National Biological Assessment and Criteria Workshop

Advancing State and Tribal Programs

Coeur d'Alene, Idaho
31 March – 4 April, 2003

SI 101

# *Step by Step through Causal Evaluation*


***Presented by***

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Environmental Protection
Agency

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Washington DC 20460

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Development
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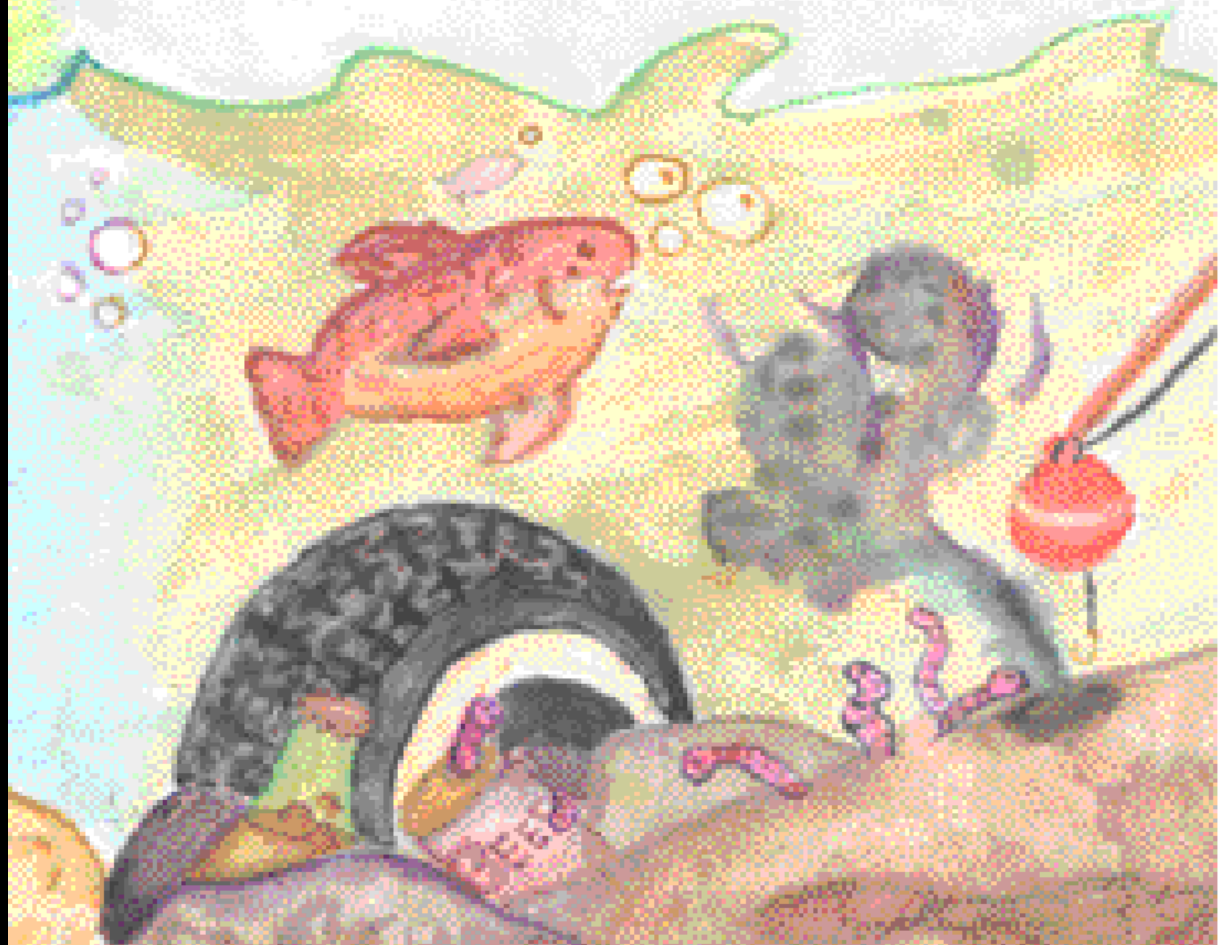
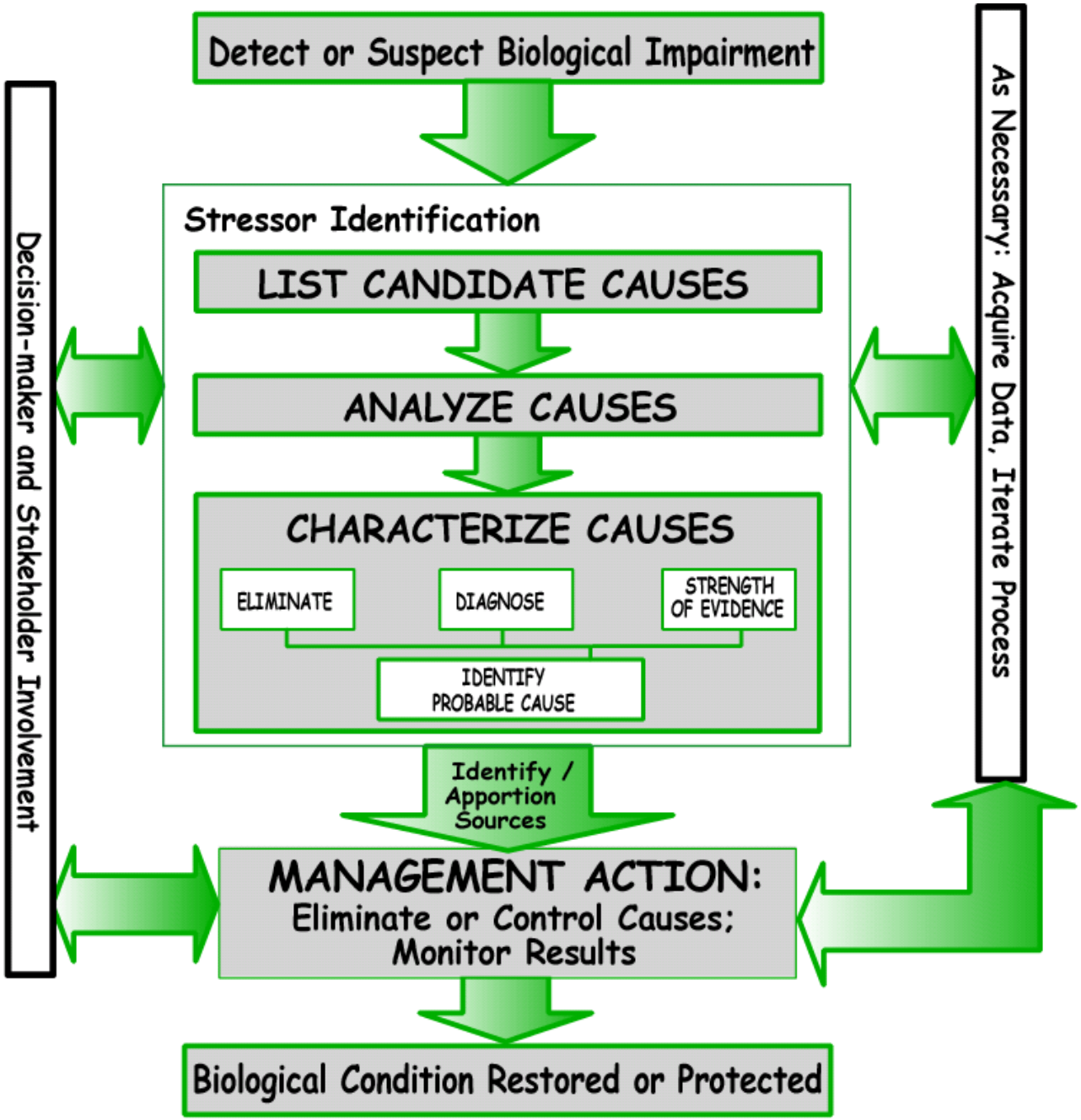
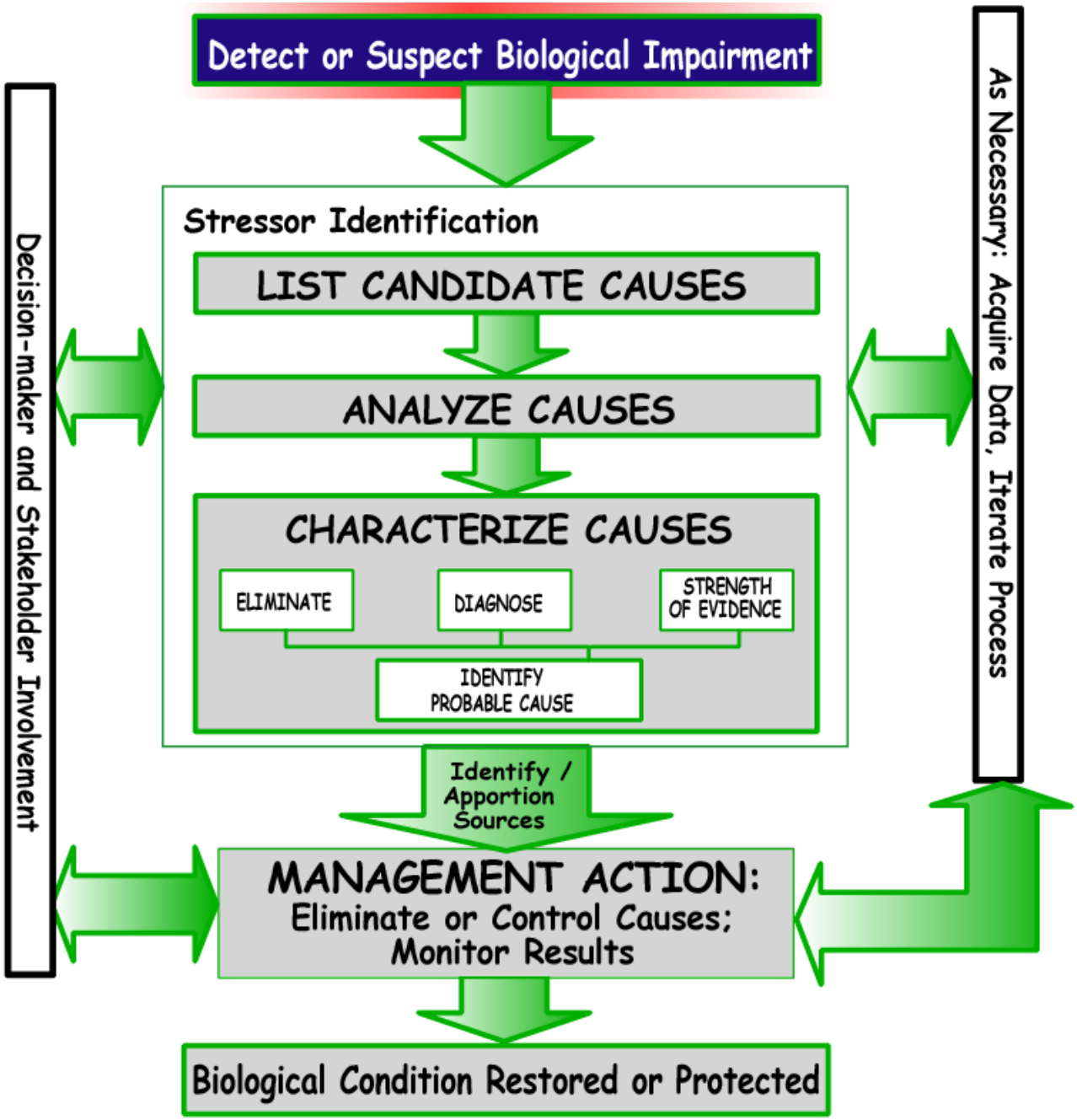
EPA

# Stressor Identification Guidance Document




Detect or Suspect Biological Impairment
Stressor Identification
LIST CANDIDATE CAUSES
ANALYZE CAUSES
CHARACTERIZE CAUSES
ELIMINATE
DIAGNOSE
STRENGTH OF EVIDENCE
IDENTIFY PROBABLE CAUSE
Identify / Apportion Sources
MANAGEMENT ACTION:
Eliminate or Control Causes;
Monitor Results
Biological Condition Restored or Protected
Decision-maker and Stakeholder Involvement
As Necessary: Acquire Data, Iterate Process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As Necessary: Acquire Data, Iterate Process

# Stressor identification is triggered by observed effects, such as:

- Kills of fish, invertebrates, plants, domestic animals, or wildlife

# Stressor identification is triggered by observed effects, such as:

- Anomalies in any life form, such as tumors, lesions, parasites, disease

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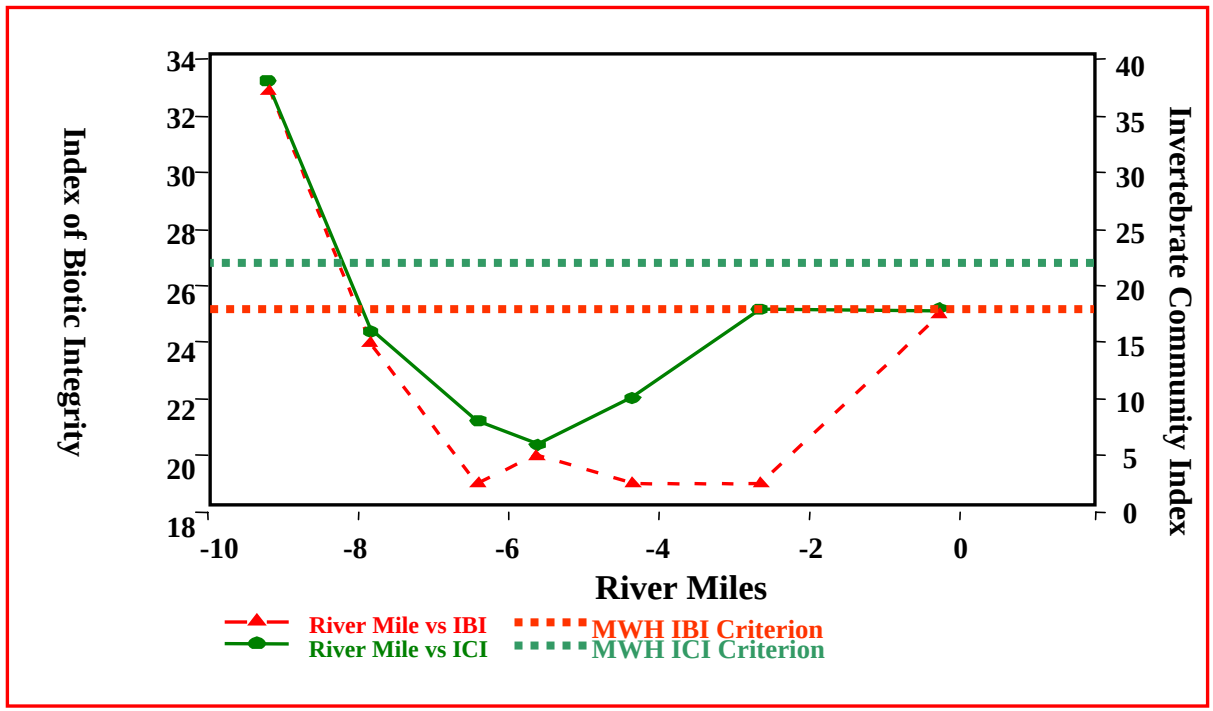
- Response of indicators such as the Index of Biotic Integrity (IBI) or the Invertebrate Community Index (ICI)



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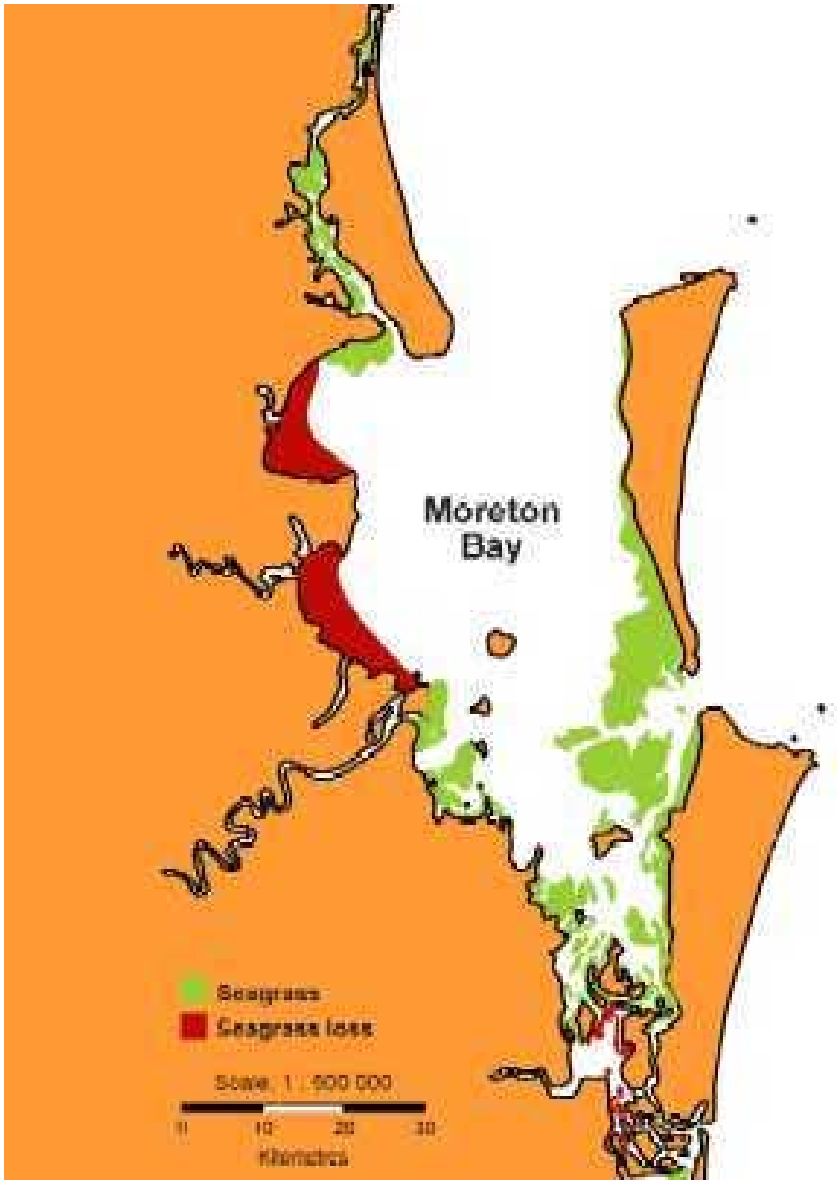
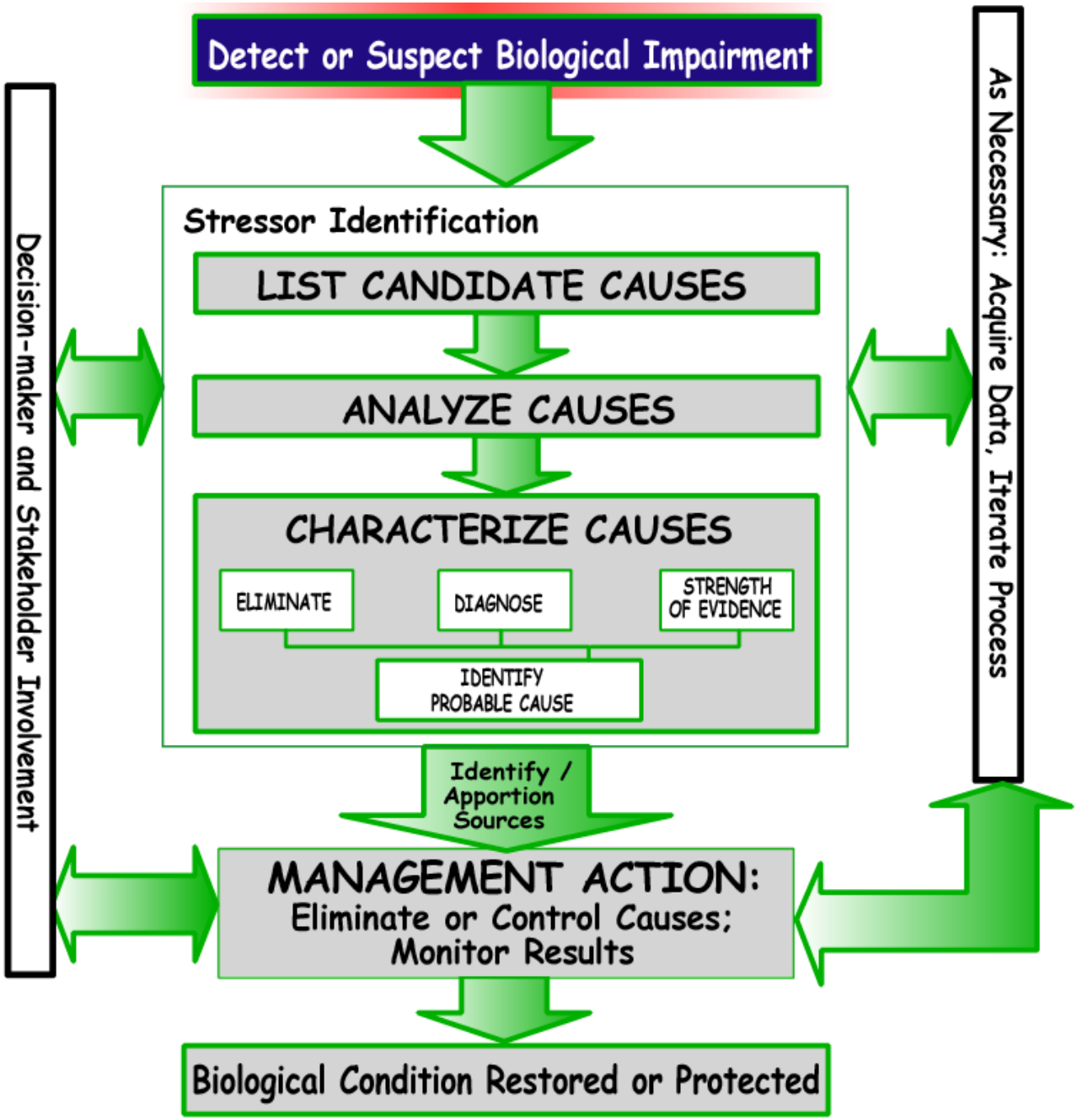



- **Changes in population, ecosystem or landscape-level endpoints**

**Approximately 15 km$^2$ of seagrass beds have been lost from southern Deception Bay Australia since 1996**

Rocky River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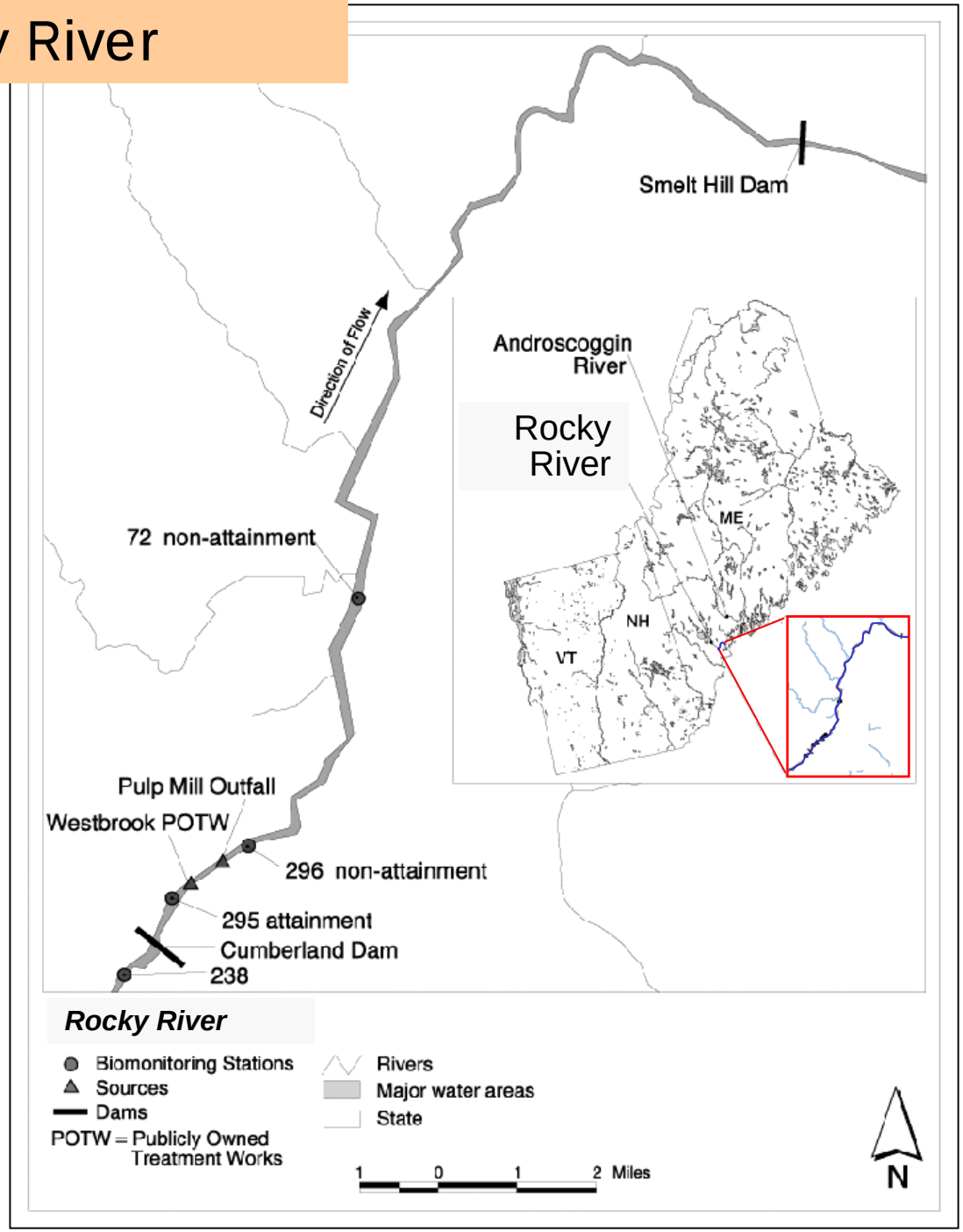
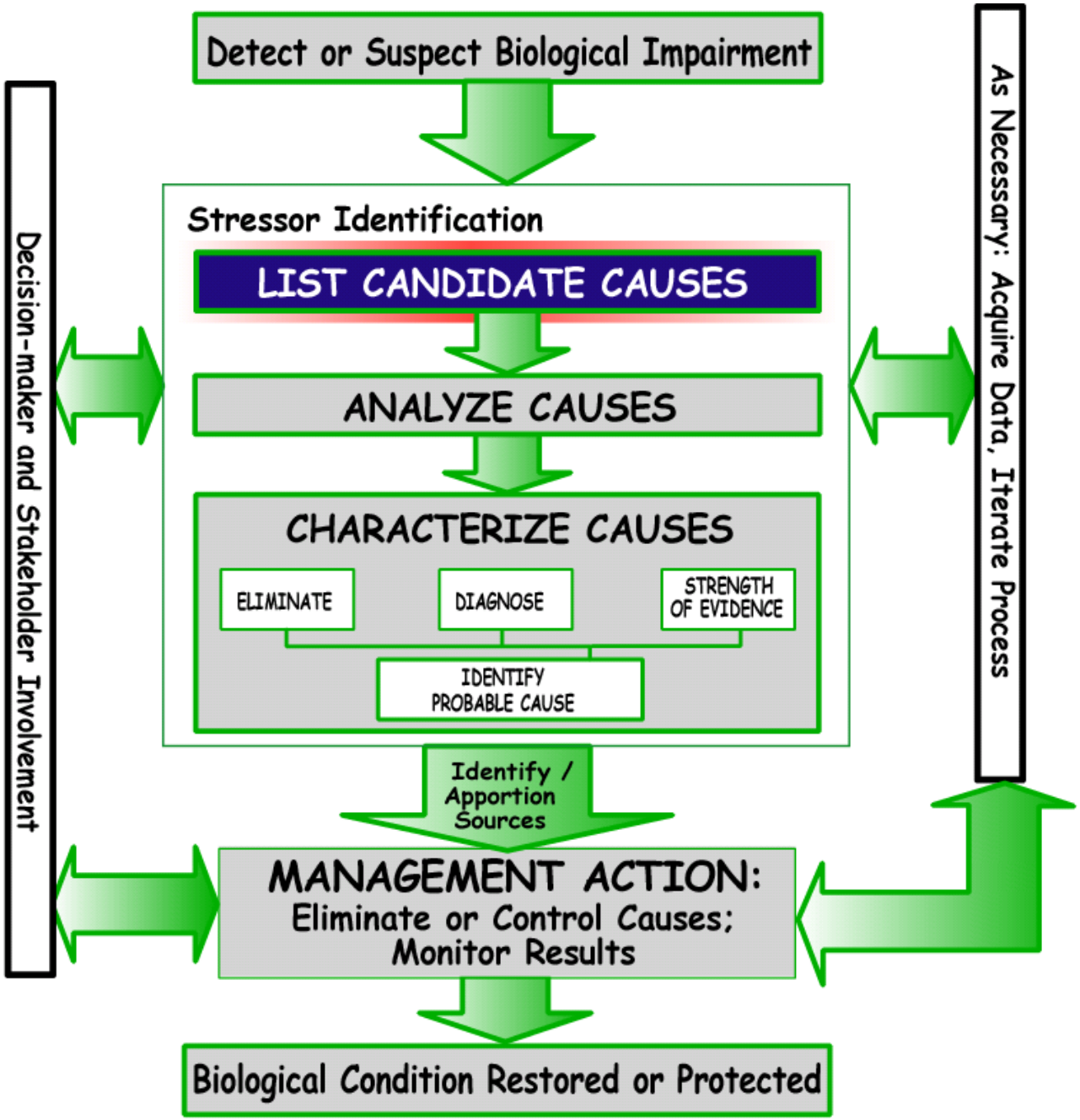
# Rocky River


Smelt Hill Dam
Direction of Flow
Androscoggin River
Rocky River
ME
NH
VT
72 non-attainment
Pulp Mill Outfall
Westbrook POTW
296 non-attainment
295 attainment
Cumberland Dam
238
Rocky River
Biomonitoring Stations
Sources
Dams
POTW = Publicly Owned Treatment Works
Rivers
Major water areas
State
1 0 1 2 Miles
N

# Biological Impairment

Sampling Point 296: Non-attainment of Class C.

Rocky River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# List Candidate Causes

- **Causes:**
  - **Must be potentially sufficient to cause the impairment**
  - **May include several causes that act together (causal scenarios)**

# List Candidate Causes

**To Develop the List:**

1. **Examine effects in more detail**
2. **Make a map**
3. **Consider potential sources**
4. **Gather information**
5. **Develop a conceptual model**

# Examine Effects in more detail. Compared with 295, Sampling point 296 had. . .

40-60% fewer mayfly, stonefly, and caddisfly taxa

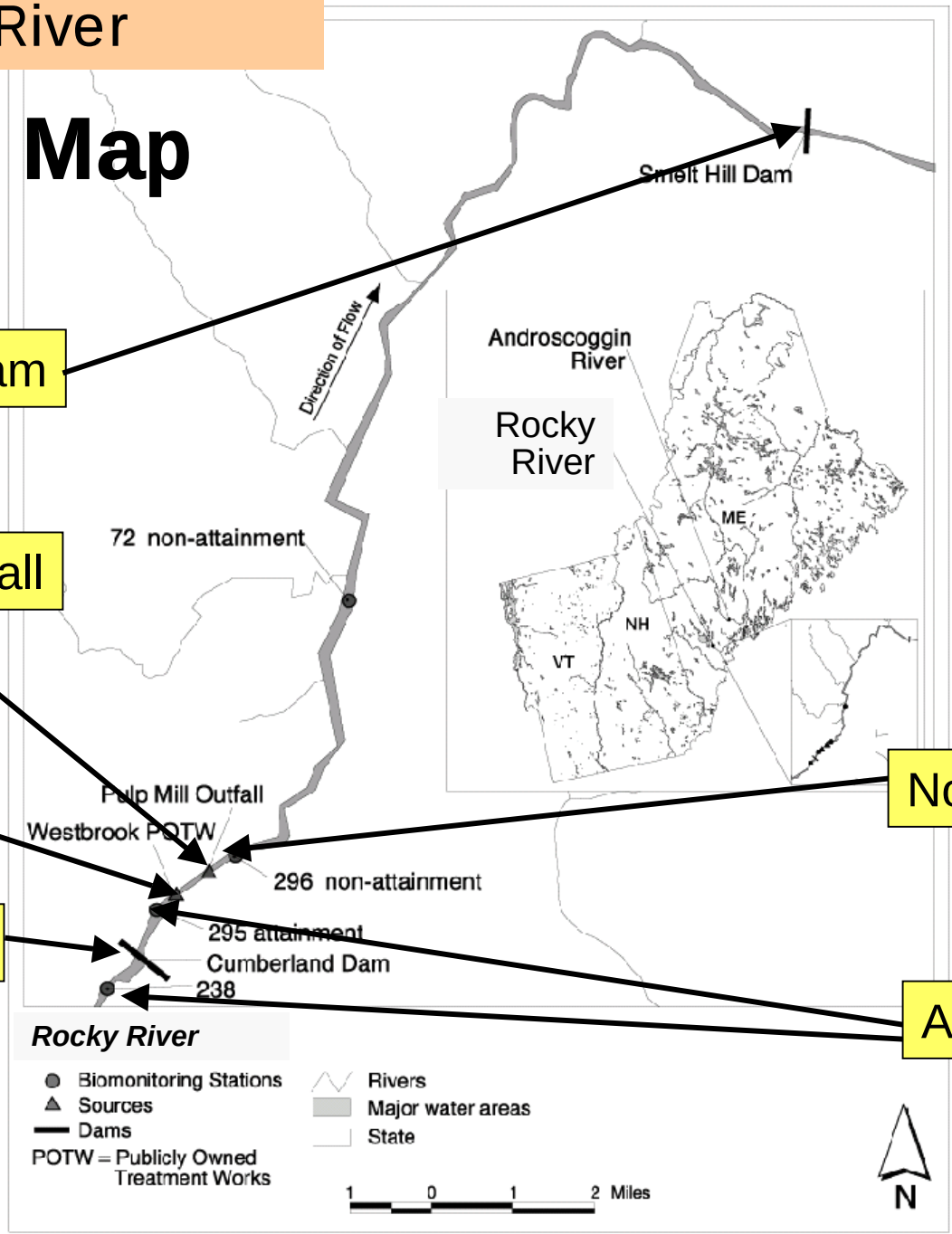
more snails and worms:
90% insects at 296
50% insects at 295

# Biological Impairment

| Evidence | Upstream of Effluent | Downstream of Effluent |
|---|---|---|
| Aquatic Life Standard | Class C | Non-Attainment |
| Benthic Macroin-vertebrate Comm. | 90% insects | 50% insects |
| Taxonomic Richness | -- | 15% - 35% decrease relative to upstream |
| Sensitive Species (EPT) | -- | 46% - 60% decrease relative to upstream |
| Snails and Worms | Low | High |

# Rocky River

# Make a Map




Downstream Dam

Pulp Mill Outfall

POTW

Upstream Dam

Non-Attainment

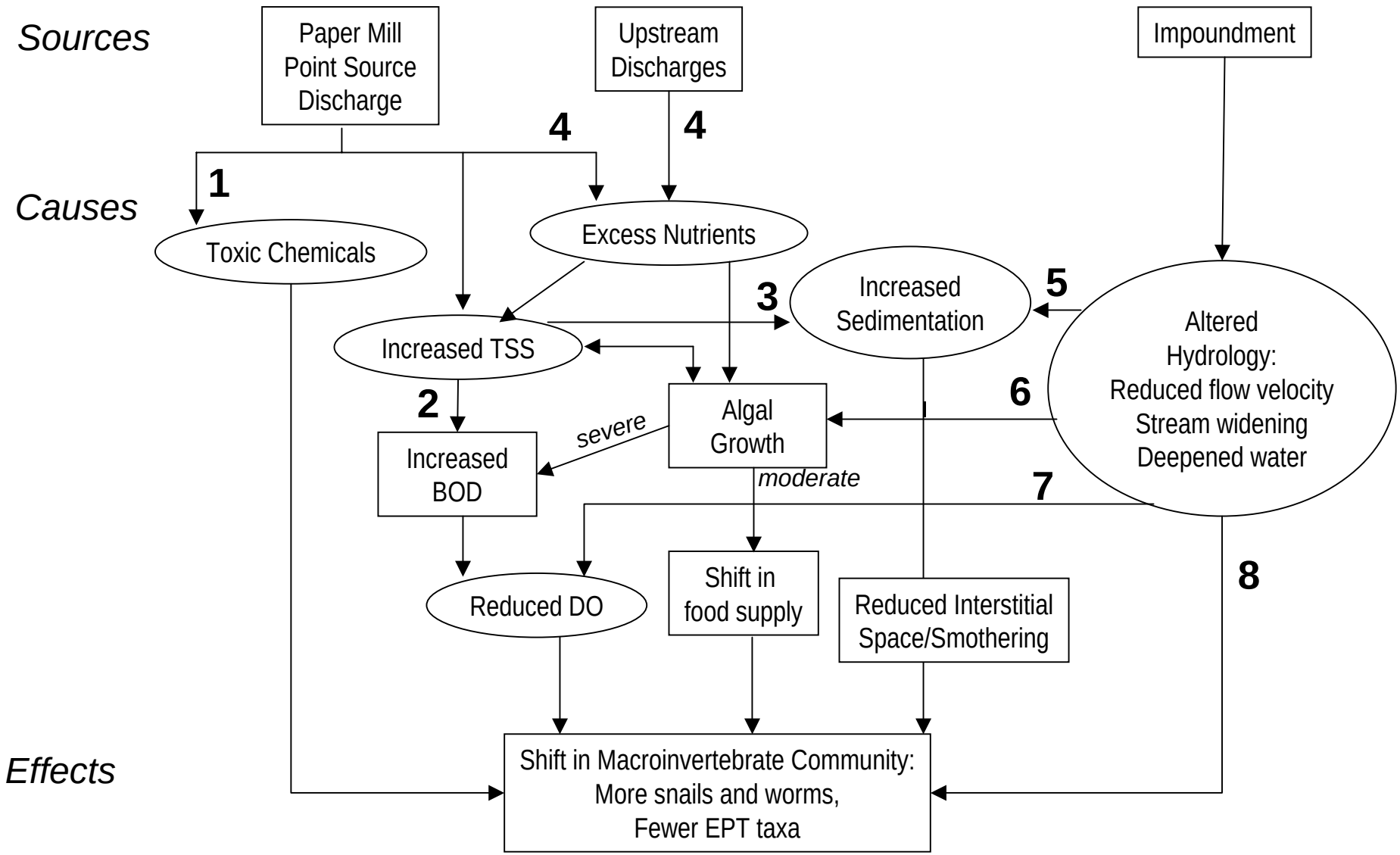
Attains Class C

# Gather Information

- Data available on:
  - Visibility in water (Secchi depth)
  - Floc on sampling equipment
  - TSS, BOD, DO, nitrate-nitrite, total phosphorus, mean orthophosphate, chlorophyll *a*
  - Metal concentrations in effluent from paper mill

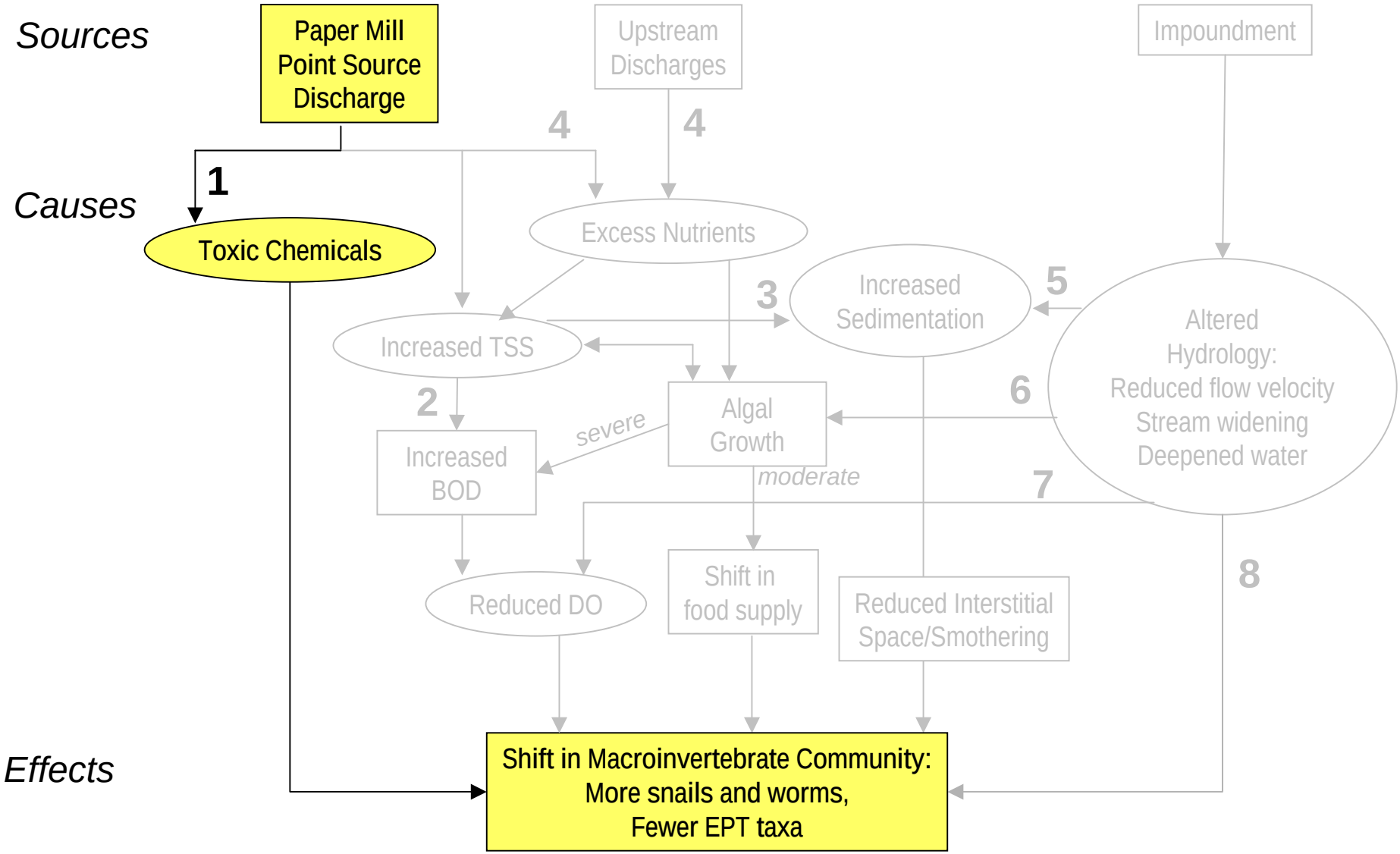
# Rocky River

# Conceptual Model



# Rocky River

# Conceptual Model



# Rocky River

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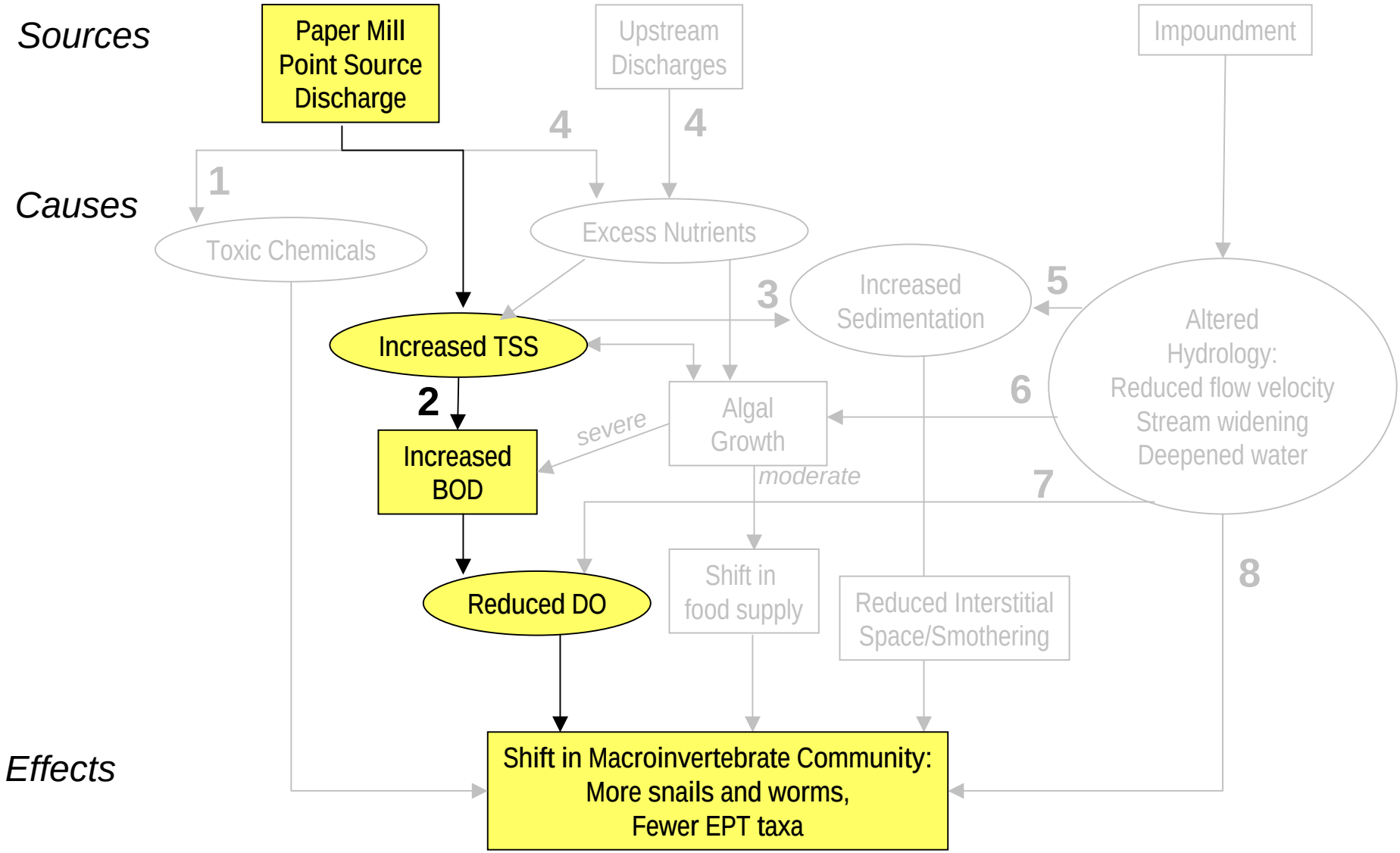

# Rocky River

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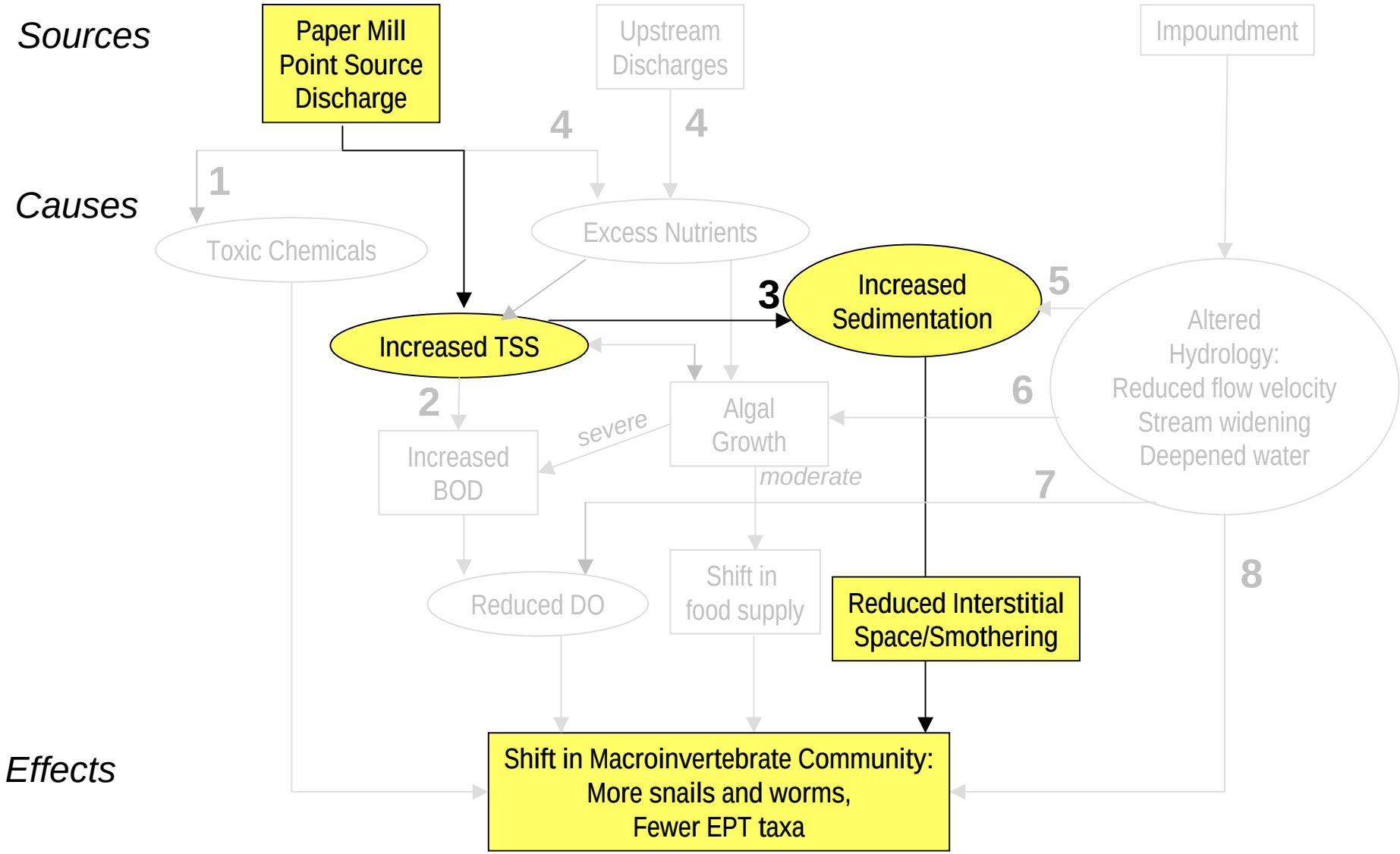

# Rocky River

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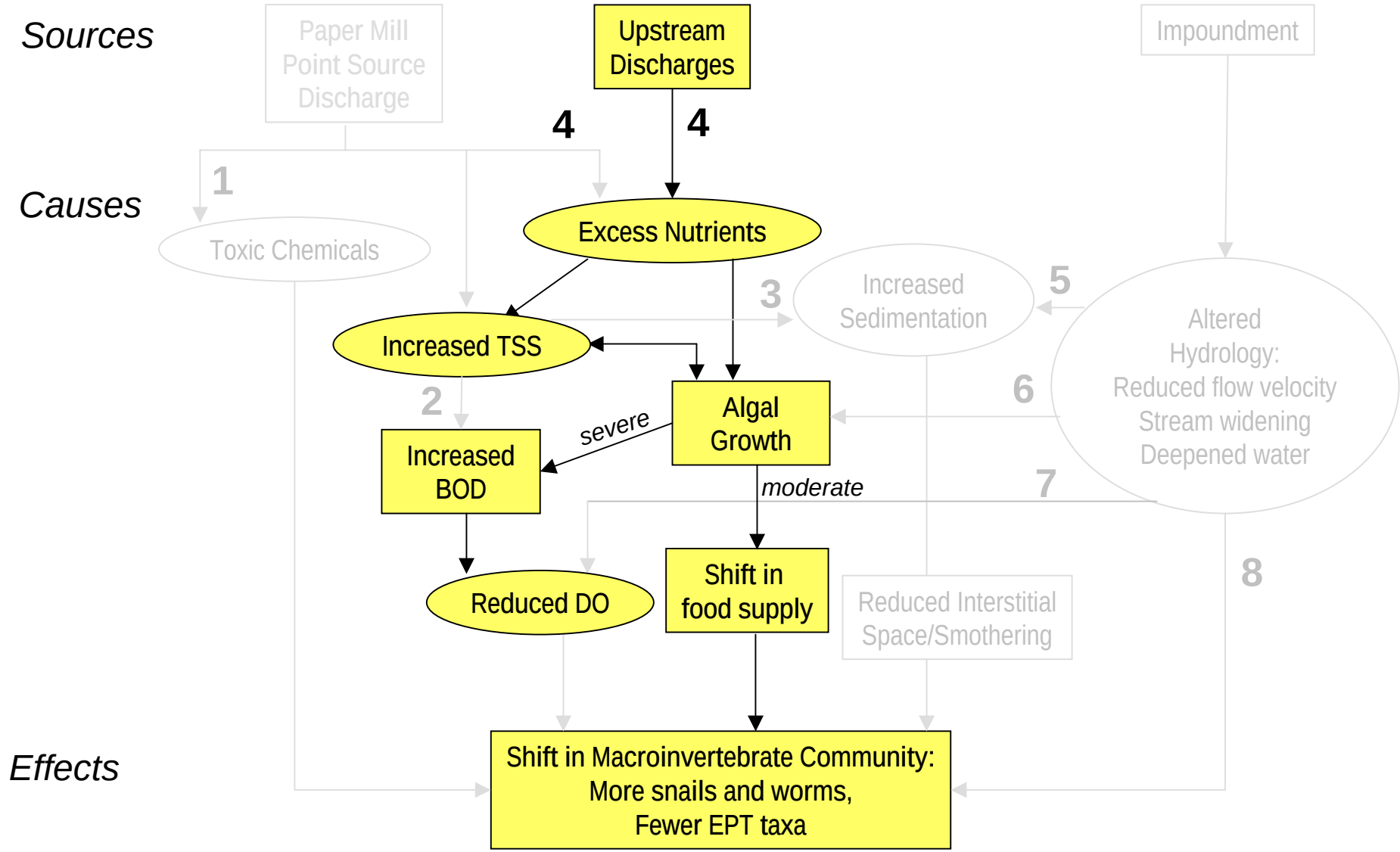

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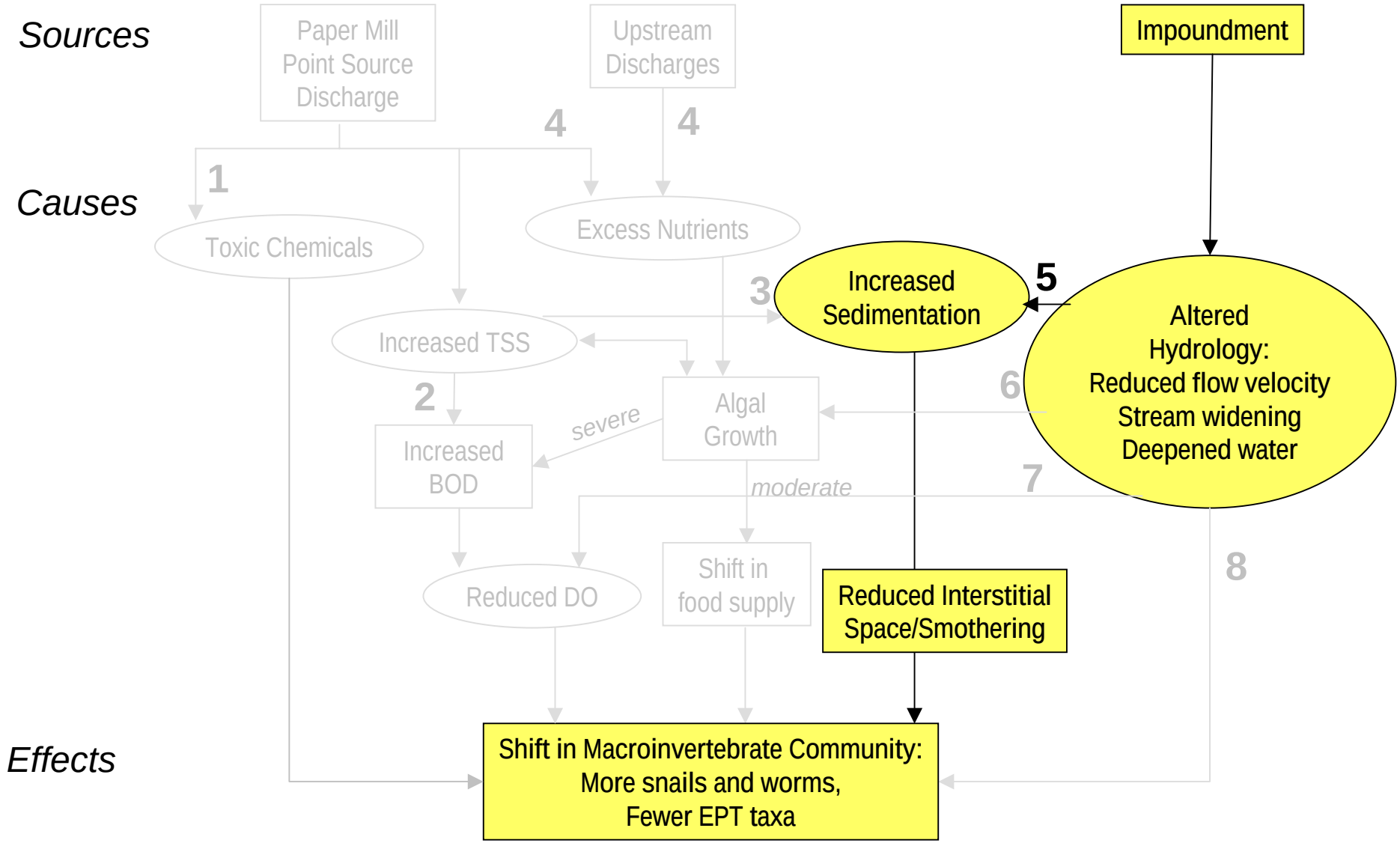

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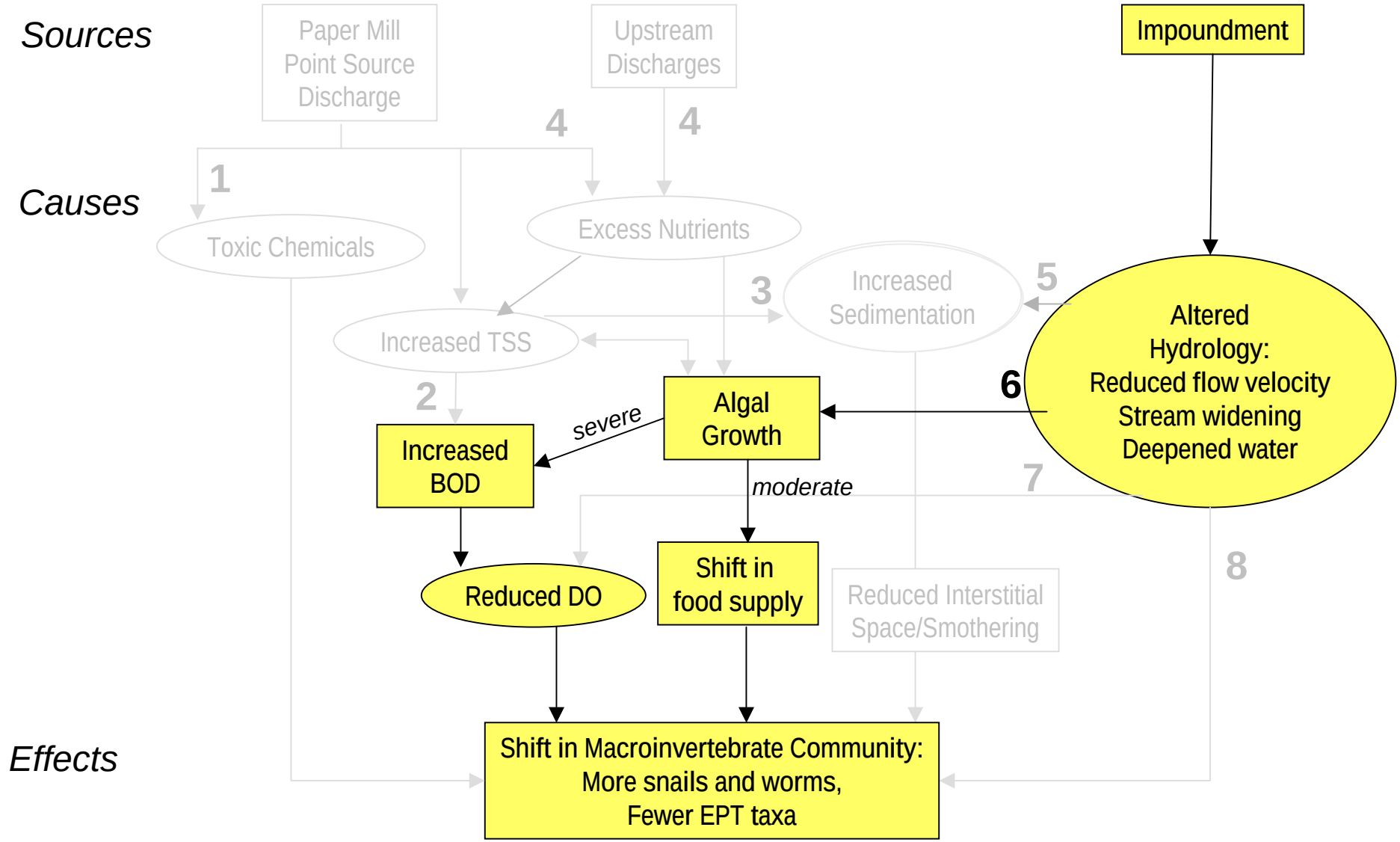

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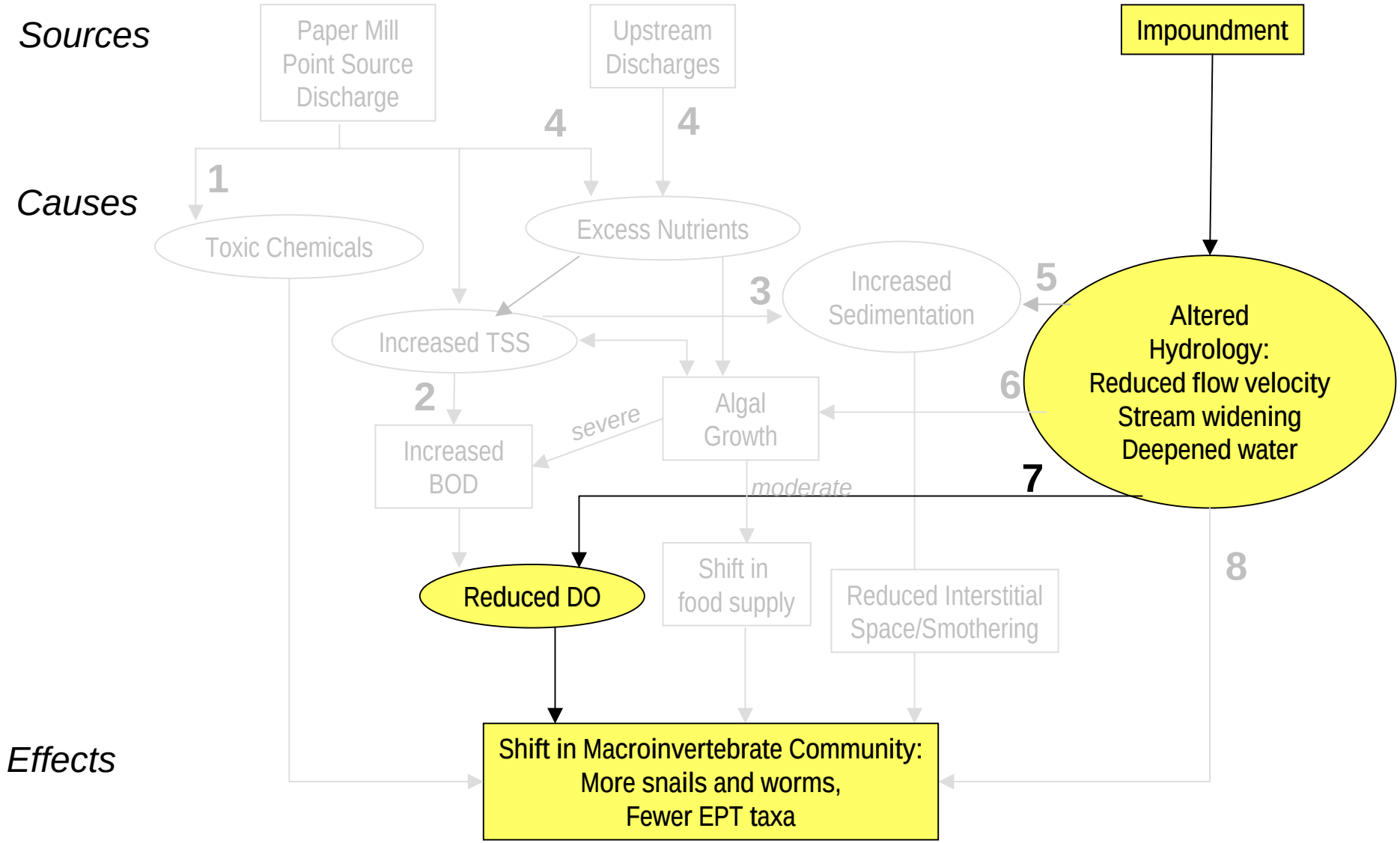

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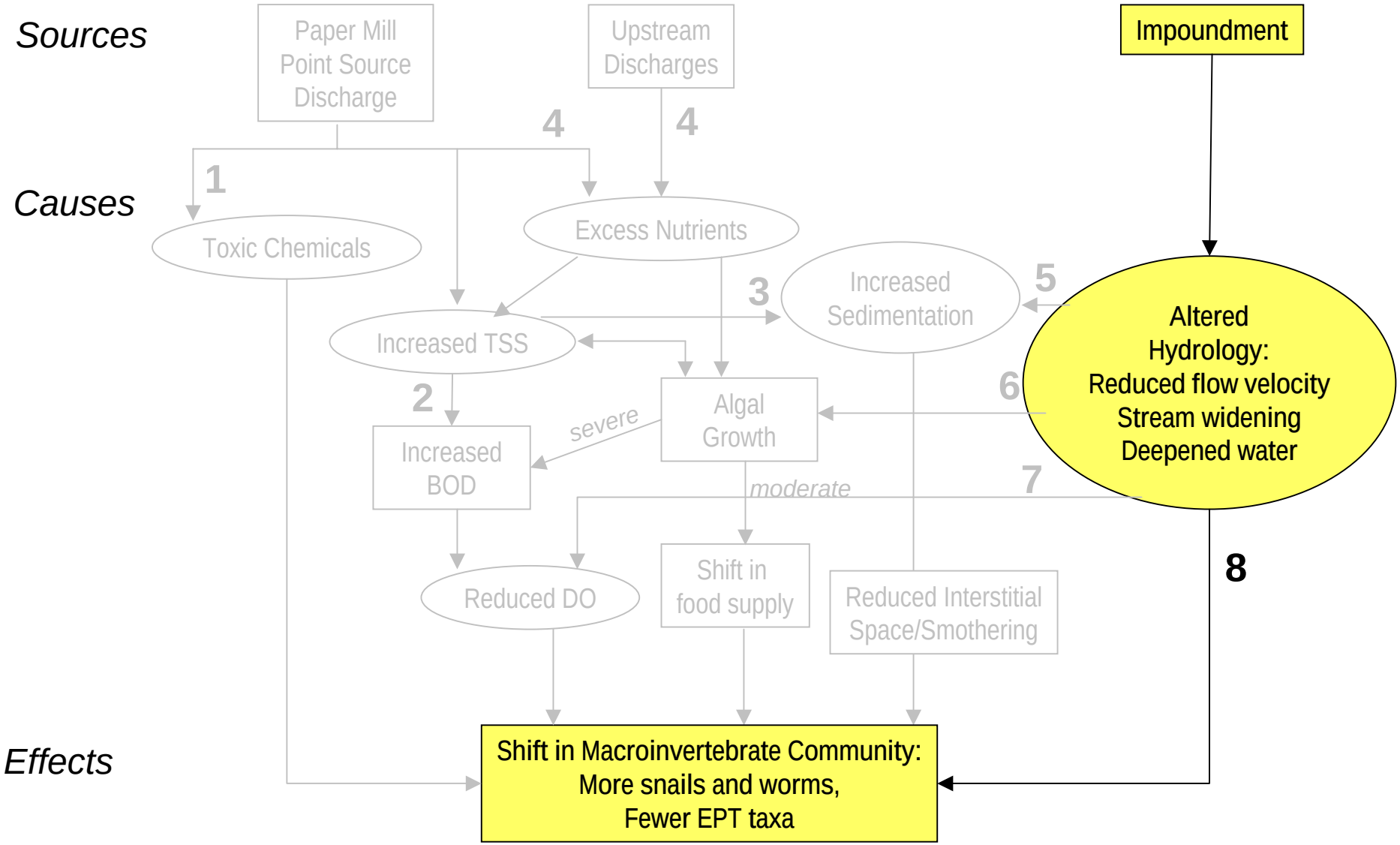
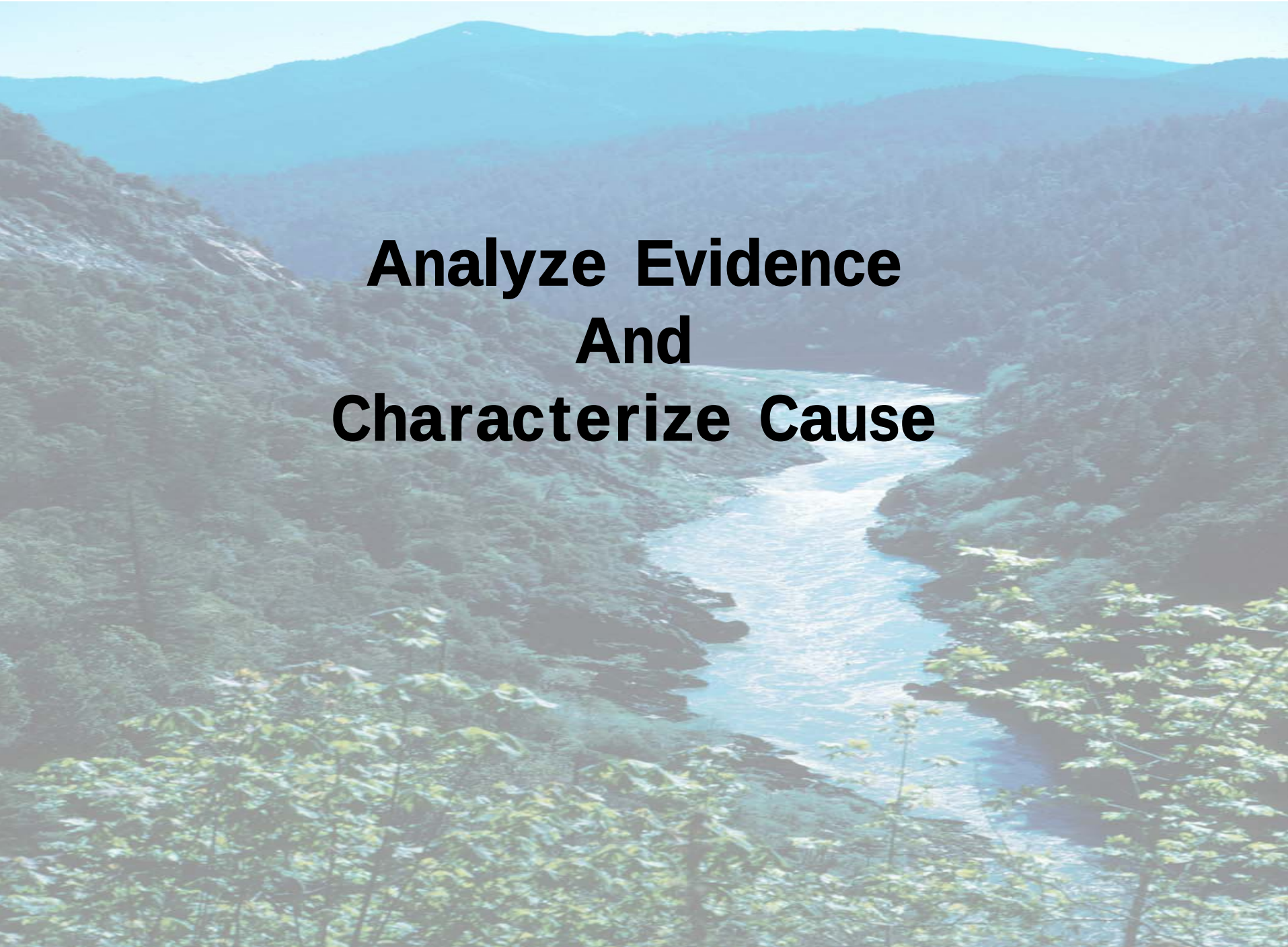


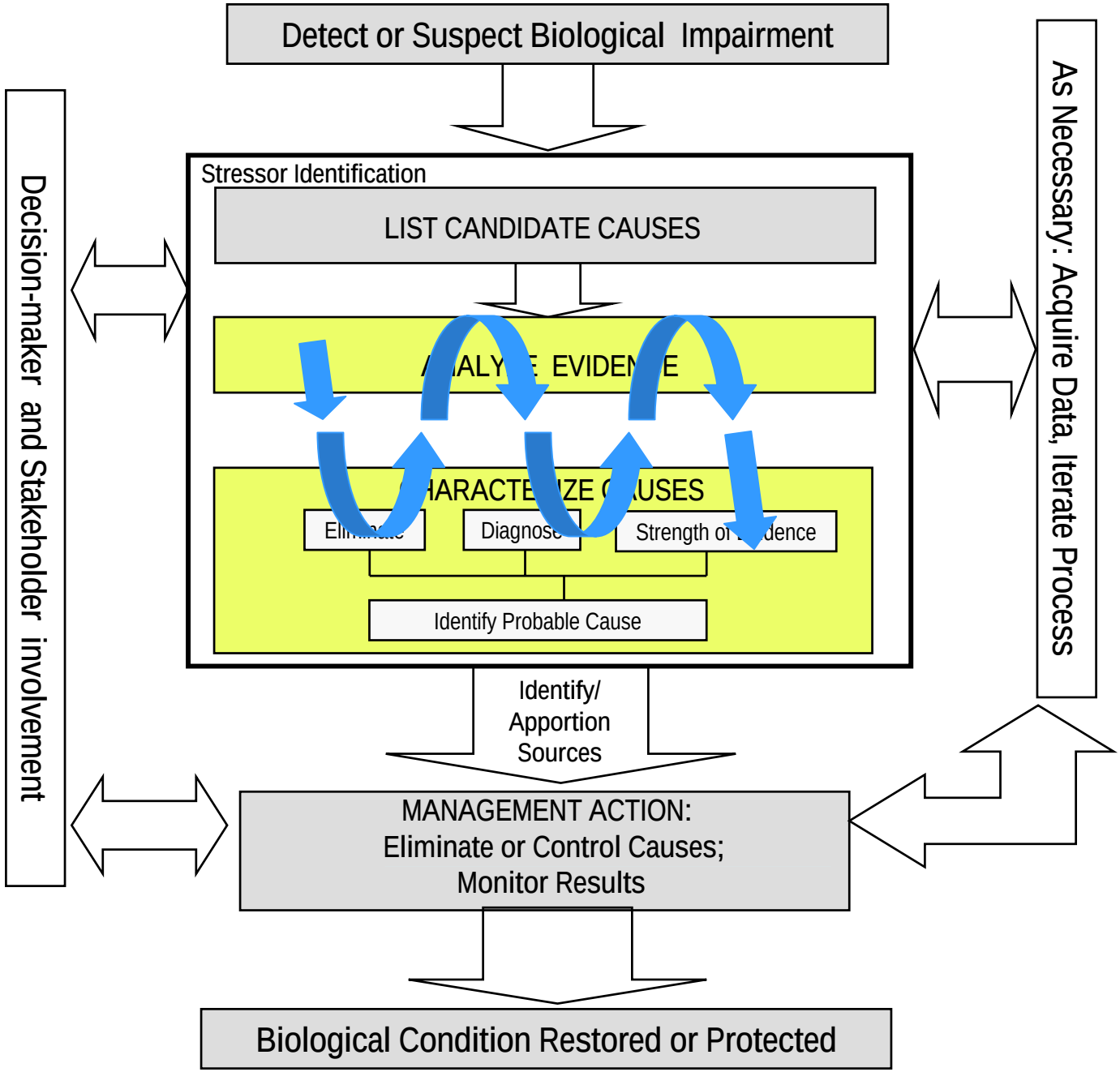
# List of Candidate Causes

1. Excess toxic chemicals
2. High TSS causes high BOD and reduced DO (*BOD & DO*)
3. High TSS smothers organisms (*TSS Smothers*)
4. Excess nutrients cause algal growth either reducing DO or altering food (*Nutrients*)

# List of Candidate Causes

5. Impoundment increases sedimentation, reducing interstitial space and smothering organisms (*Imp & Sed*)
6. Impoundment decreases flow velocity causing algal growth, reducing DO or changing the food source (*Imp & Algae*)
7. Impoundment reduces flow rate of river causing low DO (*Imp & DO*)
8. Impoundment causes loss of suitable habitat (*Imp & Hab*)


Analyze Evidence
And
Characterize Cause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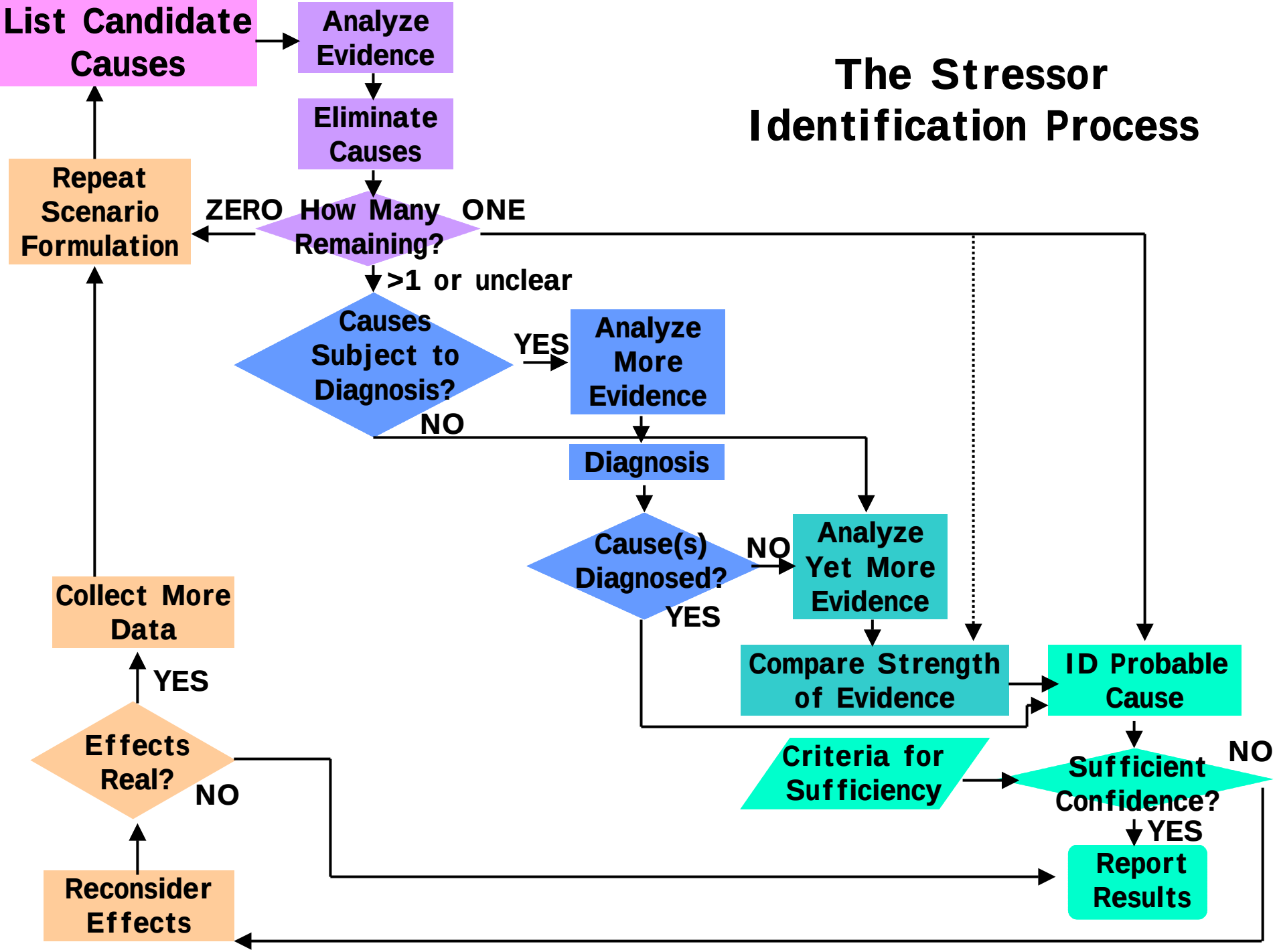
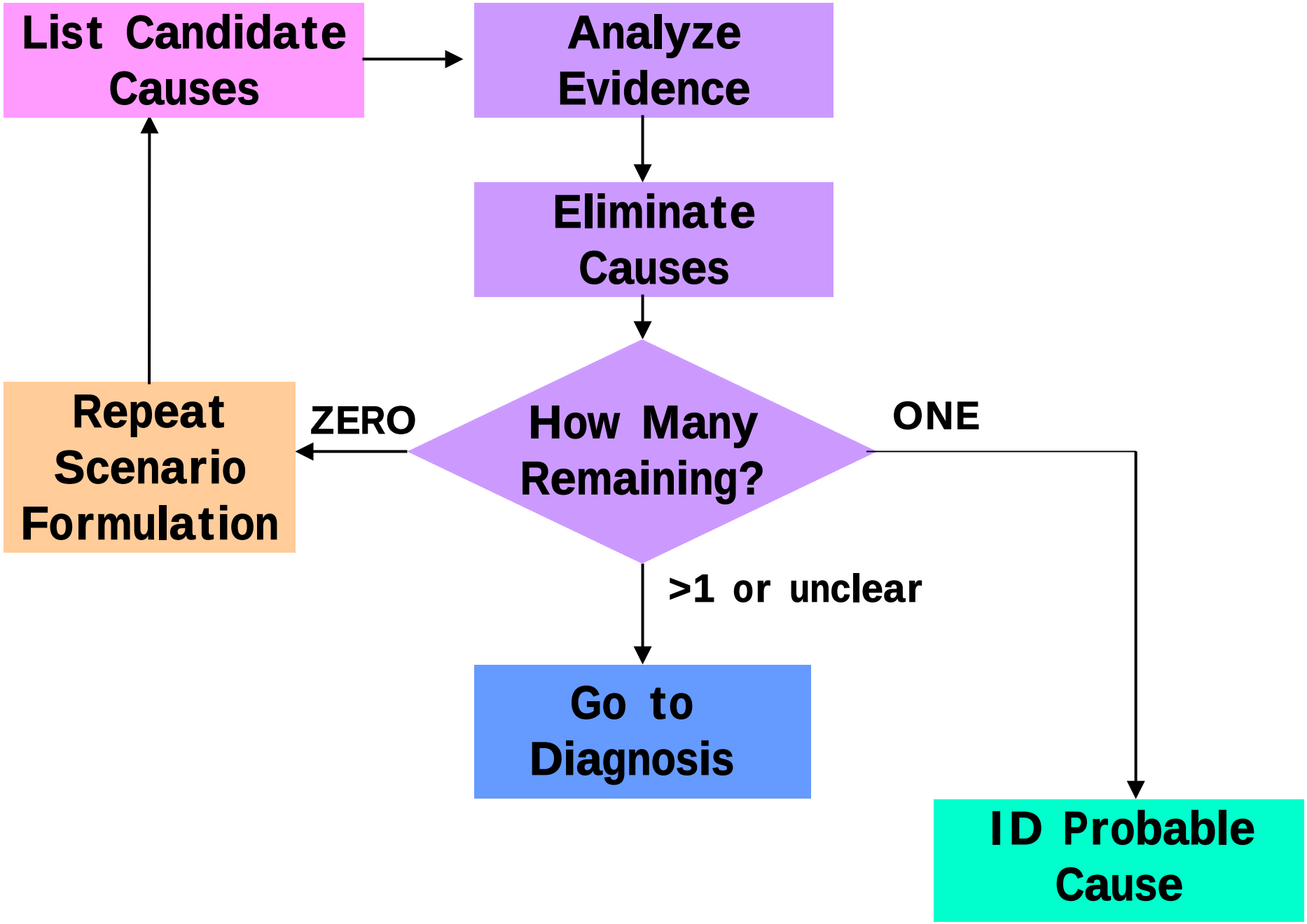
# The Stressor Identification Process



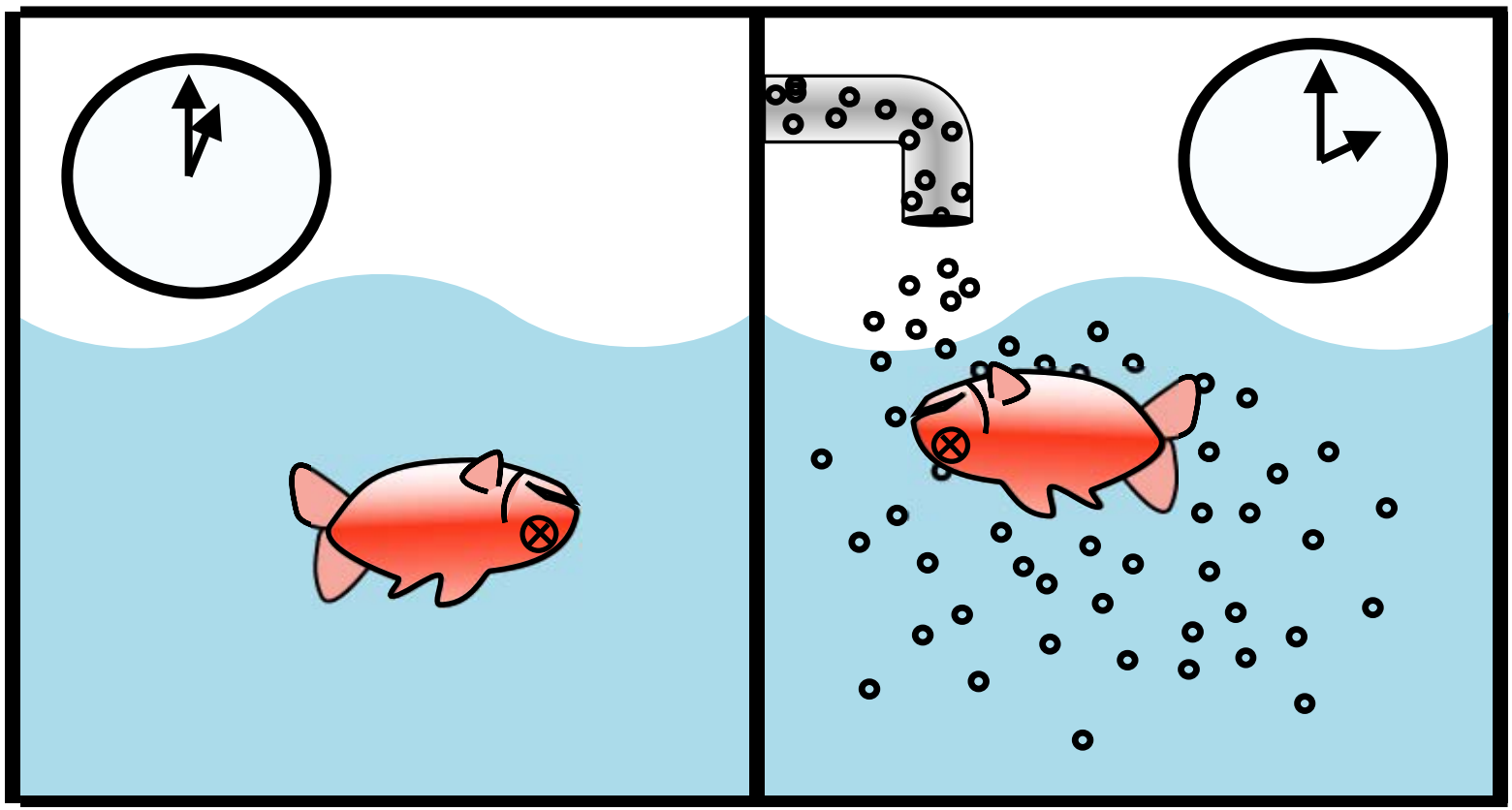

List Candidate Causes
Analyze Evidence
Eliminate Causes
How Many Remaining?
ZERO
ONE
>1 or unclear
Repeat Scenario Formulation
Go to Diagnosis
ID Probable Cause

# Eliminate

- Cleanly eliminate using logic
- Based on associations between
  - Causes with effects observed at site
  - Measurements with causal mechanism
  - Effects with unique causes
  - Changes in effects with manipulation or mitigation from the site

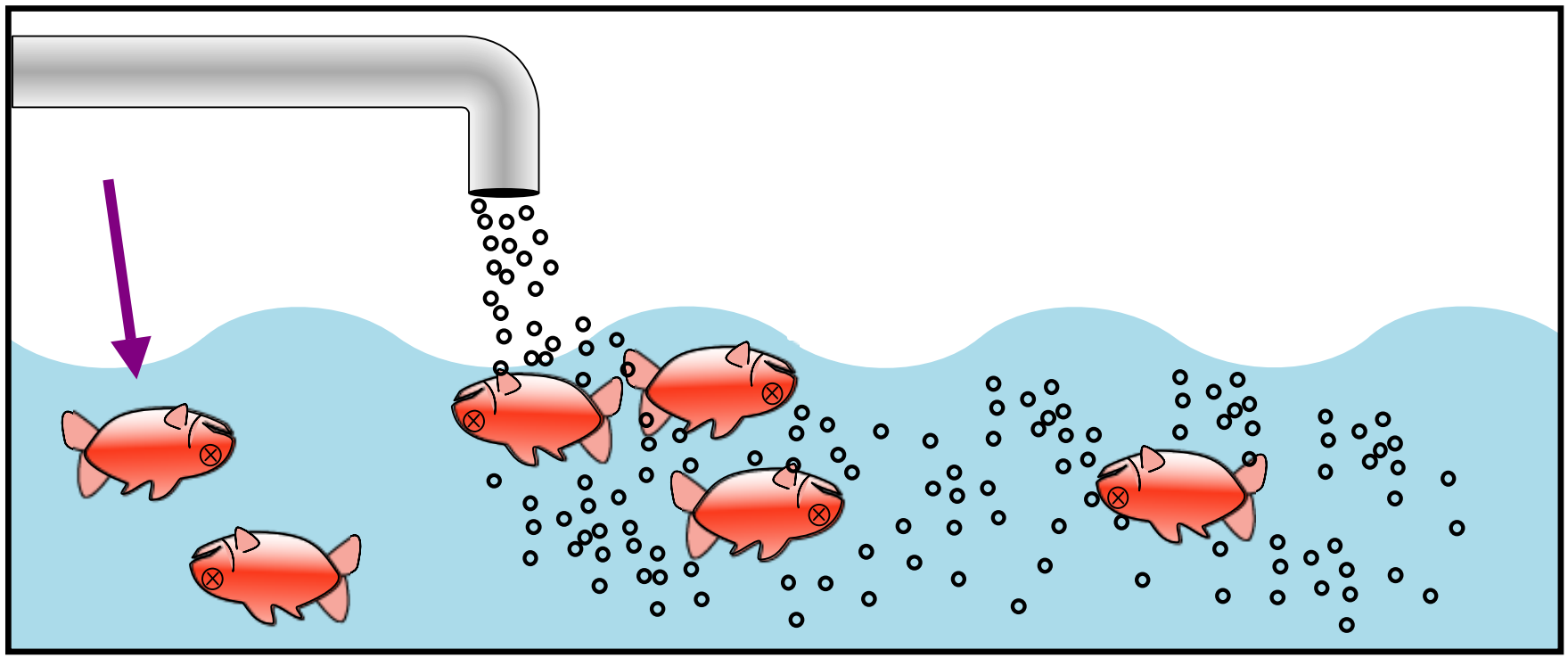
# A Candidate Cause Can Be Eliminated If . . .

the effect preceded the stressor in time



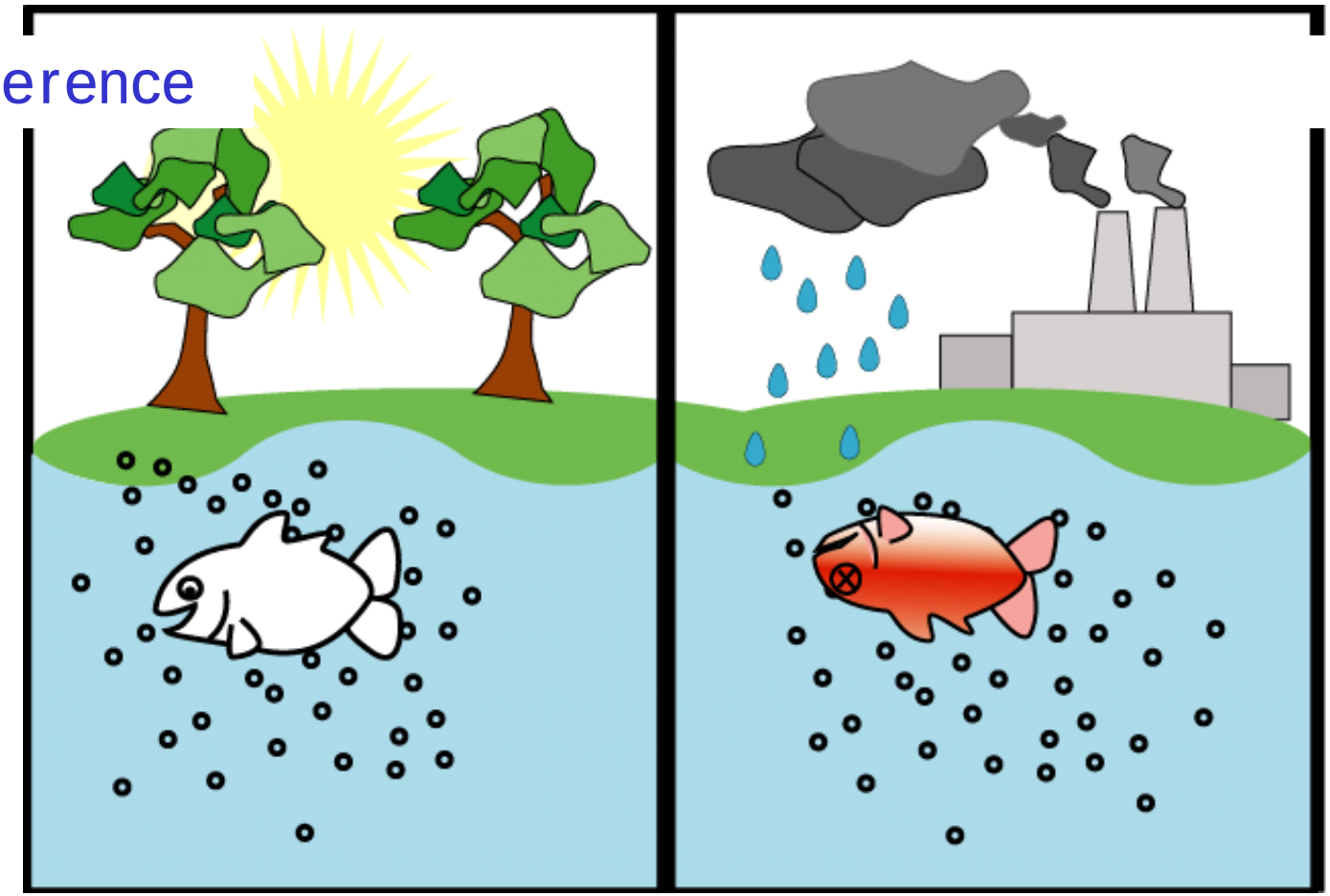
# A Candidate Cause Can Be Eliminated If . . .

the effect occurs upstream of the candidate cause*



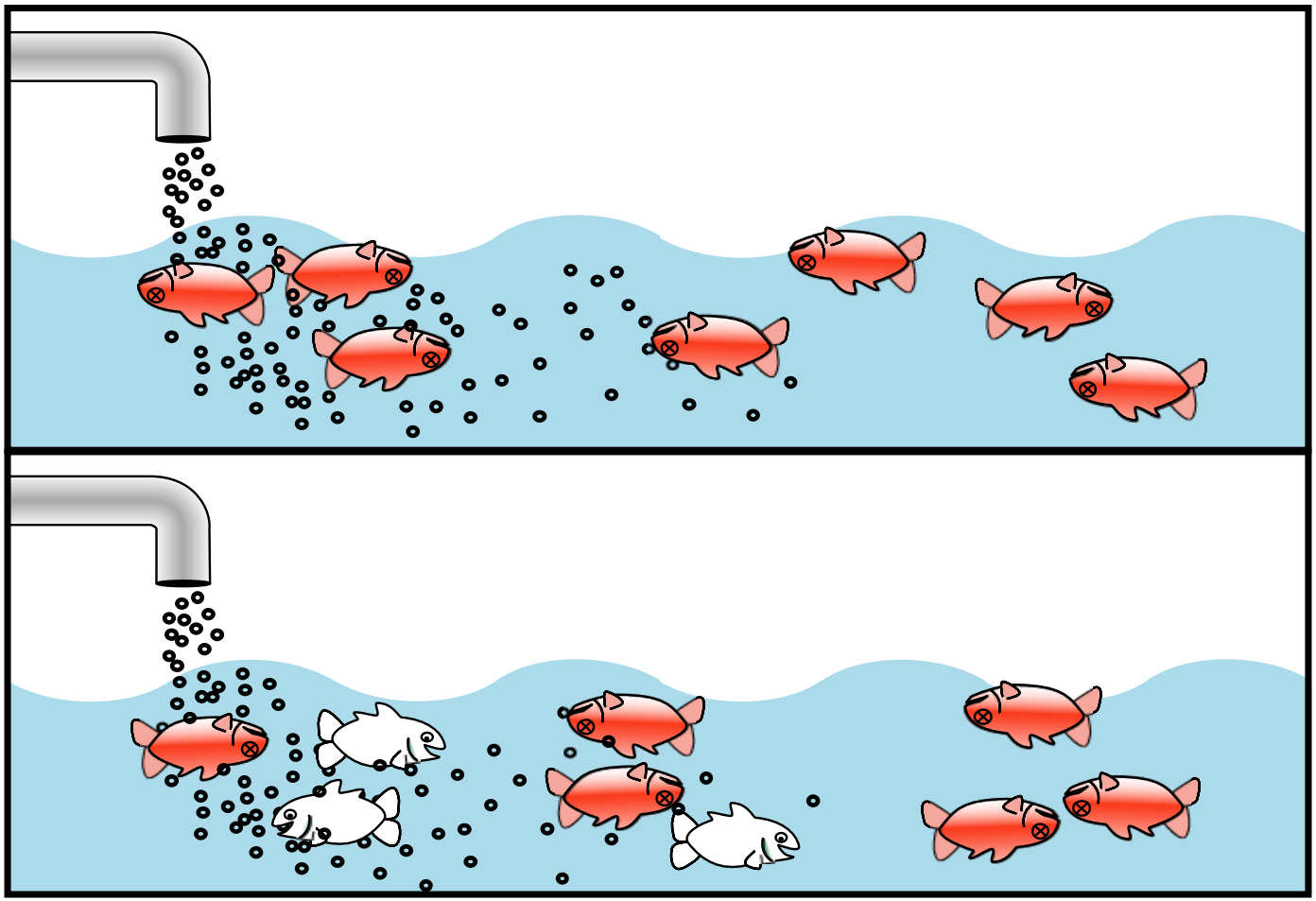
# A Candidate Cause Can Be Eliminated If. . .

The cause occurs at reference sites at the same or greater levels



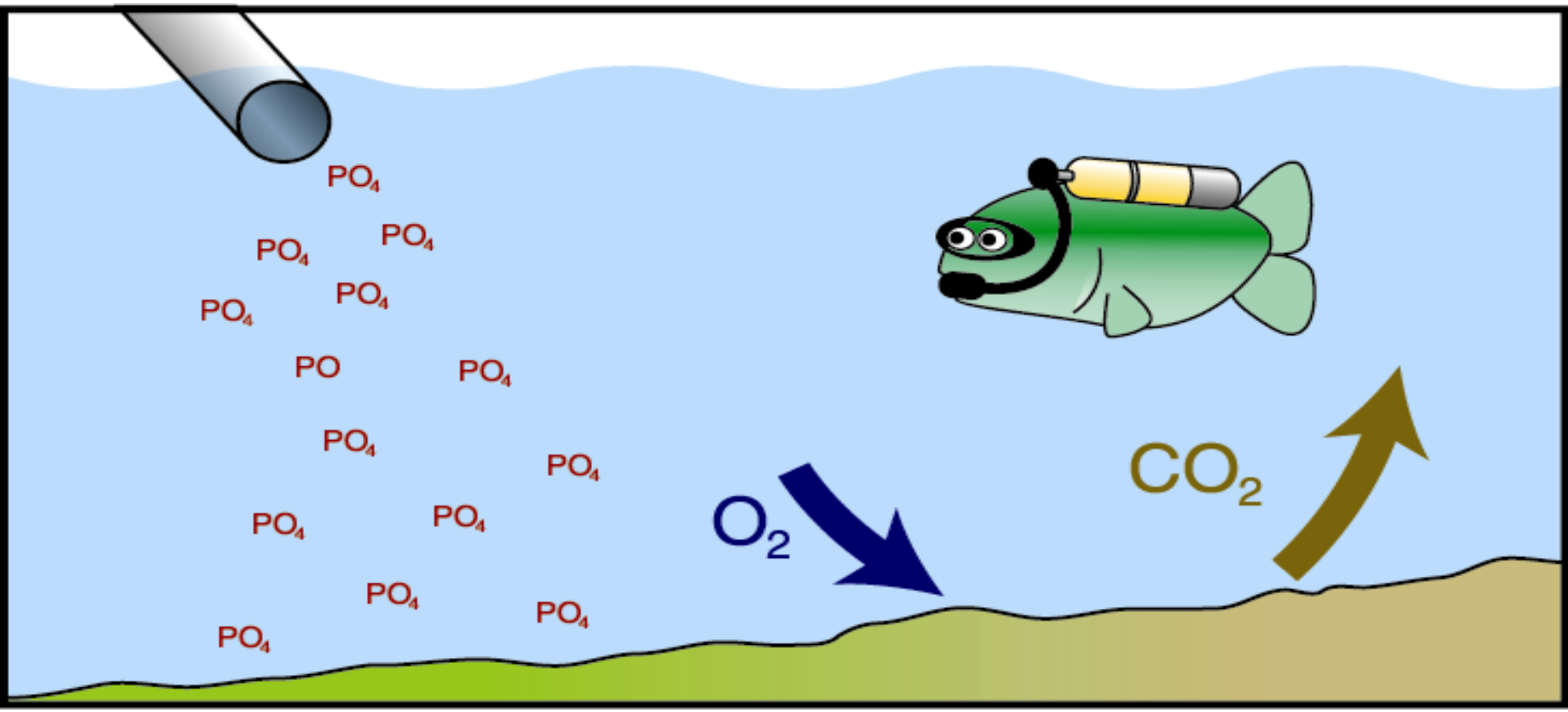
# A Candidate Cause Can Be Eliminated If . . .

a constant or increasing level of effect is seen with decreasing exposure *



# Complete Exposure Pathway

A necessary step in the causal pathway is missing.....i.e., no algae



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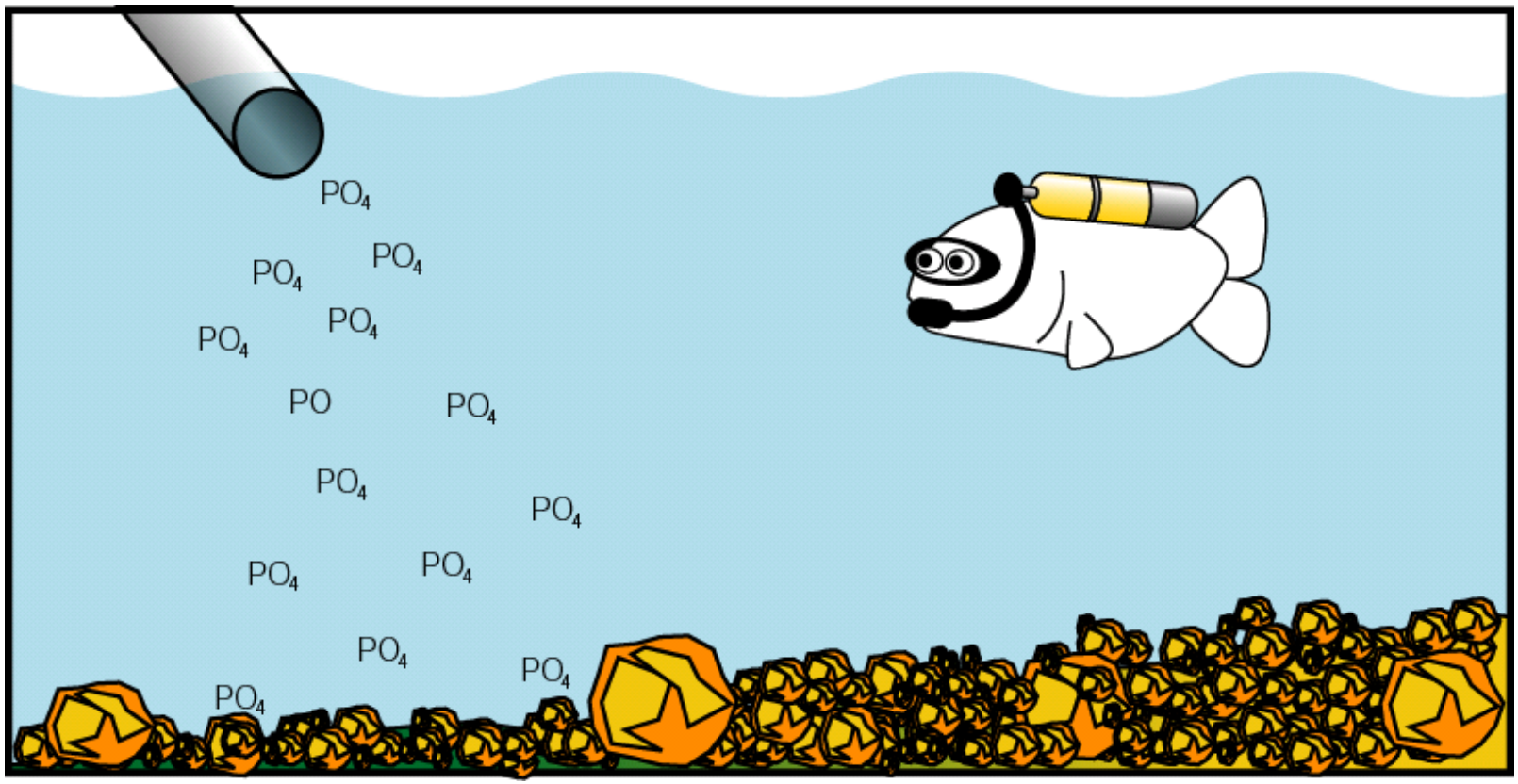
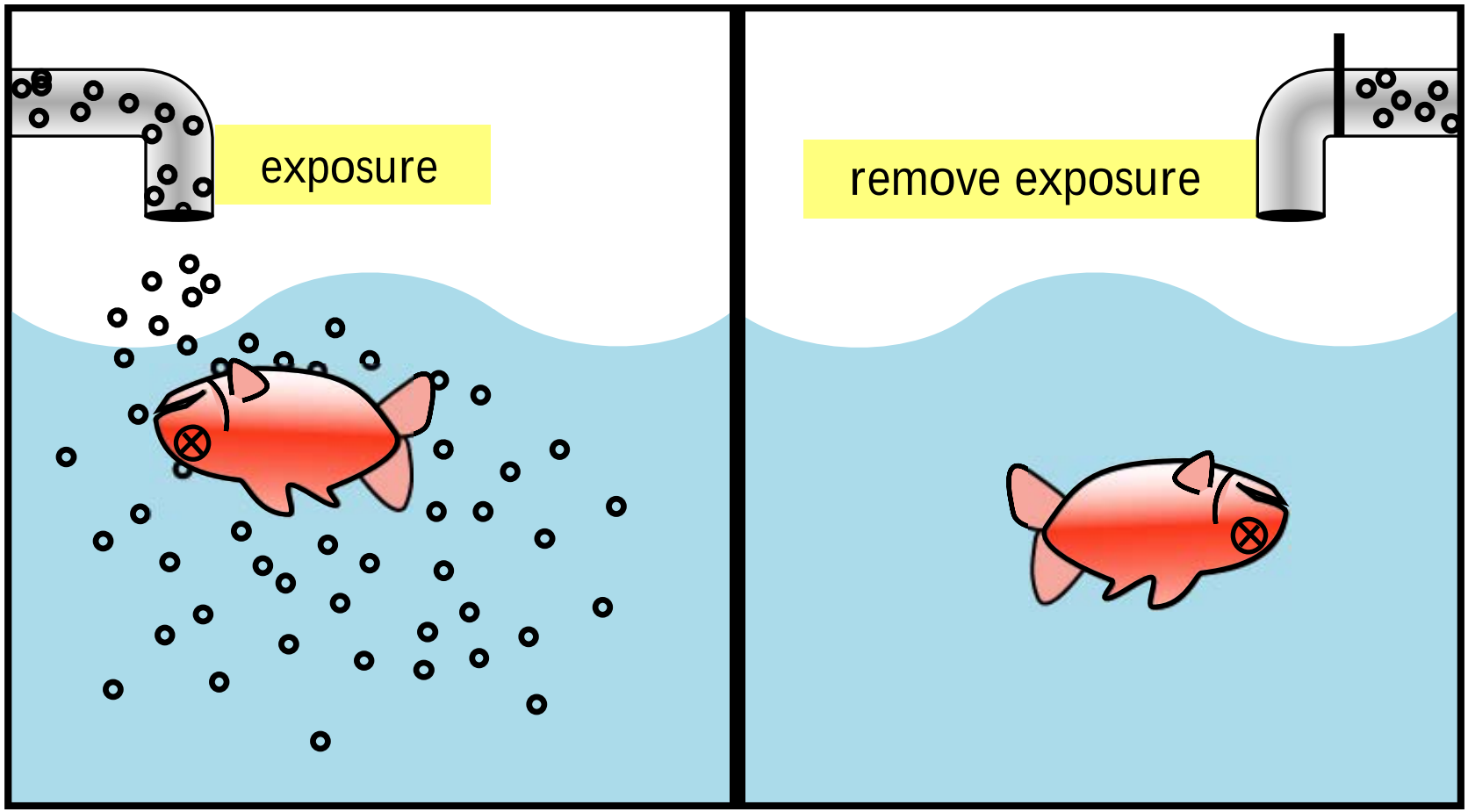


# A Candidate Cause Can Be Eliminated If . . .

effects continue even after a source or stressor was removed
(assuming no impediment to recolonization) *



## Associations between causes and effects observed at the site

| Candidate Cause | Observation | SP 295 (Attainment) | SP 296 (Non attainment) |
|---|---|---|---|
| BOD & DO, TSS Smothers, Nutrients | Visibility | 2.5 m | <0.5 m |
| BOD & DO, TSS Smothers, Nutrients | Floc on Sampling Equip. (e.g., ropes, nets) | Free of brown floc | Coated with Imp. brown floc |
| BOD & DO, TSS Smothers, Nutrients | Mean TSS (ppm) | 3 | 5.9 |
| BOD & DO, Nutrients Imp & Algae | Mean BOD (ppm) | 3.96 | 6.19 |
| BOD & DO Imp & DO | DO range (ppm) | 5.8-8.4 | 5.8-8.0 |

**Associations between causes and effects observed at the site**

| Candidate Cause | Observation | SP 295 (Attainment) | SP 296 (Non attainment) |
|---|---|---|---|
| Nutrients | Mean nitrate – nitrite (ppm) | 0.03 | 0.05 |
| Toxic Chemicals, Nutrients | Mean ammonia (ppm) | 0.03 | 0.12 |
| Nutrients | Mean Total phosphorus (ppb) | 12.8 | 61.2 |
| Nutrients | Mean Ortho-phosphate (ppb) | 3.5 | 44.3 |
| Nutrients, Imp & Algae | Mean Chlorophyll *a* (ppb) | 2.1 | 2.0 |

# Eliminate

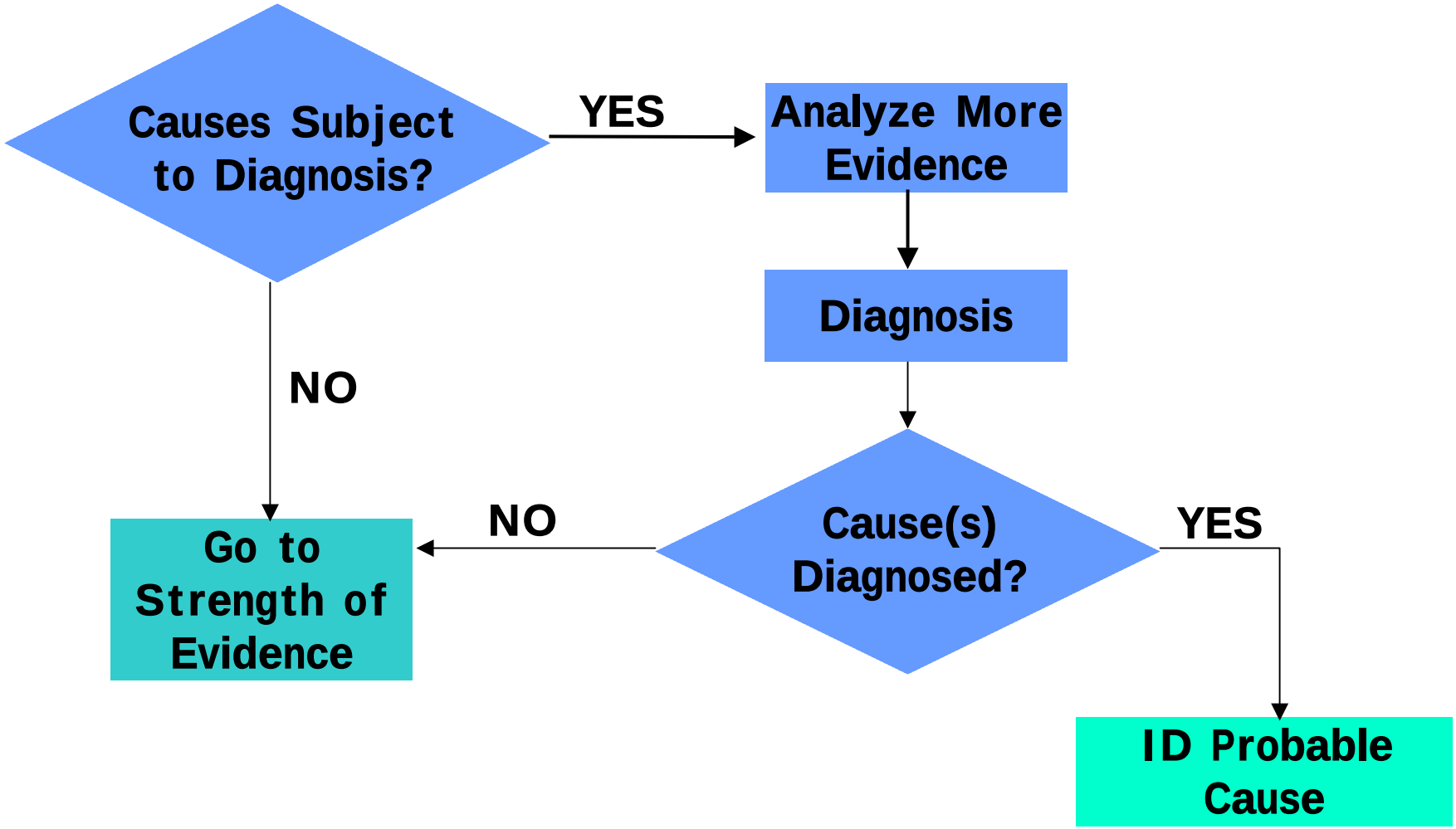
| Candidate Cause | Exposure increased compared w/ upstream location? | Exposure pathway complete | Candidate causes eliminated |
|---|---|---|---|
| 1. Toxic Chemicals | NE | NE | |
| 2. BOD & DO | BOD Yes;<br>TSS Yes;<br>DO **No** | **No** | Eliminated |
| 3. TSS Smothers | Yes | Yes | |
| 4. Nutrients | Nutrients Yes;<br>Chl A **No** | **No** | Eliminated |

# Eliminate

| Candidate Cause | Exposure increased compared w/ upstream location? | Exposure pathway complete | Candidate causes eliminated |
|---|---|---|---|
| 5. Imp & Sed | Imp: Yes<br>Sed: NE | NE | |
| 6. Imp & Algae | Imp: Yes<br>Chl A: **No** | **No** | Eliminated |
| 7. Imp & DO | Imp: Yes<br>DO: **No** | **No** | Eliminated |
| 8. Imp & Hab | Imp: Yes<br>Hab: NE | NE | |

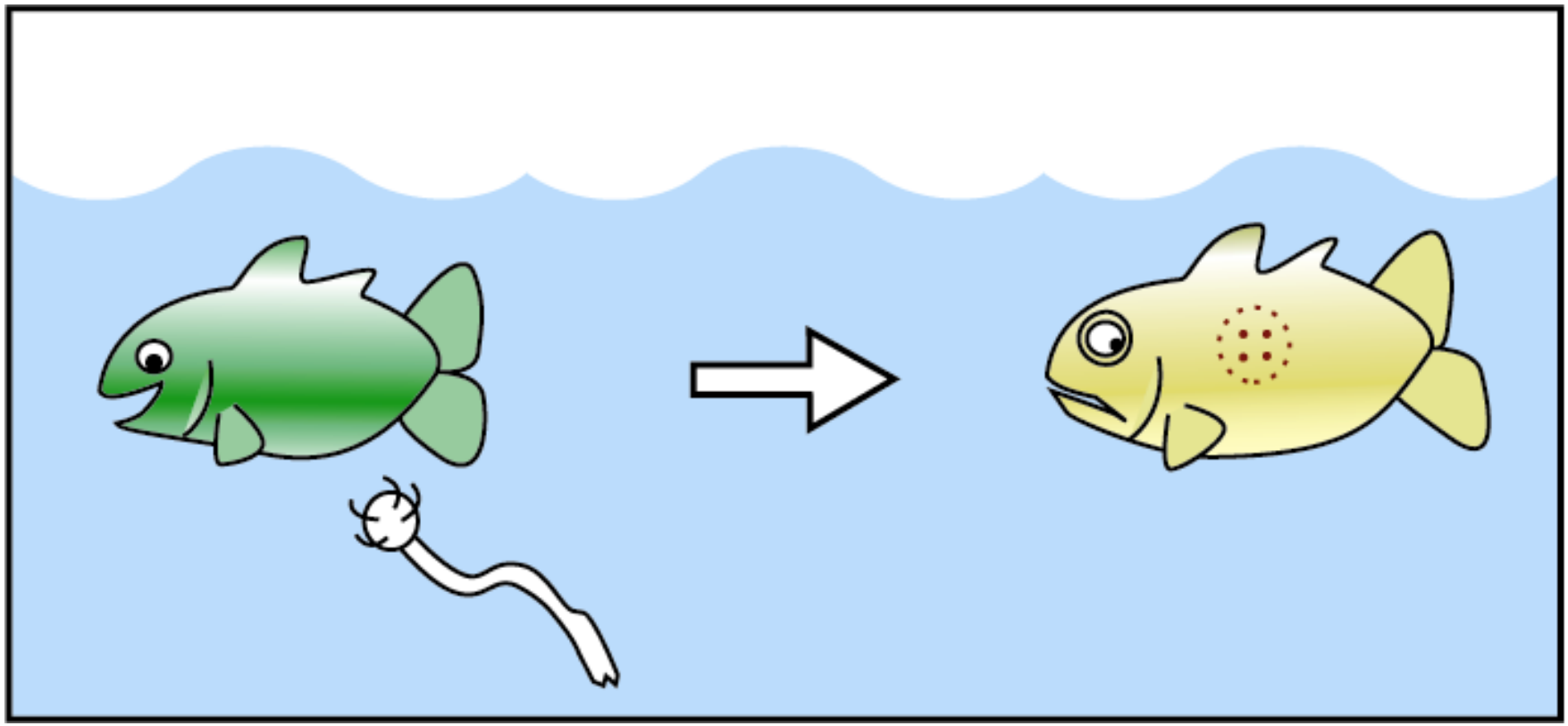
# Candidate Causes Remaining After Elimination

1. Toxic chemicals
2. TSS smothers organisms
3. Impoundment increases sediments
4. Impoundment changes habitat


Causes Subject to Diagnosis?
YES
Analyze More Evidence
Diagnosis
NO
Cause(s) Diagnosed?
NO
YES
Go to Strength of Evidence
ID Probable Cause

# Diagnosis: Symptomology

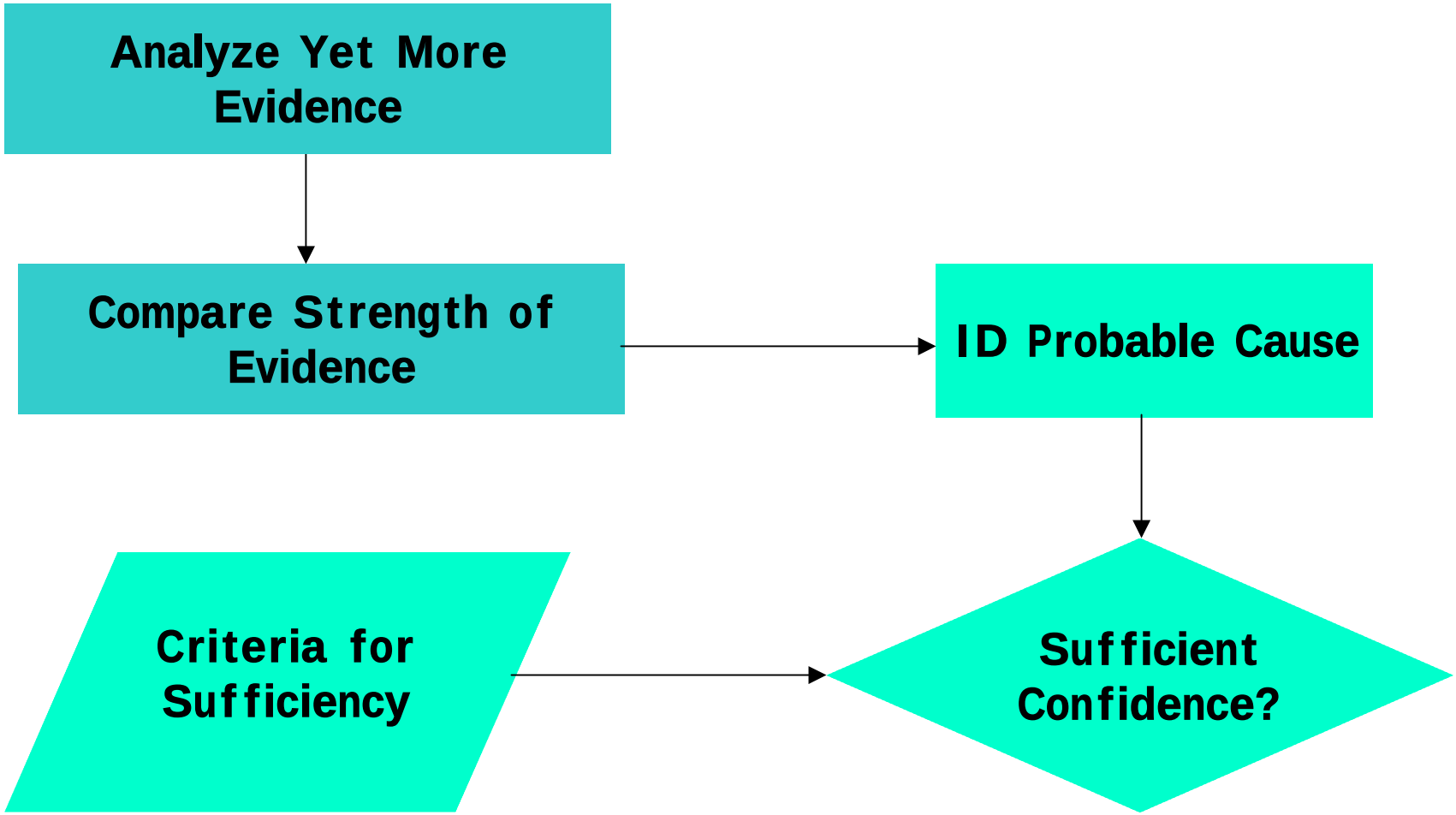
# Symptomology



Examples: Lamprey lesions, or blue stomach specific symptom of molybdenum toxicity

# Diagnosis

- Were symptoms or biomarkers measured in organisms from the site?: NO
- Are there unique causes of the observed effects?
  - Reduced EPT taxa: NO
  - Increased snails and worms: NO
  - Reduced proportion of insects: NO


Analyze Yet More Evidence
Compare Strength of Evidence
ID Probable Cause
Criteria for Sufficiency
Sufficient Confidence?

# Strength of Evidence:

- Is the most flexible of methods
- Organizes evidence using a standard set of causal considerations
- Uses all available evidence. Associations between:
  - Causes with effects observed at site
  - Measurements with causal mechanism
  - Effects with unique causes
  - Changes in effects with manipulation or mitigation from the site

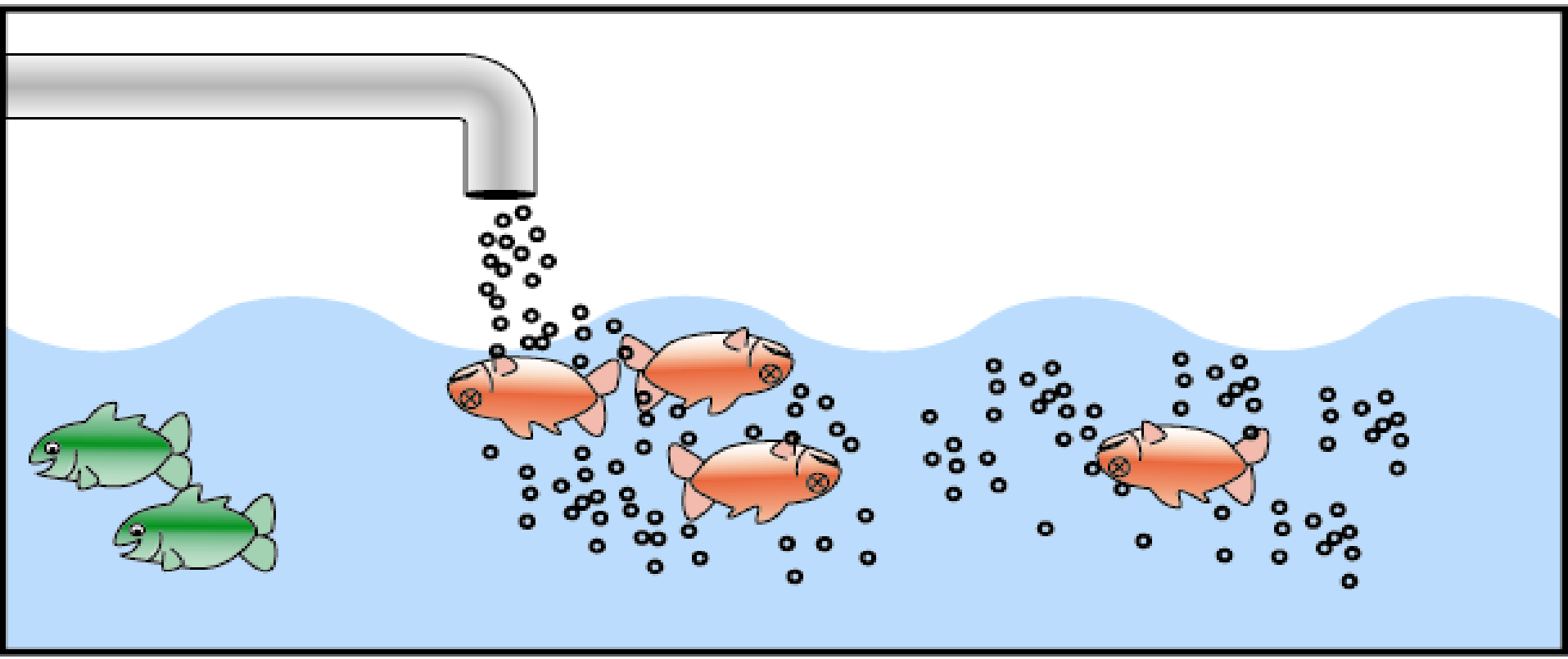
  - Exposure with effects data from other places
  - Causes with effects at other places
  - Changes in effects with manipulation or mitigation from other places

# Strength of Evidence: Case-Specific Considerations

- Uses associations between
  - Causes with effects observed at site
  - Measurements with causal mechanism
  - Changes in effects with manipulation or mitigation from the site
- If you have already analyzed evidence for elimination, this is easy.

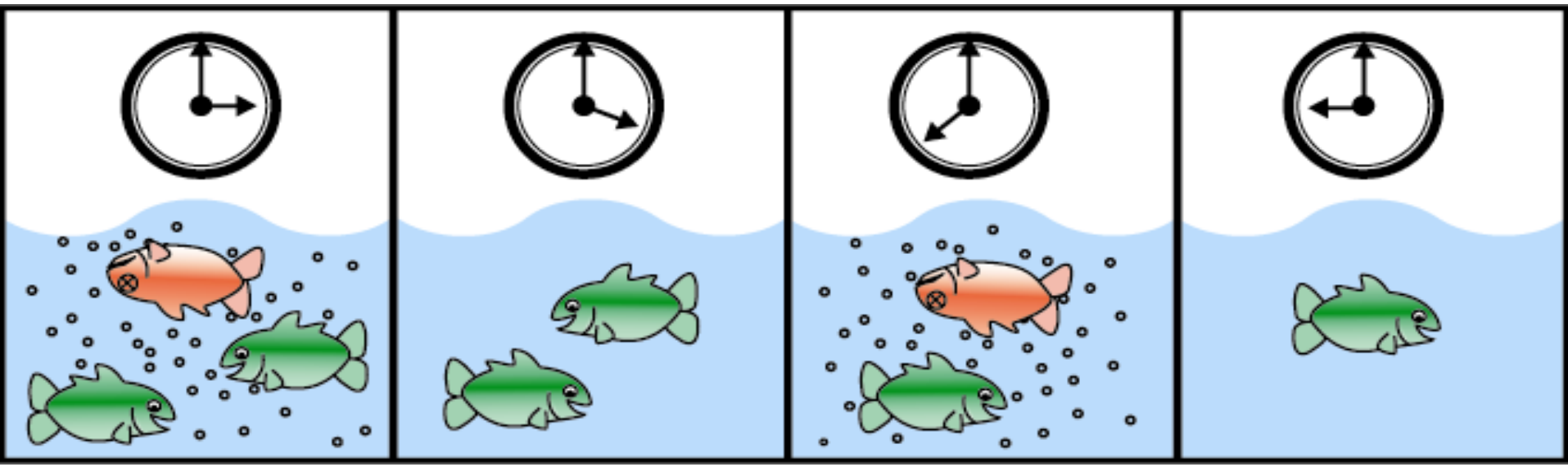
# Spatial Co-occurrence

The effect and candidate cause are co-located



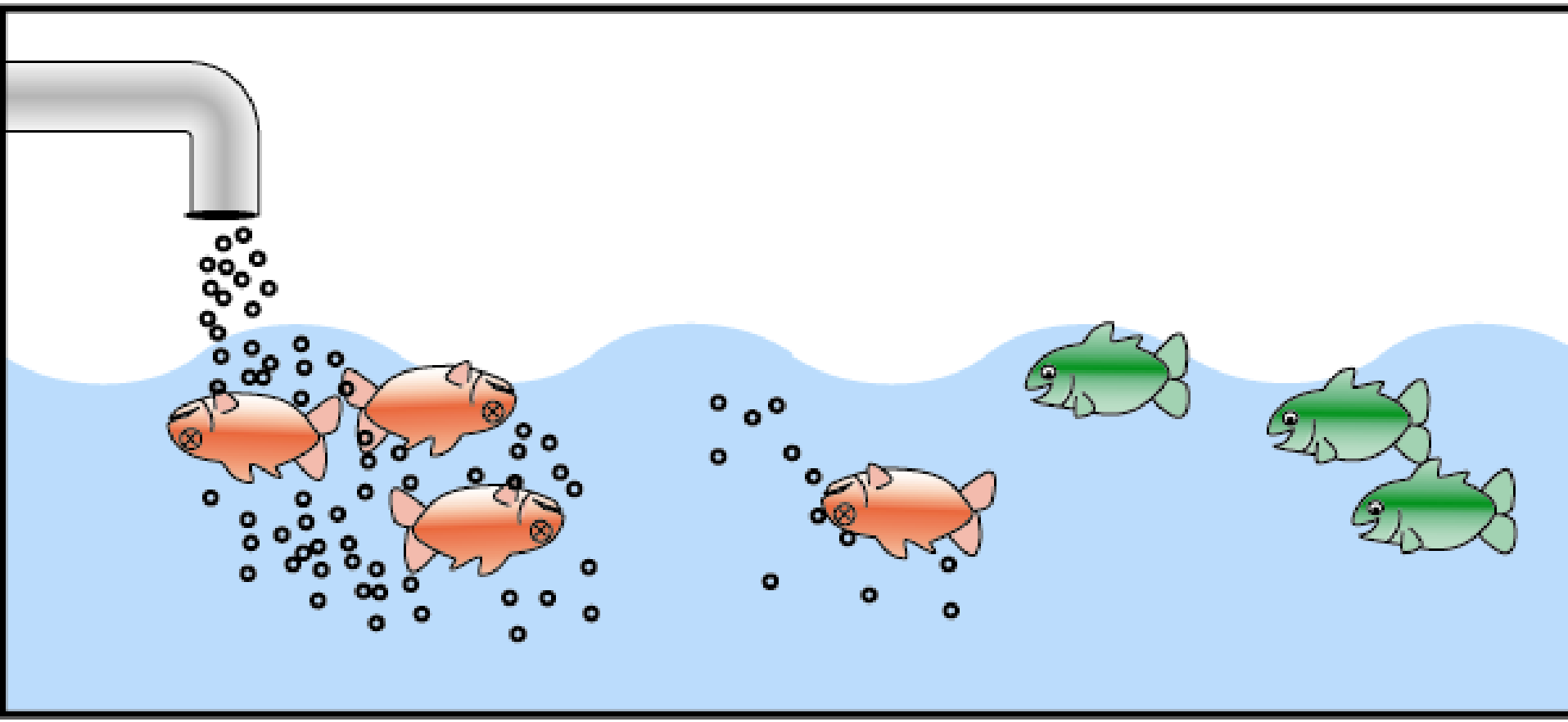
# Temporality

A cause must always precede its effects



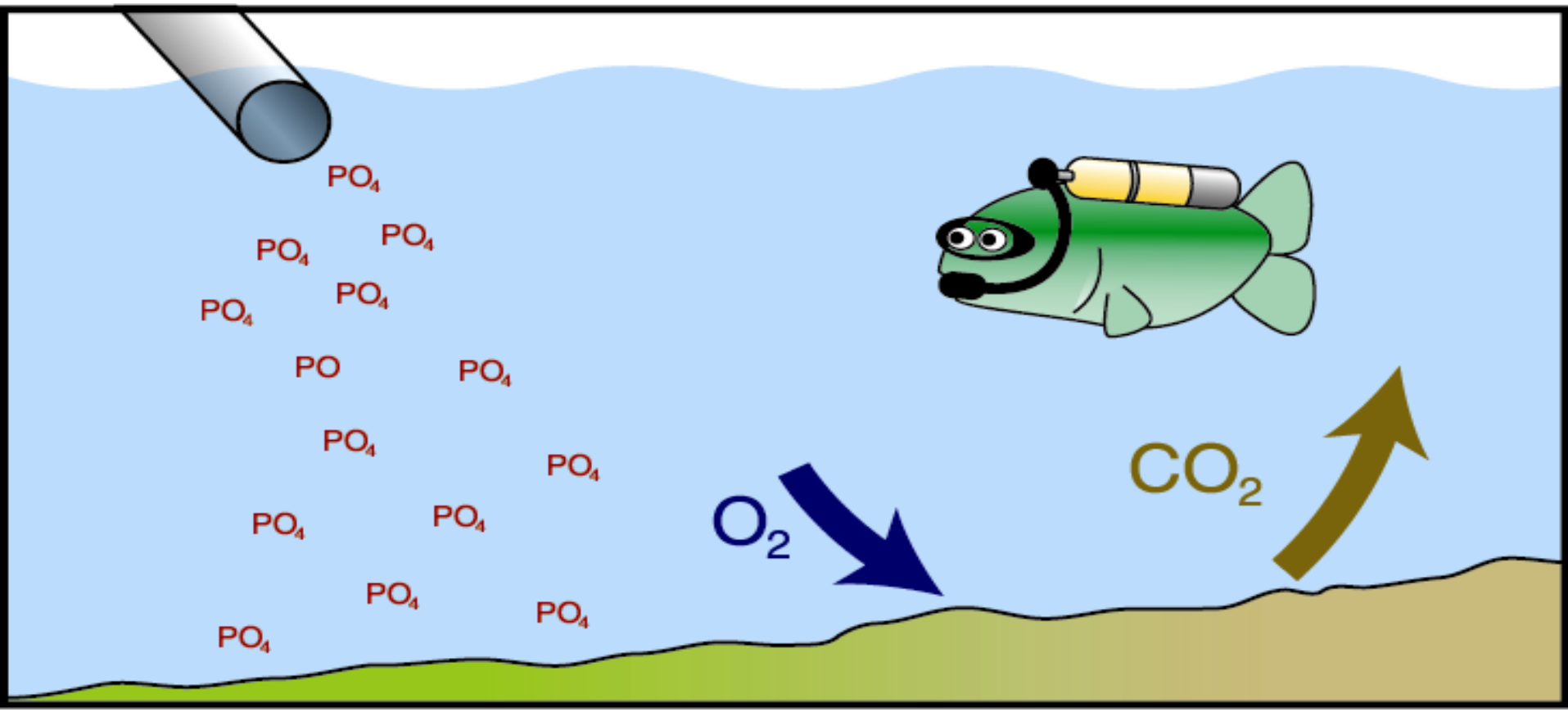
# Biological Gradient

Effects decline as exposure declines over space or time



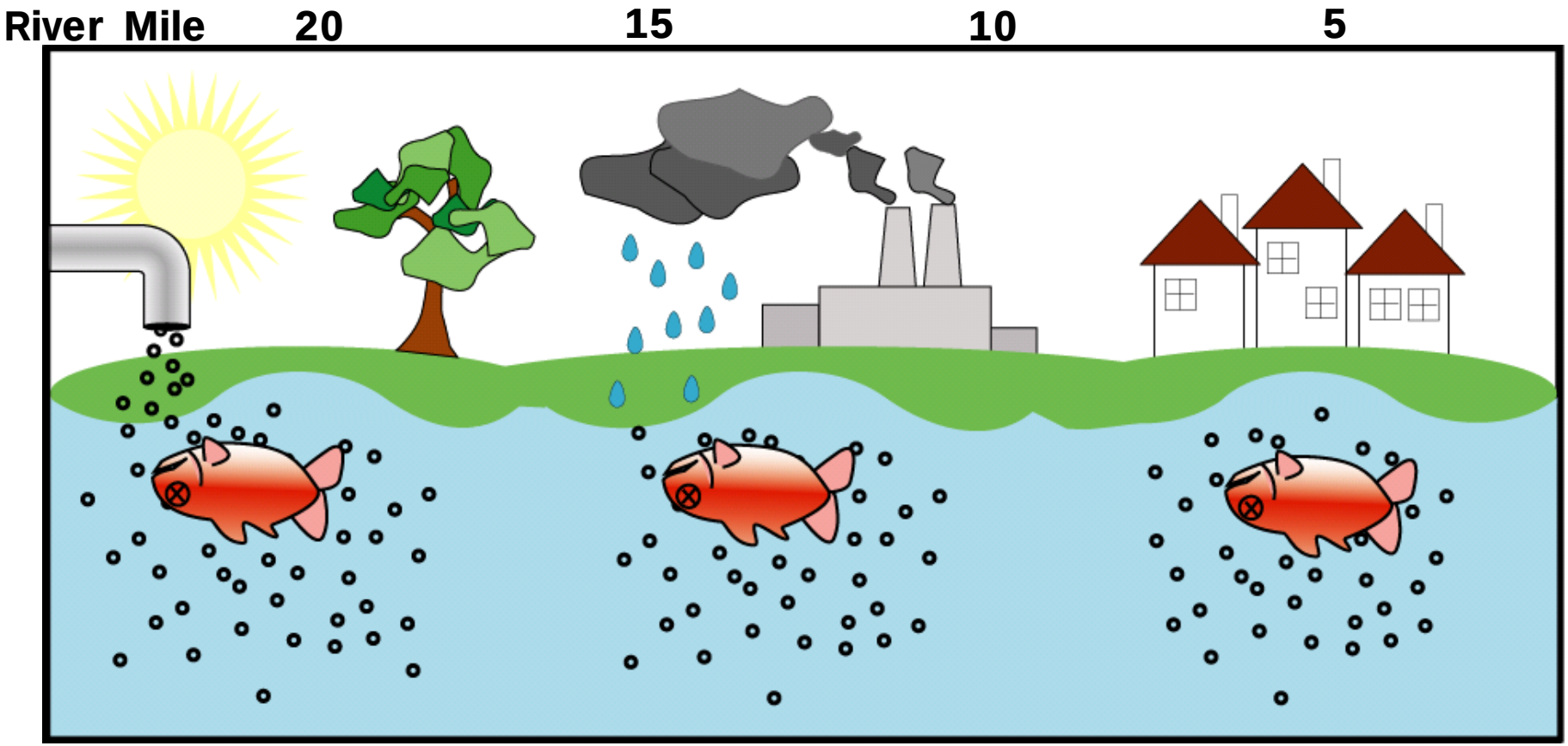
# Complete Exposure Pathway

The stressor has contacted the affected organisms, their food source, or some entity that can affect the organisms.



# Consistency of Association

The cause and the effect occur together in many different places and times in the same river.



# Summarizing Strength of Evidence Results

## Case-Specific Considerations

| Consideration | Results | Score |
|---|---|---|
| Co-occurrence | Compatible | + |
| | Uncertain | 0 |
| | Incompatible | – – – |
| Temporality | Compatible | + |
| | Uncertain | 0 |
| | Incompatible | – – – |
| Consistency of Association | Invariant | ++ |
| | In many places and times | + |
| | At background frequencies | – |
| Biological Gradient | Strong and monotonic | +++ |
| | Weak or other than monotonic | + |
| | Ambiguous | 0 |
| | None or weak but wrong sign | – |
| | Clear association but wrong sign | – – – |
| Complete Exposure Pathyway | Evidence for all steps | ++ |
| | Incomplete evidence | + |
| | Ambiguous | 0 |
| | Some steps missing or implausible | – |
| Experiment | Concordant | +++ |
| | Ambiguous | 0 |
| | Inconcordant | – – – |

Rocky River

# Scores:

## Case-Specific Considerations

| Consideration | TSS Smothers | Toxic Chemicals | Imp. Sed. | Imp. Hab. |
|---|---|---|---|---|
| Co-Occurrence | + | + | + | + |
| Complete Exposure Pathway | + | + | + | + |
| Temporality | NE | NE | NE | NE |
| Consistency of Association | + | + | - | - |
| Biological Gradient | NE | NE | NE | NE |
| Experiment | NE | NE | NE | NE |

# Strength of Evidence:

## Considerations Based on Other Situations or Biological Knowledge

Brings in all other evidence

Associations between:

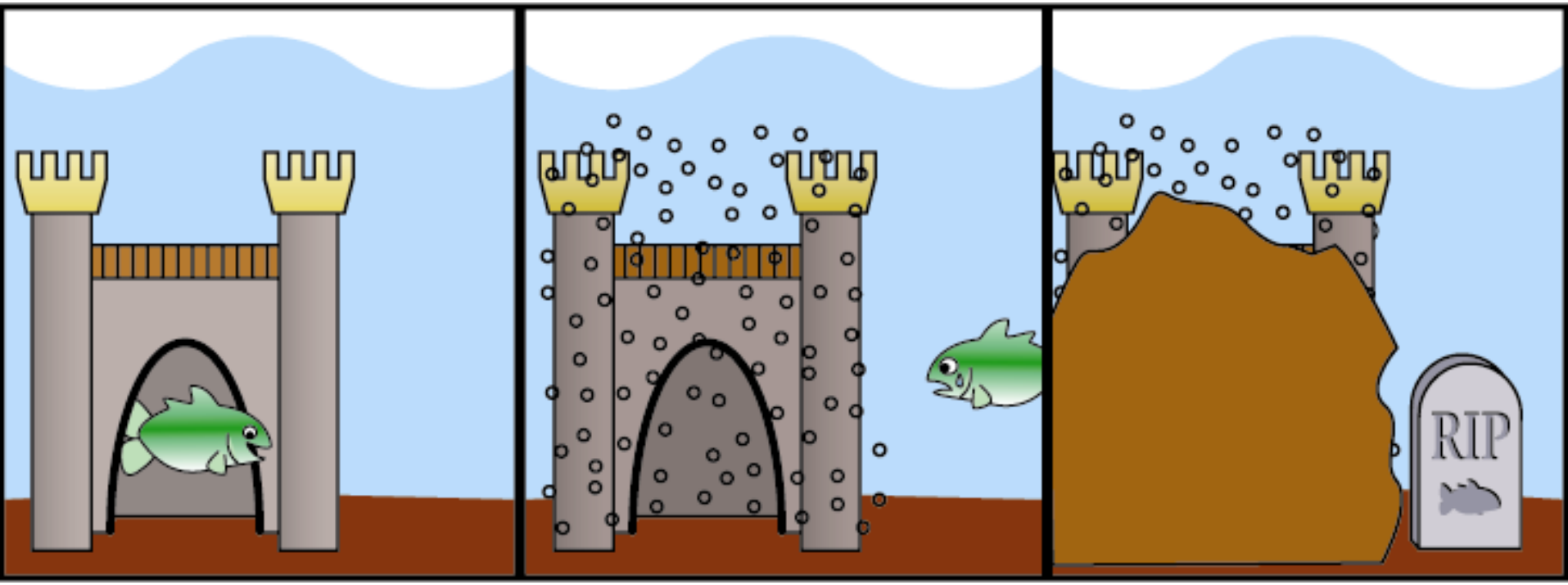
- Effects with unique causes
- Exposure with effects data from other places
- Causes with effects at other places
- Changes in effects with manipulation or mitigation from other places

# Summarizing Strength of Evidence Results

## Considerations Based on Other Situations or Biological Knowledge

| Consideration | Results | Effect |
|---|---|---|
| Plausibility | | |
| Mechanism | Evidence of Mechanism | ++ |
| | Plausible | + |
| | Not Known | 0 |
| | Implausible | - |
| Stressor-Response | Quantitatively consistent | +++ |
| | Concordant | + |
| | Ambiguous | 0 |
| | Inconcordant | - |
| Consistency of Association | Invariant | +++ |
| | In most places | ++ |
| | In some places | + |
| | At background frequency | - |
| Specificity of cause[1] | Only possible cause | +++ |
| | One of a few | ++ |
| | One of many | 0 |
| Analogy | | |
| Positive | Many | ++ |
| | Few but clear | + |
| Negative | Few | – – |
| | Unclear | – |
| Experiment | Experimental studies: Concordant | +++ |
| | Ambiguous | 0 |
| | Inconcordant | – – – |
| Predictive Performance | Confirmed specific or multiple | +++ |
| | Confirmed general | ++ |
| | Ambiguous | 0 |
| | Failed | – – – |

# Plausibility - Mechanism




It is plausible that the effect resulted from the cause given what is known about the biology, physics, and chemistry of the candidate cause, the receiving environment, and the affected organisms.

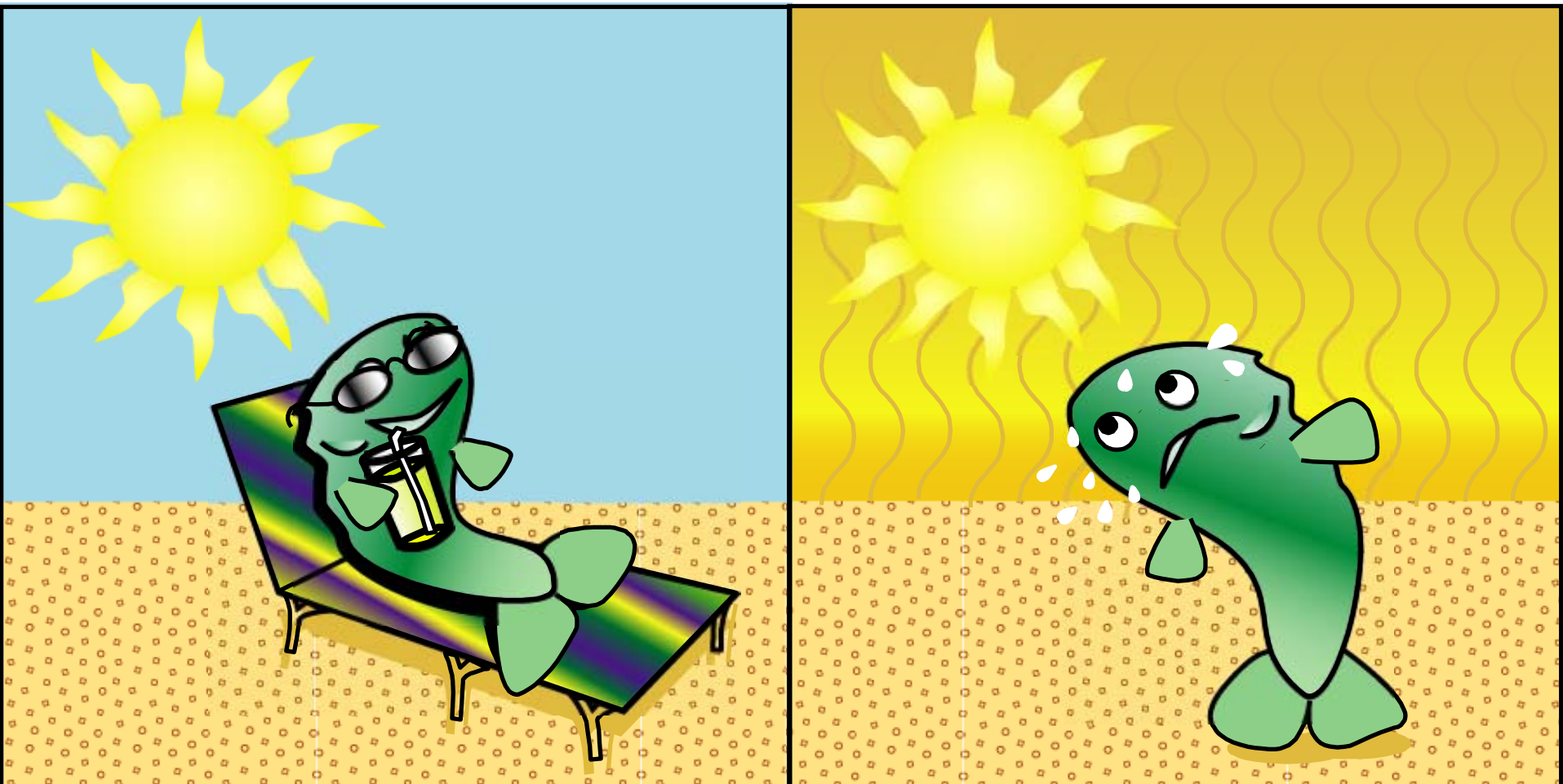
# Scores:
# Plausible Mechanism

| Consideration | TSS Smothers | Toxic Chemicals | Imp. Sed. | Imp. Hab. |
|---|---|---|---|---|
| Plausible Mechanism | + | + | + | + |

**+ = Plausible. All candidates can plausibly cause decreased EPT taxa, increases in snails and worms**

# Plausible Stressor Response

Site exposures are at levels shown to cause effects, in the laboratory or at other sites, or in simulation models.



# Analyze Evidence: Stressor Response

## Compare Toxic Chemical Concentrations with Ambient Water Quality Criteria

| Metals | Maximum Receiving Water Concen. (mg/L) at Low Flow[1] (7Q10[2]) | Chronic Criteria (mg/L) | Acute Criteria (mg/L) |
|---|---|---|---|
| Aluminum | 207.9 | 87 | 750 |
| Lead | 1.52 | 0.41 | 10.52 |
| Mercury | 0.097 | 0.012 | 2.4 |
| Silver | 1.083 | 0.12 | 0.092 |
| Ammonia | 0.12* | 1.27 @ pH 8.0 | |

* Ammonia concentrations measured at site 295

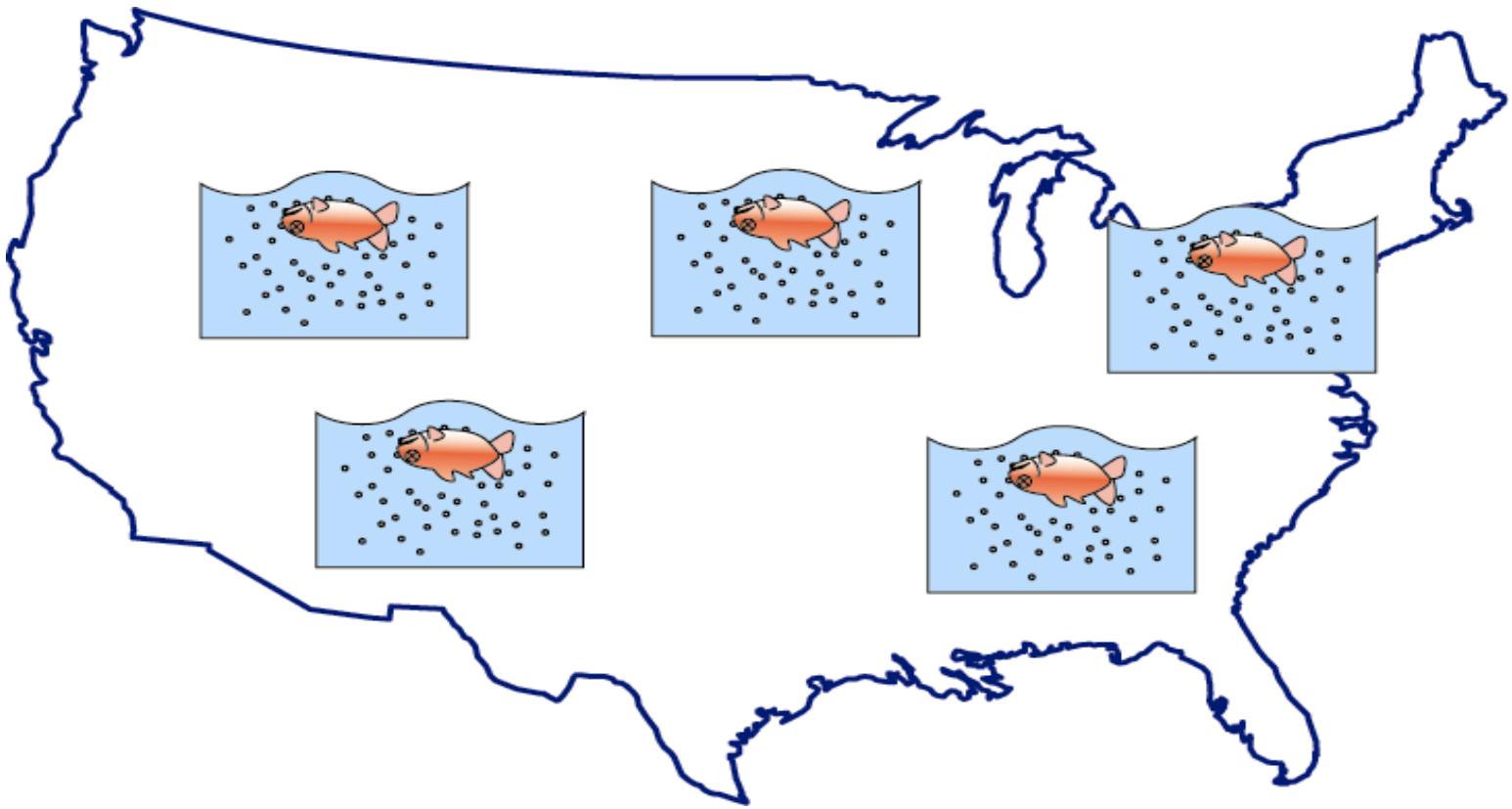
# Scores: Plausible Stressor Response

| Consideration | TSS Smothers | Toxic Chemicals | Imp. Sed. | Imp. Hab. |
|---|---|---|---|---|
| Plausible Stressor-response | NE | 0 | NE | NE |

0 = Ambiguous. Even under very conservative low flow assumptions, no chemical concentrations exceeded acute criteria. Highest modeled concentrations may exceed chronic criteria for short periods of time.

# Consistency of Association

The cause and the effect occur together in many different places and times.



# Scores: consistency of association

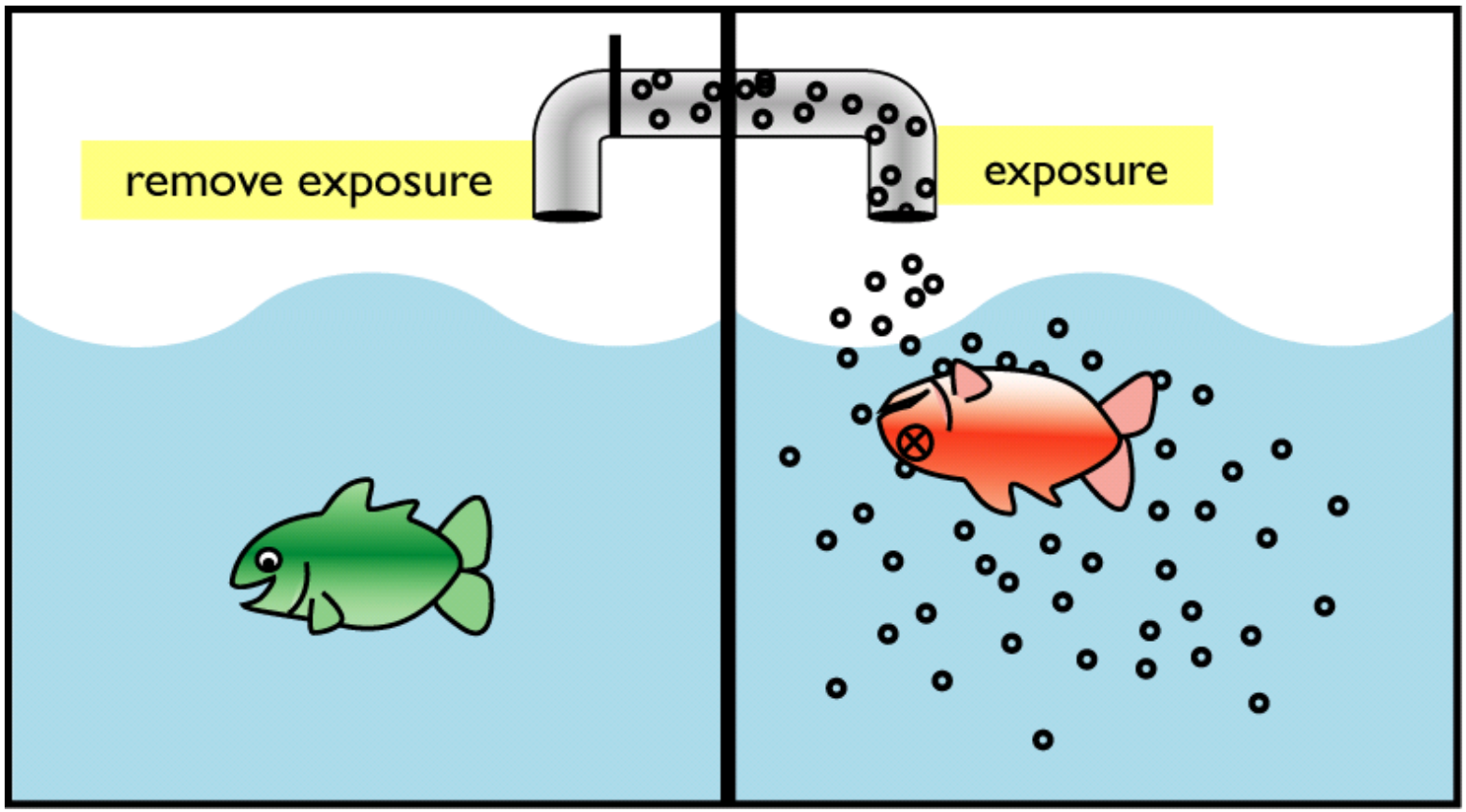
| Consideration | TSS Smothers | Toxic Chemicals | Imp. Sed. | Imp. Hab. |
|---|---|---|---|---|
| Consistency of Association | + | NE | - | - |

+ = In some places. The Androscoggin showed impairment with similar or even lower concentrations of TSS

- = Many exceptions to the Association. Several similar rivers still meet Class C biological expectation, despite being impounded.

# Experiment

Toxicity tests, controlled studies, or field experiments demonstrate that the candidate cause can induce the observed effect



# Analyze Evidence: Experiment

| | Rocky | | Androscoggin | | |
|---|---|---|---|---|---|
| **Mill & Year Sampled** | 1995 | 1996 | 1995 | 1996 | 1997 |
| **Aquatic Life Status** | Non-Attainment | Non-Attainment | Non-Attainment | Attainment | Attainment |
| **TSS treatment** | none | none | none | TSS removal | TSS removal |
| **TSS** discharged/ flow | 3.31 | 3.52 | 1.74 | 0.36 | 0.61 |

# Scores: Experiment

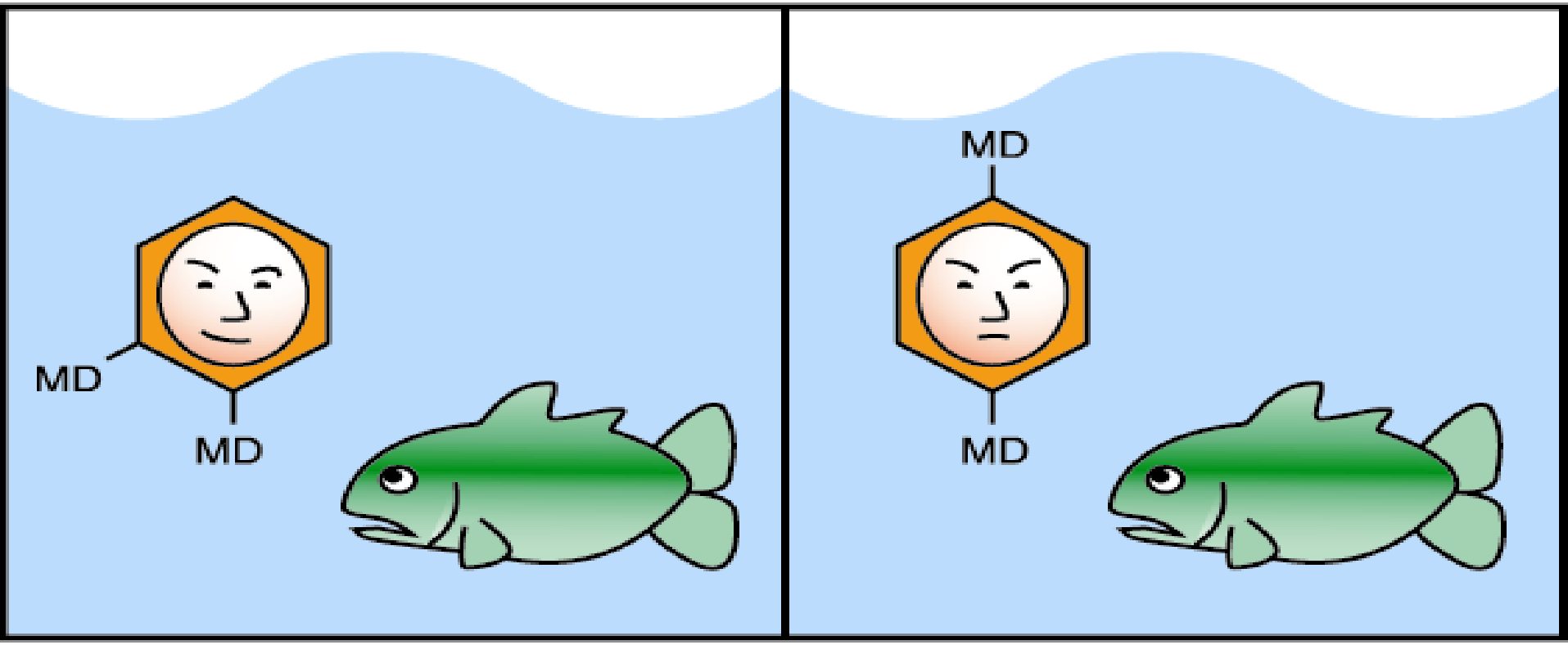
| Consideration | TSS Smothers | Toxic Chemicals | Imp. Sed. | Imp. Hab. |
|---|---|---|---|---|
| Experiment | +++ | NE | +++ | +++ |

+++ = Concordant: Following reduction of TSS in a similar river (the Androscoggin), Class C biological condition was achieved.

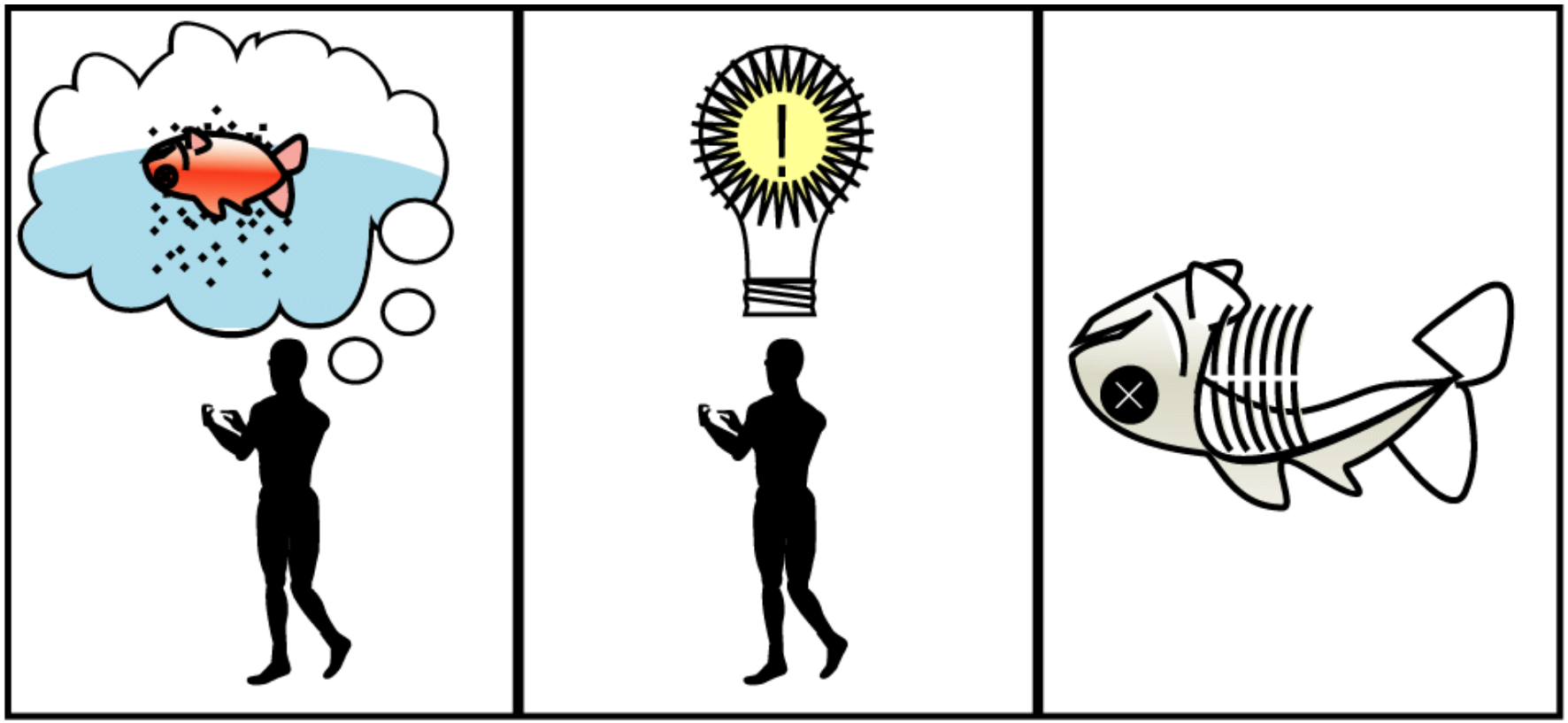
+++ = Concordant: Following dam removal in a similar river (the Kennebec), Class C biological condition was achieved.

# Analogy

Similar stressors have been shown to cause similar effects.



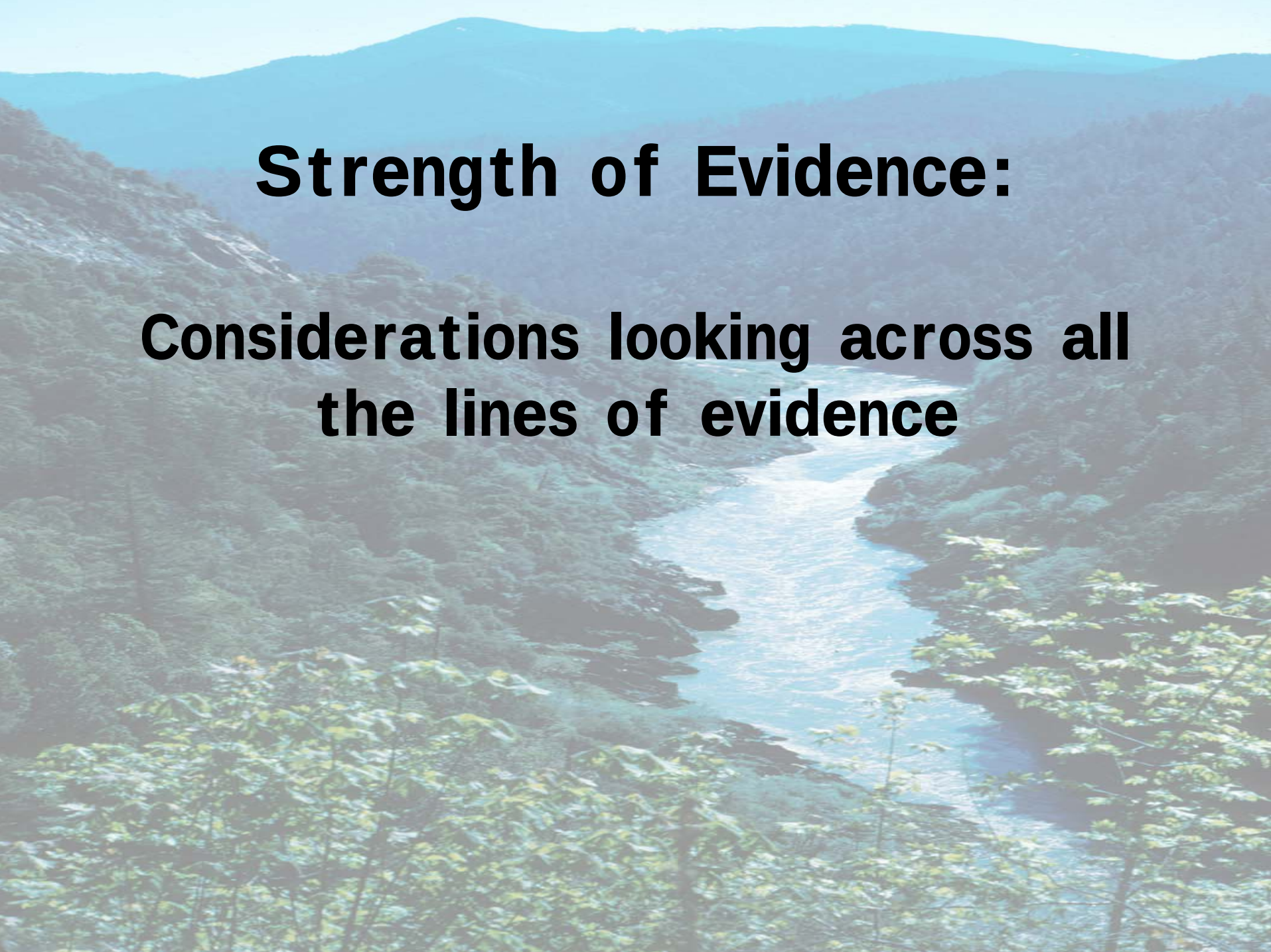
# Predictive Performance



The candidate cause has unobserved properties

that are then predicted and

the prediction is confirmed at the site.



# Strength of Evidence:

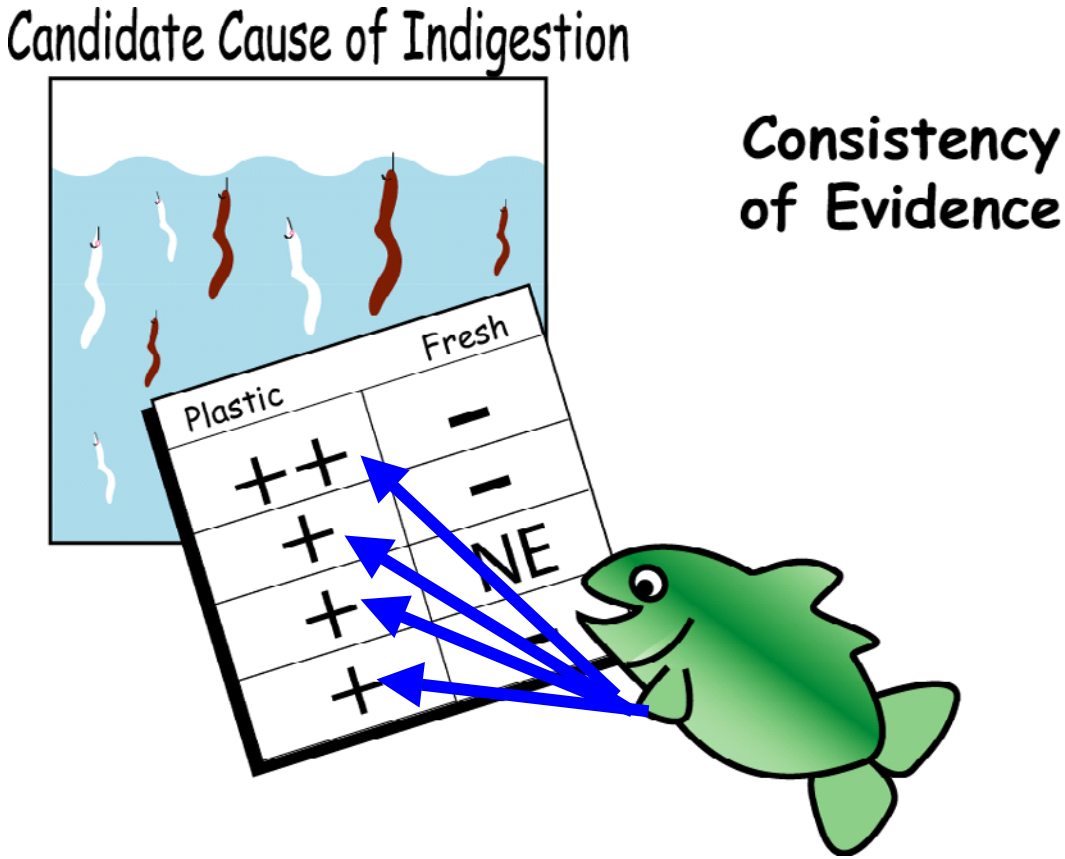
## Considerations looking across all the lines of evidence

# Summarizing Strength of Evidence Results
## Considerations Based on Multiple Lines of Evidence

| Consideration | Evidence | Score |
|---|---|---|
| Consistency | All consistent, | +++ |
| | Most consistent, | + |
| | Multiple inconsistencies | – – – |
| Coherence | Inconsistency explained by a credible mechanism | + |
| | No known explanation | 0 |

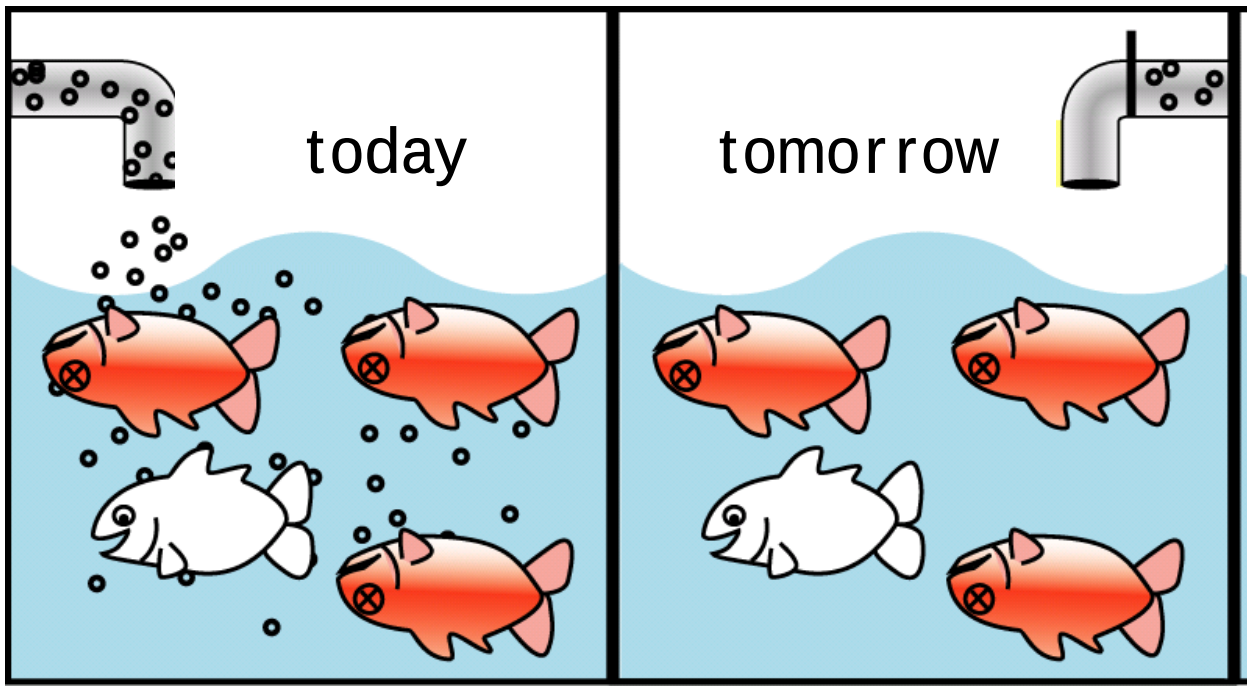
# Consistency

All evidence points in the same direction



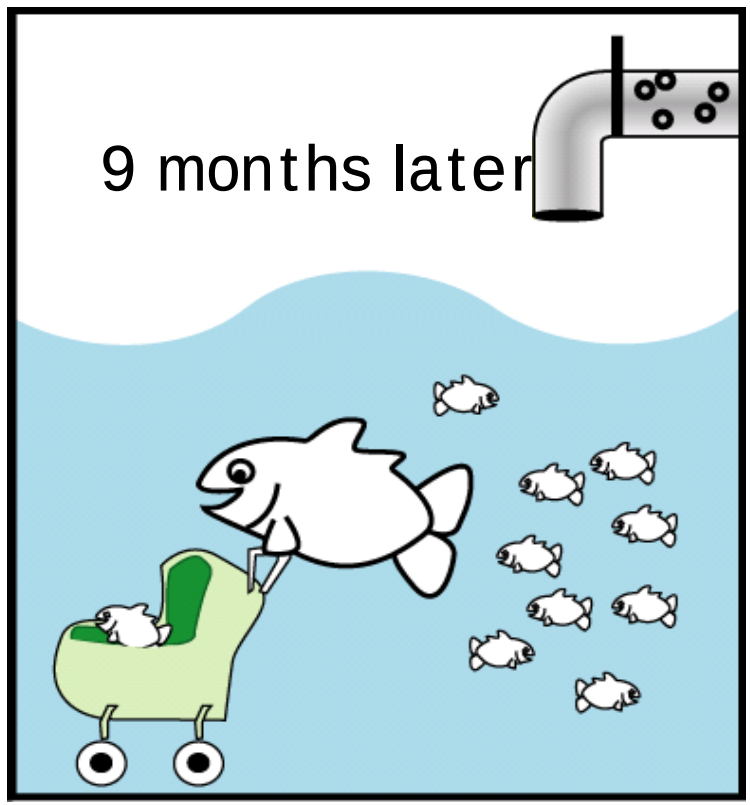
# Coherence of Evidence

There are some inconsistencies,



# Coherence of Evidence

There are some inconsistencies, but they can be explained



Rocky River

# Scores:

## Case-Specific Considerations

| Consideration | TSS Smothers | Toxic Chemicals | Imp. Sed. | Imp. Hab. |
|---|---|---|---|---|
| Co-Occurrence | + | + | + | + |
| Complete Exposure Pathway | + | + | + | + |
| Temporality | NE | NE | NE | NE |
| Consistency of Association | + | + | - | - |
| Biological Gradient | NE | NE | NE | NE |
| Experiment | NE | NE | NE | NE |

Rocky River

# Scores:

## Considerations Based on Other Situations or Biological Knowledge

| Consideration | TSS Smothers | Toxic Chemicals | Imp. Sed. | Imp. Hab. |
|---|---|---|---|---|
| Plausible Mechanism | + | + | + | + |
| Plausible Stressor-response | NE | 0 | NE | NE |
| Consistency of Association | + | NE | - | - |
| Specificity of Cause | 0 | 0 | NA | NA |
| Analogy | NE | NE | NE | NE |
| Experiment | +++ | NE | +++ | +++ |
| Predictive Perf. | NE | NE | NE | NE |

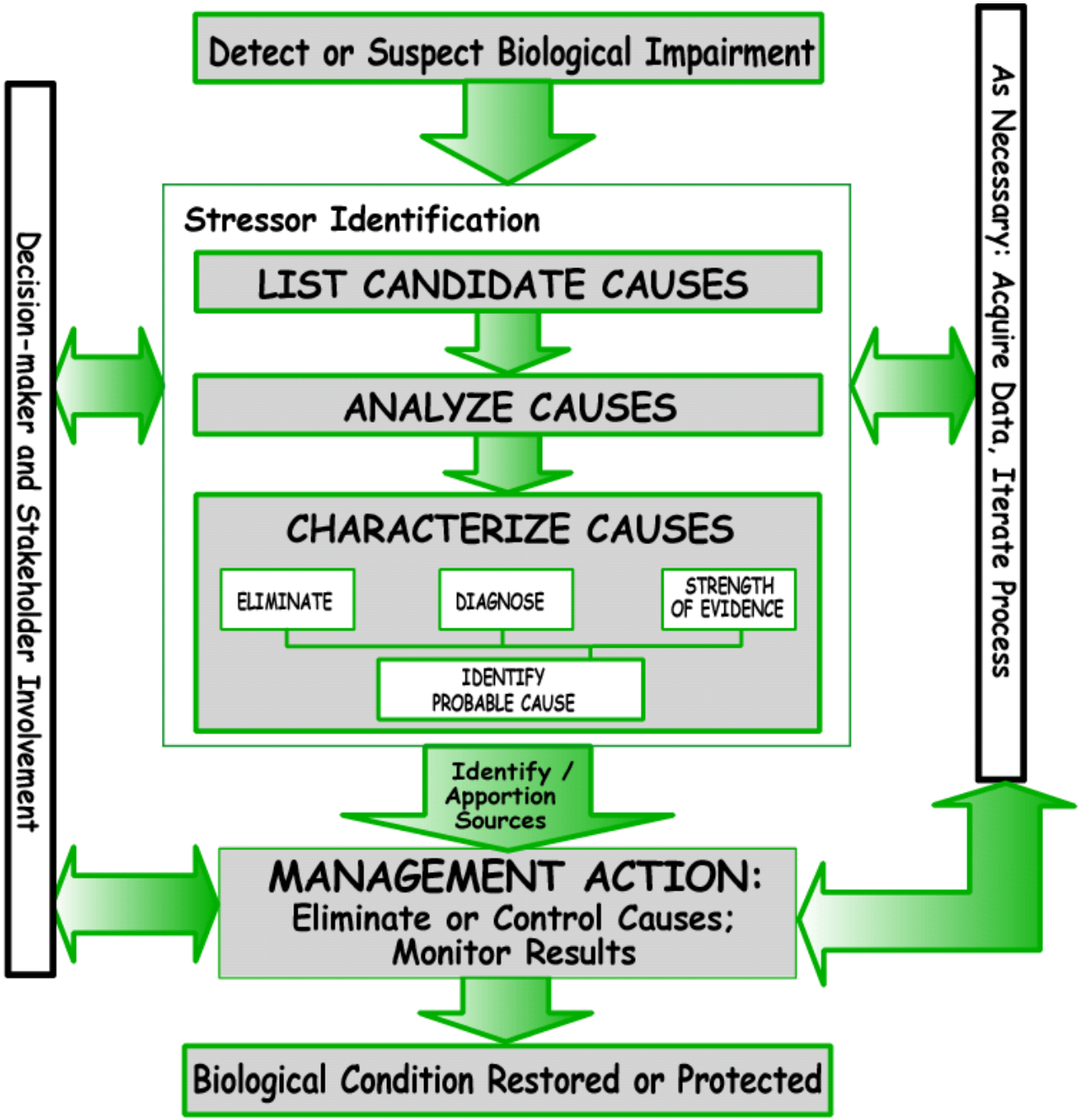
# Scores:
## Considerations Based on Multiple Lines of Evidence

| Consideration | TSS Smothers | Toxic Chemicals | Imp. Sed. | Imp. Hab. |
|---|---|---|---|---|
| Consistency | + | --- | --- | --- |
| Coherence | NA | 0 | 0 | 0 |

**+ = Most Consistent**
**--- = Multiple inconsistencies**
**0 = no known explanation for inconsistencies**

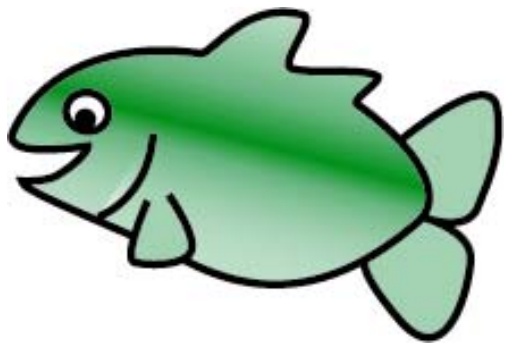
# Probable Cause

# TSS


Detect or Suspect Biological Impairment
Stressor Identification
LIST CANDIDATE CAUSES
ANALYZE CAUSES
CHARACTERIZE CAUSES
ELIMINATE
DIAGNOSE
STRENGTH OF EVIDENCE
IDENTIFY PROBABLE CAUSE
Identify / Apportion Sources
MANAGEMENT ACTION:
Eliminate or Control Causes;
Monitor Results
Biological Condition Restored or Protected
Decision-maker and Stakeholder Involvement
As Necessary: Acquire Data, Iterate Process

# Significance and Outcome

- **December 1998, the EPA approved a TMDL prepared by Maine DEP, for the Rocky River.**
  - **First TMDL addressing 303 (d) water in Region 1**
  - **First time in New England that bioassessment findings served as quantitative response variable**



# Significance and Outcome

## Factors Influencing Success

- Sound legal basis
- Data essential to the modeling
- Teamwork and collaboration