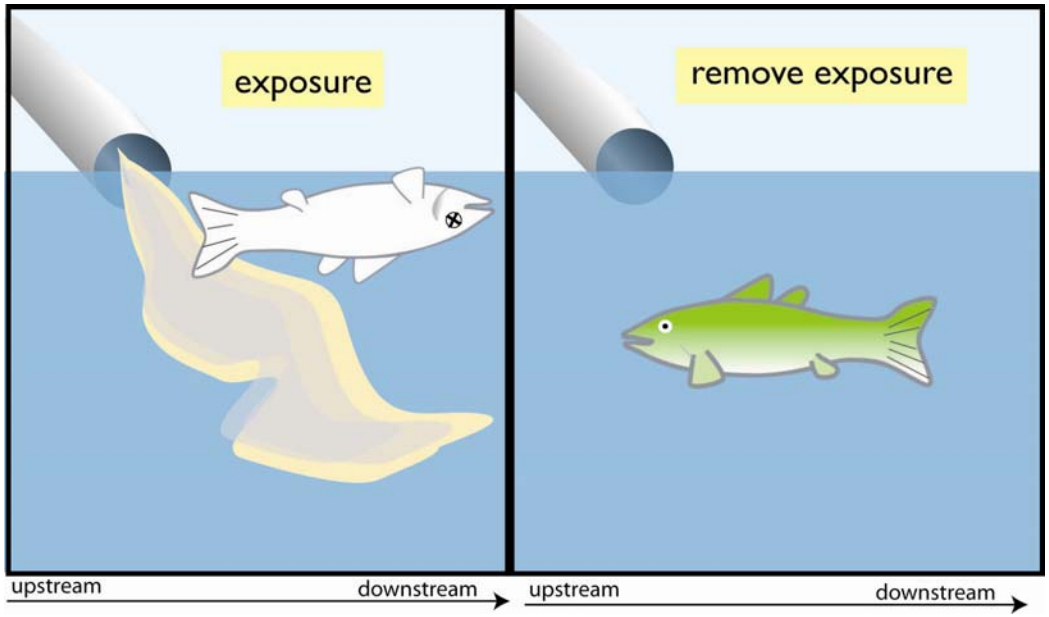


Weakens

Manipulation of Exposure



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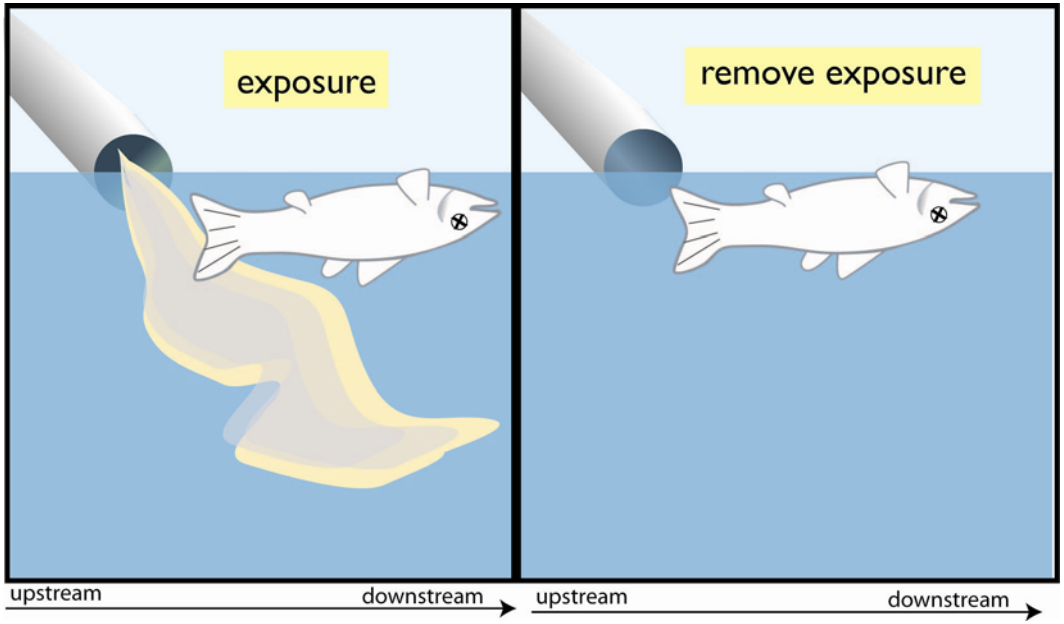
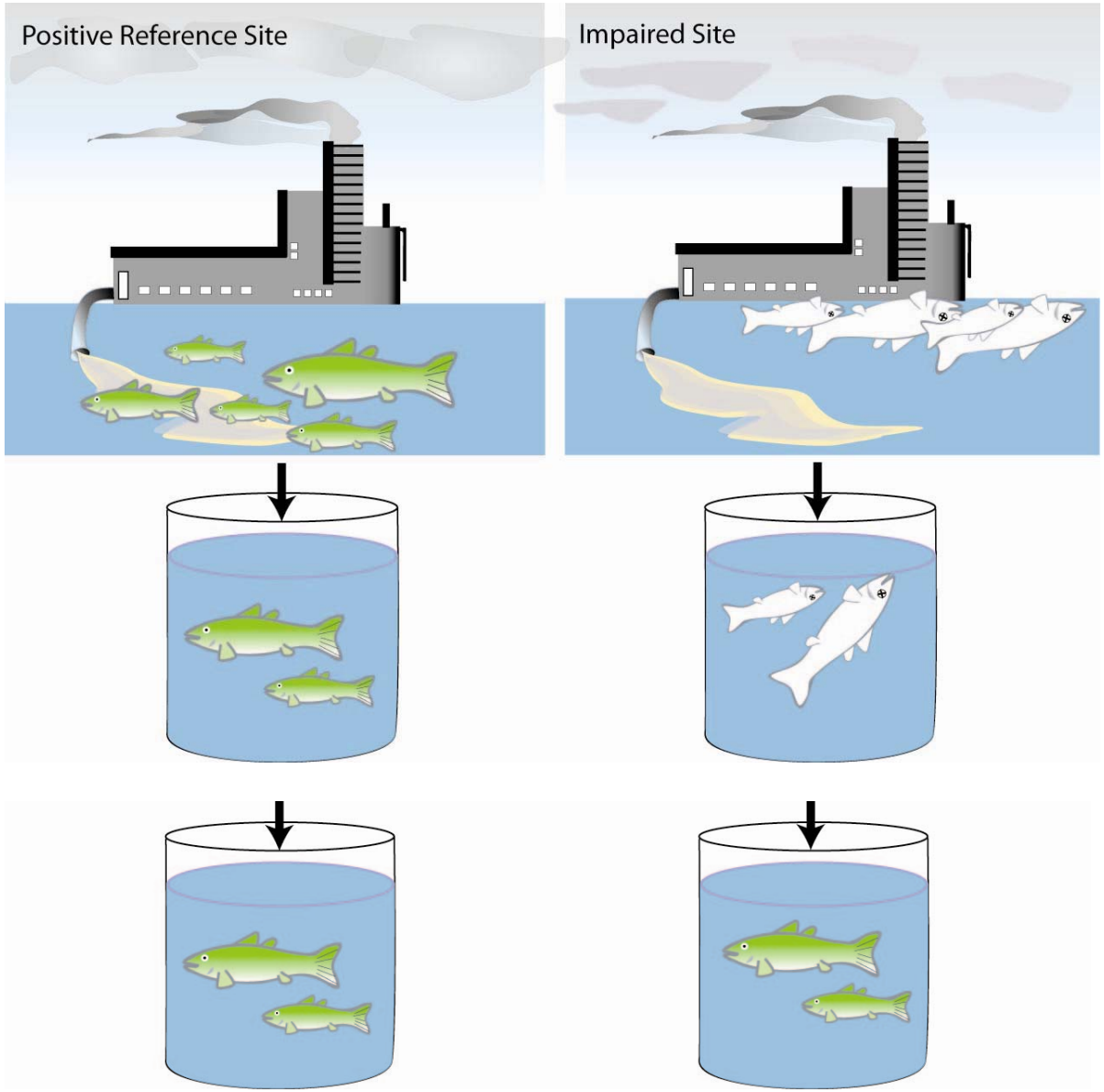
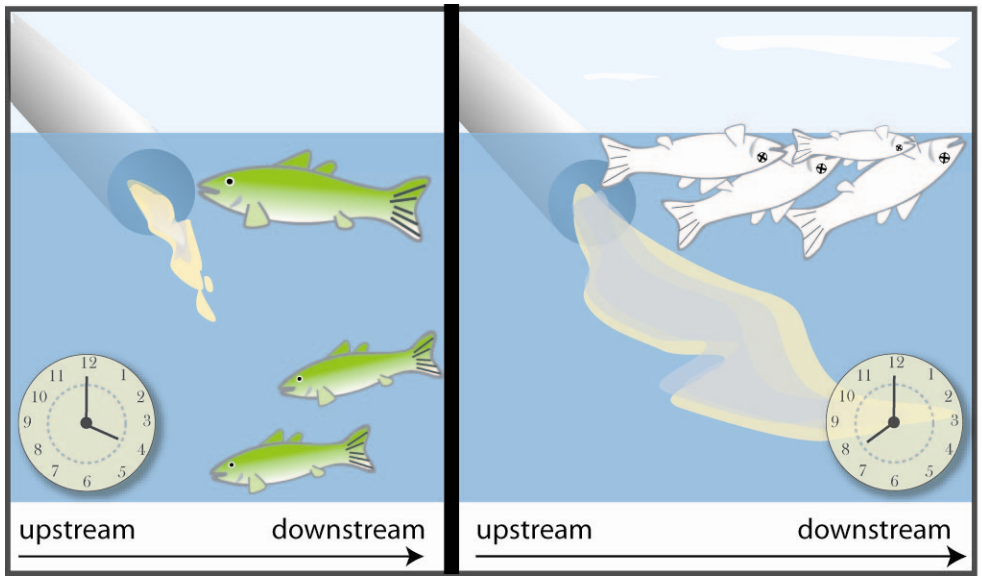


Refutes

Laboratory Tests of Site Media



Temporal Sequence



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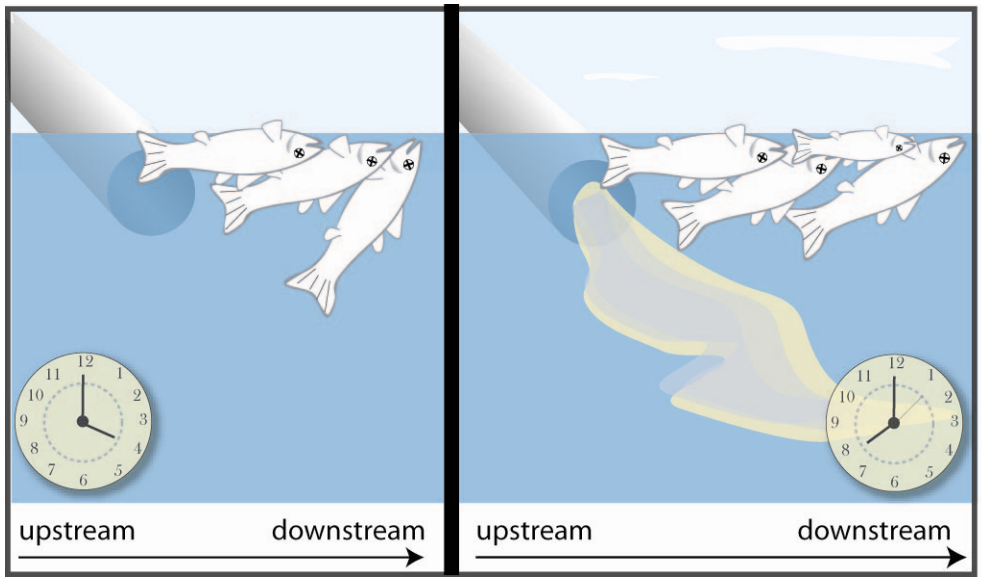
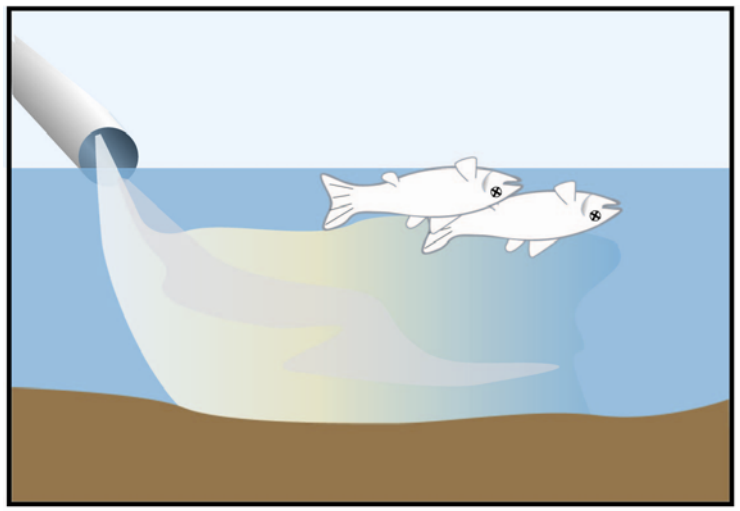
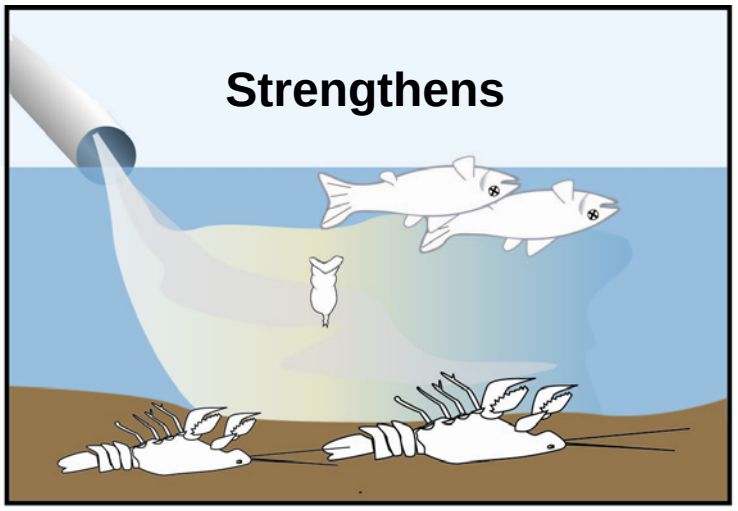


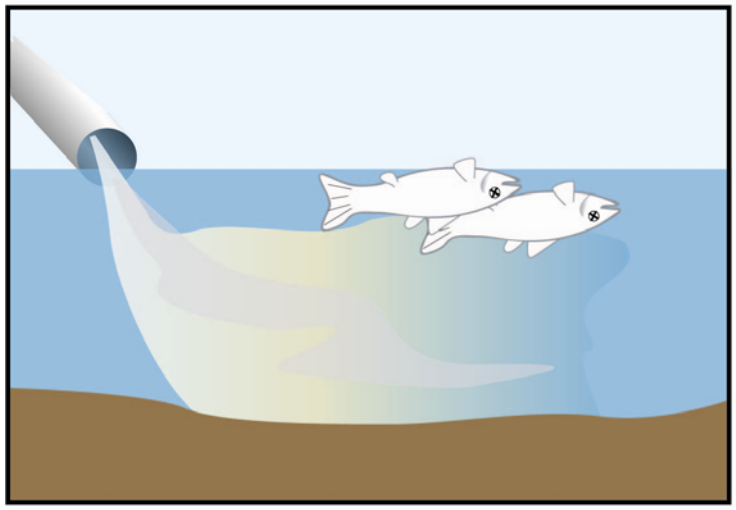
Refutes

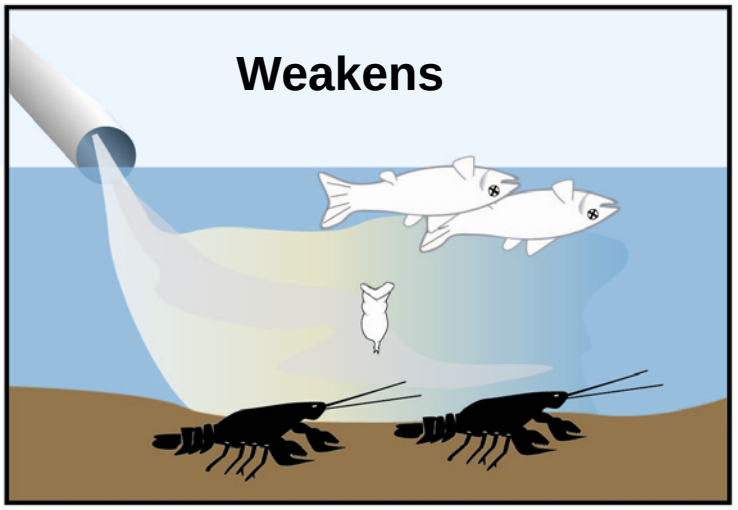
Verified Predictions





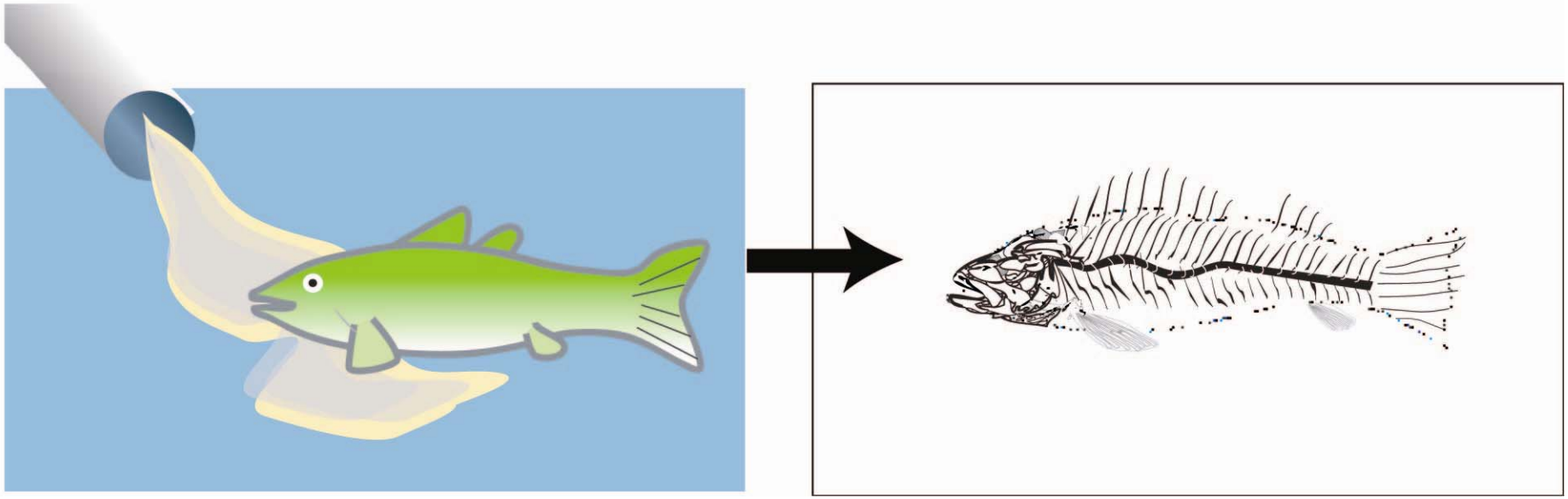
strengthens





weakens

Symptoms

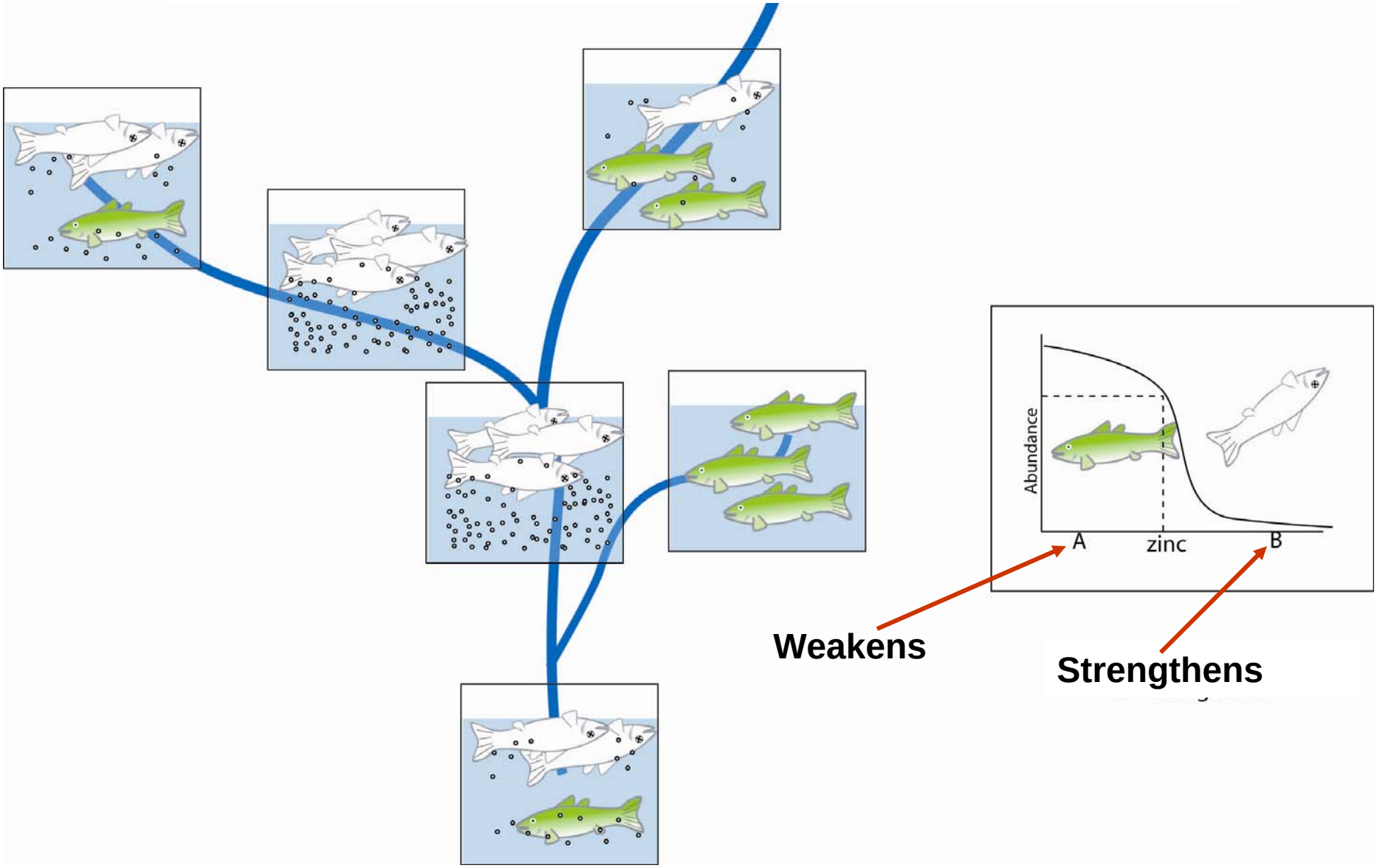


Strengthens

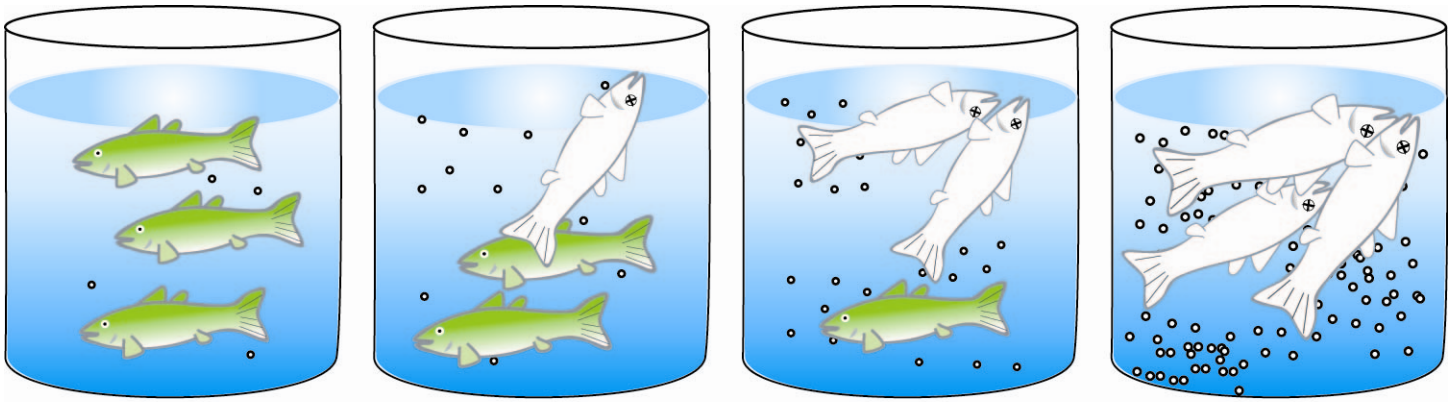
Types of Evidence that Use Data from Elsewhere

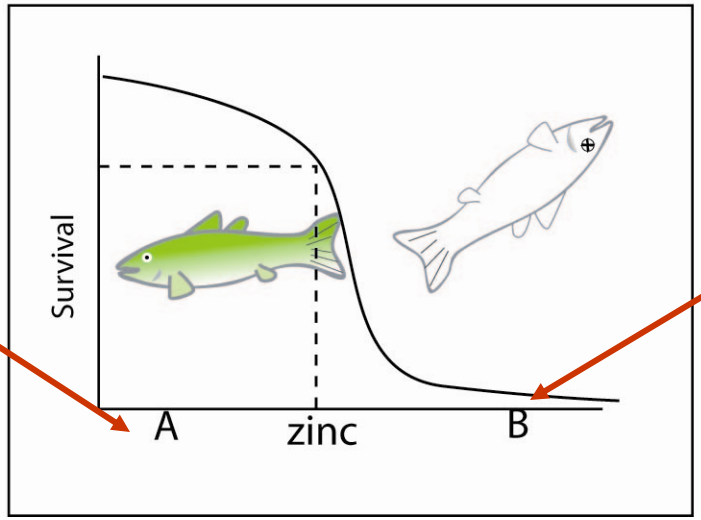
- Stressor-Response Relationships from Other Field Studies
- Stressor-Response Relationships from Laboratory Studies
- Stressor-Response Relationships from Ecological Simulation Models
- Mechanistically Plausible Cause
- Manipulation of Exposure at Other Sites
- Analogous Stressors

Stressor-Response Relationships from Other Field Studies



Stressor-Response Relationships from Laboratory Studies

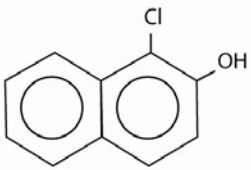




Weakens

Strengthens

Stressor-Response Relationships from Ecological Simulation Models

a + b 

=

c + d 

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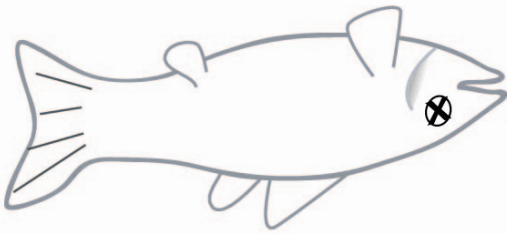
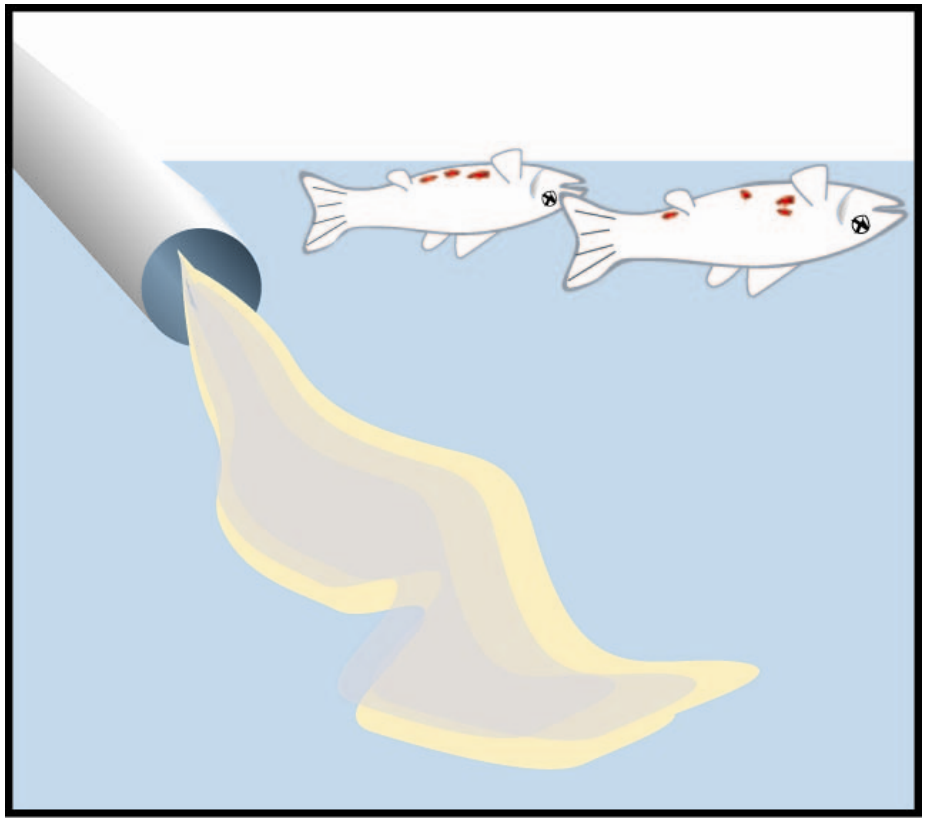


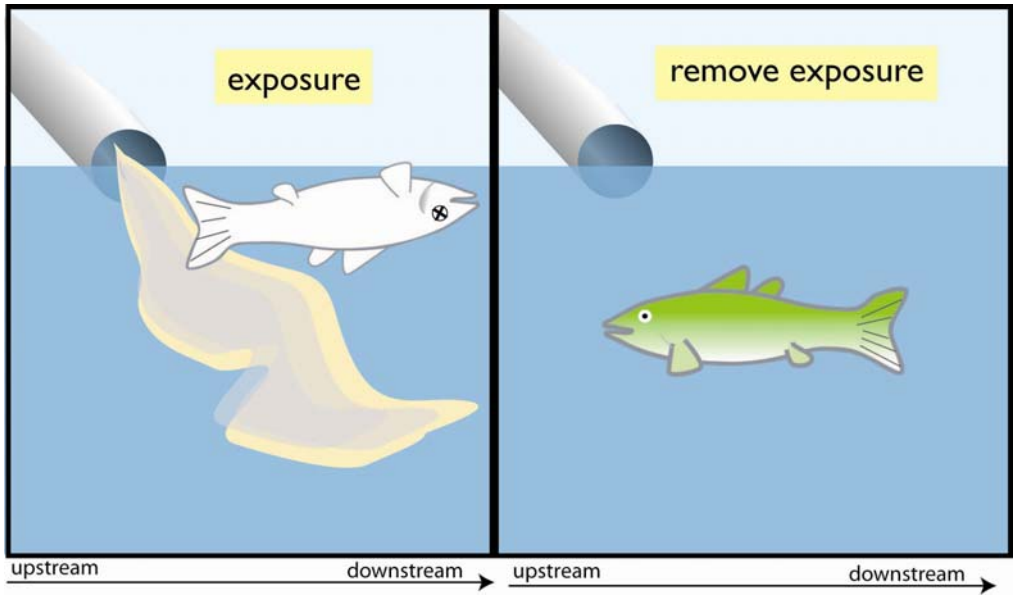
Mechanistically Plausible Cause



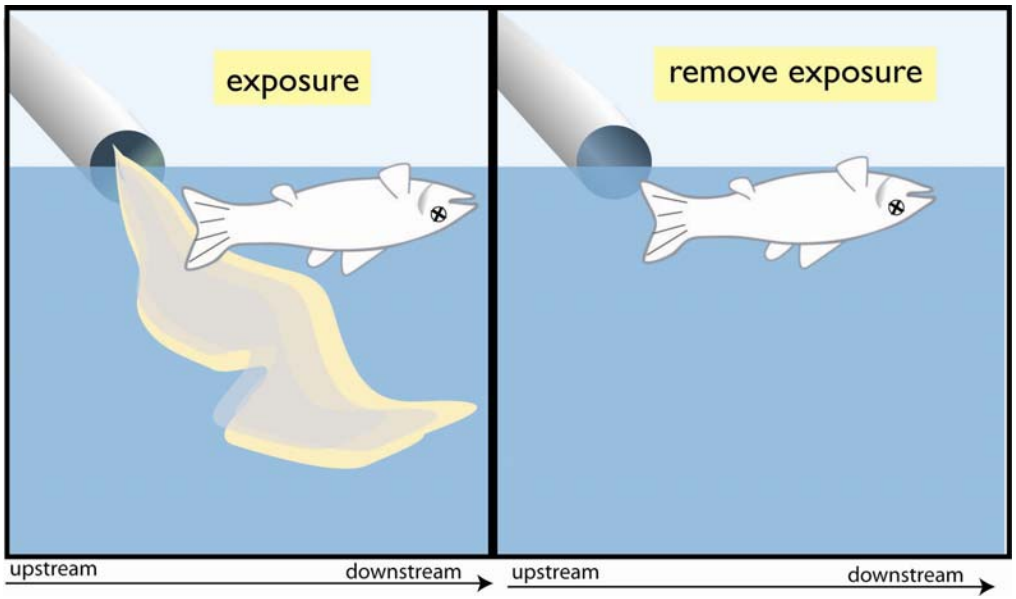
Weakens

Manipulation of Exposure

at Other Sites



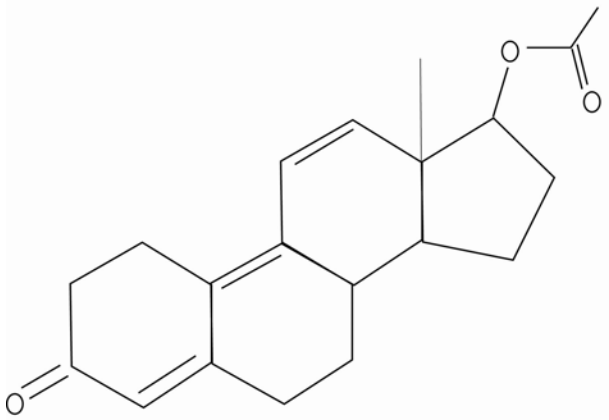
Strengthens



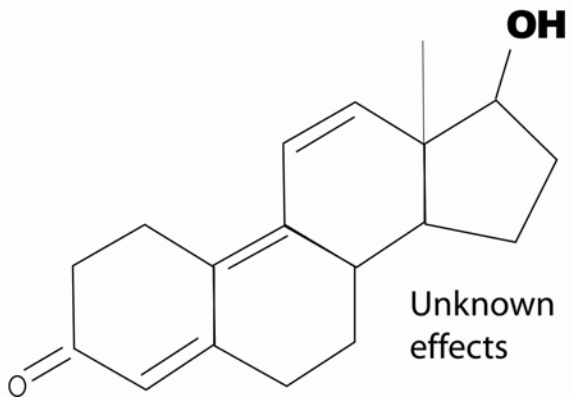
Weakens

Analogous Stressors

Trenbolone
Acetate
(anabolic steroid)



17B Trenbolone
(metabolite excreted in
animal waste)



Unknown
effects

Strengthens

Score Each Type of Evidence for Each Candidate Cause

R	refutes
D	diagnoses
+++	convincingly supports (or weakens)
++	strongly supports (or weakens)
+	somewhat supports (or weakens)
0	neither supports nor weakens
NE	no evidence

Scoring Example: Spatial/Temporal Co-occurrence

+	Weakly supports, because it could be a coincidence
0	Ambiguous evidence is neutral
- - -	Lack of co-occurrence convincingly negates, because exposure must occur
R	Refutes if negative evidence is indisputable

Scoring Example: Laboratory Tests of Site Media

+++	Laboratory toxic effects similar to site effects are convincing support media toxicity as a cause
+	Laboratory toxic effects that are not clearly related to site effects weakly support
0	Ambiguous evidence is neutral
-	Lack of laboratory toxicity weakly negates, because the test species, responses or conditions may be inappropriate
no R	Laboratory tests cannot refute toxic effects in the field.

Weigh the Evidence for Each Candidate Cause

- Evaluate the quantity and quality of evidence
  - Do not add the pluses and minuses
- Evaluate consistency and credibility
- Summarize the compelling evidence

Evaluating Multiple Types of Evidence

Type of Evidence	The Concept
Consistency of Evidence	Confidence in the argument for or against a candidate cause is increased when many types of evidence consistently support or weaken it.
Explanation of the Evidence	Confidence in the argument for a candidate cause is increased when a post hoc mechanistic, conceptual, or mathematical model reasonably explains any inconsistent evidence.

Consistency of Evidence

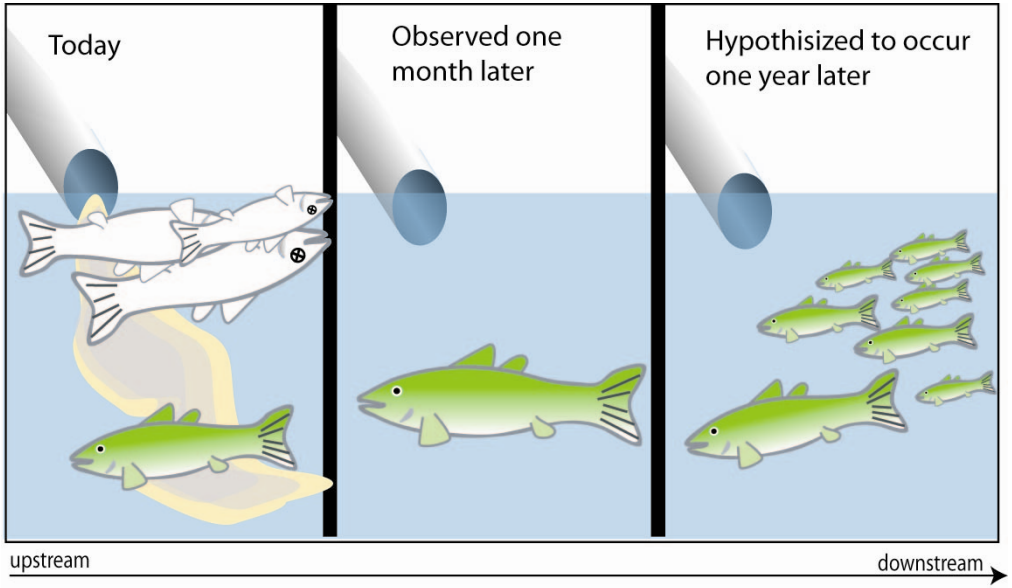
	Candidate Causes		
Types of Evidence	NH_3	CU	TSS
Co-occurrence	+	-	+
Causal Pathway	+	-	-
Manipulation	+	-	+
Stressor-Response	+	-	-

Strengthens

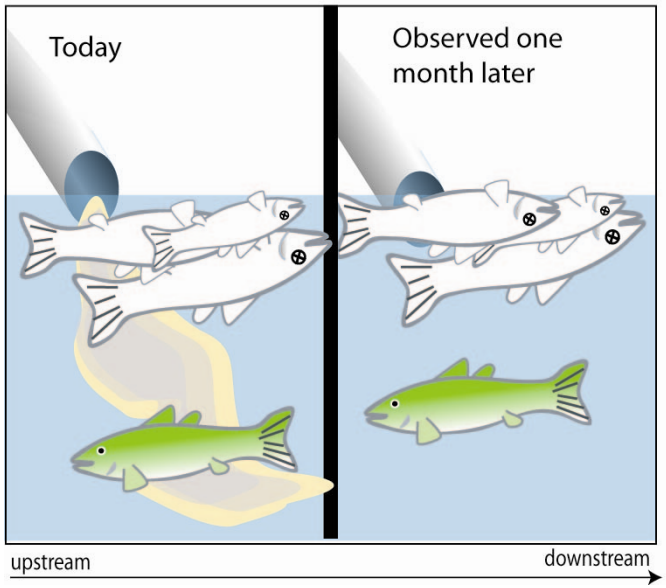
Weakens

Weakens

Explanation of the Evidence



Strengthens



Weakens

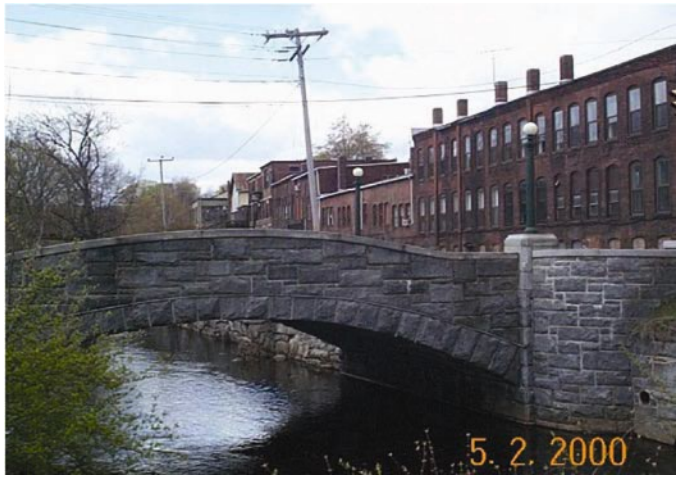
Scoring Explanation of Evidence

Consideration	Possible Results	Scores
Reasonable Explanation of the Evidence	A credible explanation exists for any negative inconsistencies in an otherwise positive case	+
	No explanation for inconsistencies	0
	A credible explanation for any positive inconsistencies in an otherwise negative case	-

Connecticut Case Study

Willimantic River

- Identified source
- Remediated
- Biotic condition improved
- Removed from 303d list
- Residual impairment
- Associated with upstream dams
  - Temperature
  - Allocthonous trophic structure



Willimantic	Metals	NH_3	Flow	Silt	Low DO	T	Food	Episodic Mix
Types of Evidence that Use Data from the Case								
Spatial/Temporal Co-Occurrence	+	-	-	+	- - -	+		+
Evidence of Exposure or Biological Mechanism	+	+	+	--	+	+	-	+
Causal Pathway		-	+	-	+	+	-	+
Stressor-Response Relationships from the Field	+	-		-	+	+		
Manipulation of Exposure								+ + +
Verified Predictions								+ + +
Types of Evidence that Use Data from Elsewhere								
Stressor-Response Relationships from Other Field Studies	- -							
Stressor-Response Relationships from Laboratory Studies	+	-			-	+		
Evaluating Multiple Types of Evidence								
Consistency of Evidence	-	-	-	-	-	+	-	+ + +

Possible Outcomes

- Strong evidence for one cause
  - Celebrate and remediate
- Inconclusive evidence across causes
  - Remediate as adaptive management
  - Gather more data and reanalyze
  - Redefine the impairment
  - Consider more candidate causes
  - Consider joint action of causes

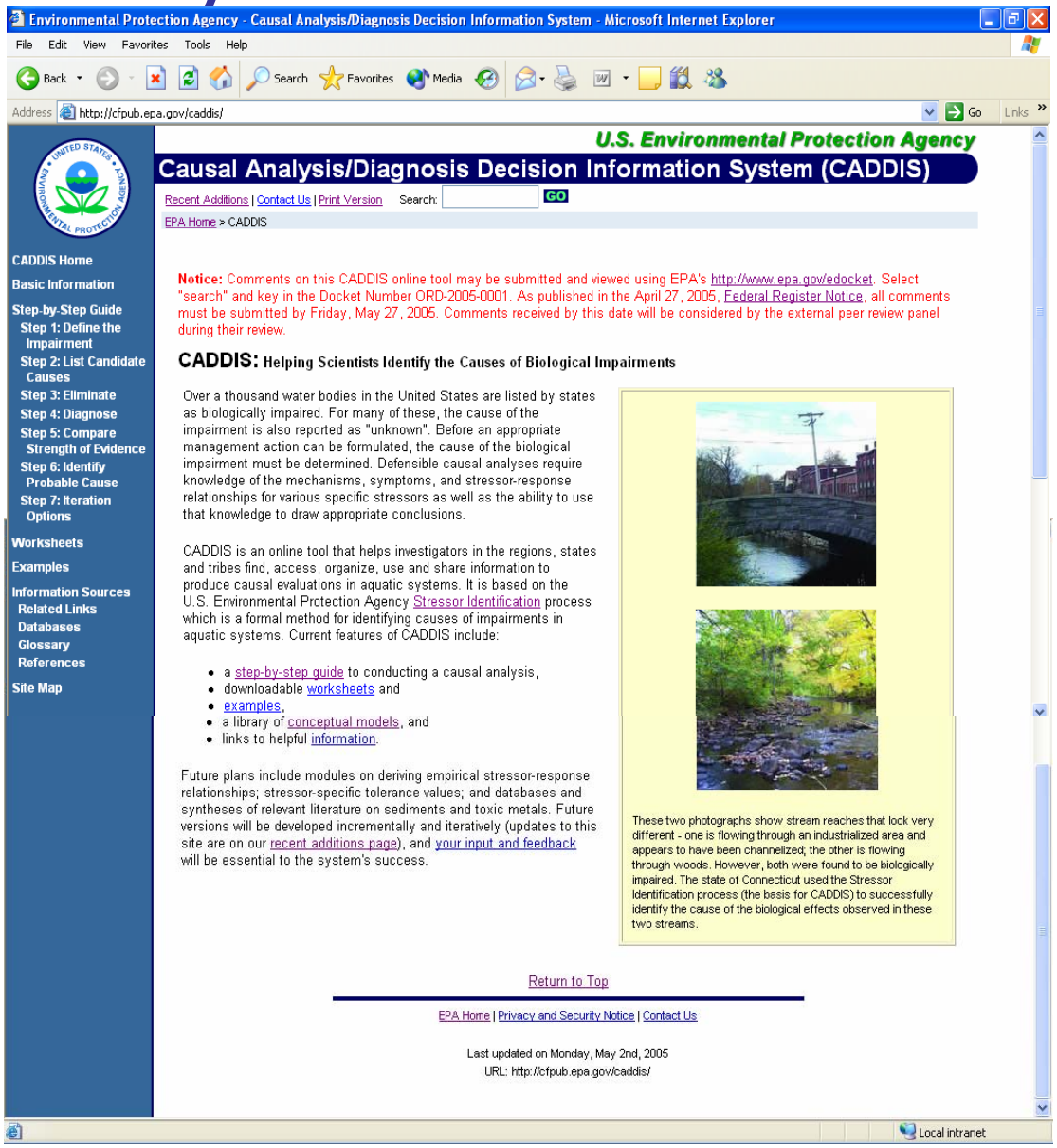
Causal Analysis/Diagnosis Decision Information System CADDIS

An online system that helps

- Organize
- Use
- Access, and
- Share

Information

To Identify Causes of Biological Impairments



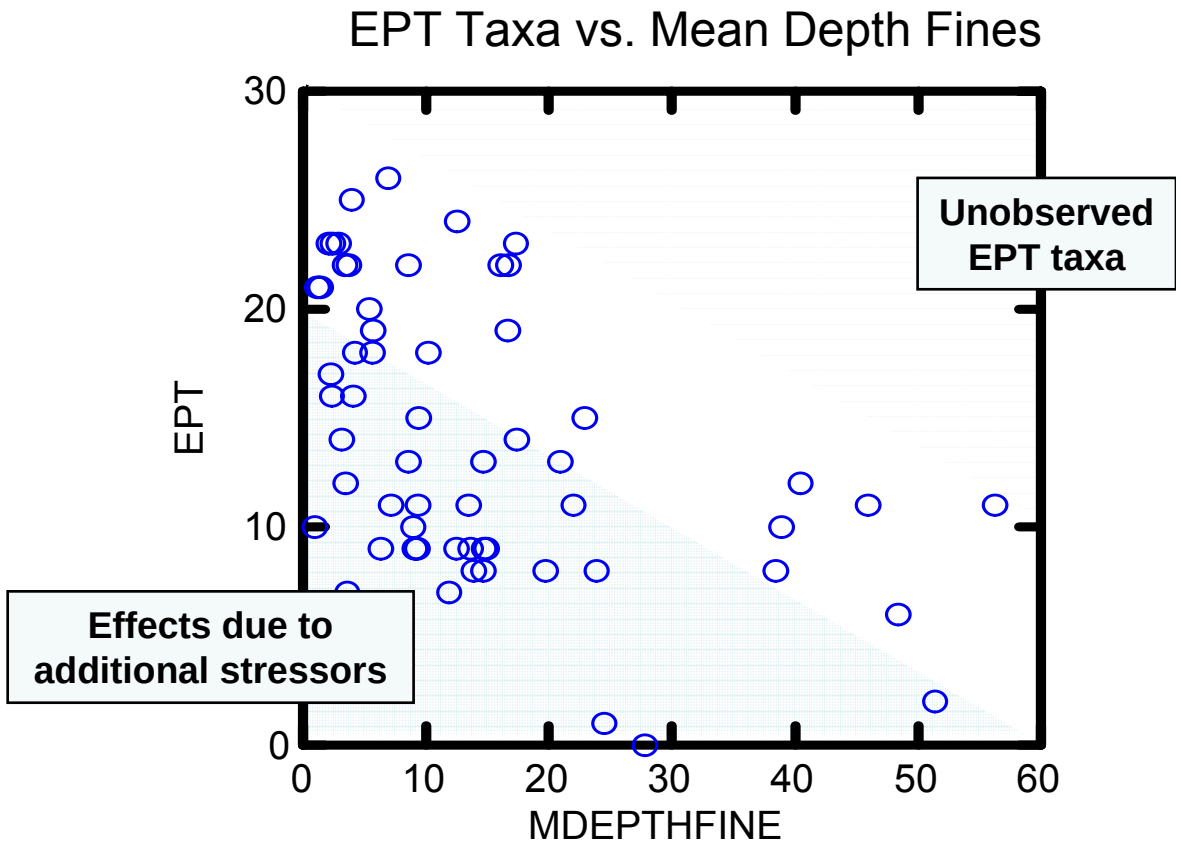
CADDIS 1 Includes

- Step-by-Step Guide
- Worksheets and Examples
- Conceptual Models
- Case Studies
- External links
- References
- Search Glossary

www.epa.gov/caddis/

CADDIS 2 Technical Content

- **Stressor-Response relationships**
  - Stressor syntheses
    - Metals (Fall 2005)
    - Nutrients
    - Suspended and Bedded Sediments
    - Dissolved oxygen
    - Temperature
    - Salinity
  - Analytical methods
    - Stressor-specific tolerance values
    - Regional stressor-response curves



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Other CATs are standing by