

Data Useful for Causal Analysis

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Useful Measurements

- Measures of the Specific Effect – species, number, life stage/size, location, etc.
- Measures of the Candidate Causes – chemical concentrations, presence of pathogens, etc.
 - Location and status of potential sources
- Symptomology – pathologies, injuries, behavior, body burdens, etc.
- Covariates/modifying factors – temperature, pH, etc.
- Other Relevant Observations – odors, other affected species, etc.

Setting a Sound Foundation

- **What** effects have been observed?
 - What species have been affected?
 - Fish? Macroinvertebrates?
 - Amphibians, reptiles, mammals, algae, macrophytes, birds?
- **What** age classes/sizes have been affected?
 - What distinctive symptoms have been observed?
- **When** have effects been observed?
 - Time of day? Season?
 - When did effects begin? When did they end?
- **Where** have effects been observed?
 - What is the geographic extent of effects?
 - Are there reference areas (e.g., upstream sites, other watersheds) where effects have NOT been observed?

Note: the “case” includes the location(s) where effects are observed and matched locations where effects are not observed, or different effects are observed

Listing Candidate Causes

- Maps or other data on potential sources or land use activities
- Monitoring data on other factors that may interact with stressors (e.g., precipitation, karst geology)
- Monitoring data on in-stream stressors

Organizing the Data: Example

Effect: May 2006 Small-Mouth Bass Kill, Shenandoah River RM X to RM Y

Candidate Cause	Relevant Measurements	Notes/Source
Low Dissolved Oxygen	Dissolved oxygen pH Chlorophyll A	Point DO measurements taken at Woodstock biweekly Source=D. Kain
Ammonia	Ammonia Nitrate/nitrite pH Temperature
Temperature	Wastewater treatment plant temperature. Air temperature
Pathogens	Fish Density Microbiological results	
. . . .		

Monitoring Data Useful for Evidence

Sampling Design

- Co-locate candidate cause and effect sampling in space and time
 - Time sampling to identify exposures
 - Effectively continuous exposures – time sampling to match susceptibility
 - Presence of sensitive life stages
 - Conditions that enhance exposure or effects
 - Episodic exposures – time sampling to characterize episodes
 - Continuous sampling
 - Event sampling – storms, kills, low flows, treatment failures, etc.
 - Post-event sampling – after kills
- Reference sampling
 - Take measurements upstream of the kill
 - Take measurements in tributaries
 - Take measurements in similar streams where no kills have occurred
 - At same time as sampling affected locations

Quality Assured

Don't forget replication

Analyzing the Data

- Data are turned into evidence by making associations:
 - Spatial associations
 - Temporal associations
 - Mechanistic associations
 - Associations between magnitude of cause and magnitude of effect
- Side by side comparisons
- Correlation and regression
 - Use statistics methods freely
 - Use statistical tests cautiously

*Example worksheets available at
www.epa.gov/caddis*

Developing Evidence: Start with 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
- Laboratory Tests of Site Media
- Temporal Sequence
- Verified Predictions
- Symptoms

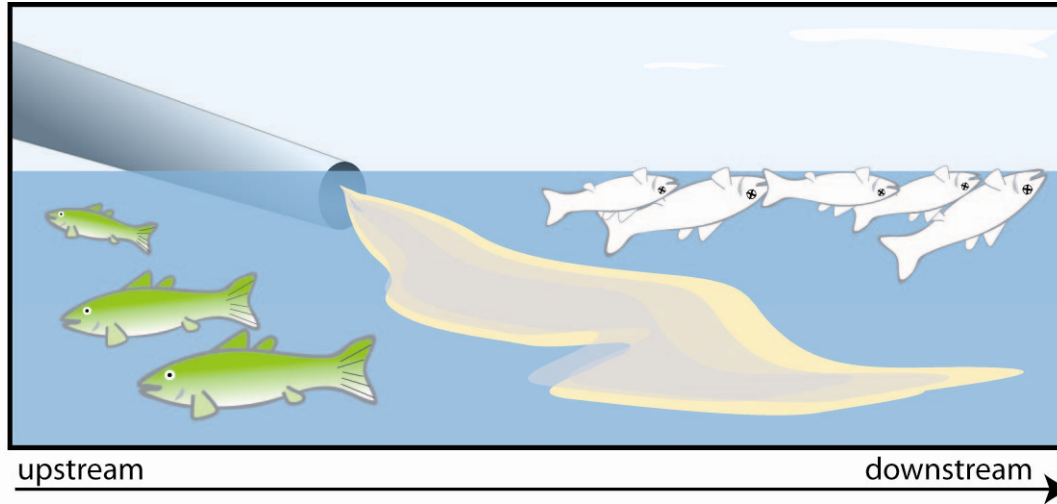
In general, looking for:

- *Data sets where biological response and candidate cause measurements are collected at the same time and place.*

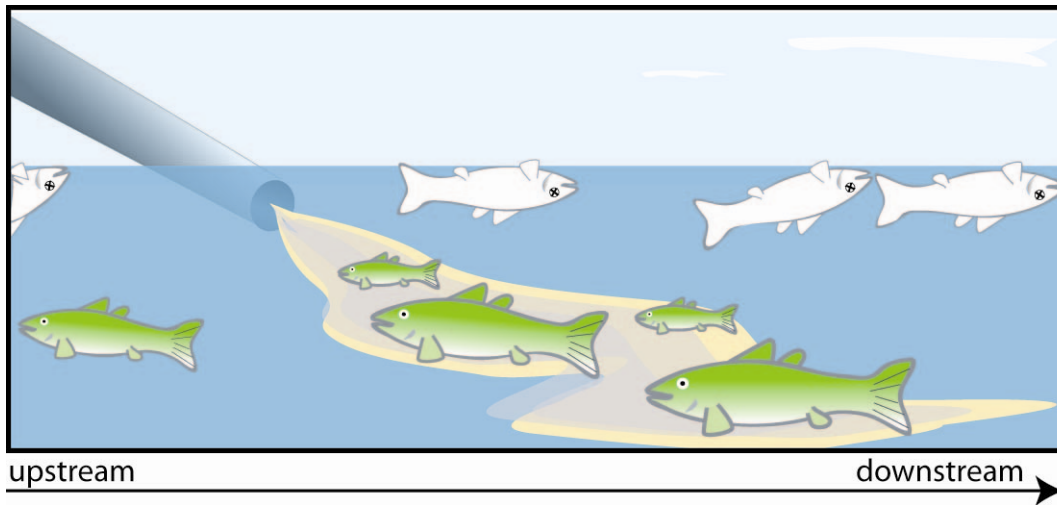
Spatial/Temporal Co-Occurrence

Upstream Downstream Comparison

Looking for: paired measurements of candidate causes and responses at locations where effects are observed AND where effects are not observed.

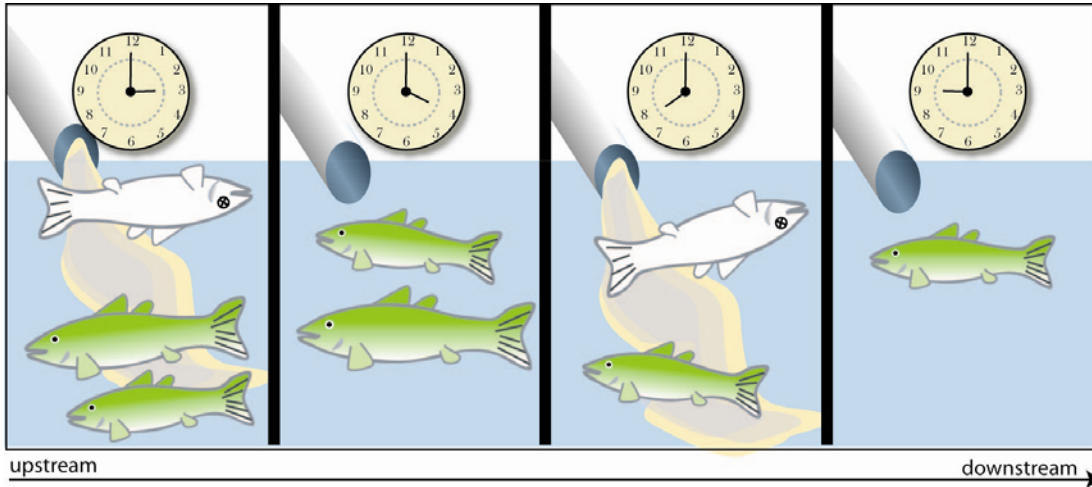


Supports



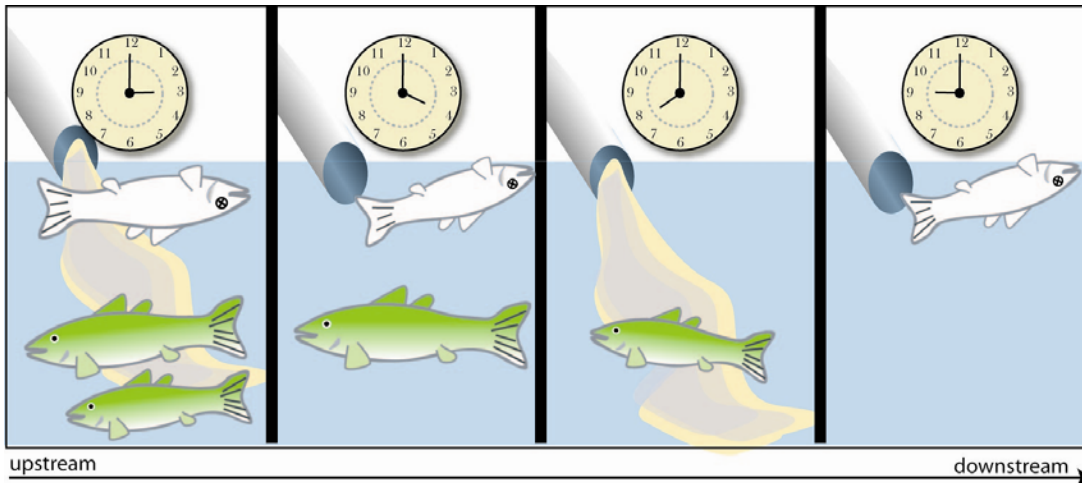
Weakens

Spatial/Temporal Co-Occurrence Through Time



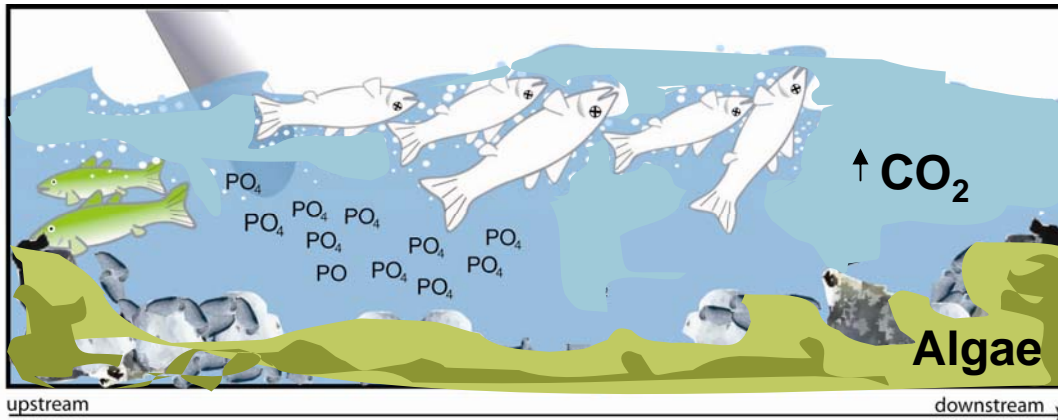
Looking for: paired measurements of candidate causes and responses at times where effects are observed AND when effects are not observed.

Supports



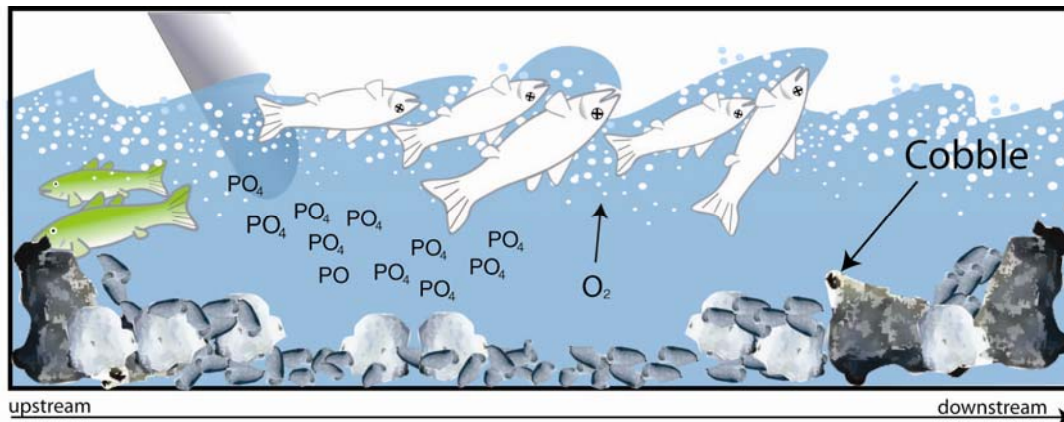
Weakens

Causal Pathway



Looking for: measurements demonstrating steps in the causal chain of events from lead from sources to the proximate stressor. Handy for stressors that are difficult to measure, intermittent or ephemeral.

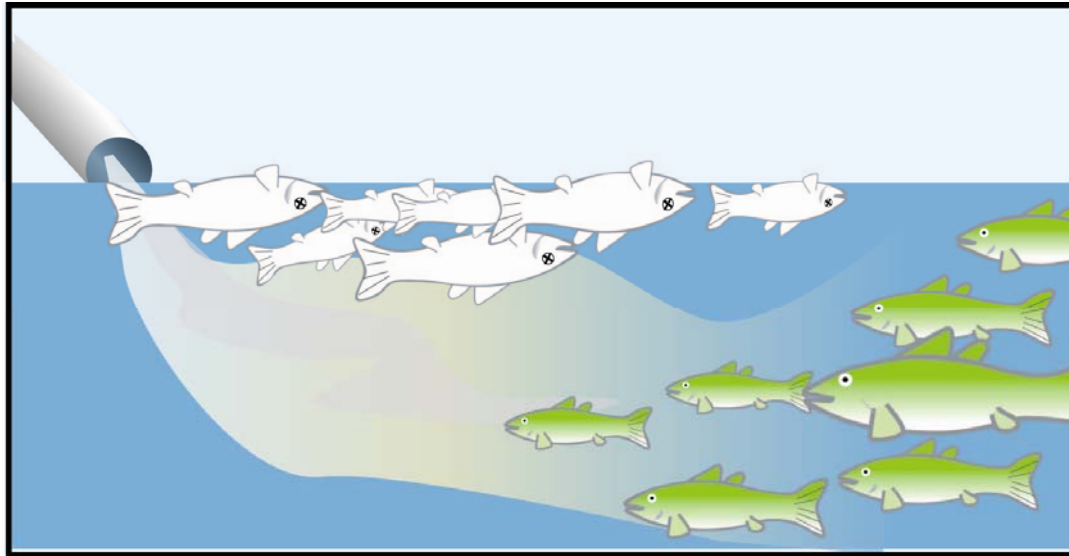
Supports



Weakens

Stressor-Response Relationships

from the Field

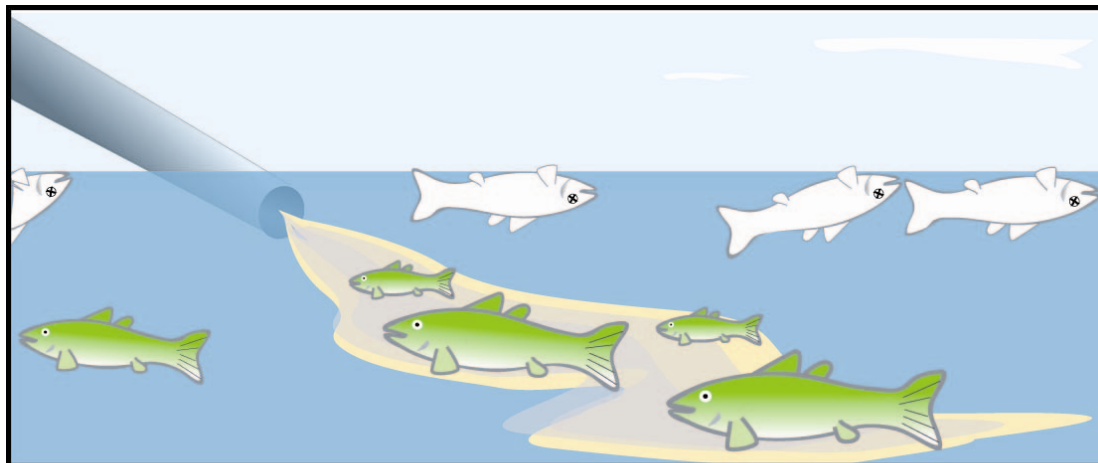


upstream

downstream

Looking for: spatially contiguous samples where biological responses and the candidate cause are both measured.

Strengthens



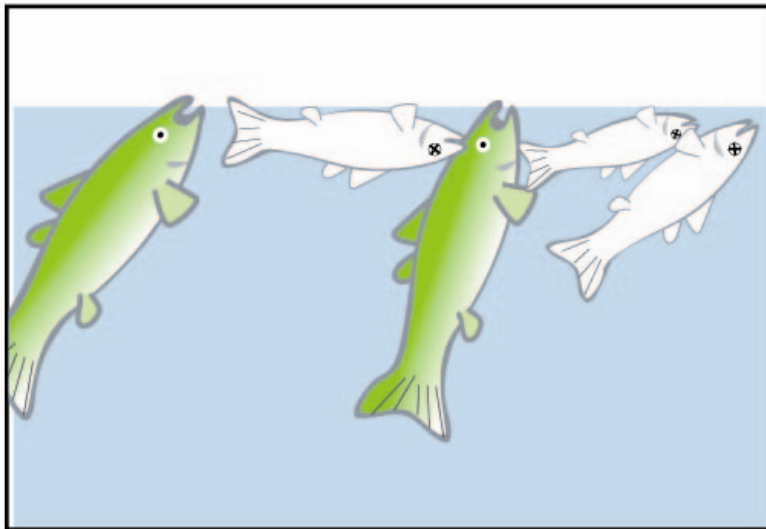
upstream

downstream

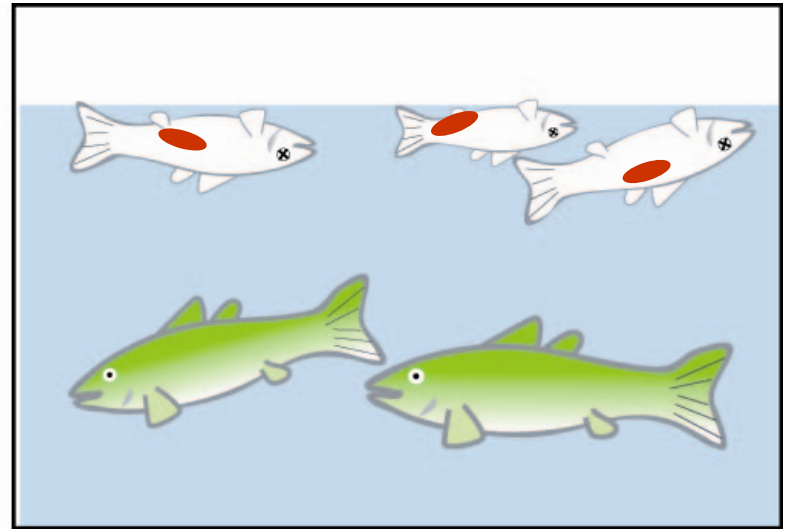
Weakens

Evidence of Exposure or Biological Mechanism

Looking for: measurements demonstrating that the proposed mechanism is actually occurring. Useful measurements include biomarkers, tissue residues, behavioral responses.



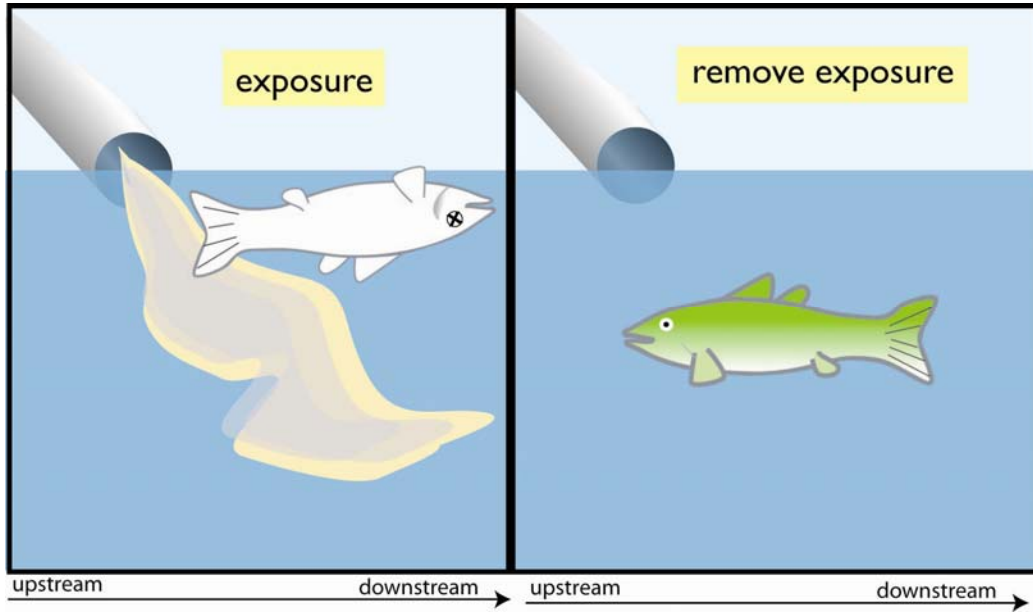
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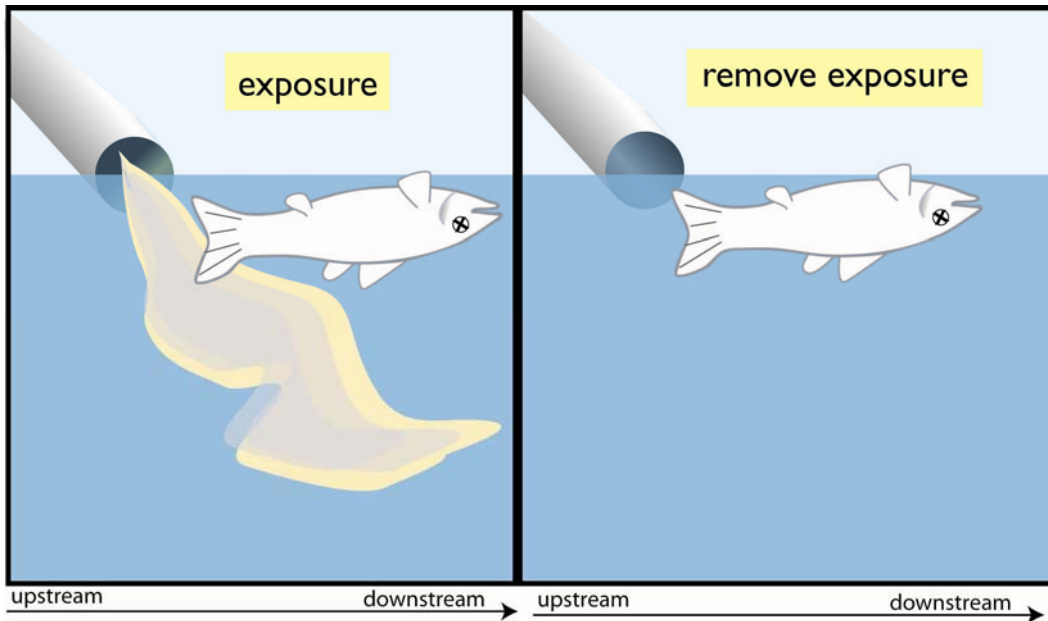
Note: Figure illustrates evidence supporting or weakening the candidate cause of dissolved oxygen

Manipulation of Exposure



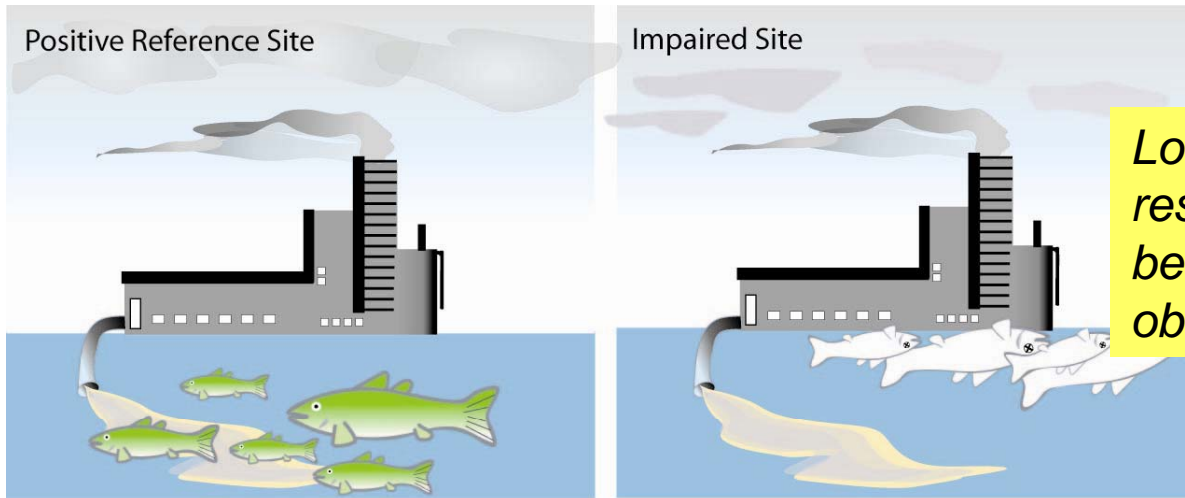
Looking for: situations where a candidate cause has been deliberately manipulated, and the incidence of effects has been monitored.

Supports

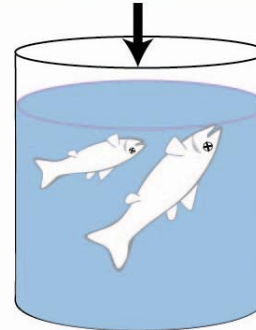
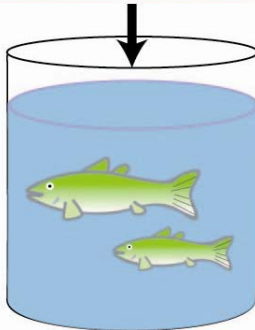


Weakens

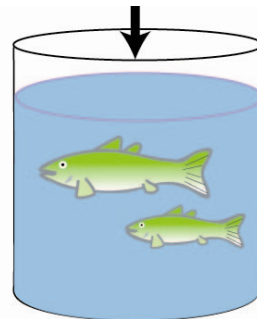
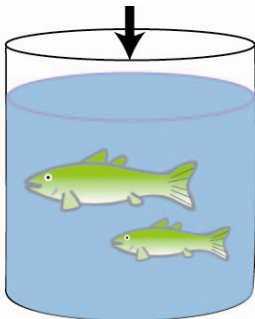
Laboratory Tests of Site Media



Looking for: toxicity test results where effects have been observed AND also not observed.

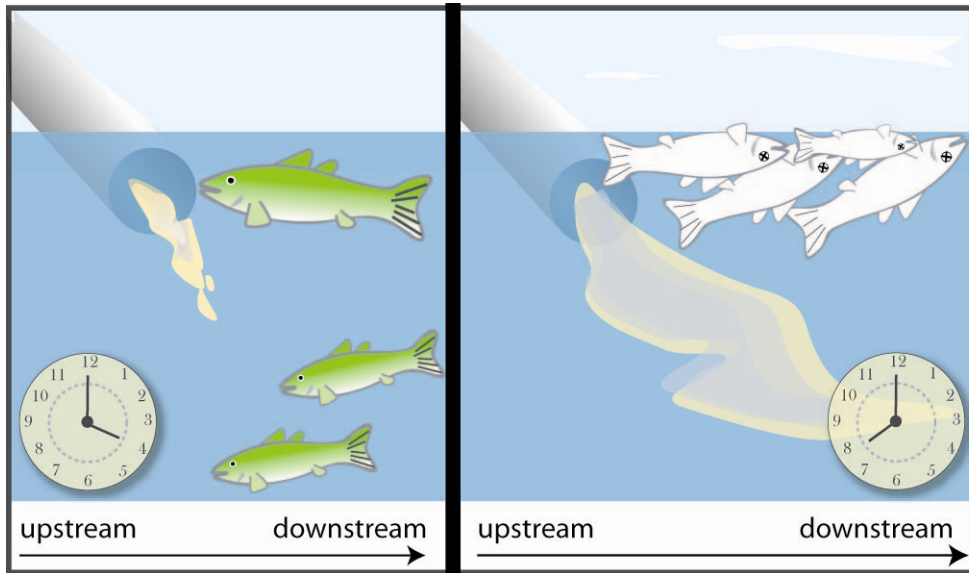


Supports



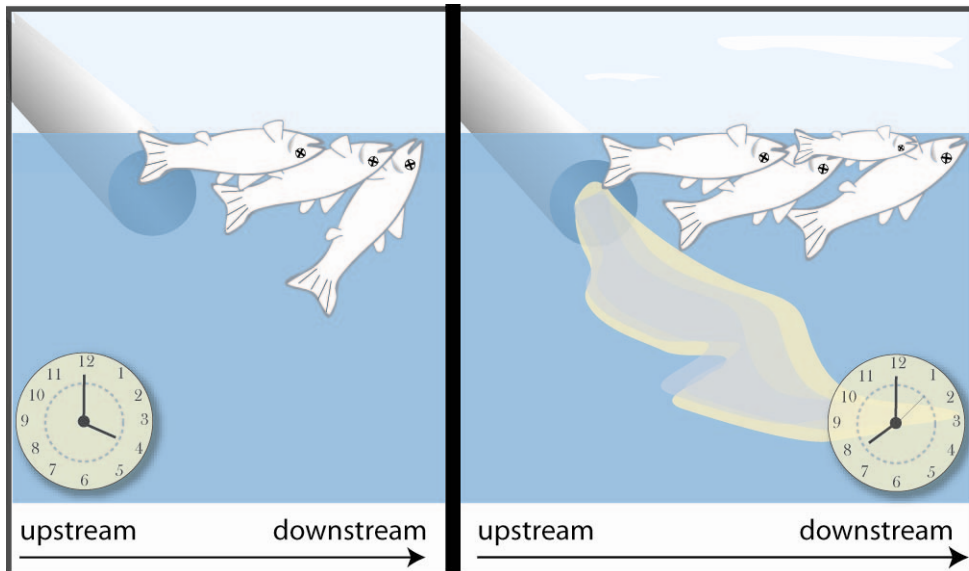
Weakens

Temporal Sequence



Looking for: evidence that exposure to a candidate cause preceded the observed effects.

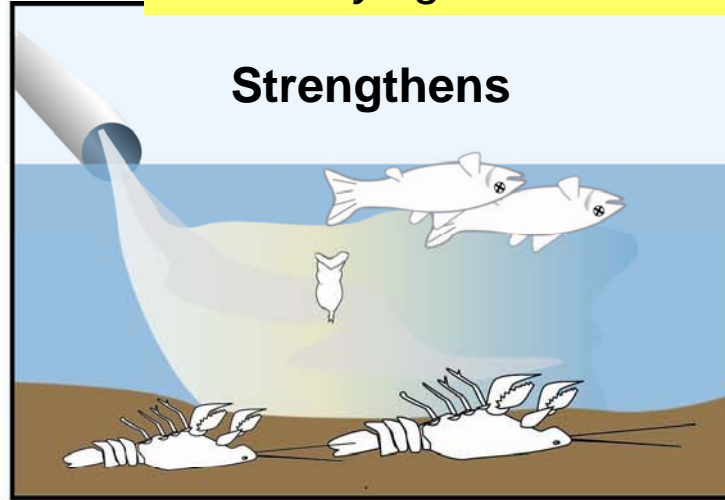
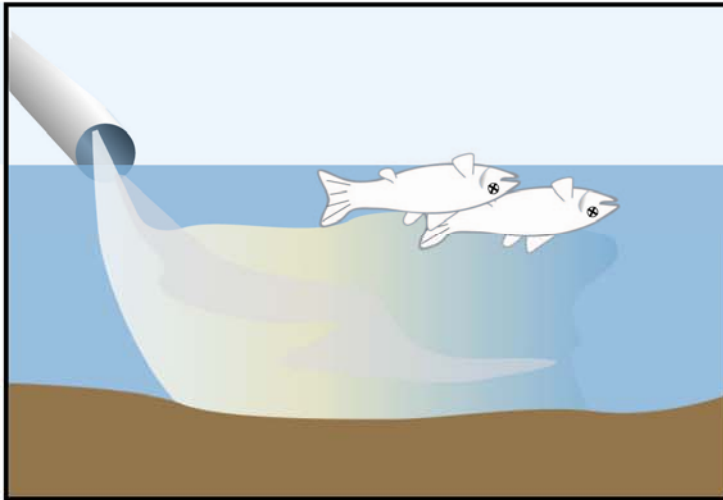
Supports



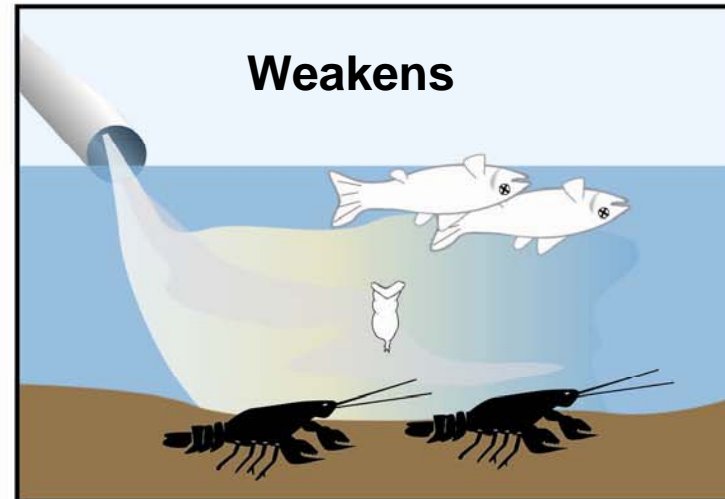
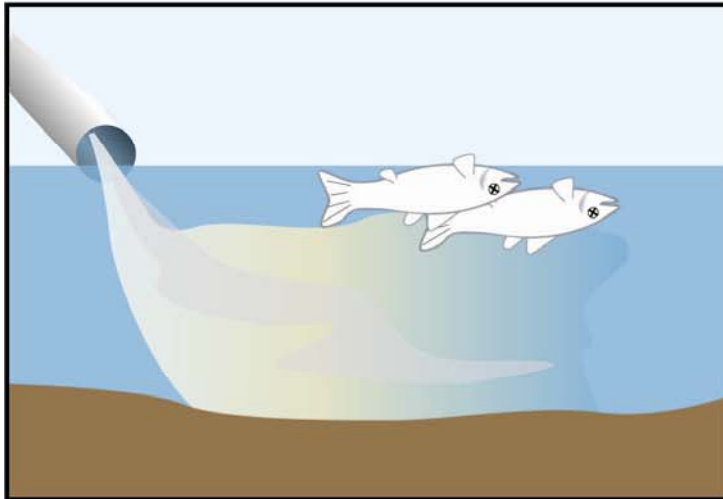
Weakens

Verified Predictions

Looking for:
If the candidate cause is **this**, then
We should observe **that**.
And verifying that is so!



strengthens

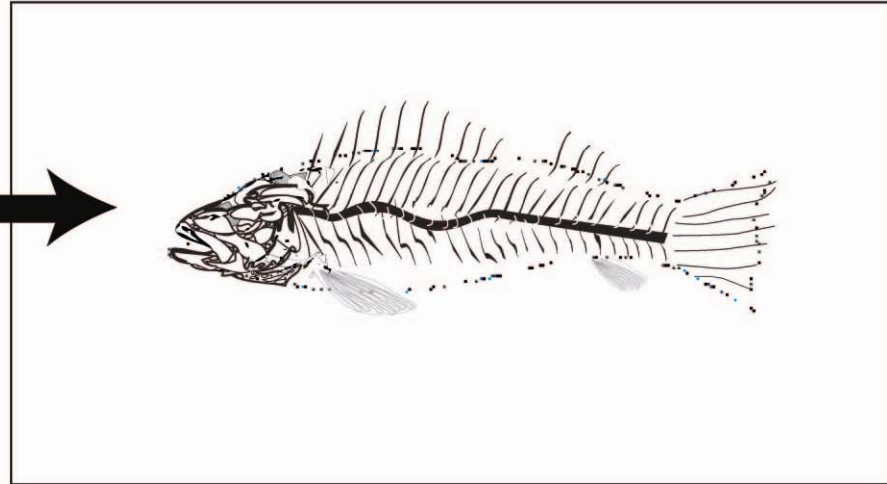
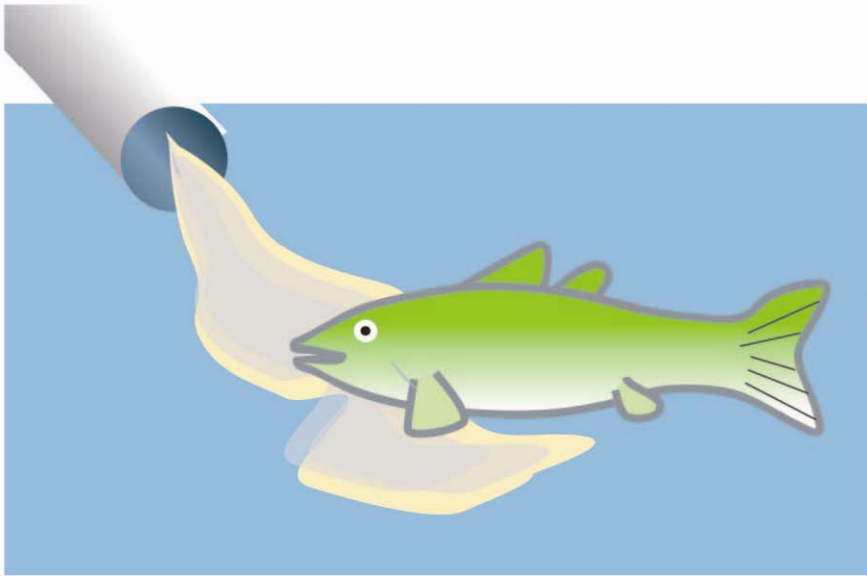


weakens



Symptoms

*Looking for:
Symptoms that are specific to only
one cause*



Strengthens

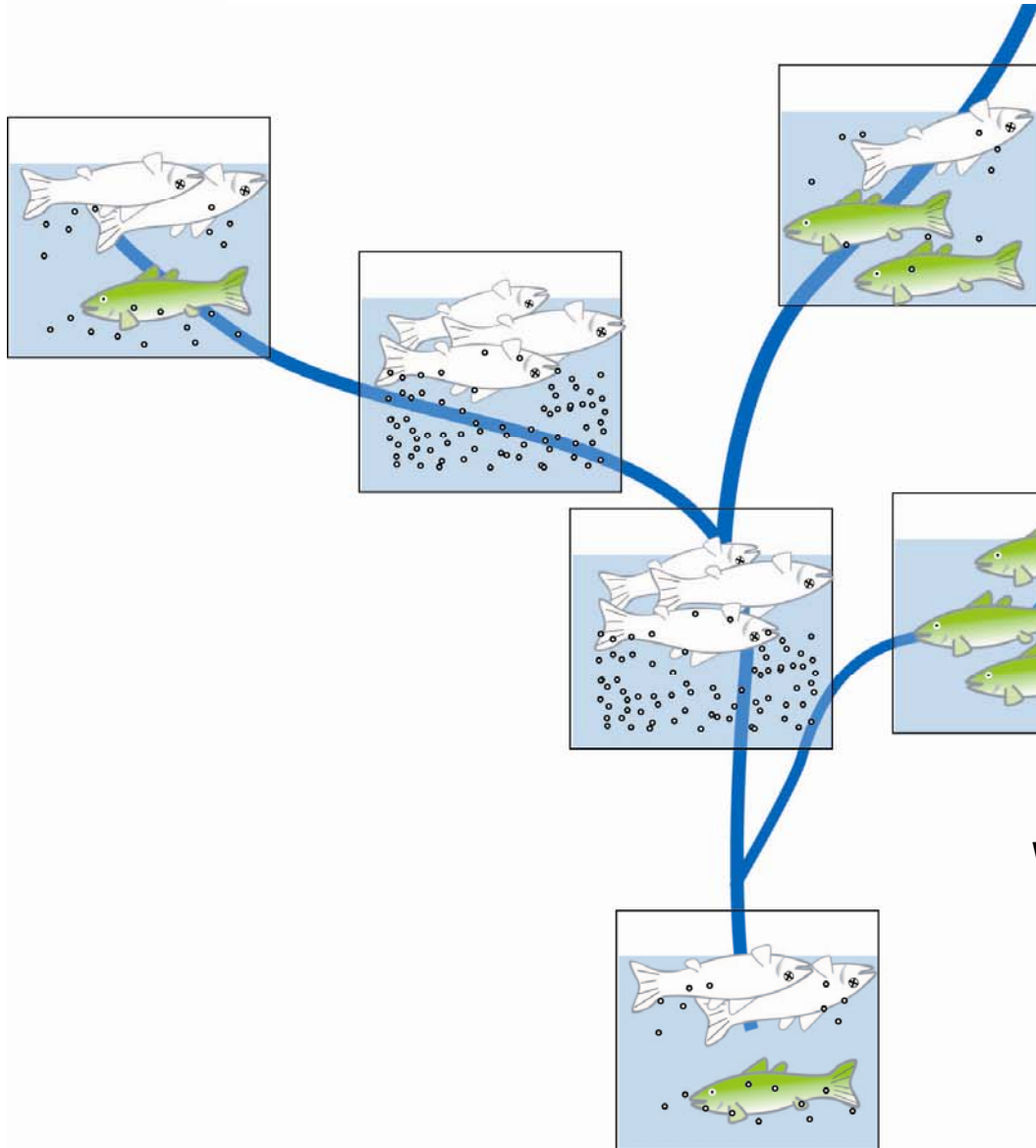
Developing Evidence

Pull in Data from Other Situations, Biological Knowledge

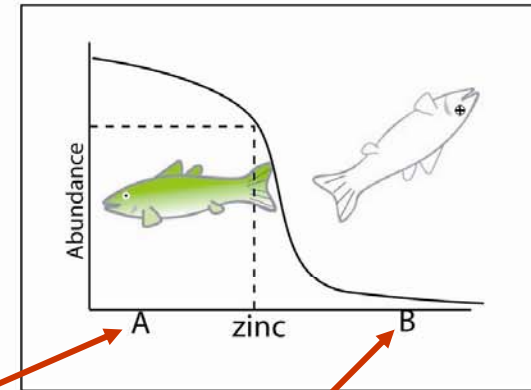
- Stressor-Response Relationships from Other Field Studies
- Stressor-Response Relationships from Laboratory Studies
- Stressor-Response Relationships from Ecological Simulation Models
- Mechanistically Plausible Cause
- Manipulation of Exposure at Other Sites
- Analogous Stressors

Important for determining whether the candidate cause is sufficient to have produced the observed effects.

Stressor-Response Relationships from Other Field Studies



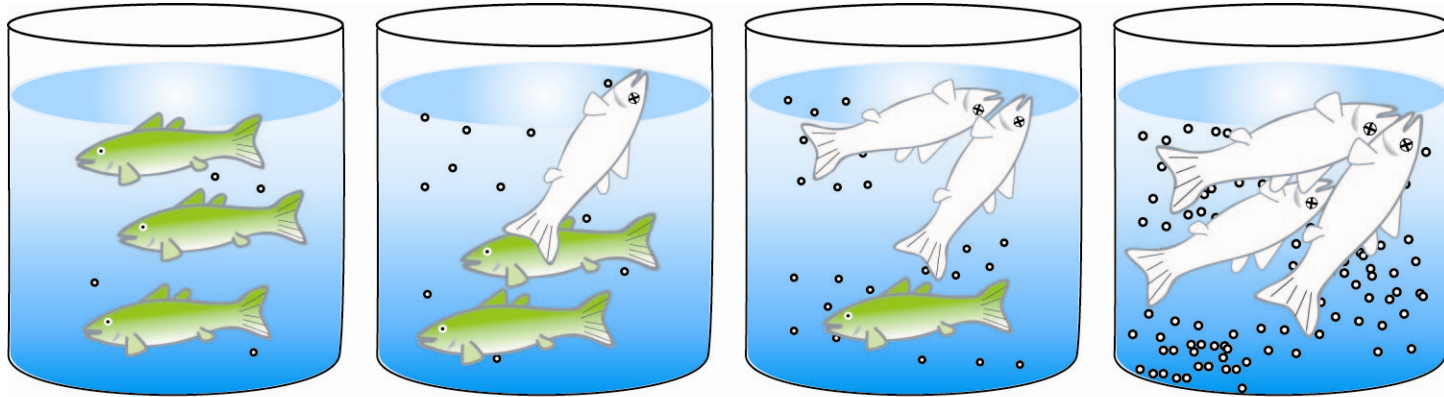
*Looking for:
Relevant relationships that can be
paired with high quality exposure
data.*



Weakens

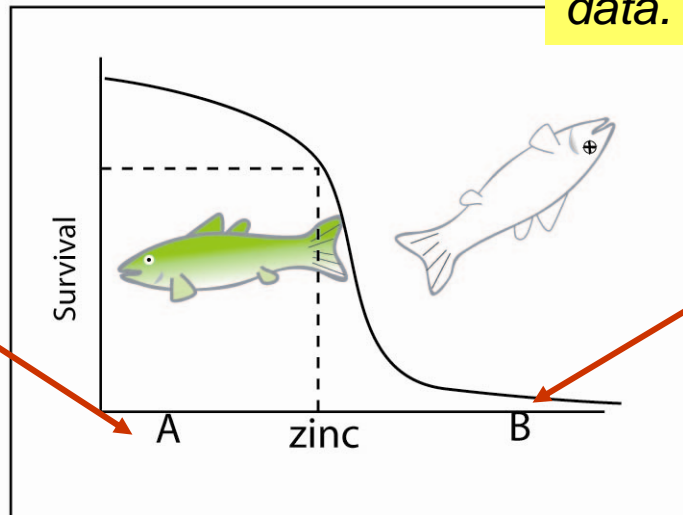
Strengthens

Stressor-Response Relationships from Laboratory Studies



*Looking for:
Relevant relationships that can be
paired with high quality exposure
data.*

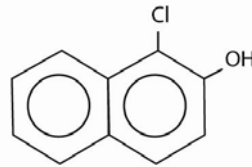
Weakenes



Strengthens

Stressor-Response Relationships from Ecological Simulation Models

a + b



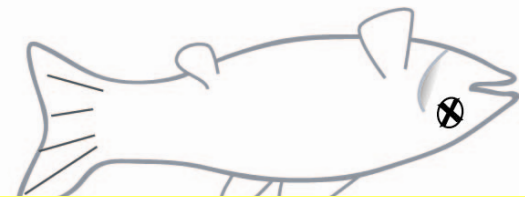
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c + d



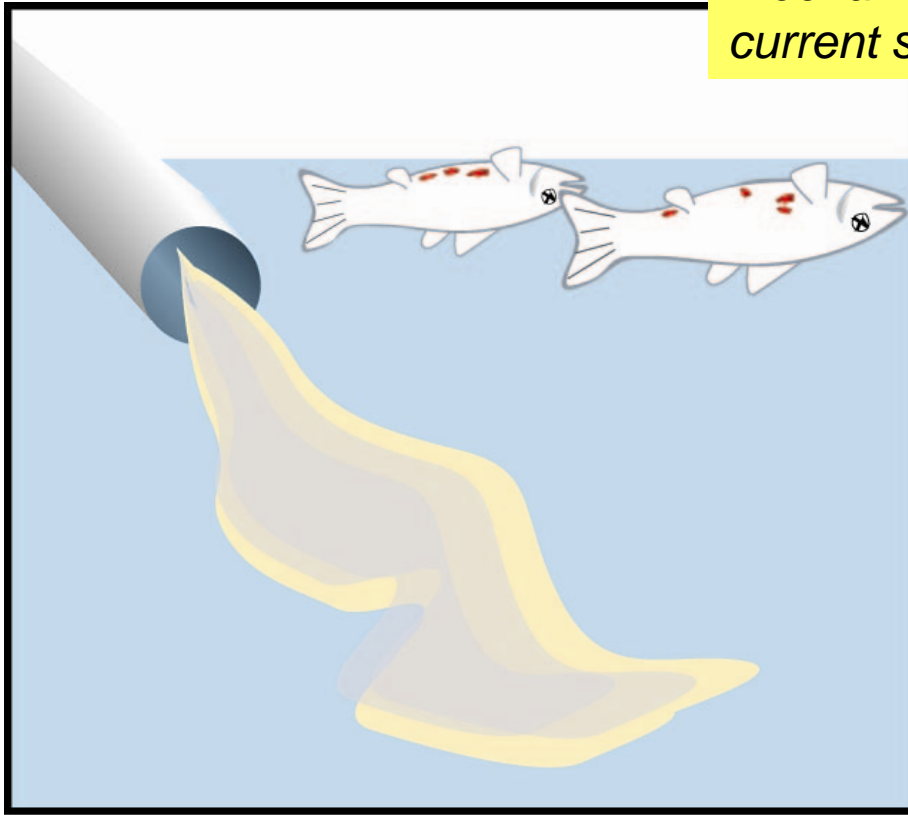
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*Looking for:
Results of a simulation model
predicting that the observed effects
would be expected.*

Mechanistically Plausible Cause

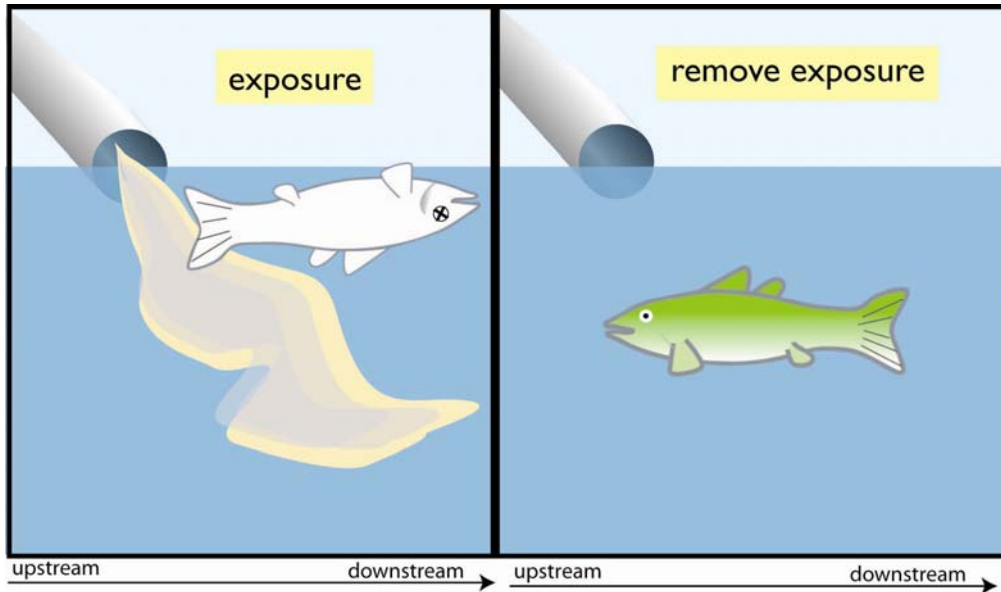
*Looking for:
Evidence that the proposed
mechanism is consistent with
current scientific knowledge.*



Weakens

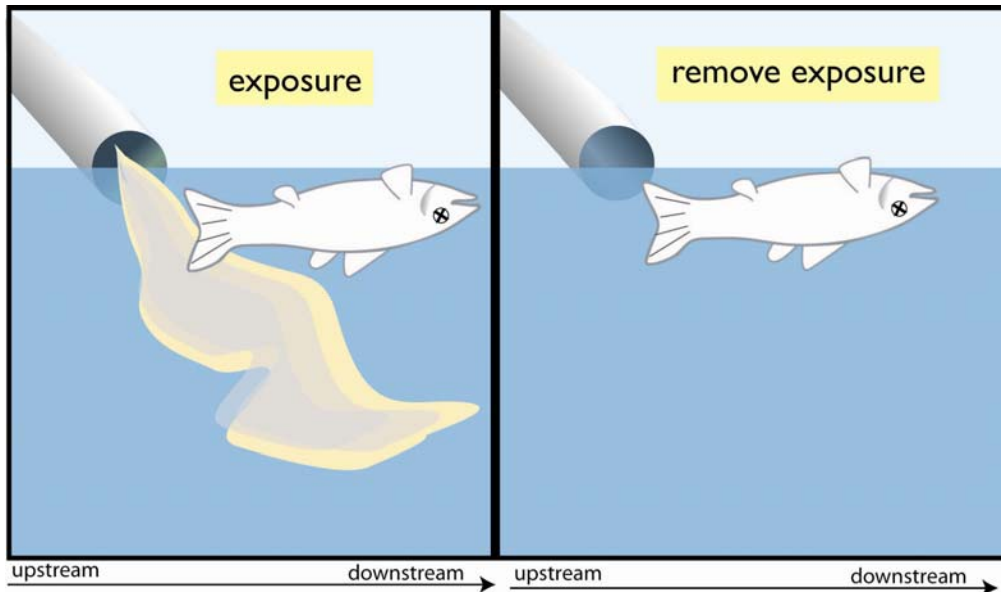
Manipulation of Exposure

at Other Sites



Looking for: situations where a candidate cause has been deliberately manipulated, and the incidence of effects has been monitored.

Strengthens

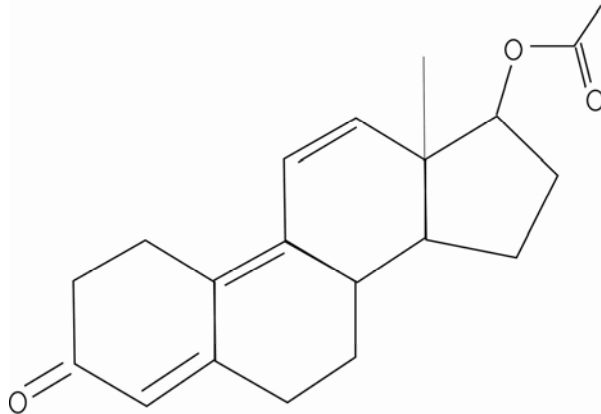


Weakens

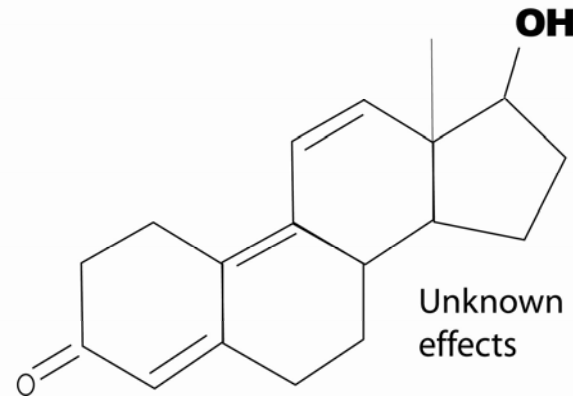
Analogous Stressors

*Looking for:
Evidence that candidate causes
present are structurally similar to
others that are known to produce
the observed effects.*

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

Weigh the Evidence for Each Candidate Cause

- Evaluate the quantity and quality of evidence
- 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.

Credibility of Multiple Types 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	-

Output of process: example scoring table

	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 Biological Mechanism	+	+	+	-	+	+	-	+
Causal Pathway		-	+	-	-	+	-	+
Stressor-Response from the Field	+	-		-	+	+		
Manipulation of Exposure								+
Verified Predictions								+
Types of Evidence that Use Data from Elsewhere								
Stressor-Response from Other Field	- -	+						
Stressor-Response from Laboratory	+	-			-	+		
Evaluating Multiple Types of Evidence								
Consistency of Evidence	-	-	-	-	-	+	-	+

Output of process: example annotated conceptual model asphyxiation due to low dissolved oxygen

