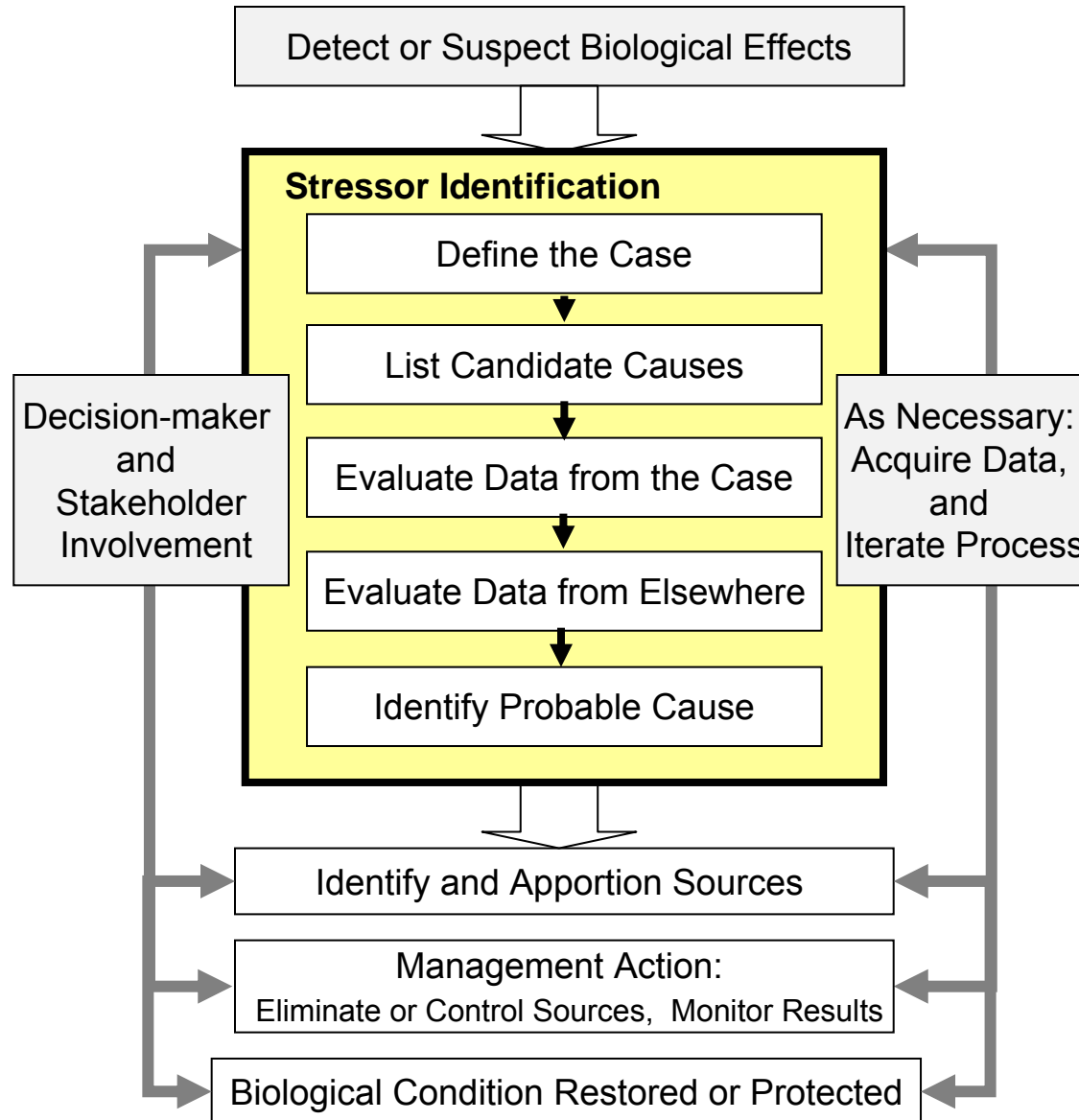


Causal Analysis Using Stressor Identification & CADDIS

Glenn Suter, Susan Cormier & Sue Norton
USEPA

Office of Research & Development
National Center for Environmental Assessment

Our Causal Strategy: Stressor Identification

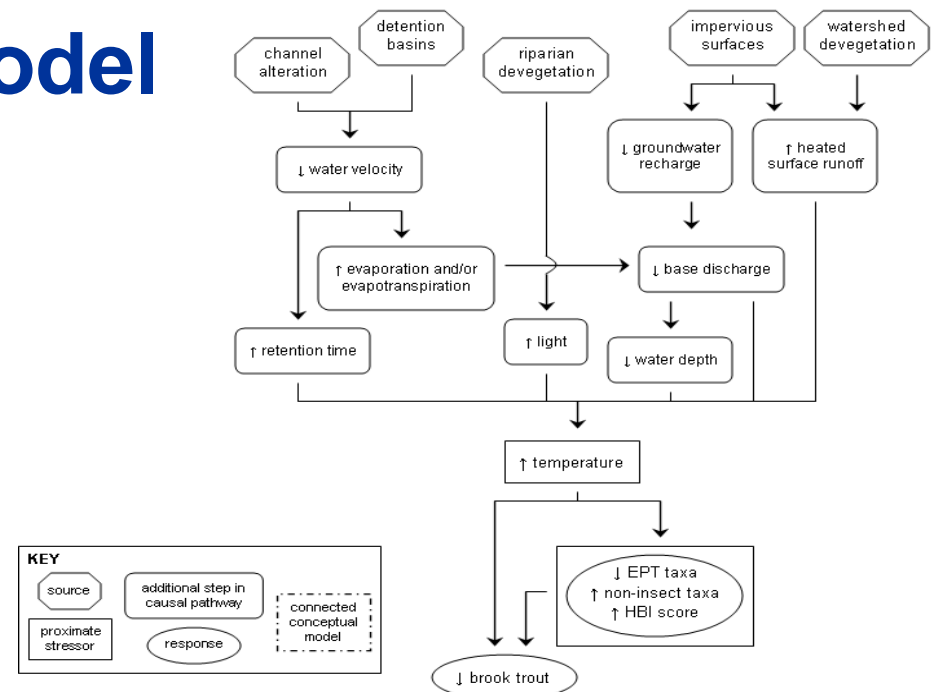


Define the Case

- **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:

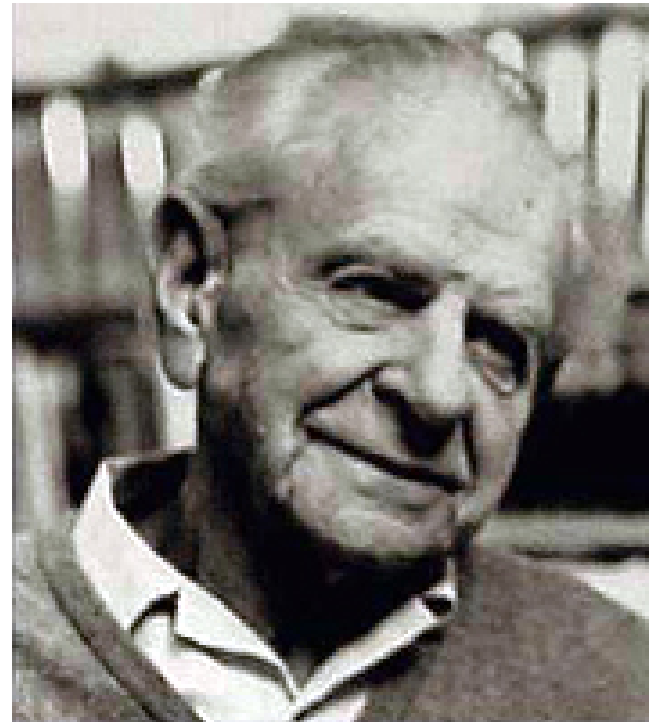
- Every time I wash my car it _____

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

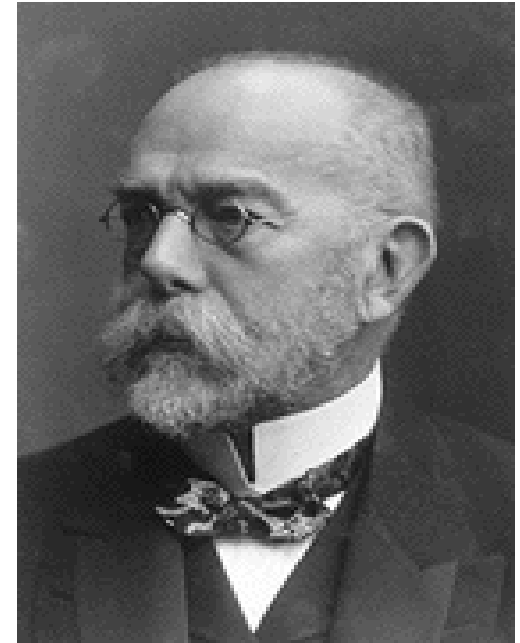
Disproof

Popperian disproof

- Based on crucial experiment
- Based on observation
- Cannot identify cause
 - No finite list
- But can shorten the list



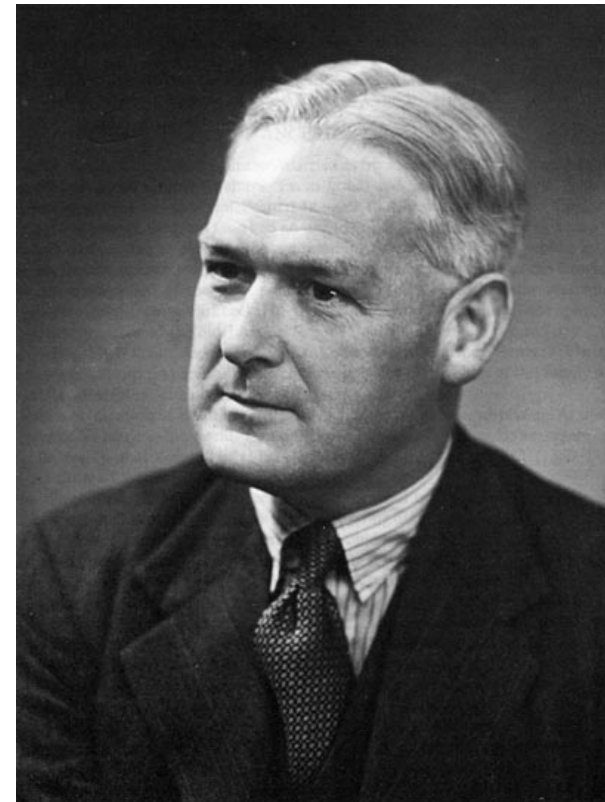
Diagnostics



- **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**



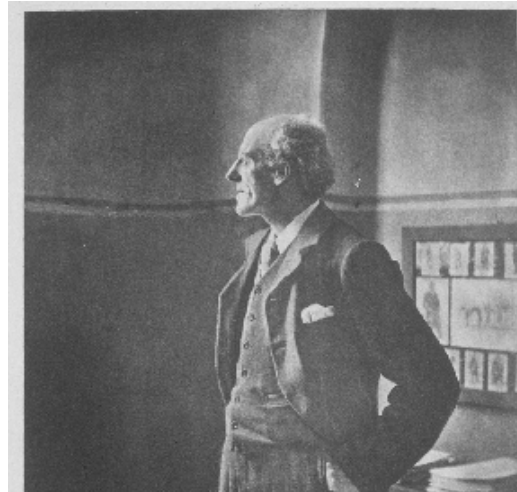
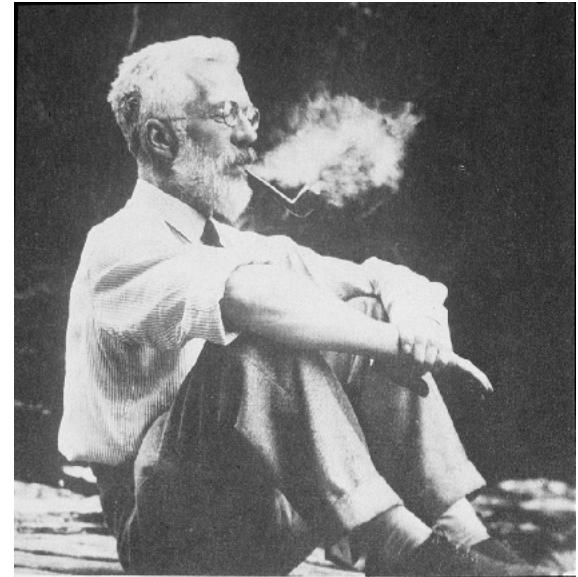
Statistical Methods

Fisherian Disproof / NHT

- Only for experiments
- Cannot identify cause

Probabilistic Association

- Correlation \neq 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)

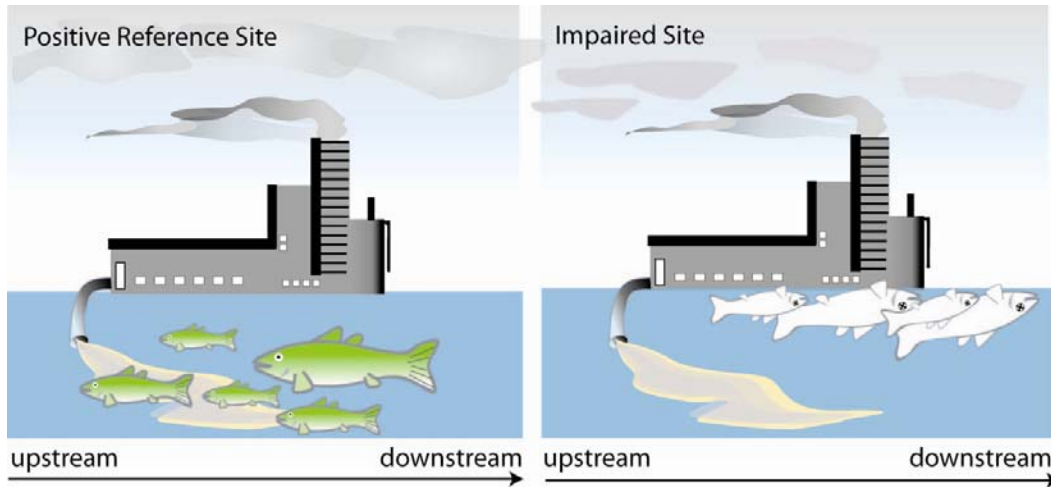
Our Solution, 2

- 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

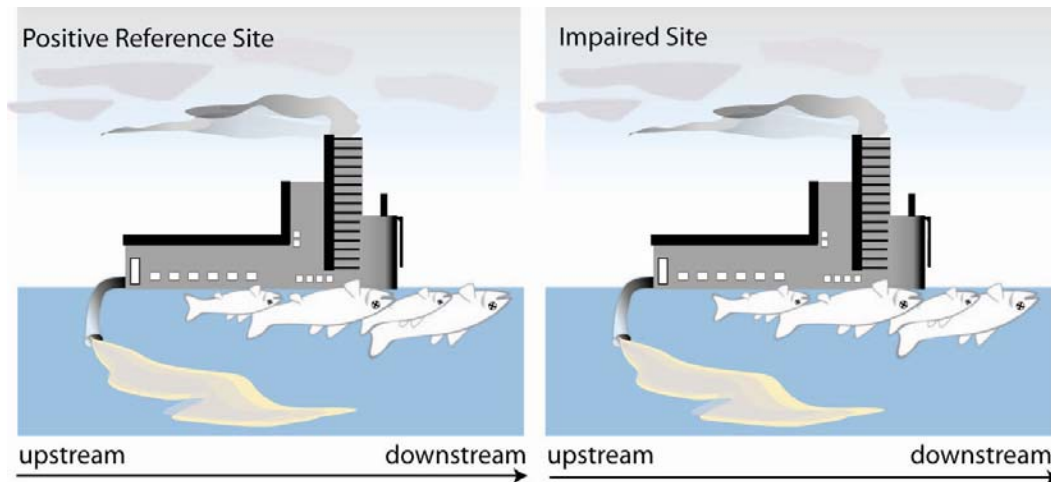
Types of Evidence that Use Data from the Case

- 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

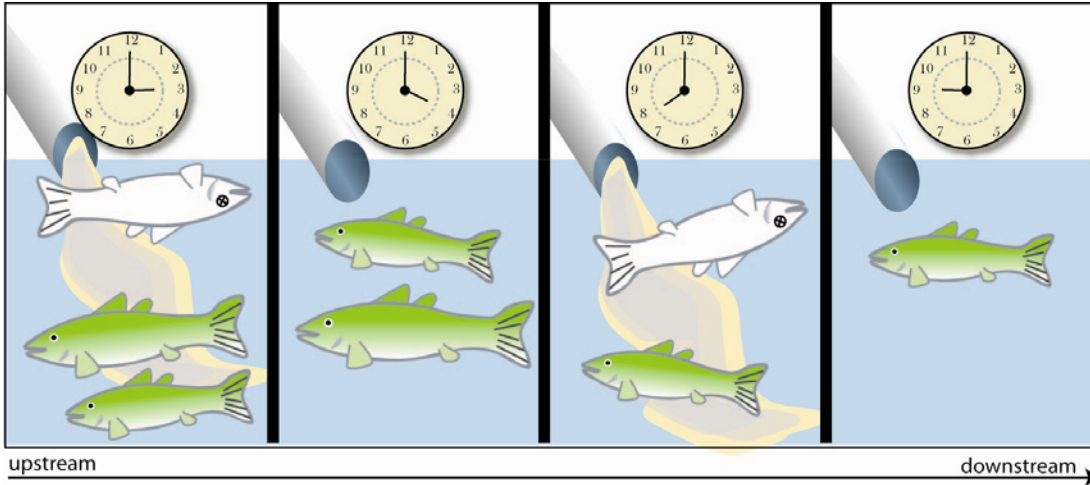


Refutes

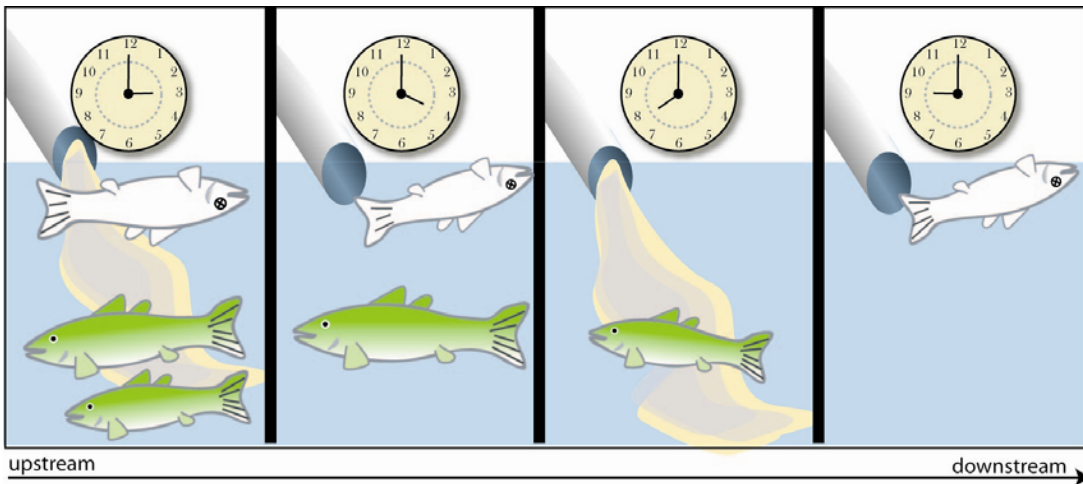


Supports

Spatial/Temporal Co-Occurrence Through Time



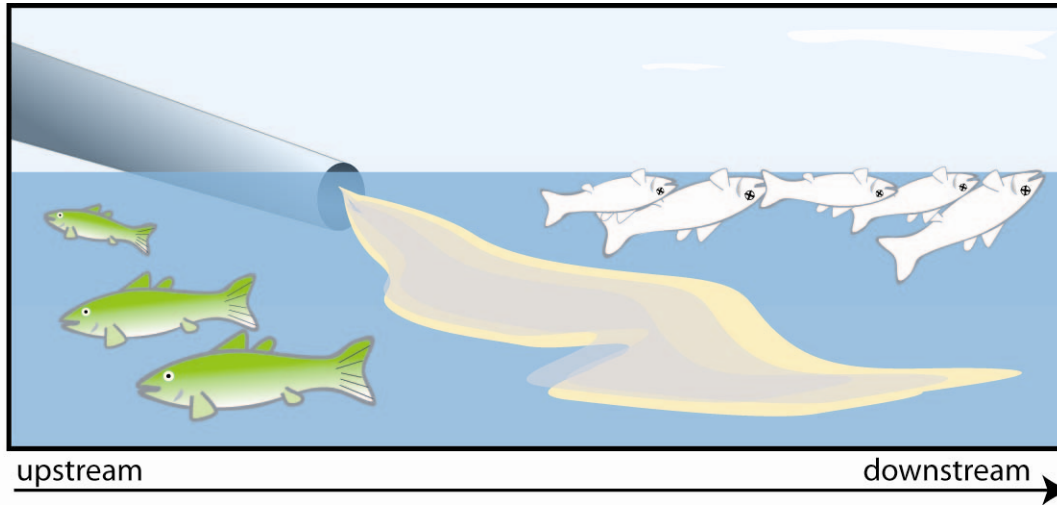
Supports



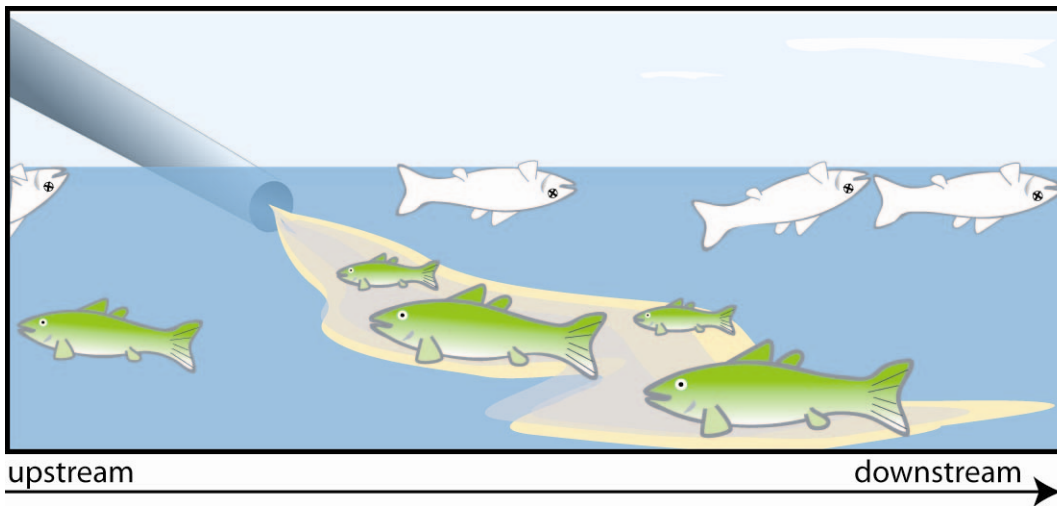
Refutes

Spatial/Temporal Co-Occurrence

Upstream Downstream Comparison

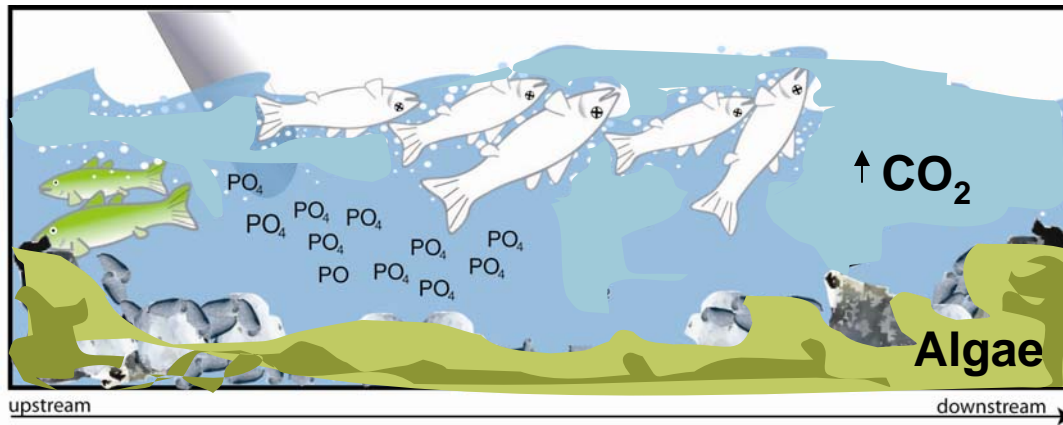


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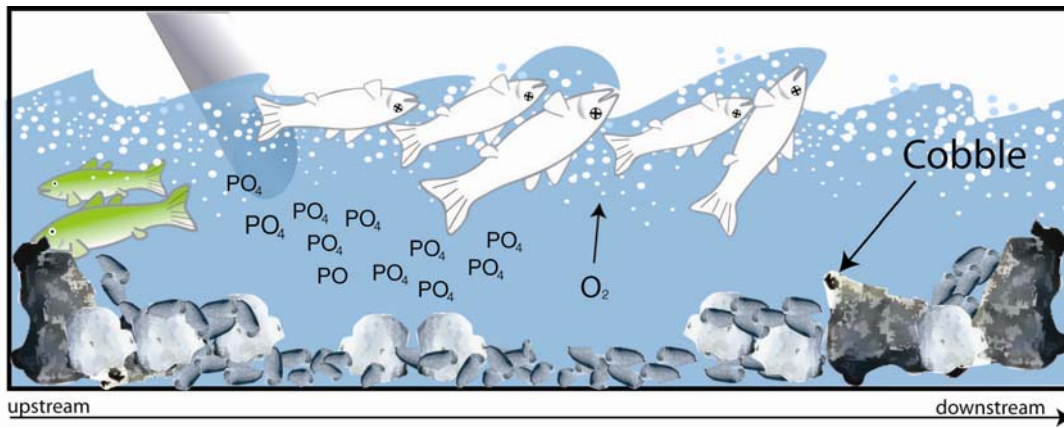


Refutes

Causal Pathway

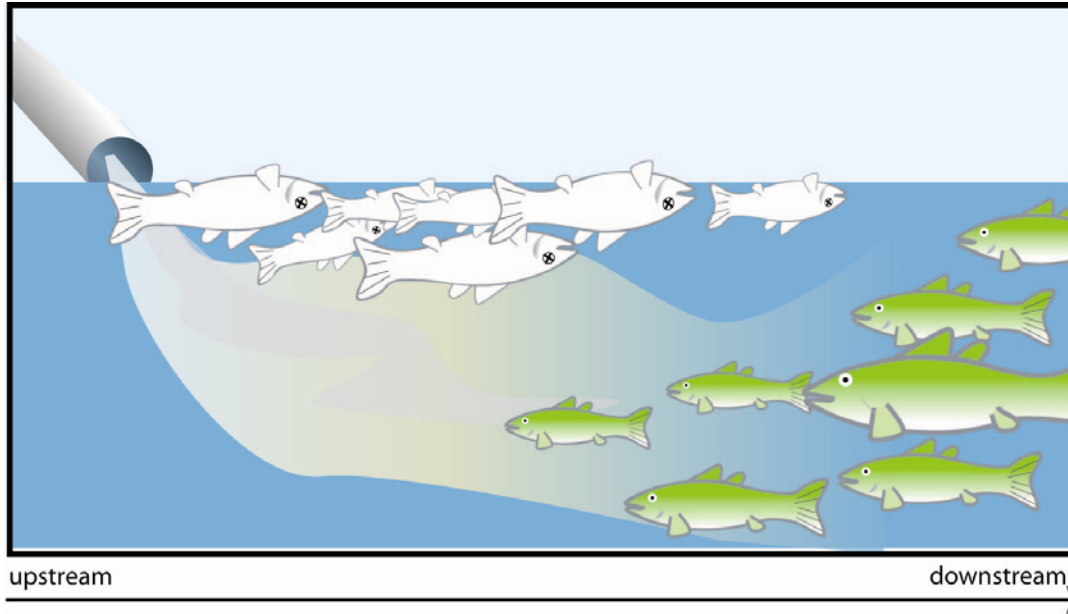


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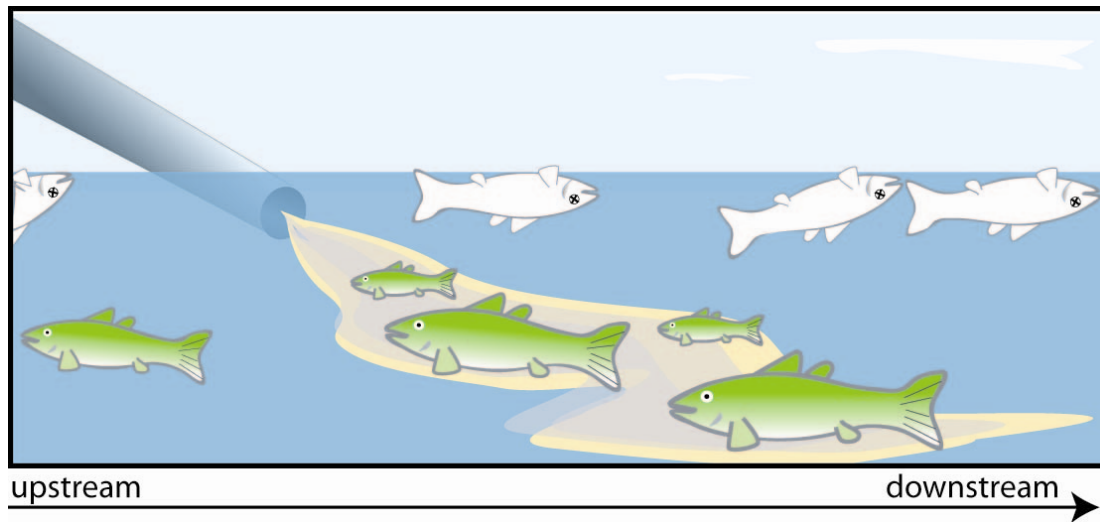


Refutes

Stressor-Response Relationships from the Field

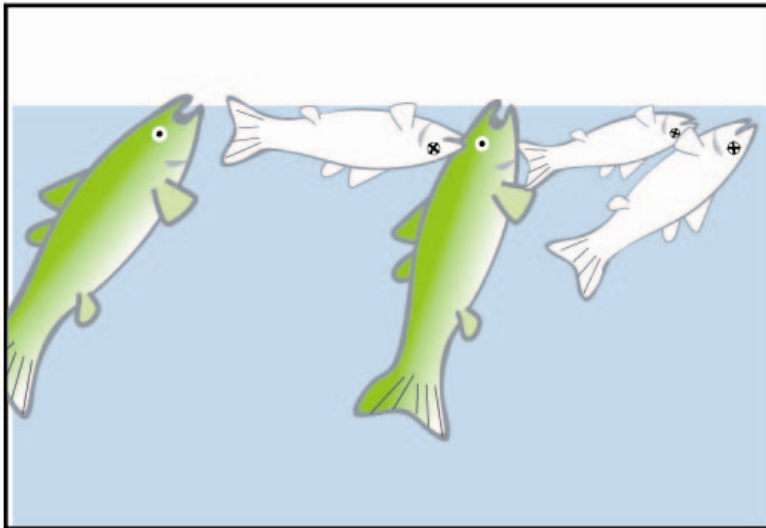


Strengthens

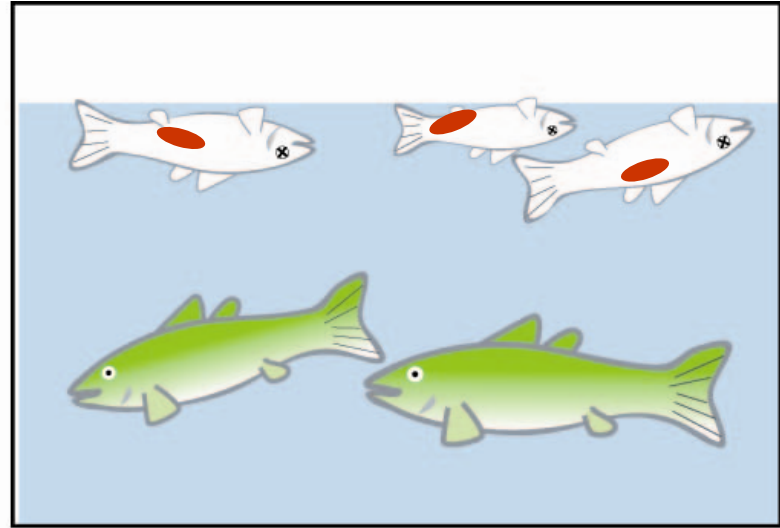


Weakens

Evidence of Exposure or Biological Mechanism

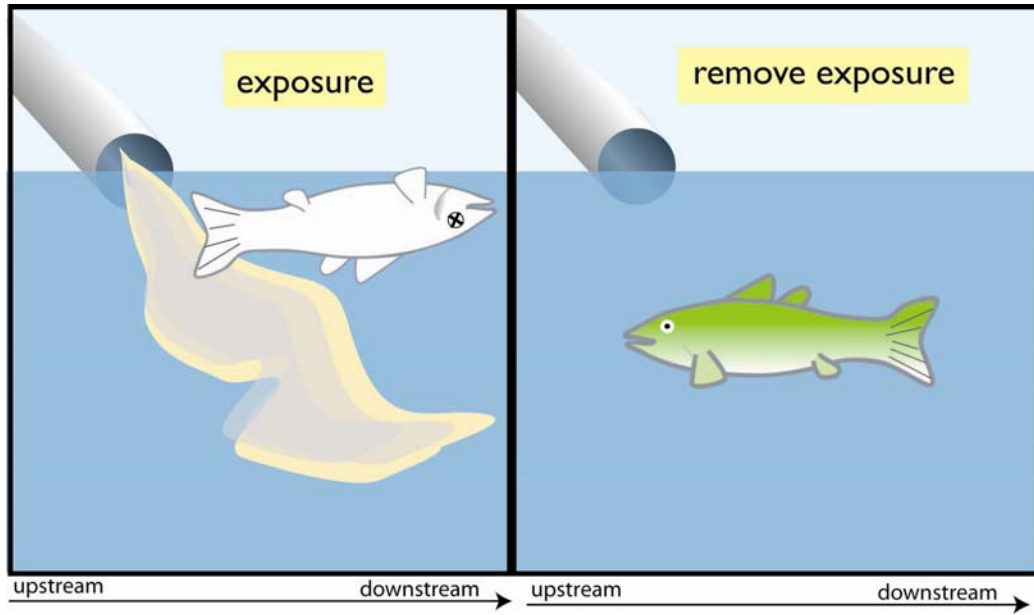


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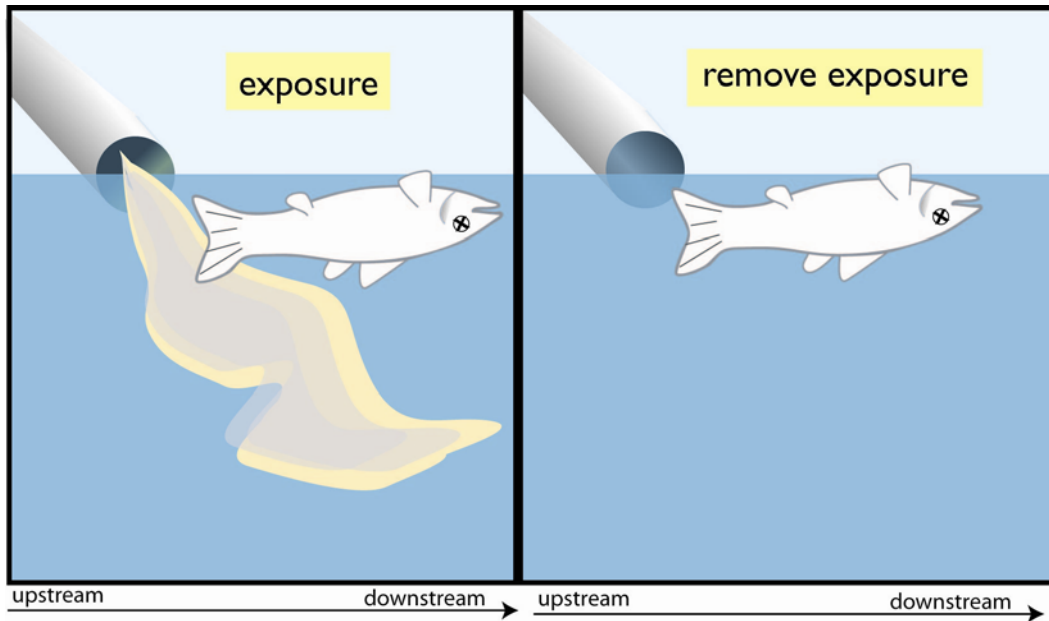


Weakens

Manipulation of Exposure

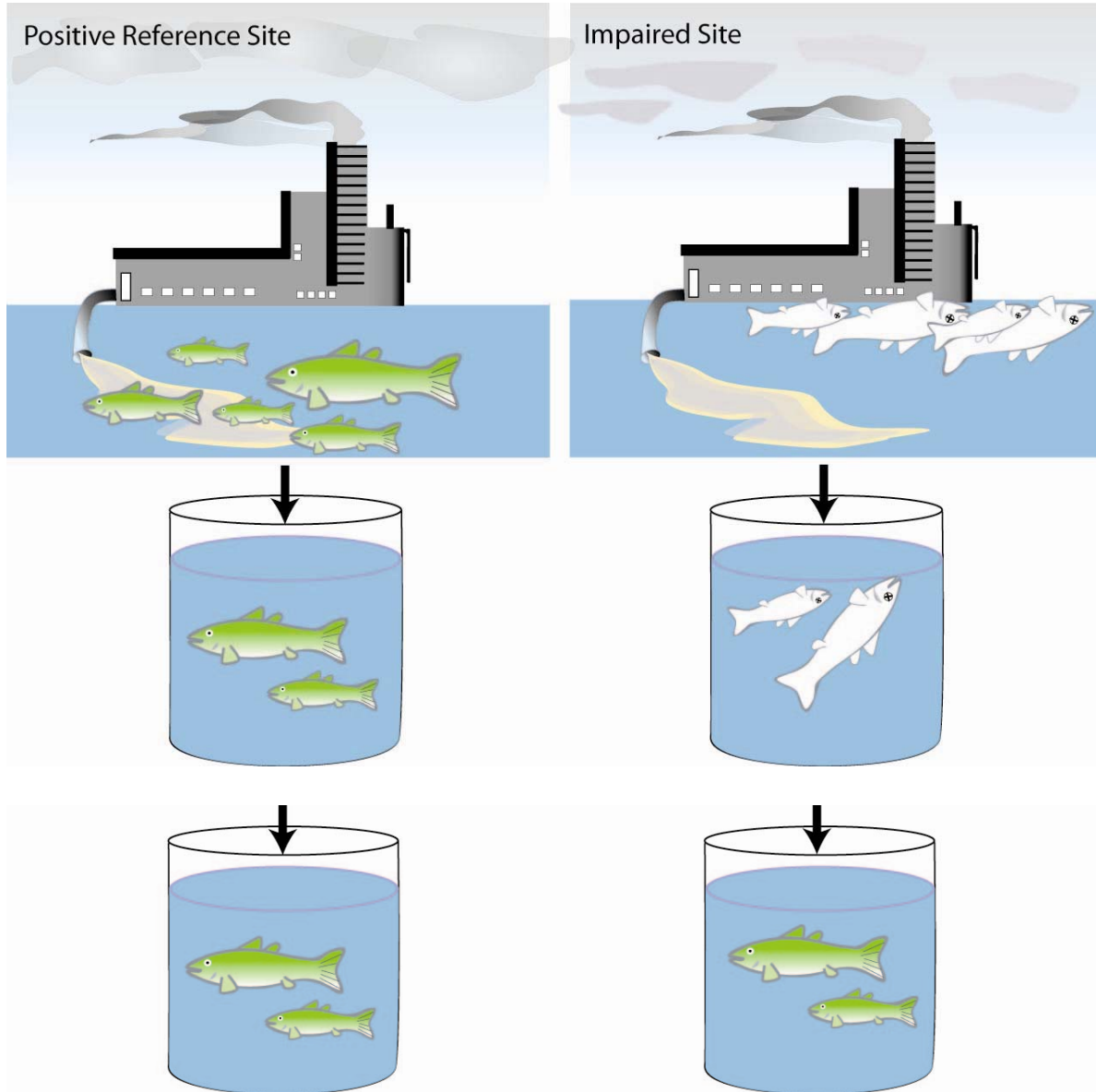


Supports



Refutes

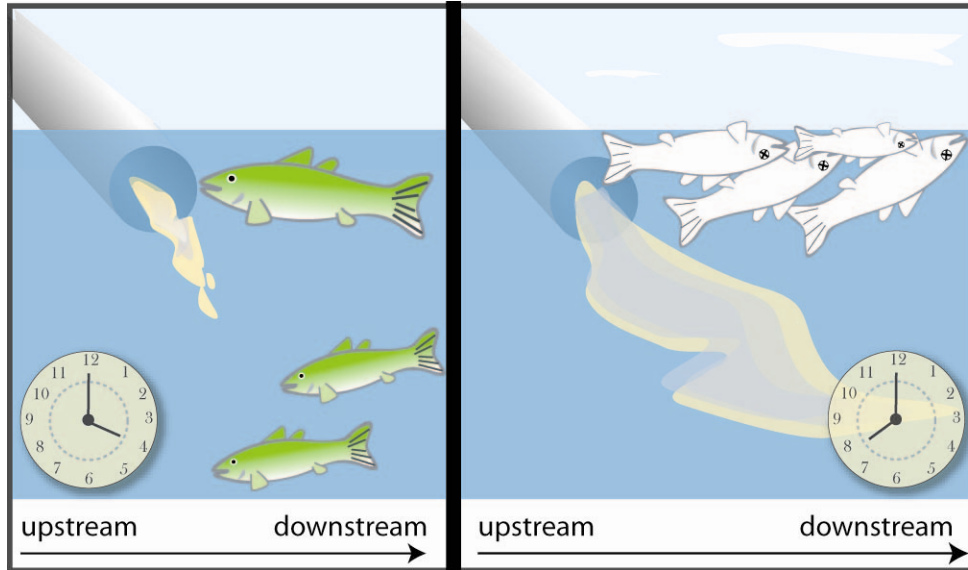
Laboratory Tests of Site Media



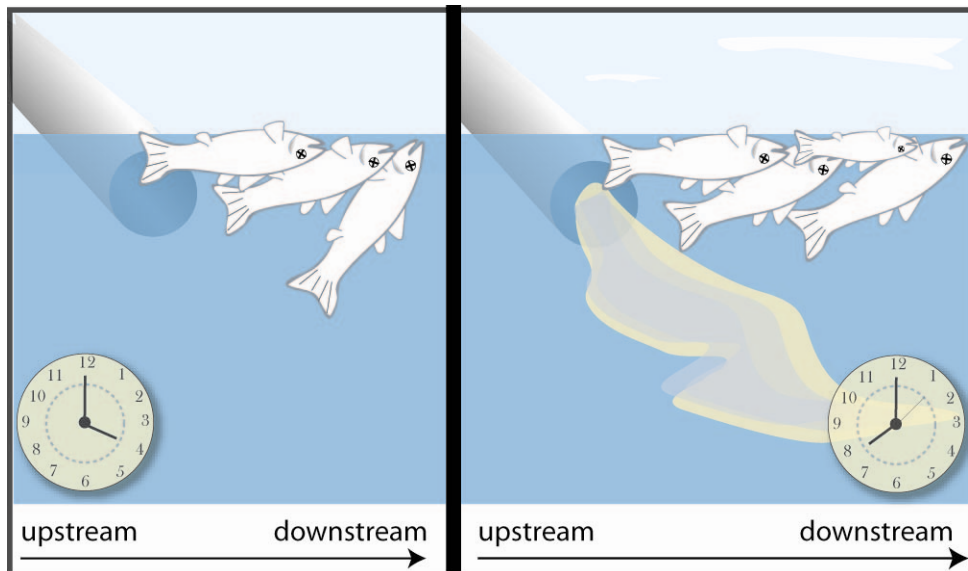
Supports

Refutes

Temporal Sequence

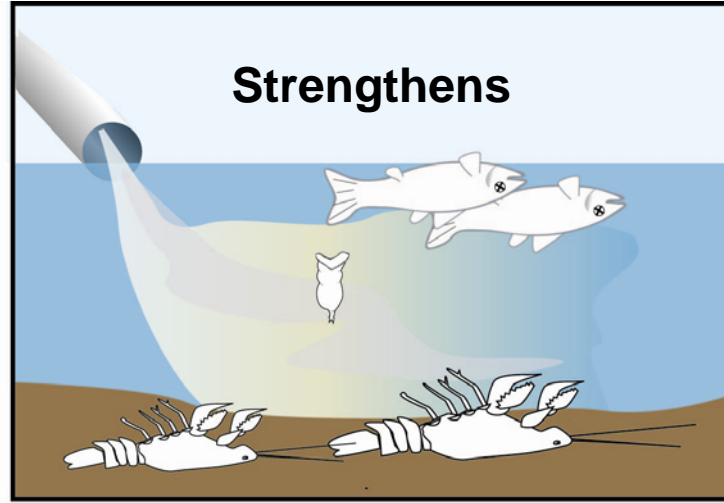
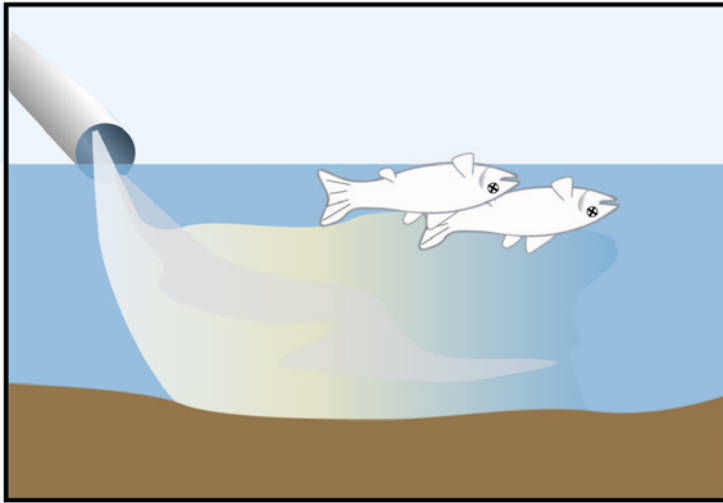


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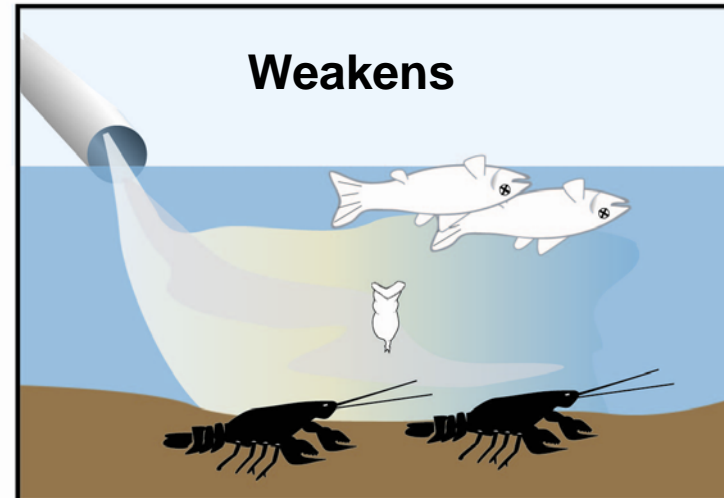
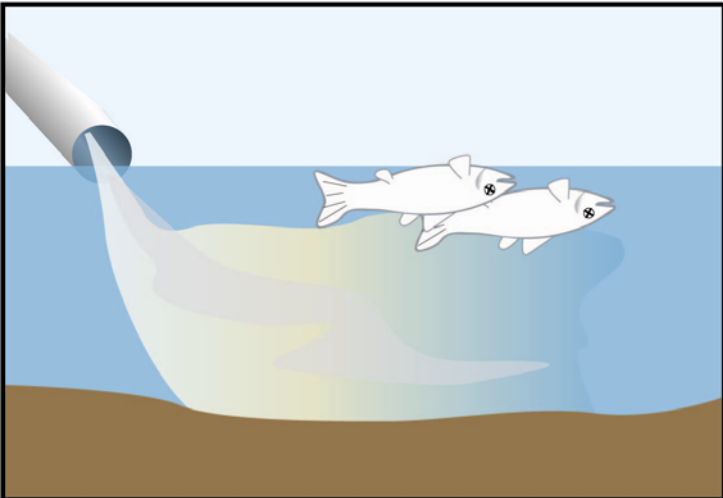


Refutes

Verified Predictions



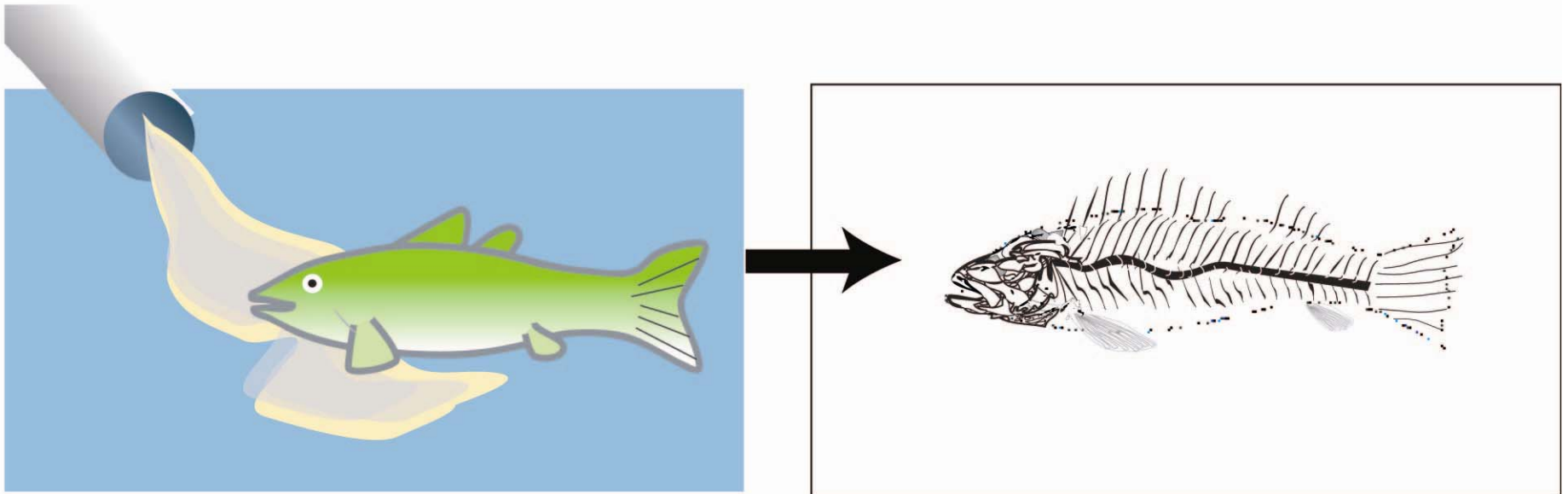
strengthens



weakens



Symptoms

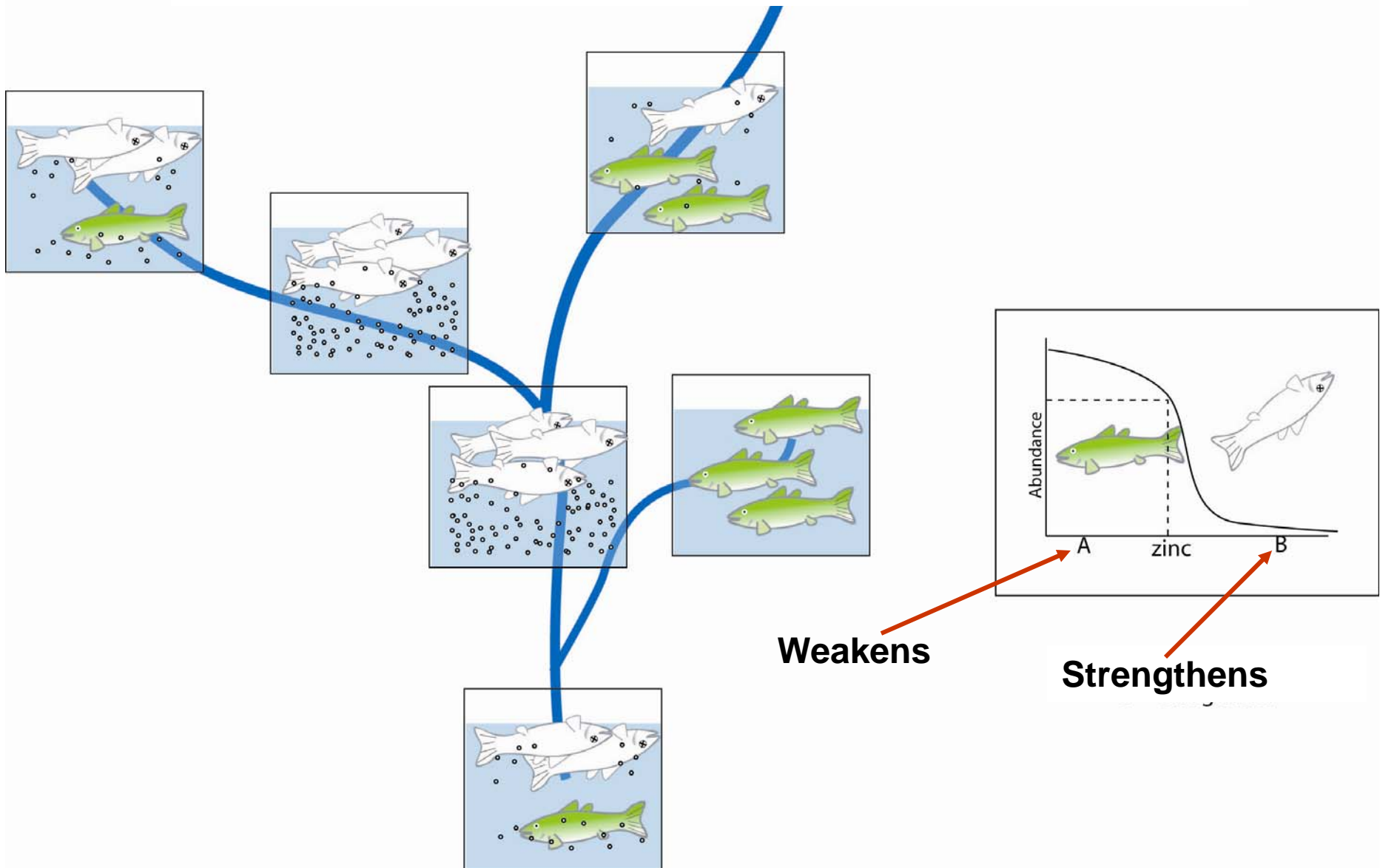


Strengthens

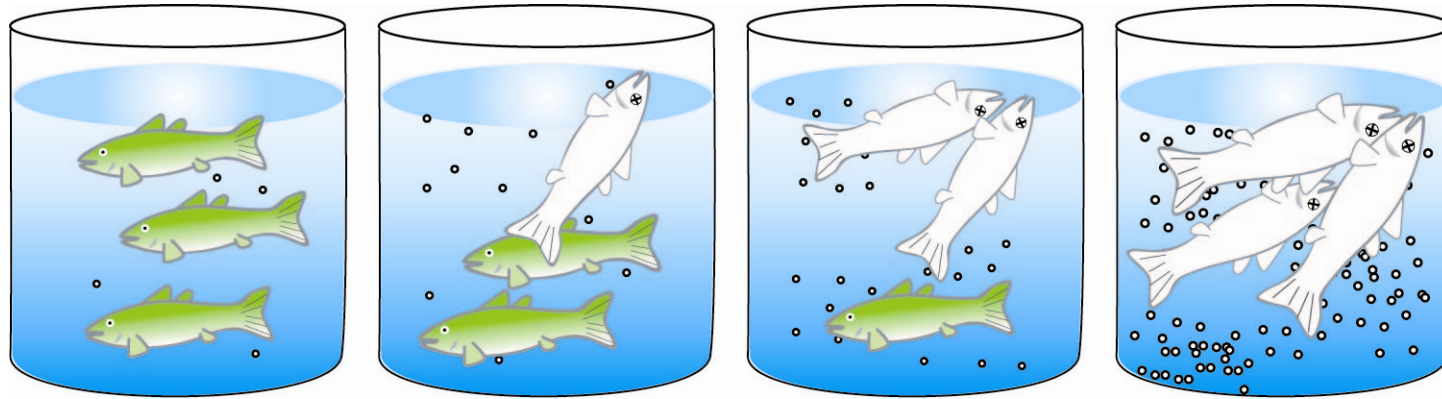
Types of Evidence that Use Data from Elsewhere

- 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

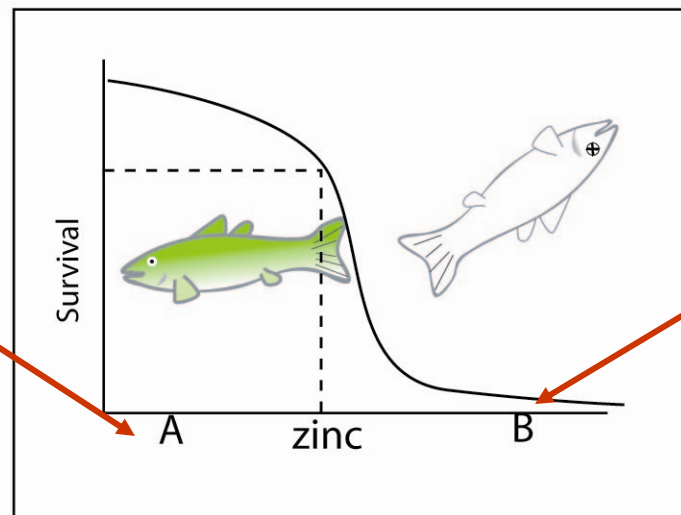
Stressor-Response Relationships from Other Field Studies



Stressor-Response Relationships from Laboratory Studies



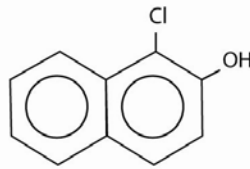
Weakens



Strengthens

Stressor-Response Relationships from Ecological Simulation Models

a + b



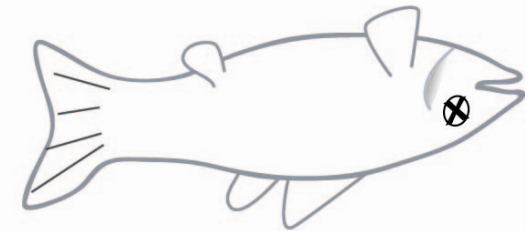
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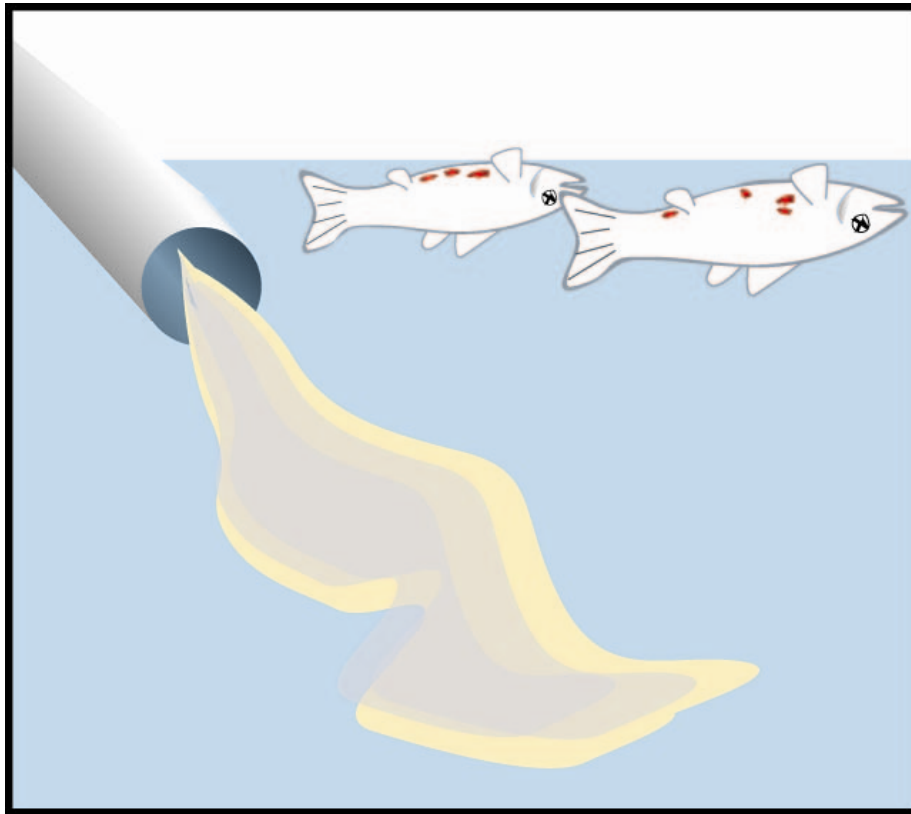
c + d



=

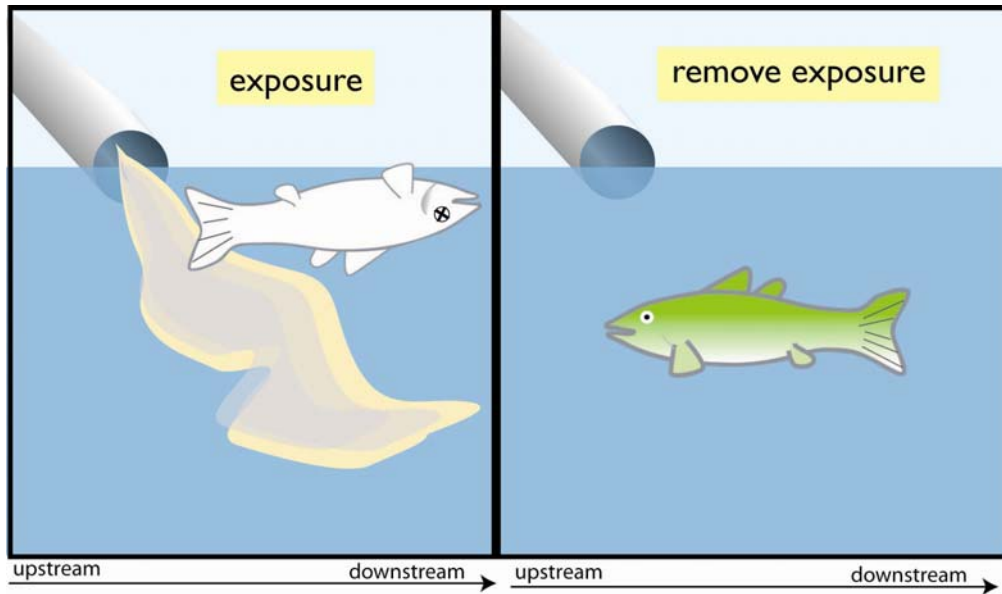


Mechanistically Plausible Cause

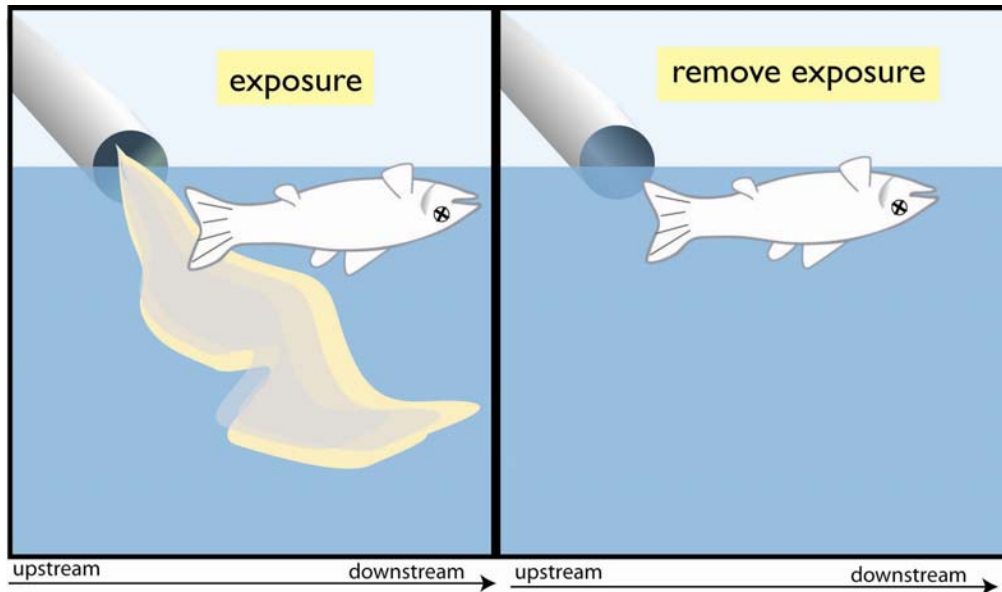


Weakens

Manipulation of Exposure at Other Sites



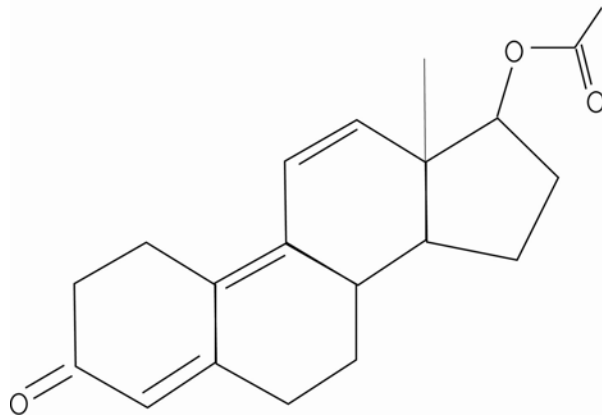
Strengthens



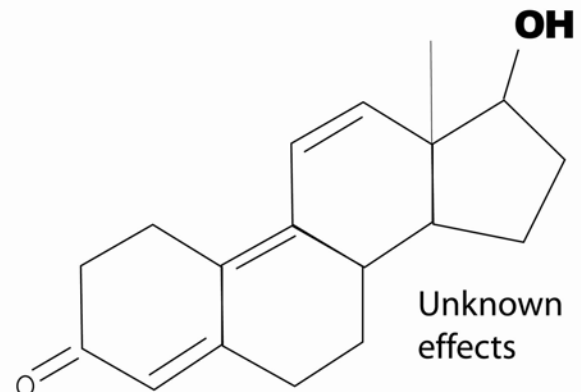
Weakens

Analogous Stressors

Trenbolone
Acetate
(anabolic steroid)



17B Trenbolone
(metabolite excreted in
animal waste)



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

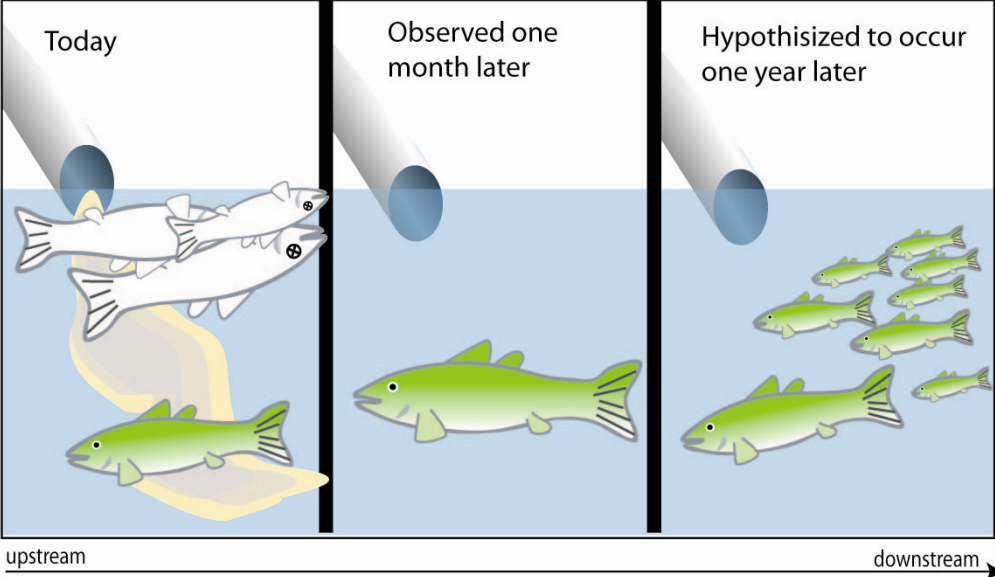
Types of Evidence	Candidate Causes		
	NH ₃	CU	TSS
Co-occurrence	+	-	+
Causal Pathway	+	-	-
Manipulation	+	-	+
Stressor-Response	+	-	-

Strengthens

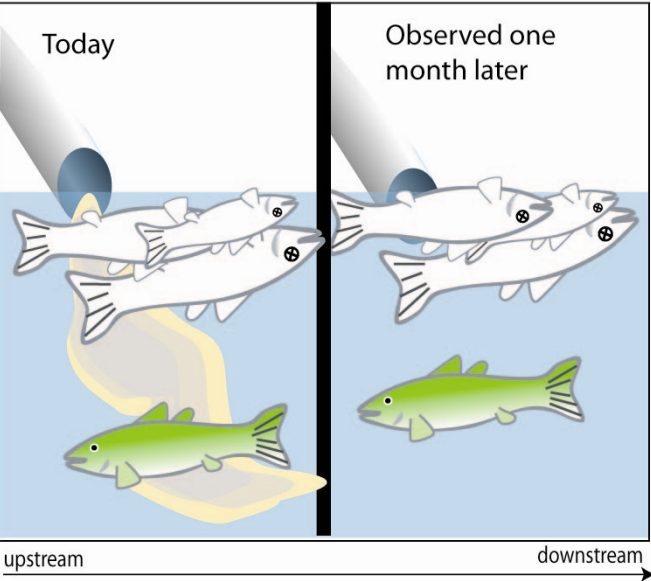
Weakens

Weakens

Explanation of the Evidence



Strengthens



Weakens

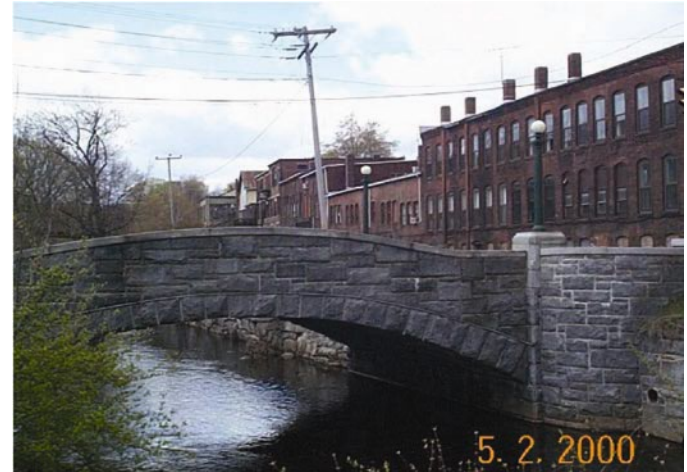
Scoring Explanation of Evidence

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
 - 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

The screenshot shows the CADDIS website in a Microsoft Internet Explorer browser window. The address bar displays "http://cfpub.epa.gov/caddis/". The page header includes the U.S. Environmental Protection Agency logo and the title "Causal Analysis/Diagnosis Decision Information System (CADDIS)". A navigation menu on the left lists various sections: CADDIS Home, Basic Information, Step-by-Step Guide (Steps 1-7), Worksheets, Examples, Information Sources, Related Links, Databases, Glossary, References, and Site Map. The main content area features a "Notice" about comments, a section titled "CADDIS: Helping Scientists Identify the Causes of Biological Impairments" with a paragraph of text, a list of features, and two photographs of stream reaches. The bottom of the page includes a "Return to Top" link, "EPA Home | Privacy and Security Notice | Contact Us" links, and the date "Last updated on Monday, May 2nd, 2005" with the URL "http://cfpub.epa.gov/caddis/".

Environmental Protection Agency - Causal Analysis/Diagnosis Decision Information System - Microsoft Internet Explorer

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Address <http://cfpub.epa.gov/caddis/>

U.S. Environmental Protection Agency

Causal Analysis/Diagnosis Decision Information System (CADDIS)

[Recent Additions](#) | [Contact Us](#) | [Print Version](#) Search:

EPA Home > CADDIS

Notice: Comments on this CADDIS online tool may be submitted and viewed using EPA's <http://www.epa.gov/edocket>. Select "search" and key in the Docket Number ORD-2005-0001. As published in the April 27, 2005, [Federal Register Notice](#), all comments must be submitted by Friday, May 27, 2005. Comments received by this date will be considered by the external peer review panel during their review.

CADDIS: Helping Scientists Identify the Causes of Biological Impairments

Over a thousand water bodies in the United States are listed by states as biologically impaired. For many of these, the cause of the impairment is also reported as "unknown". Before an appropriate management action can be formulated, 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 tool that helps investigators in the regions, states and tribes find, access, organize, use and share information to produce 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 CADDIS include:

- a [step-by-step guide](#) to conducting a causal analysis,
- downloadable [worksheets](#) and
- [examples](#),
- a library of [conceptual models](#), and
- links to helpful [information](#).

Future plans include modules on deriving empirical stressor-response relationships; stressor-specific tolerance values; and databases and syntheses of relevant literature on sediments and toxic metals. Future versions will be developed incrementally and iteratively (updates to this site are on our [recent additions page](#)), and [your input and feedback](#) will be essential to the system's success.

These two photographs show stream reaches that look very different - one is flowing through an industrialized area and appears to have been channelized, the other is flowing through woods. However, both were found to be biologically impaired. The state of Connecticut used the Stressor Identification process (the basis for CADDIS) to successfully identify the cause of the biological effects observed in these two streams.

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Last updated on Monday, May 2nd, 2005
URL: <http://cfpub.epa.gov/caddis/>

Local intranet

CADDIS 1 Includes

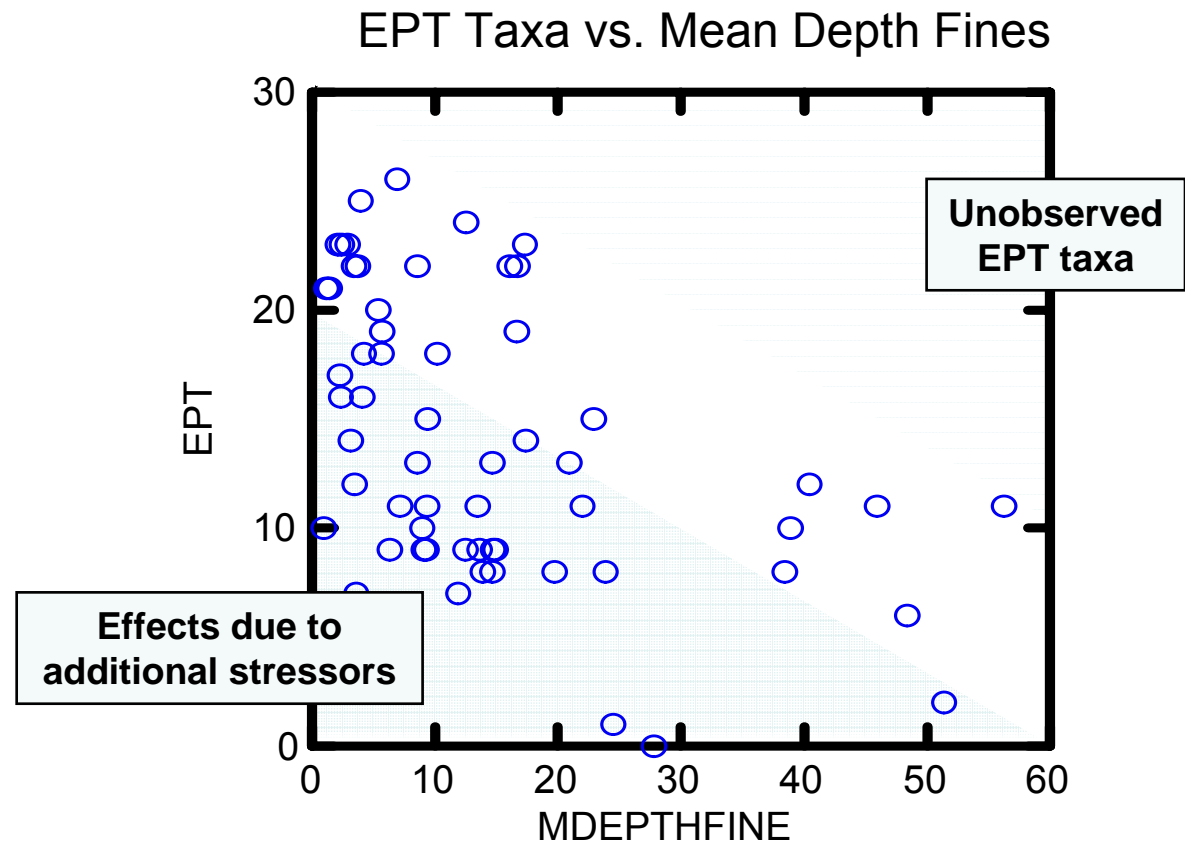
- Step-by-Step Guide
- Worksheets and Examples
- Conceptual Models
- Case Studies
- External links
- References
- Search Glossary

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



ORD Potomac / Shenandoah Team

Sue Norton

Patricia Shaw-Allen

Glenn Suter

Sharon Taylor

Other CATs are standing by