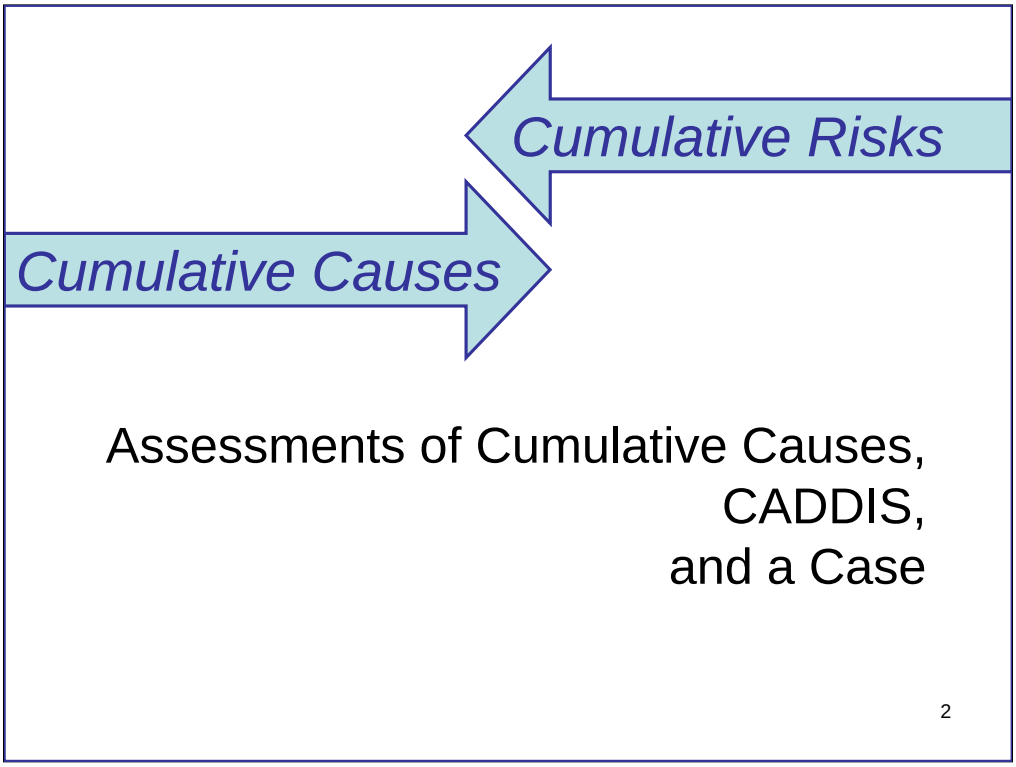
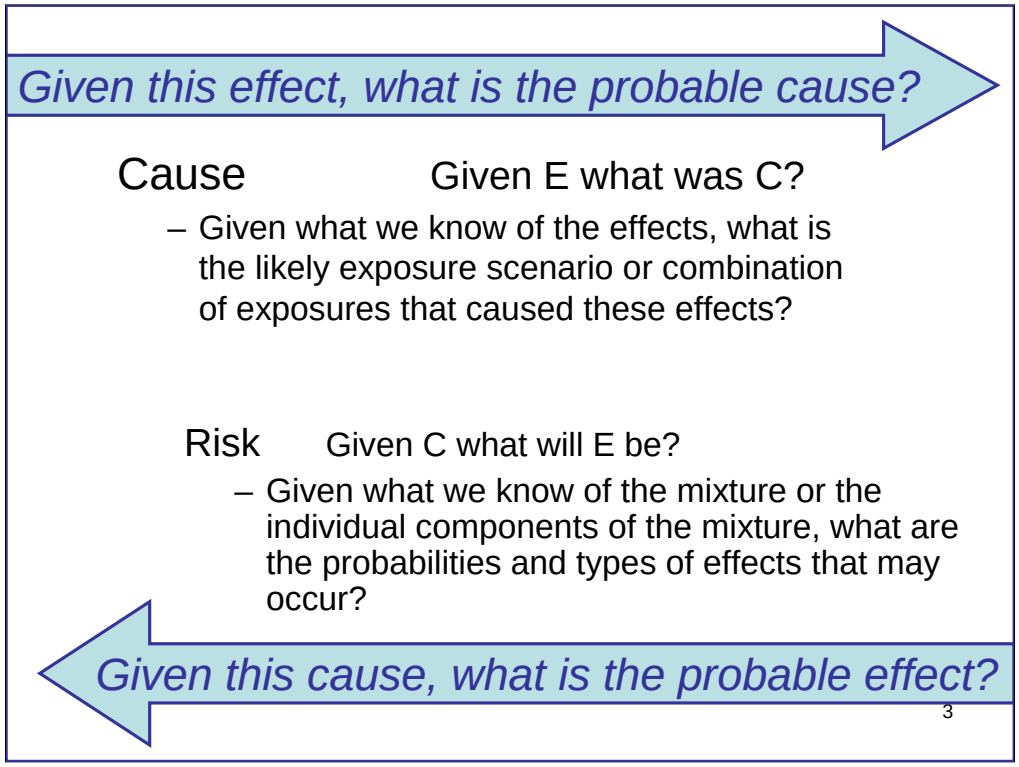
CADDIS - Risk-based Prioritization and Diagnosing the Risk Drivers

Susan Cormier, Ph.D.
NCEA-Cincinnati
and the whole CADDIS team

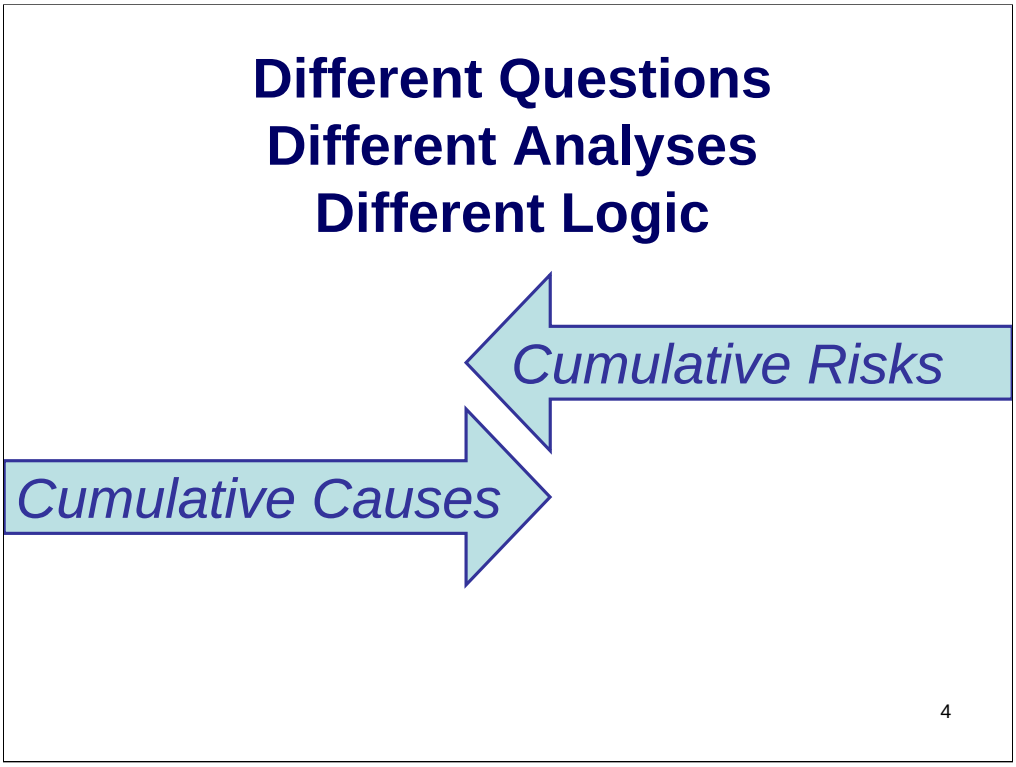


This will be a challenging seminar because it may be outside your normal type of assessment

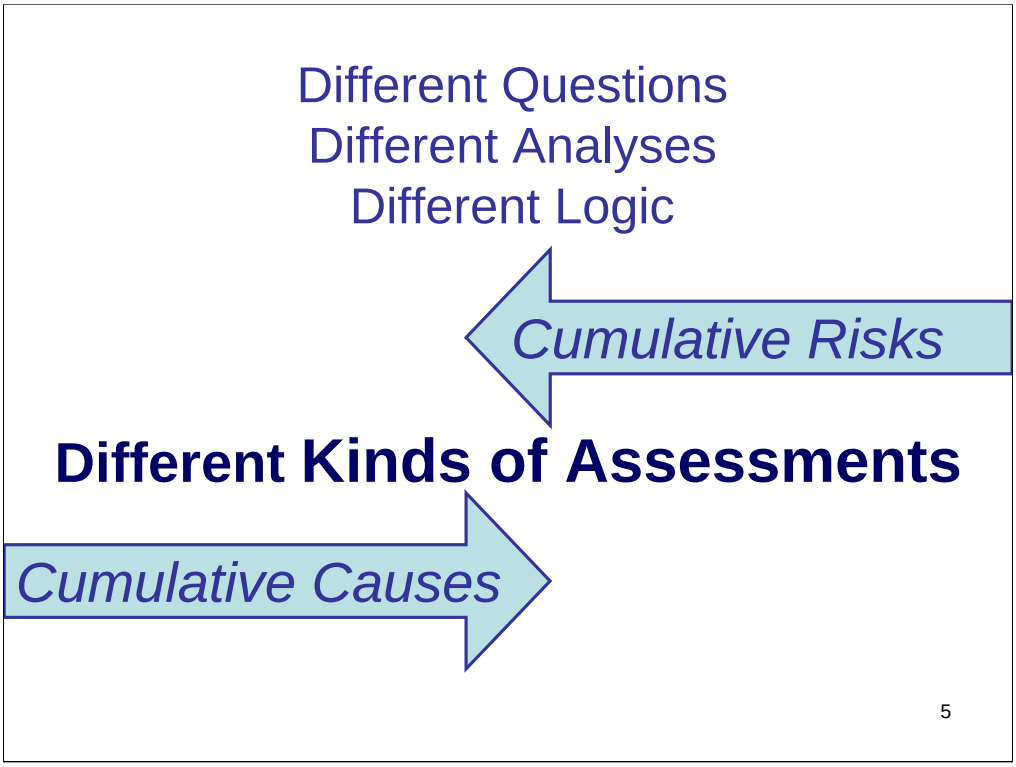
1. causal assessment, not risk assessment
2. Ecological not human
3. So, there are 2 parts. Background of the differences, and then a case study to illustrate how cumulative causes of impaired life in a stream are assessed



For cumulative causes and complex causes



Linda Teuschler shared with us a bit of the pedigree for cumulative risk to humans.The questions,The basic paradigm

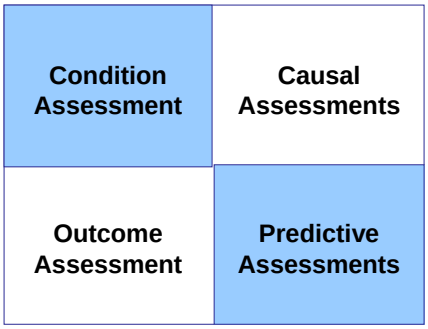


Linda Teuschler shared with us a bit of the pedigree for cumulative risk to humans.The questions,The basic paradigm

I'd like to take us back to first principles for a moment

- A more basic paradigm
- Some examples
- A quick intro to CADDIS

The Basic EA Framework



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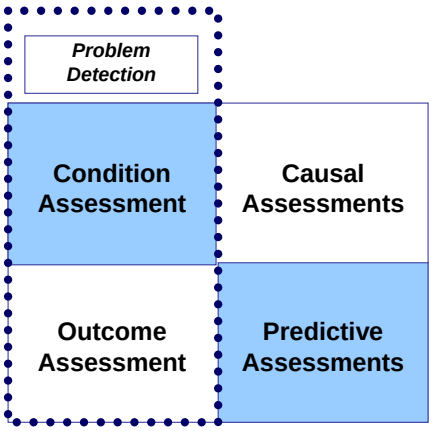
Here is a convenient way to sort through different terminology in different EPA programs

The Basic EA Framework



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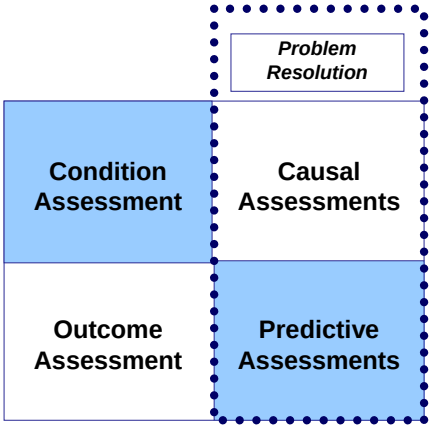
Is the condition Ok?

Did the management control work?

The Basic EA Framework



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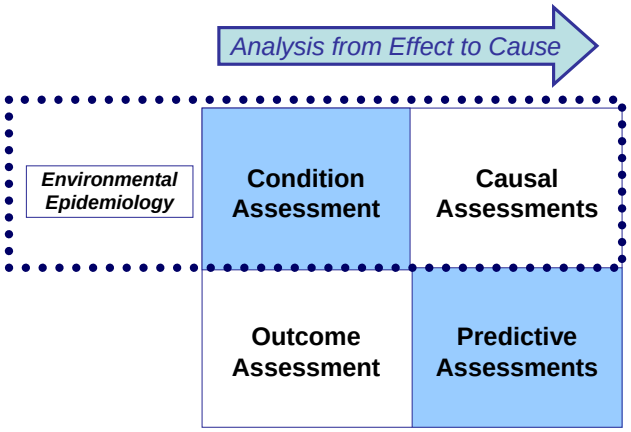
Find the cause and fix it

The Basic EA Framework



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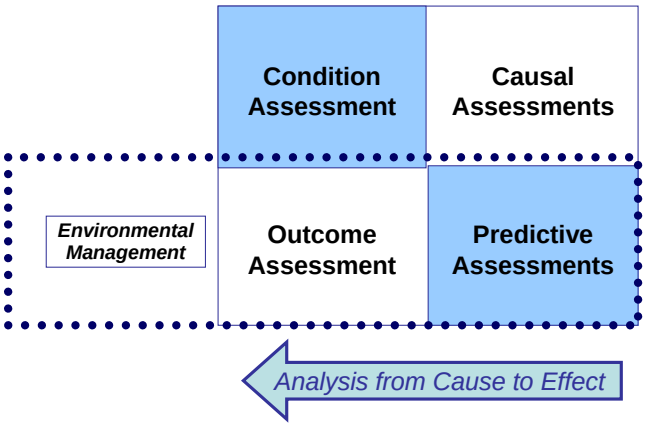
By doing these you figure out the cause

The Basic EA Framework



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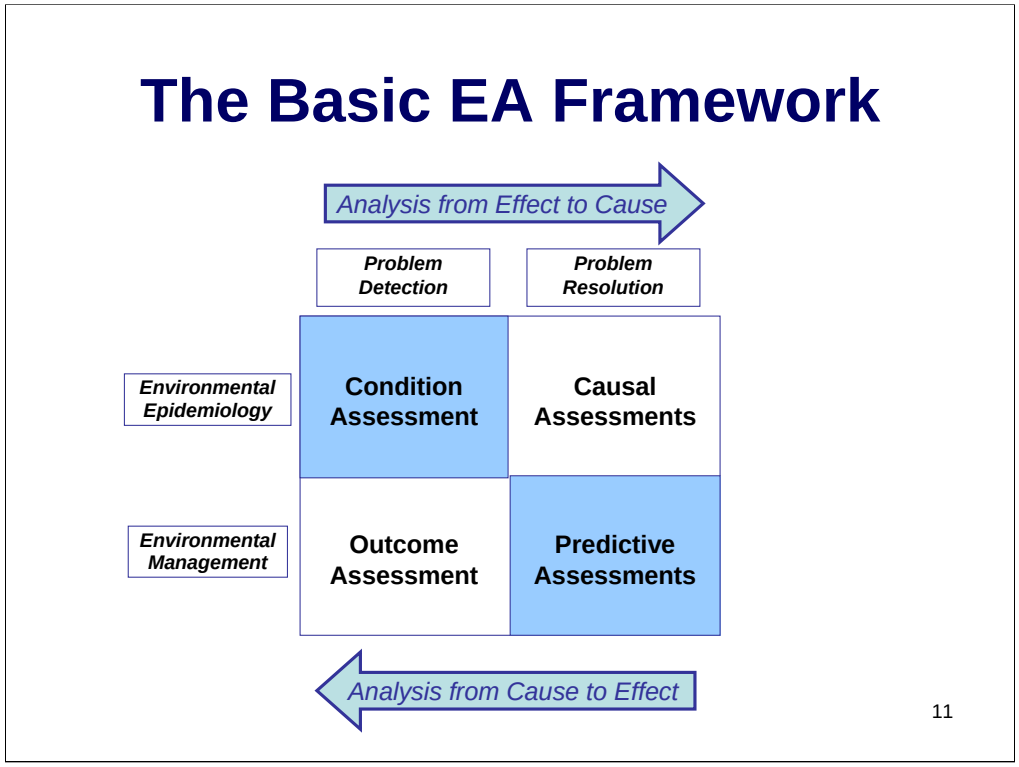
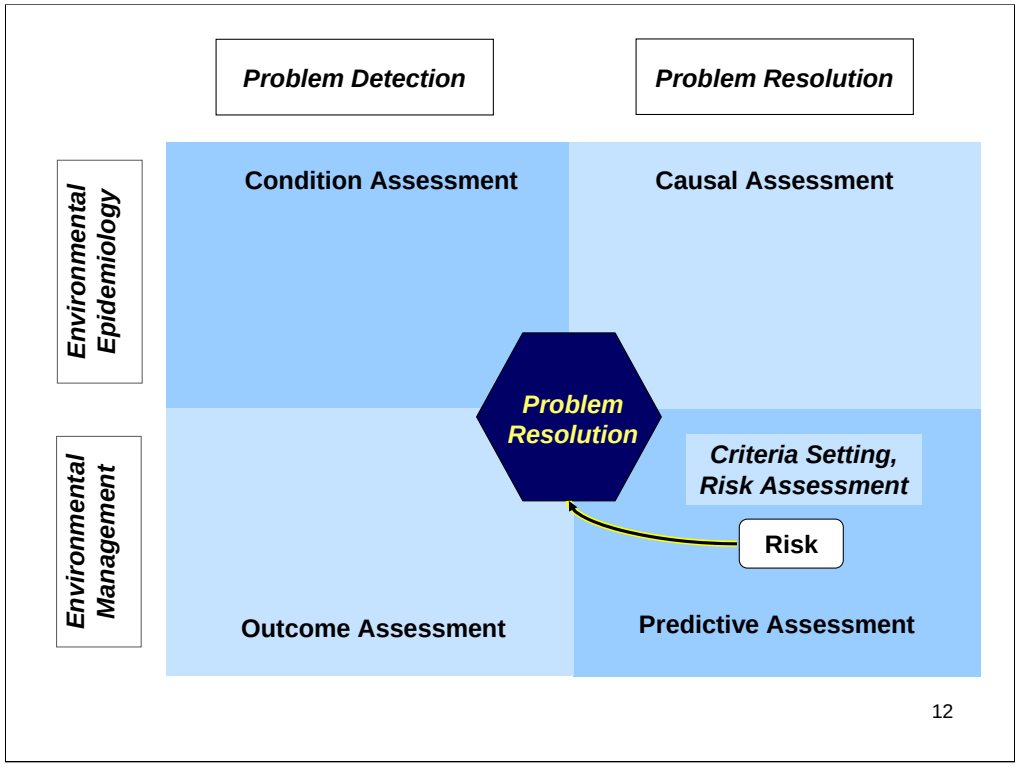
By doing these you manage risks and remediate problems.



Here's the whole 2 X 2 matrix

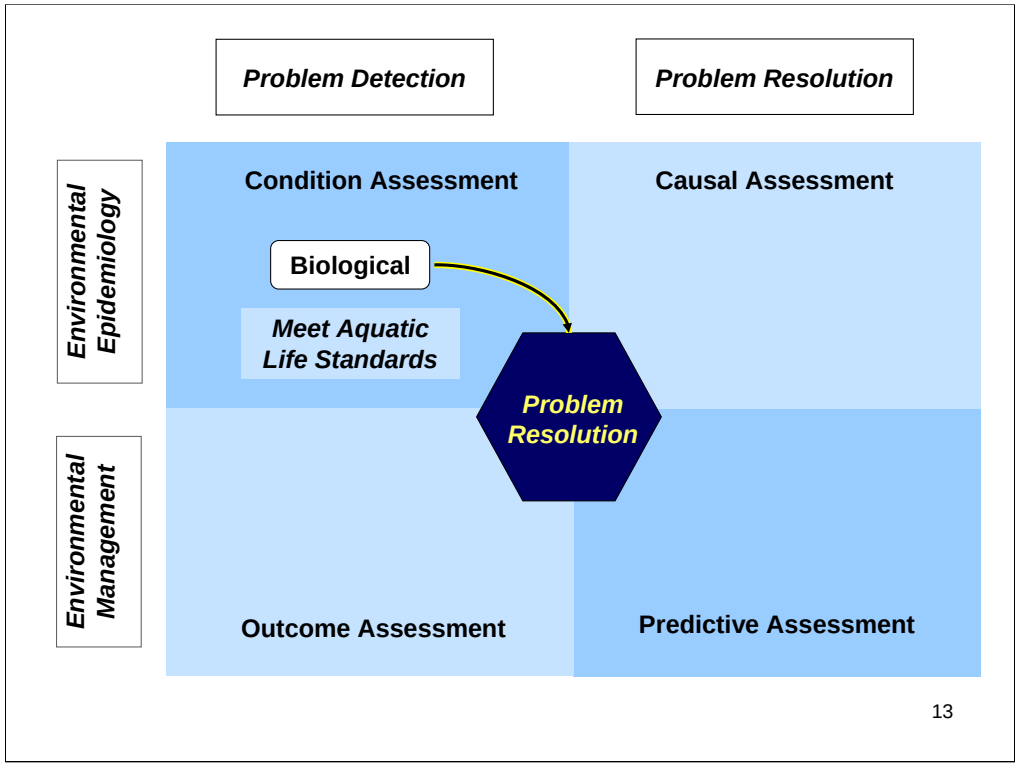
For me it feels right because it has symmetry and tidiness. Physicists like this sort of thing, the simpler the equation the better.



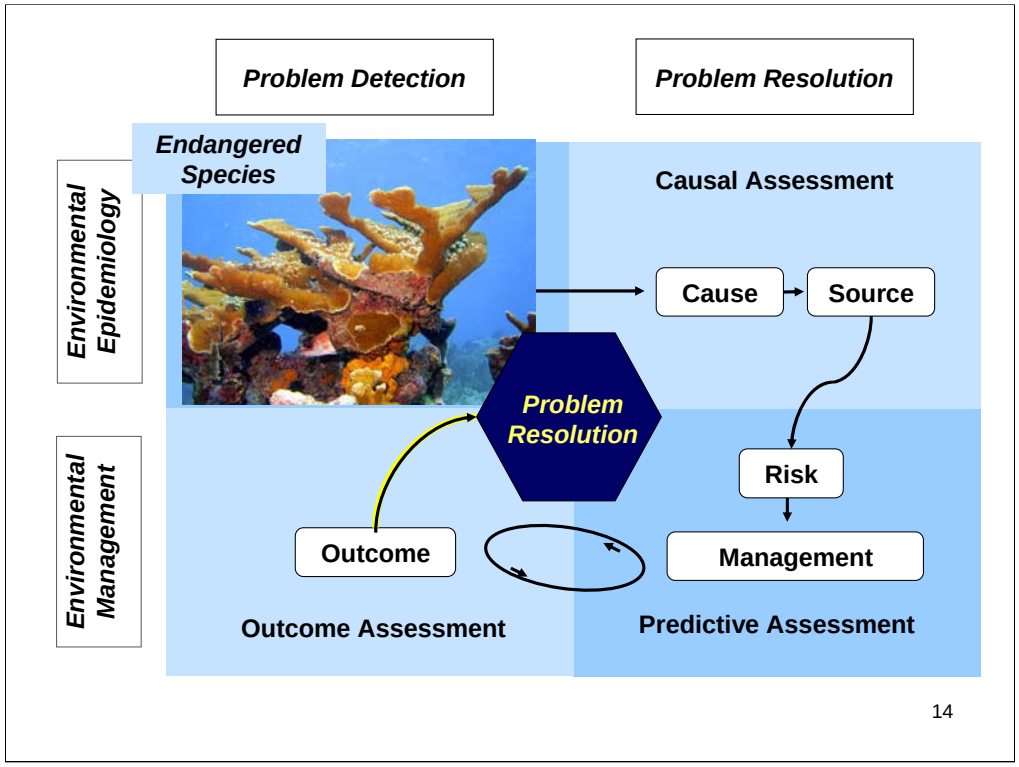
Here's what most of you are familiar with.

You do predictive assessments. You start with an "assigned" chemical or mixture, estimate exposure, develop a model of the causal relationship, and estimate the effect

For criteria setting, an effect level that meets policy is used and exposure that is predicted to achieve that acceptable risk level is estimated from the model of the causal relationship

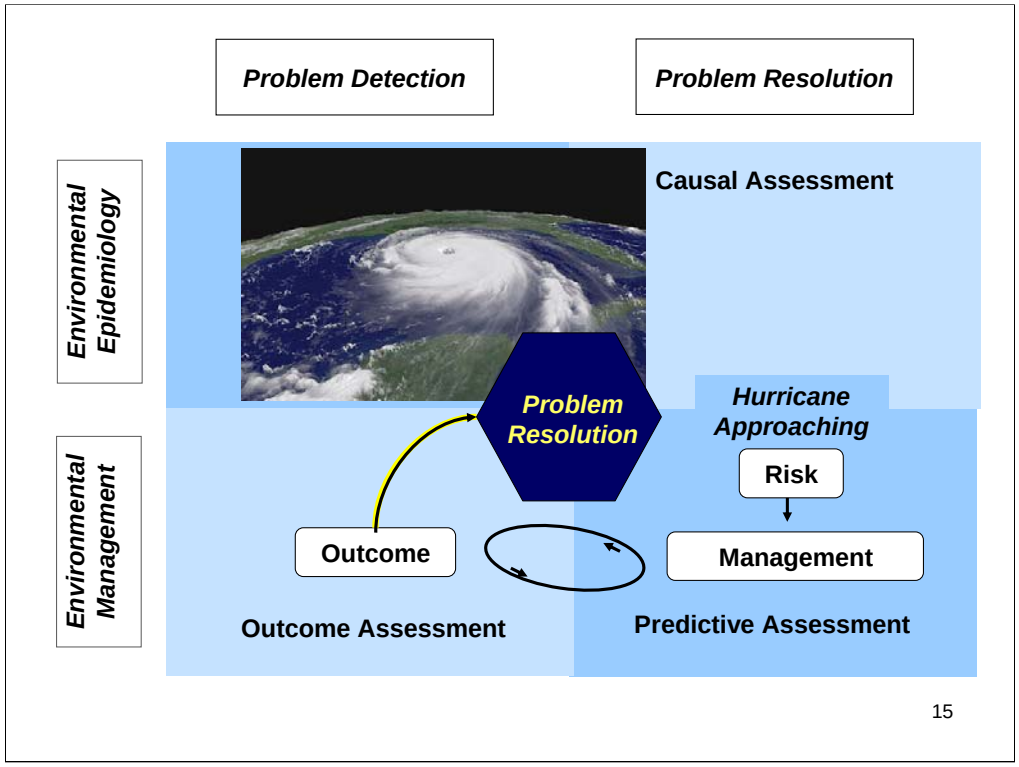


States monitor waterbodies and report to Congress if they are fishable, swimmable, support aquatic life. Here they estimate the condition and if they meet standards, no problem.

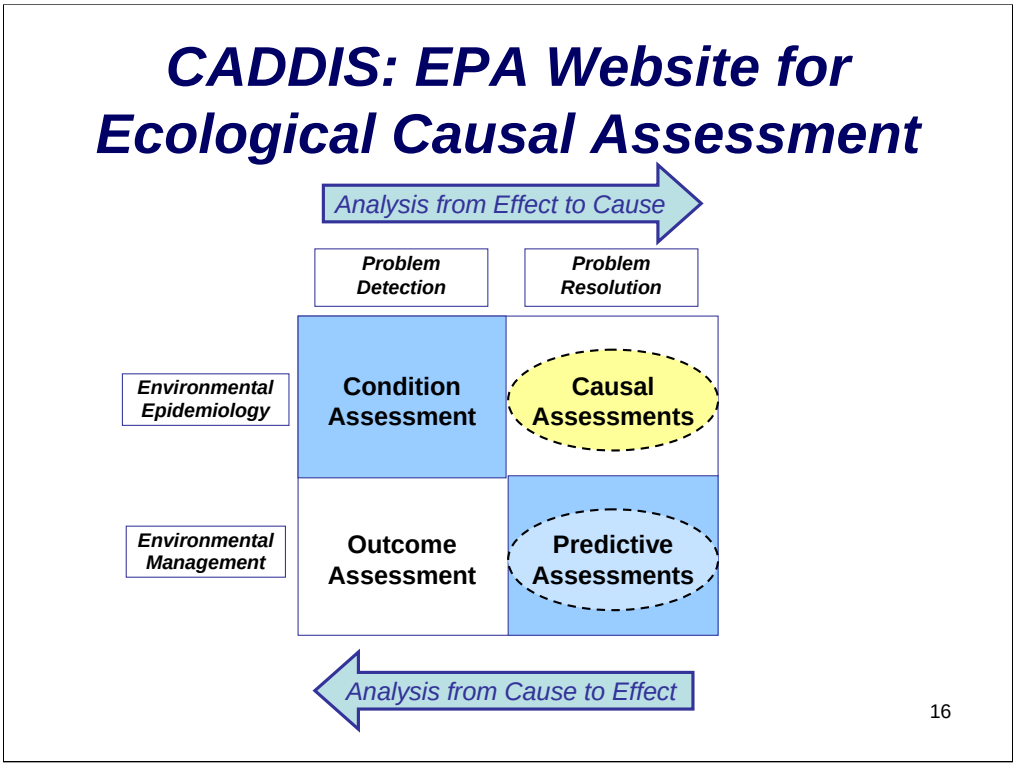


What if they don't? What if a species is put on the endangered species list? Then we must determine the cause, sources, levels to reduce cause to minimize risk, find management options that can reduce risks, then measure recovery of the population while refining management actions until species is not longer threatened.

These may of course have cumulative causes, sources and risks.



What if you don't have time for a deliberate assessment?



Most of the talks in this series are about predictive assessments. I am going to focus on causal assessment by showing you a method, a website, and an illustrative case.

CADDIS
is a guide to causal inference for specific cases

Ecoepidemiological assessments reflect cumulative causes and effects

www.epa.gov/caddis

Condition Assessment

Causal Assessments

Outcome Assessment

Predictive Assessments

larvae

adult

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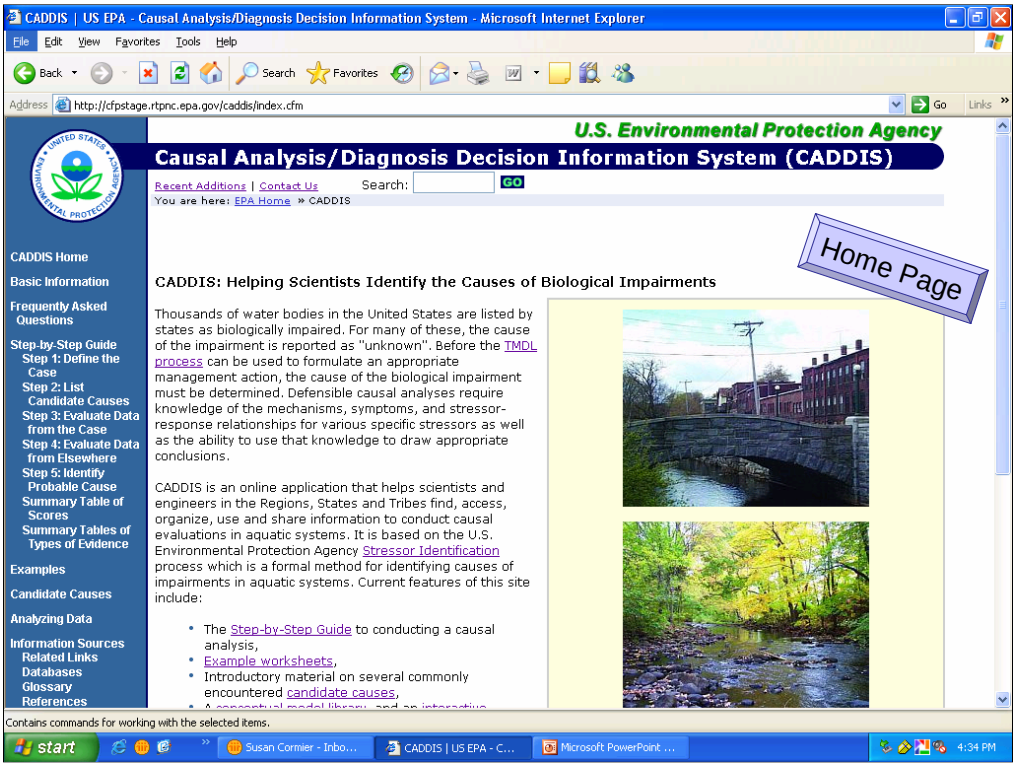
We define the effect and determine the proximate cause that may lead to a manageable source.

EPA website to help

Pictures are of larval caddisfly and adult. Caddisfly larvae are like a catterpillar in the water. The case is for protection like a shell of a hermit crab,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Go Links
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CADDIS: Helping Scientists Identify the Causes of Biological Impairments
Thousands of water bodies in the United States are listed by states as biologically impaired. For many of these, the cause of the impairment is reported as "unknown". Before the TMDL process can be used to formulate an appropriate management action, 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 application that helps scientists and engineers in the Regions, States and Tribes find, access, organize, use and share information to conduct 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 this site include:
The Step-by-Step Guide to conducting a causal analysis,
Example worksheets,
Introductory material on several commonly encountered candidate causes,
Contains commands for working with the selected items.
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CADDIS | US EPA - C...
Microsoft PowerPoint ...
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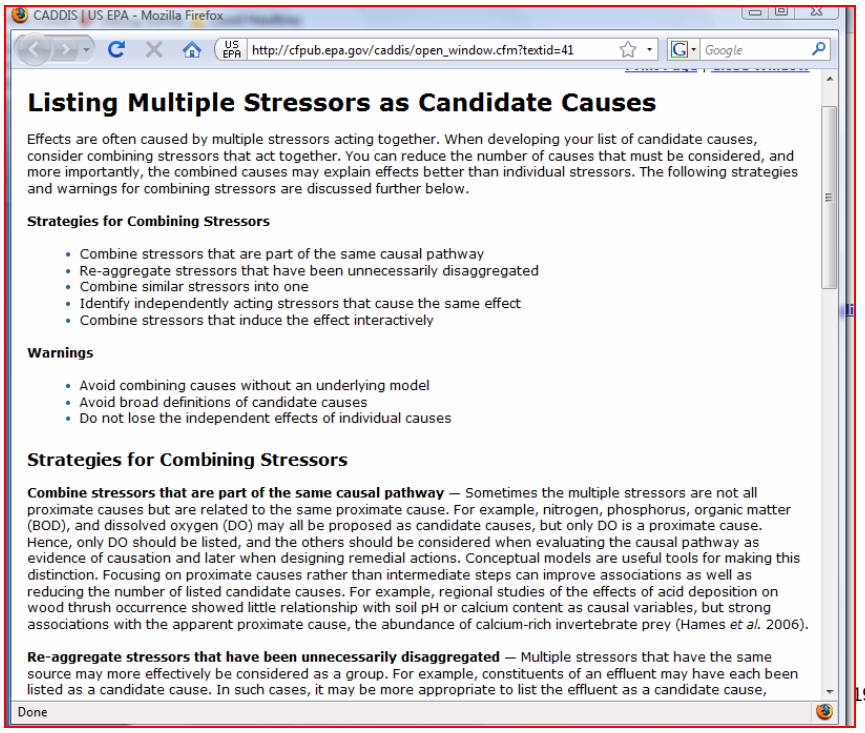
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Listing Multiple Stressors as Candidate Causes
Effects are often caused by multiple stressors acting together. When developing your list of candidate causes, consider combining stressors that act together. You can reduce the number of causes that must be considered, and more importantly, the combined causes may explain effects better than individual stressors. The following strategies and warnings for combining stressors are discussed further below.
Strategies for Combining Stressors
Combine stressors that are part of the same causal pathway
Re-aggregate stressors that have been unnecessarily disaggregated
Combine similar stressors into one
Identify independently acting stressors that cause the same effect
Combine stressors that induce the effect interactively
Warnings
Avoid combining causes without an underlying model
Avoid broad definitions of candidate causes
Do not lose the independent effects of individual causes
Strategies for Combining Stressors
Combine stressors that are part of the same causal pathway — Sometimes the multiple stressors are not all proximate causes but are related to the same proximate cause. For example, nitrogen, phosphorus, organic matter (BOD), and dissolved oxygen (DO) may all be proposed as candidate causes, but only DO is a proximate cause. Hence, only DO should be listed, and the others should be considered when evaluating the causal pathway as evidence of causation and later when designing remedial actions. Conceptual models are useful tools for making this distinction. Focusing on proximate causes rather than intermediate steps can improve associations as well as reducing the number of listed candidate causes. For example, regional studies of the effects of acid deposition on wood thrush occurrence showed little relationship with soil pH or calcium content as causal variables, but strong associations with the apparent proximate cause, the abundance of calcium-rich invertebrate prey (Hames et al. 2006).
Re-aggregate stressors that have been unnecessarily disaggregated — Multiple stressors that have the same source may more effectively be considered as a group. For example, constituents of an effluent may have each been listed as a candidate cause. In such cases, it may be more appropriate to list the effluent as a candidate cause,
Done
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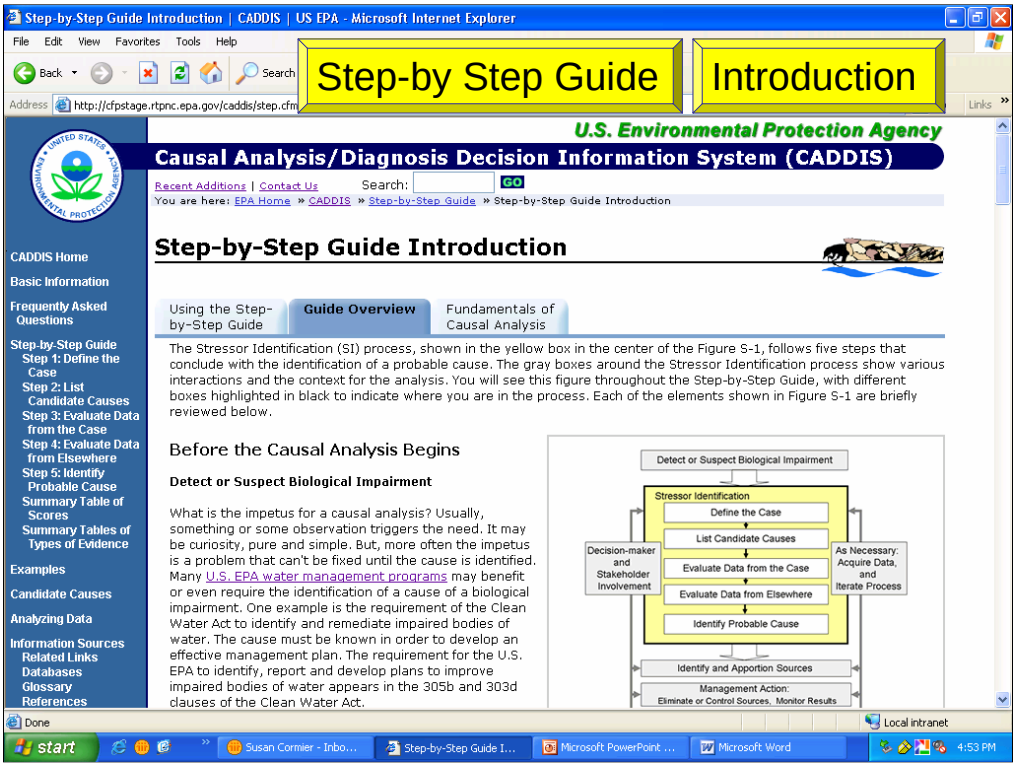
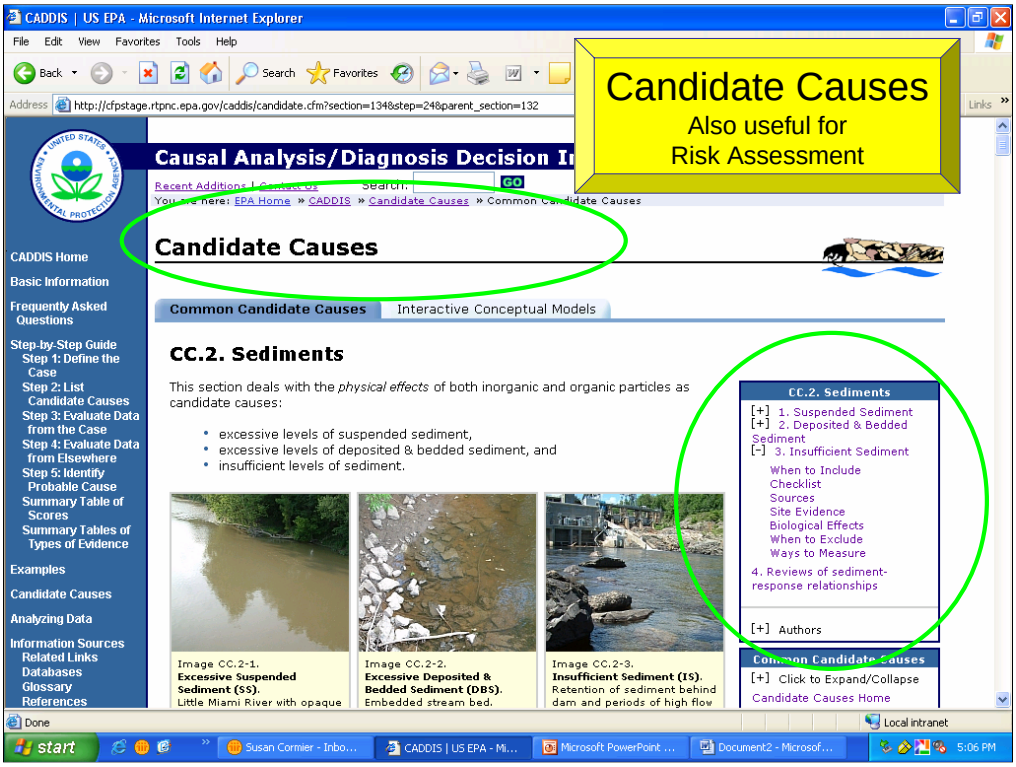

Step-by-Step Guide Introduction | CADDIS | US EPA - Microsoft Internet Explorer
Step-by Step Guide
Introduction
U.S. Environmental Protection Agency
Causal Analysis/Diagnosis Decision Information System (CADDIS)
Step-by-Step Guide Introduction
Using the Step-by-Step Guide
Guide Overview
Fundamentals of Causal Analysis
The Stressor Identification (SI) process, shown in the yellow box in the center of the Figure S-1, follows five steps that conclude with the identification of a probable cause. The gray boxes around the Stressor Identification process show various interactions and the context for the analysis. You will see this figure throughout the Step-by-Step Guide, with different boxes highlighted in black to indicate where you are in the process. Each of the elements shown in Figure S-1 are briefly reviewed below.
Before the Causal Analysis Begins
Detect or Suspect Biological Impairment
What is the impetus for a causal analysis? Usually, something or some observation triggers the need. It may be curiosity, pure and simple. But, more often the impetus is a problem that can't be fixed until the cause is identified. Many U.S. EPA water management programs may benefit or even require the identification of a cause of a biological impairment. One example is the requirement of the Clean Water Act to identify and remediate impaired bodies of water. The cause must be known in order to develop an effective management plan. The requirement for the U.S. EPA to identify, report and develop plans to improve impaired bodies of water appears in the 305b and 303d clauses of the Clean Water Act.
Detect or Suspect Biological Impairment
Stressor Identification
Define the Case
List Candidate Causes
Evaluate Data from the Case
Evaluate Data from Elsewhere
Identify Probable Cause
Decision-maker and Stakeholder Involvement
As Necessary: Acquire Data, and Iterate Process
Identify and Apportion Sources
Management Action: Eliminate or Control Sources, Monitor Results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Candidate Causes
Also useful for
Risk Assessment
Causal Analysis/Diagnosis Decision I
Candidate Causes
Common Candidate Causes
Interactive Conceptual Models
CC.2. Sediments
This section deals with the physical effects of both inorganic and organic particles as candidate causes:
excessive levels of suspended sediment,
excessive levels of deposited & bedded sediment, and
insufficient levels of sediment.
CC.2. Sediments
[+] 1. Suspended Sediment
[+] 2. Deposited & Bedded Sediment
[-] 3. Insufficient Sediment
When to Include
Checklist
Sources
Site Evidence
Biological Effects
When to Exclude
Ways to Measure
4. Reviews of sediment-response relationships
[+] Authors
Common Candidate Causes
[+] Click to Expand/Collapse
Candidate Causes Home
Image CC.2-1. Excessive Suspended Sediment (SS). Little Miami River with opaque
Image CC.2-2. Excessive Deposited & Bedded Sediment (DBS). Embedded stream bed.
Image CC.2-3. Insufficient Sediment (IS). Retention of sediment behind dam and periods of high flow
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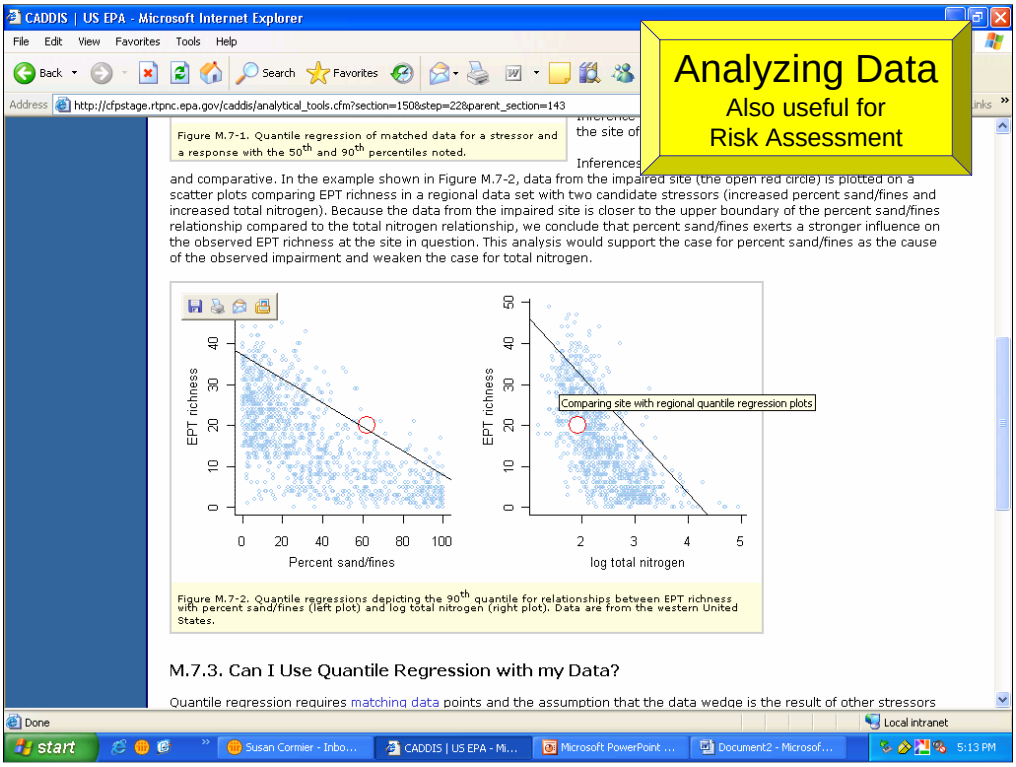
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Analyzing Data
Also useful for
Risk Assessment
Figure M.7-1. Quantile regression of matched data for a stressor and a response with the 50th and 90th percentiles noted.
and comparative. In the example shown in Figure M.7-2, data from the impaired site (the open red circle) is plotted on a scatter plots comparing EPT richness in a regional data set with two candidate stressors (increased percent sand/fines and increased total nitrogen). Because the data from the impaired site is closer to the upper boundary of the percent sand/fines relationship compared to the total nitrogen relationship, we conclude that percent sand/fines exerts a stronger influence on the observed EPT richness at the site in question. This analysis would support the case for percent sand/fines as the cause of the observed impairment and weaken the case for total nitrogen.
EPT richness
Percent sand/fines
log total nitrogen
Comparing site with regional quantile regression plots
Figure M.7-2. Quantile regressions depicting the 90th quantile for relationships between EPT richness with percent sand/fines (left plot) and log total nitrogen (right plot). Data are from the western United States.
M.7.3. Can I Use Quantile Regression with my Data?
Quantile regression requires matching data points and the assumption that the data wedge is the result of other stressors
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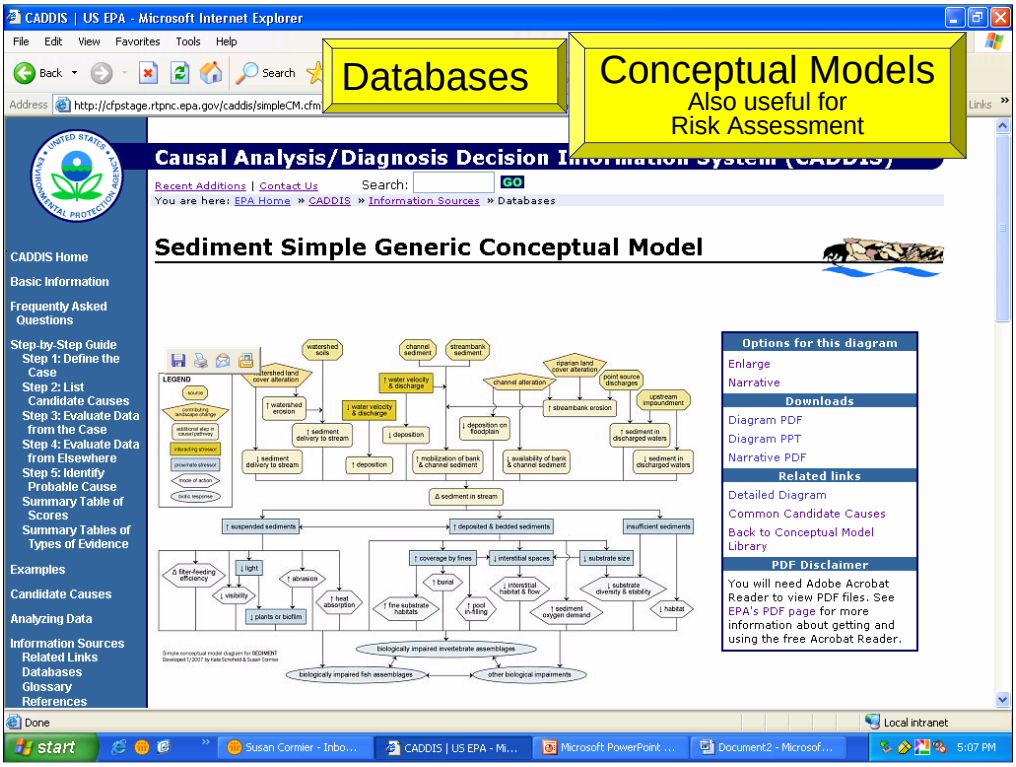
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Common Candidate Causes
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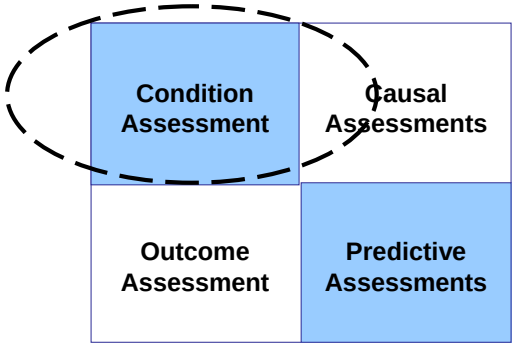
The Basic EA Framework



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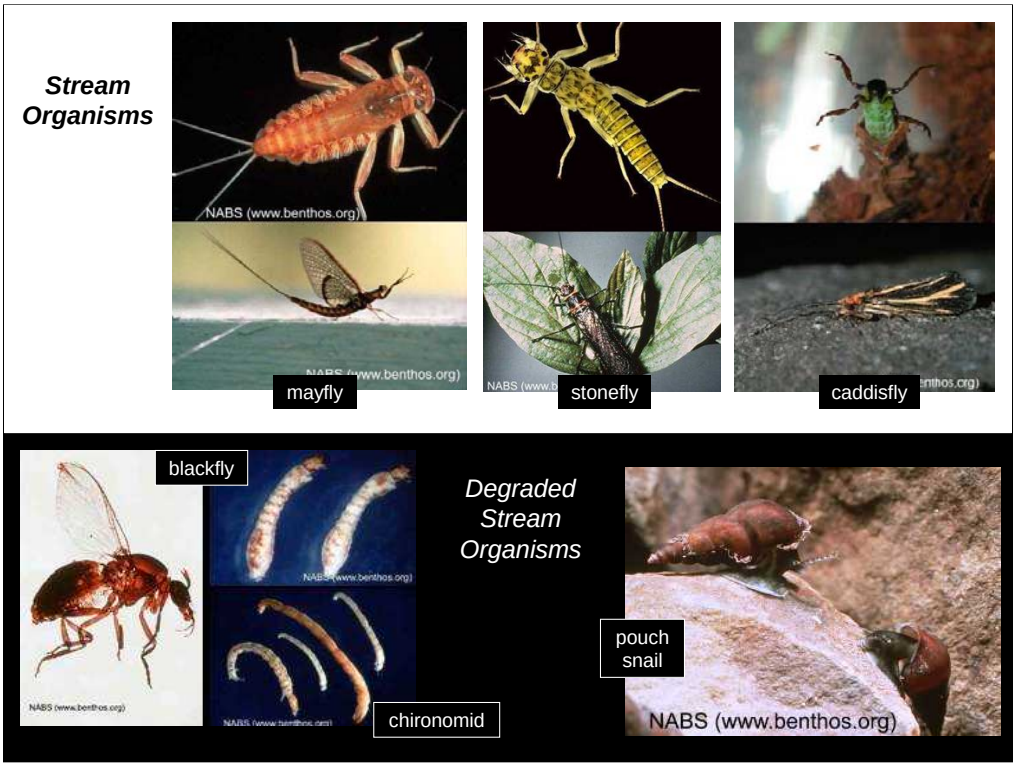

Top: Mayfly larva (Heptageniidae)
Bottom: Adult mayfly
Source: The North American Benthological Society

Top: Stonefly larva (Baumanella sp.)
Bottom: Adult stonefly (Pteronarcys princeps)
Source: The North American Benthological Society

Top: Caddisfly Larva (Brachycentrus americanus)
Bottom: Adult Caddisfly (Nerophilus californicus)
Source: Both photos are from The North American Benthological Society

Left: Adult black fly (Simuliidae)
Top Right: Black fly larva (Simuliidae)
Bottom Right: Midge larvae (Chironomidae)
Source: All photos from The North American Benthological Society

Photo: Snails (Pleuroceridae)
Source: The North American Benthological Society

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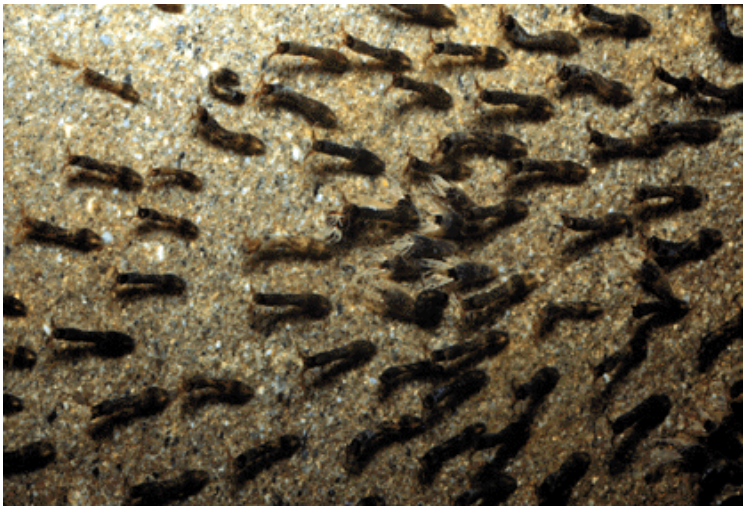

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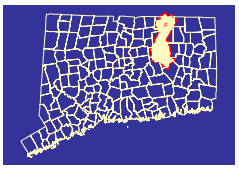
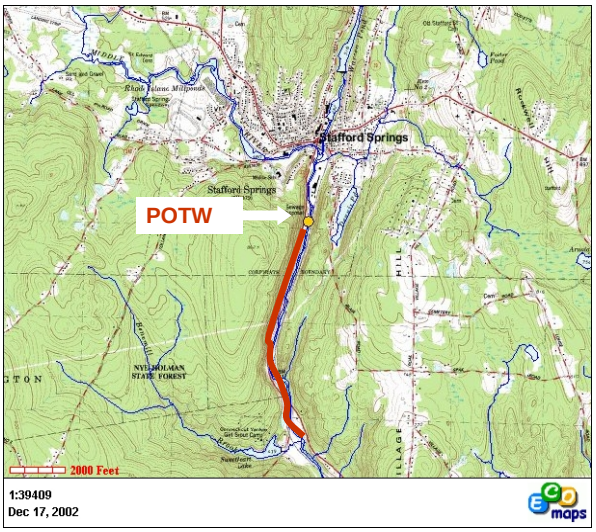


Case Study - Willimantic River, CT



Clean Water Act 305b report to Congress

TMDLs target Cu, Pb, Zn

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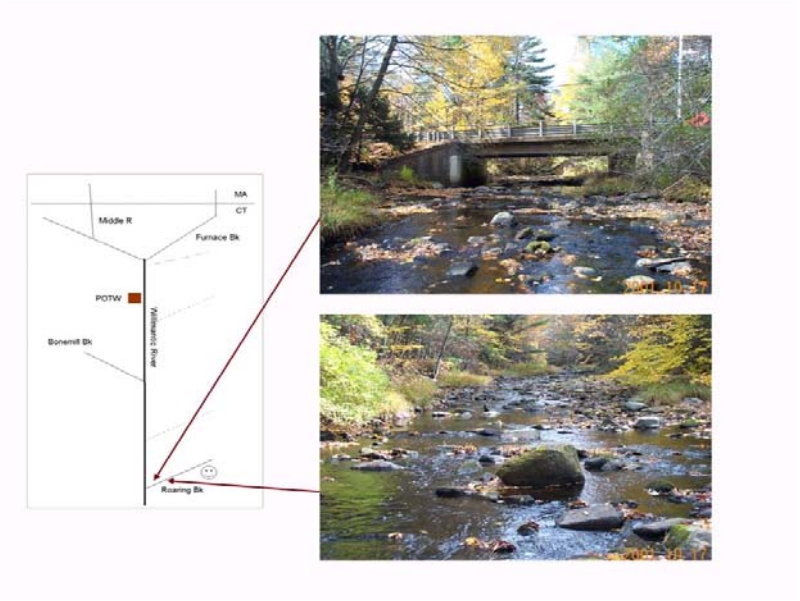
Famous Mineral Springs used by native americans and settlers.

Listed based on aquatic tox monitoring reports and dilution studies

POTW receives effluent from a few industries.

Roaring Brook, Willimantic River Watershed



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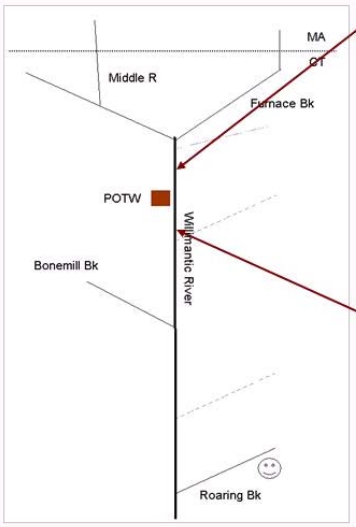
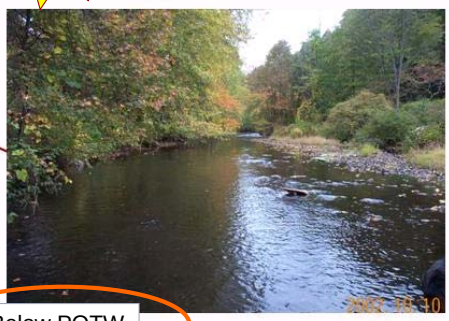
Willimantic River



Above POTW



Below POTW

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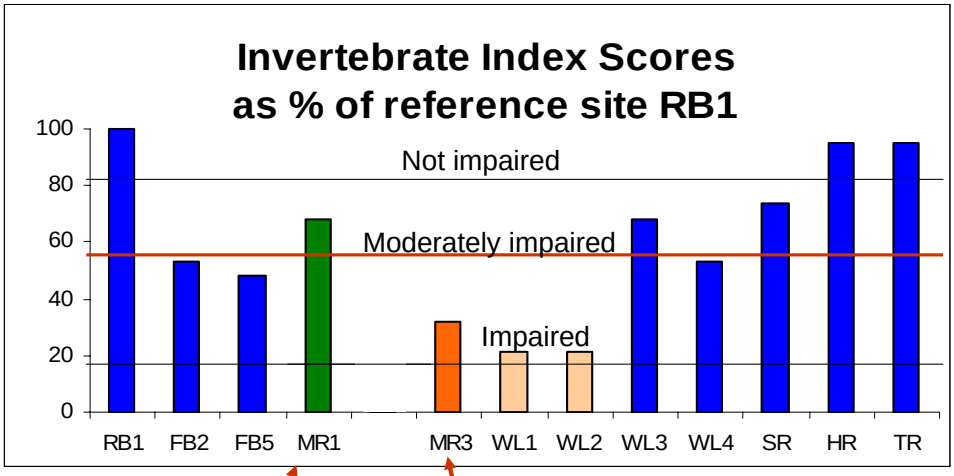
Define the Biological Impairment



Compared to further upstream

First appearance of downstream impairment

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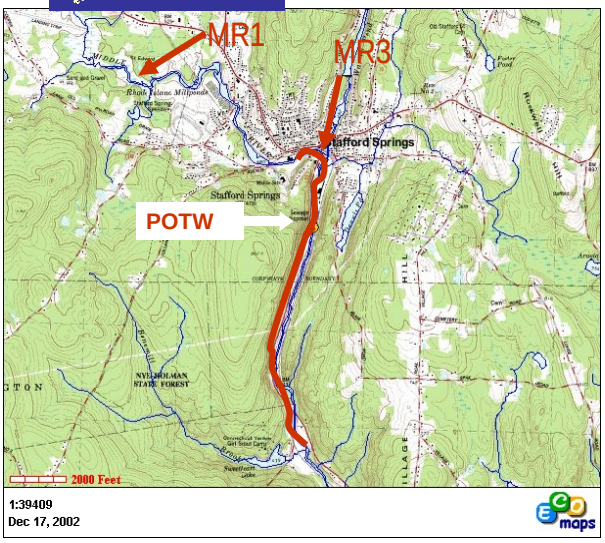
Willimantic River Study Area



- Area of concern
- Upstream impairment identified

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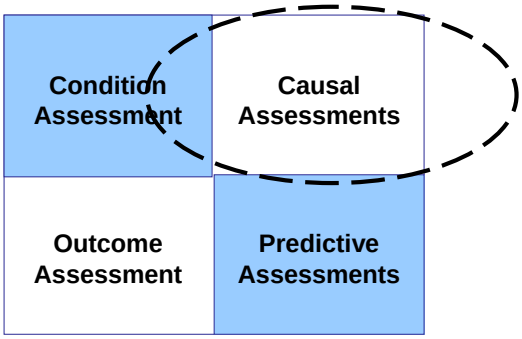
The Basic EA Framework



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Types of Causation

- Specific Causation
  - *Causal:* Did smoking cause my cancer
  - *Risk:* Will my smoking cause cancer
- General Causation
  - *Causal:* Does smoking cause cancer
  - *Risk:* Can smoking cause cancer

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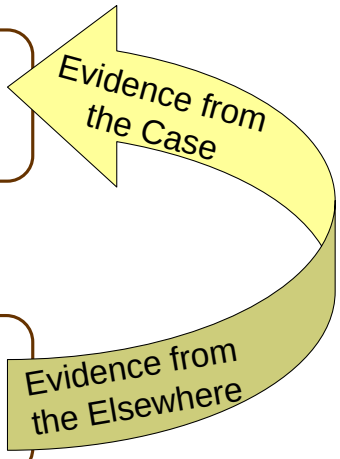
Types of Causation

Sources of Data for Evidence

- **Specific Causation**
  - Did C cause E
  - Will C cause E

- **General Causation**
  - Does C cause E
  - Can C cause E



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Develop and Evaluate Evidence

- Refutation
- Diagnosis
- Weight of evidence

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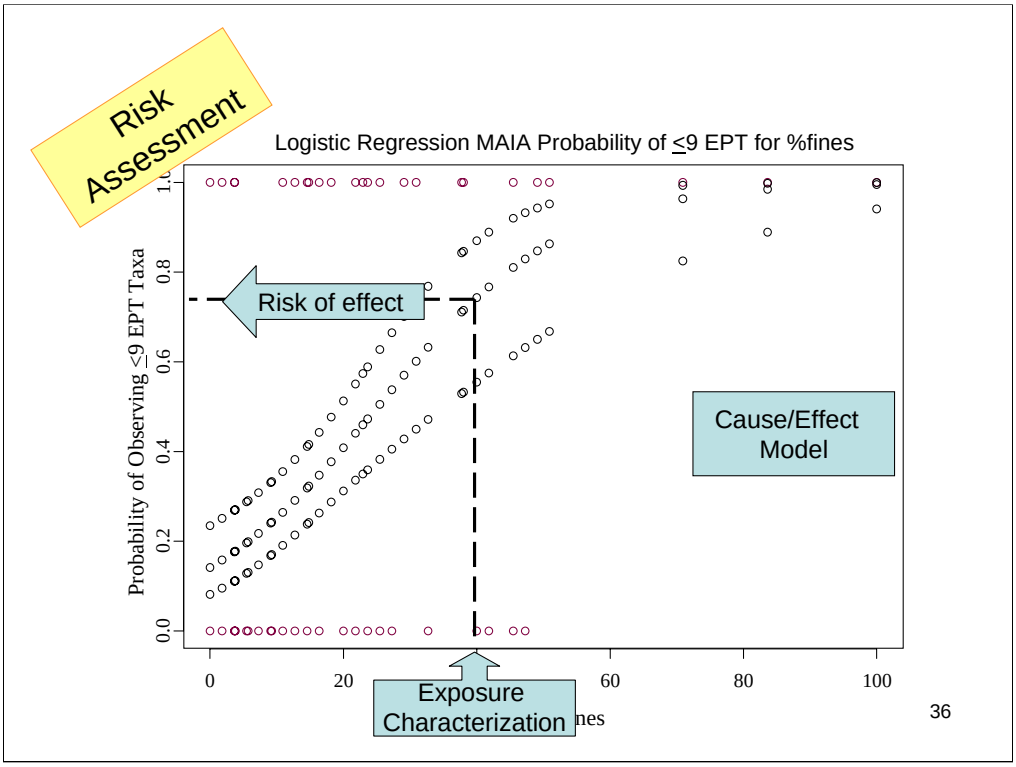
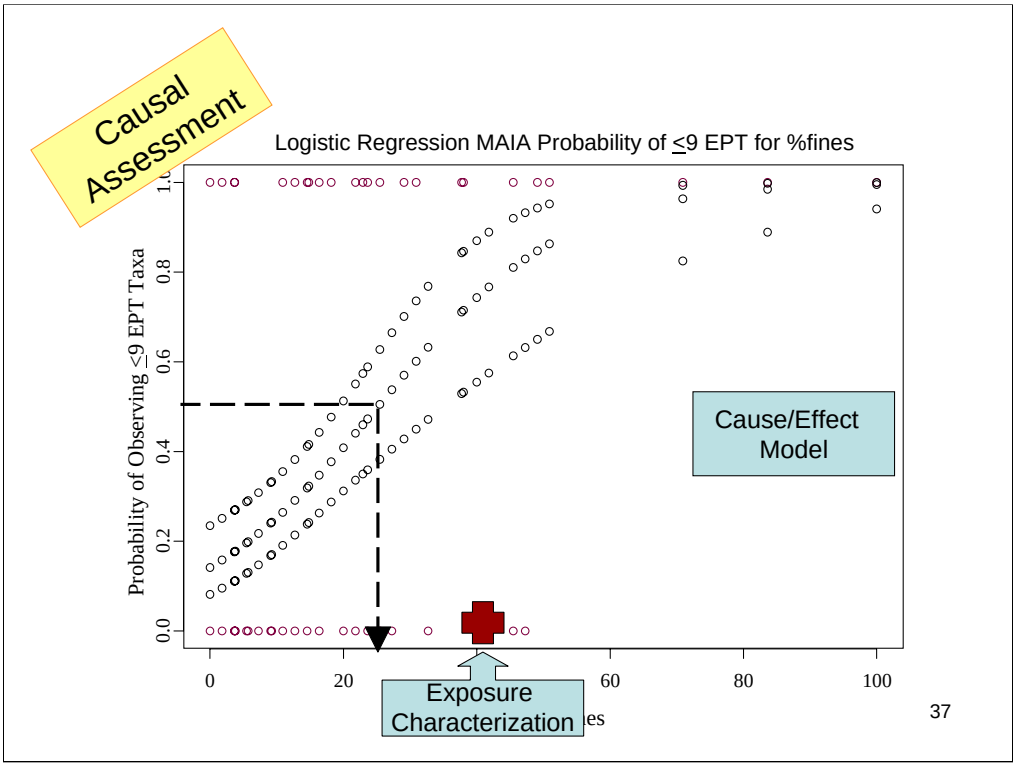
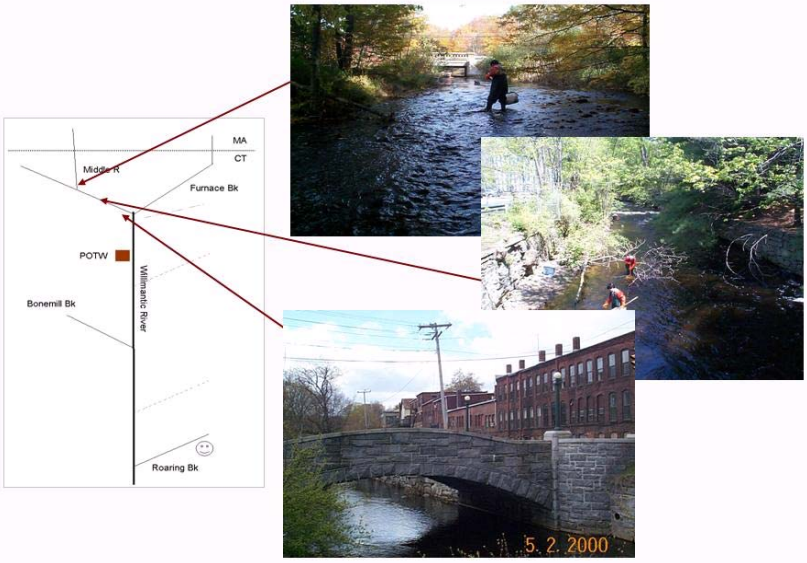


In risk assessment, at the exposures at my site, the probability of an effect is 0.75

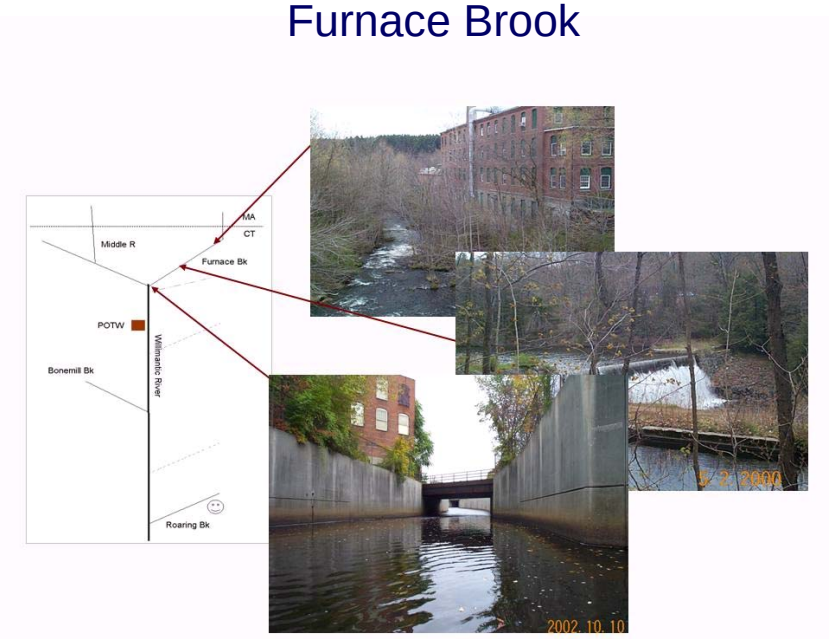


In causal assessment, evidence is expressed: at the exposures at my site, the probability of observing the effect is greater than chance alone.

Middle River



Furnace Brook



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List of Candidate Causes

1. **toxicity** from metals, ammonia (NH3), or a complex mixture
2. **high flows** removal of organisms during
3. **settled particles** filling interstitial habitat
4. **low dissolved oxygen**
5. **thermal stress**
6. **altered food resources** favoring filter feeders

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Weight of evidence

- Types of evidence
  - Adapted from Hill's Considerations
- Scoring
  - Source of information
    - Observation
    - Manipulation
    - General Knowledge
  - Quality of evidence
    - From the case or elsewhere
    - Specificity, Consistency and other qualities

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Weighted Body of Evidence

Willimantic case study	Metals	NH_3	Flow	Silt	Low DO	Temp	Food	Episodic Mix
Spatial/Temporal Co-Occurrence	+	-		+	- - -	+		+
Evidence of Biological Mechanism	+	+	-	-	+	+	+	+
Causal Pathway		-	+	-	-	+	+	+
Stressor-Response from the Field	+	-		-	+	+		
Manipulation of Exposure								+ + +
Verified Predictions								+ + +
Stressor-Response from Other Field Studies	- -	+						
Stressor-Response from Laboratory	+ +	-			-	+		
Consistency of Evidence	-	-	-	-	-	+	+	+ + +

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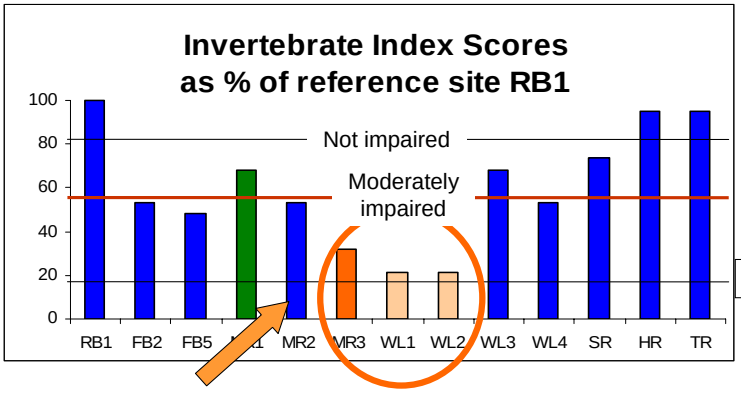
Cause: Toxic mixture

Source: Broken effluent pipe



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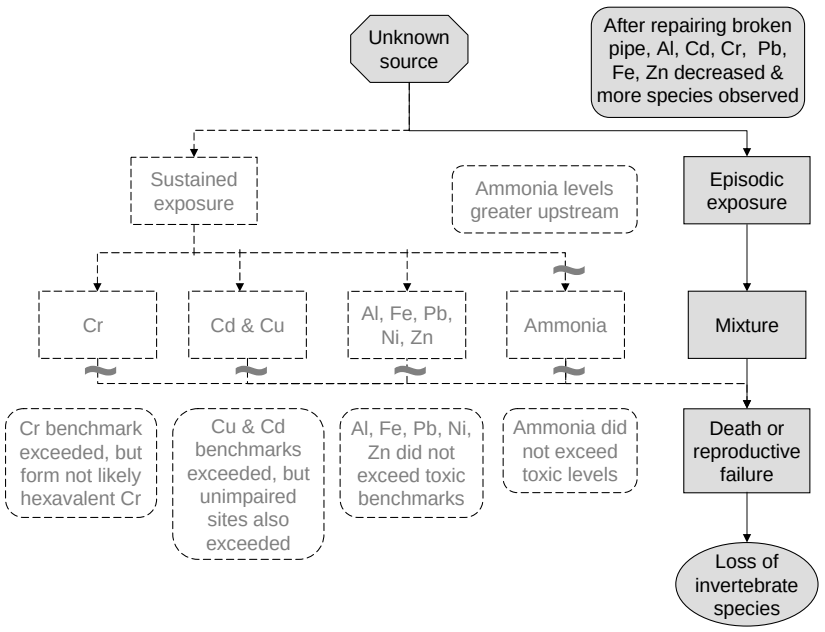
Unknown source
After repairing broken pipe, Al, Cd, Cr, Pb, Fe, Zn decreased & more species observed
Sustained exposure
Ammonia levels greater upstream
Episodic exposure
Cr
Cd & Cu
Al, Fe, Pb, Ni, Zn
Ammonia
Mixture
Cr benchmark exceeded, but form not likely hexavalent Cr
Cu & Cd benchmarks exceeded, but unimpaired sites also exceeded
Al, Fe, Pb, Ni, Zn did not exceed toxic benchmarks
Ammonia did not exceed toxic levels
Death or reproductive failure
Loss of invertebrate species

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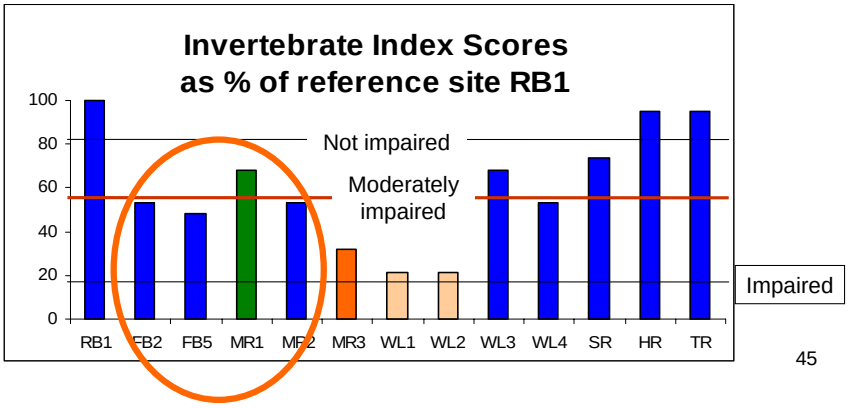
Cause: Heat & Altered food resources

Sources: Impoundments



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Predictive Assessment

Risk: Repairing broken effluent pipe and reducing metal release from POTW—no risk assessment, legally required remedies and no associated risks.

Expectation: reduce toxic effects, returning this segment to condition similar to those upstream. Moderate effects from stressors associated unless old mill dams were removed.

Risk: Removing dams: risk assessments of removal options necessary because unmanaged release of sediment would bury downstream reach and may contain toxic substances

Predictive Assessment

Management:

- Repair pipe —None, responsible parties complied.
- More stringent NPDES permit at POTW—none, responsible parties complied and monitoring of effluent continues.

- Removal of dams—Due to concerns about cost, social acceptance, and uncertainty of causes, CT DEP chose to study effects of impervious surfaces and dams on biological condition throughout the state. Small dams could provide aesthetically attractive cascades. Consultation with public would be required for optimizing benefits of selective dam removal.

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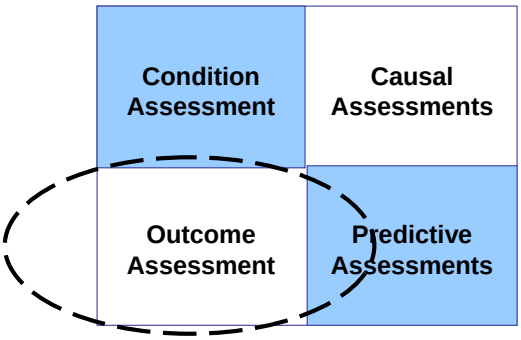
The Basic EA Framework



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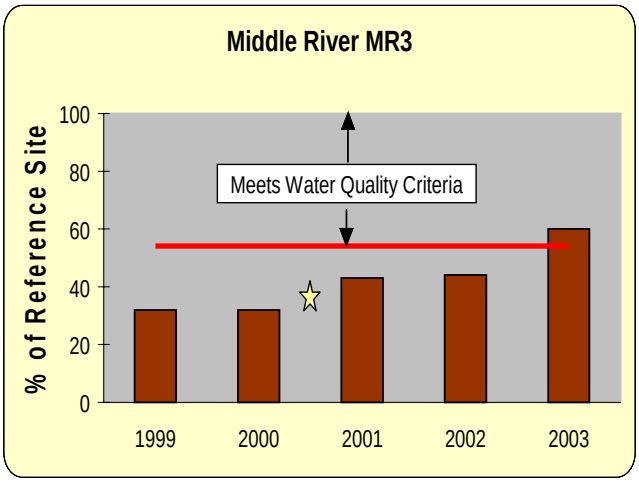
After fixing the illicit discharge



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CADDIS is a guide to causal inference for specific cases

www.epa.gov/caddis

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513-569-7995

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SETAC North Atlantic Chapter
15th Annual Meeting

Photo: New England Center, UNH, Durham, NH

15th Annual Meeting & Short Course

offered by

Society of Environmental Toxicology & Chemistry
North Atlantic Chapter

June 10-12, 2009
New England Center - Hotel & Conference Center,
University of New Hampshire, Durham, NH

SHORT COURSE: ***Causal Analysis/Stressor Identification***

by Susan Cormier

National Center for Environmental Assessment, USEPA, Cincinnati

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Thank You

After viewing the links to additional resources, please complete our online feedback form.

Links to Additional Resources

Feedback Form

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