CADDIS: The Causal Analysis/Diagnosis Decision Information System

EPA Tools and Resources Webinar
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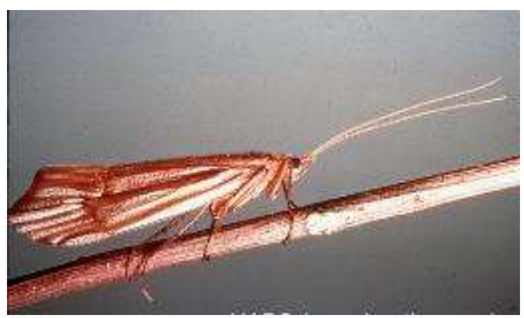
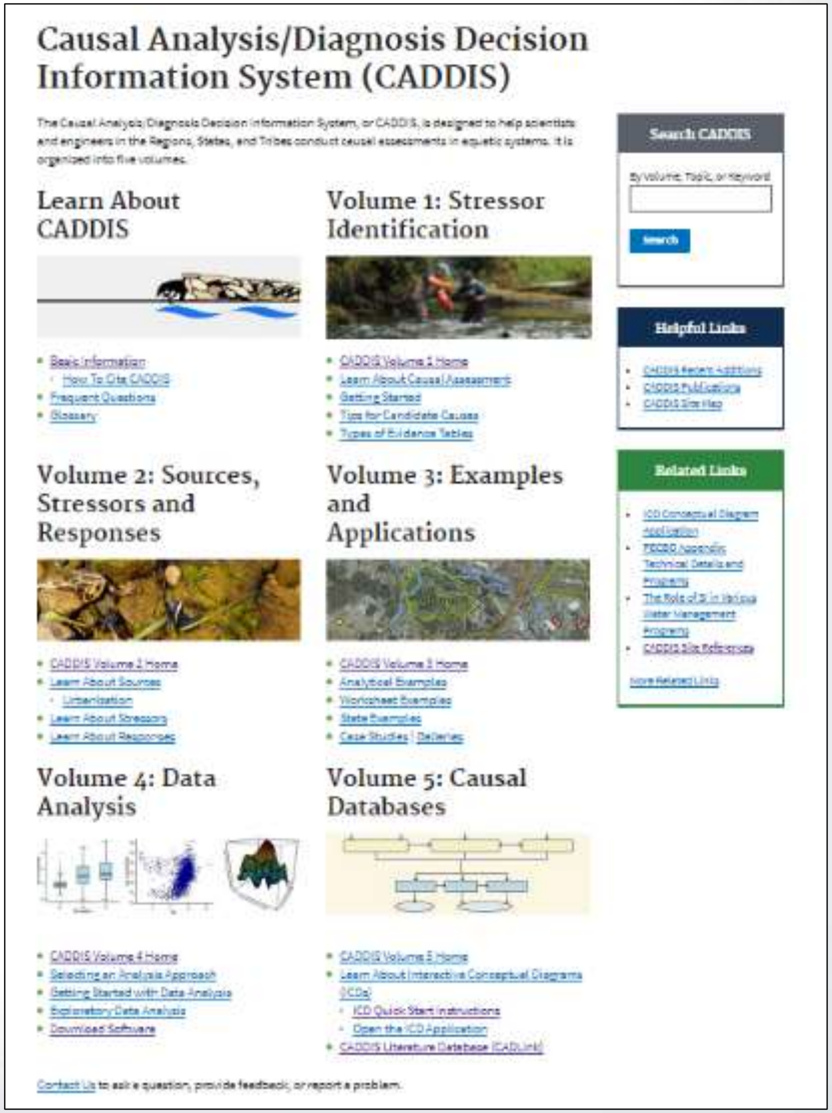
Introduction: What's a Caddis?



What is CADDIS? (www.epa.gov/caddis)

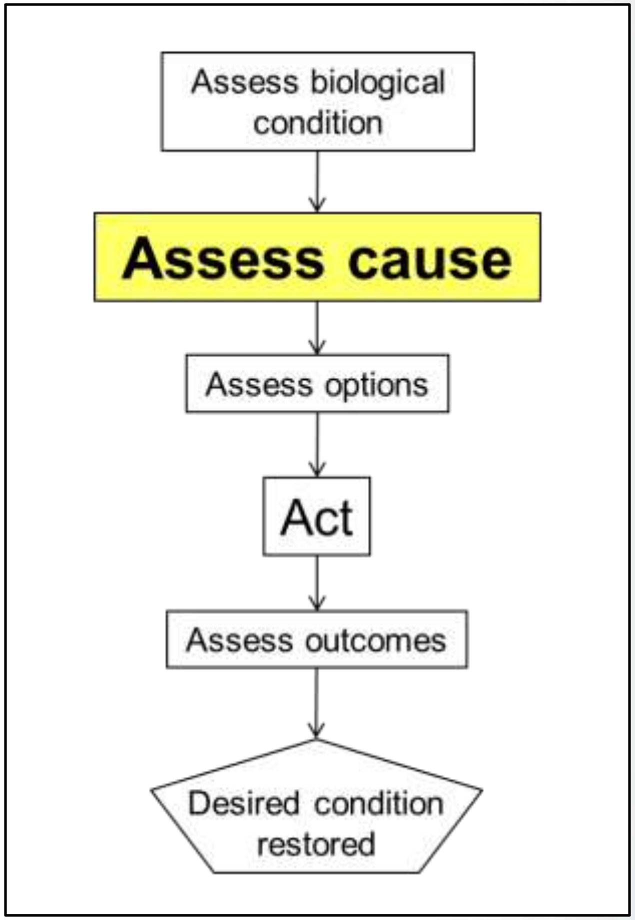
The Causal Analysis/Diagnosis Decision Information System (CADDIS)

- A web-based technical support system that provides guidance, tools and useful information for identifying causes of biological degradation of streams, rivers and other bodies of water
- Today's webinar
  - Overview of the website and our motivations for developing it
  - Case studies and examples of applications
  - Next steps



Our Goal

*Improve
the biological condition
of the Nation's waters
by identifying the stressors
most responsible for
degradation.*



Causal assessment (yellow box) is typically one step in a sequence of assessments

Why was CADDIS Developed?

- Under the **Clean Water Act** (Section 303(d)), EPA helps states, territories and authorized tribes submit lists of impaired waters and developing watershed management plans (i.e., Total Maximum Daily Loads) to restore designated uses of the water body
- Remediating sources before identifying the actual cause of impairment may not restore designated uses
- Identifying causes of *biological* impairment is challenging
  - Biological indices are the principal monitoring tool for evaluating the biological condition of water bodies in all 50 states, many territories and tribal lands
  - Biological indices are constructed using data from field samples of fish and macroinvertebrate communities
  - Biological indices indicate that there is a problem; they don't identify the cause or the fix
  - Over 85,000 miles of rivers and streams (out of 579,241 impaired miles) are classified now as "Cause Unknown"

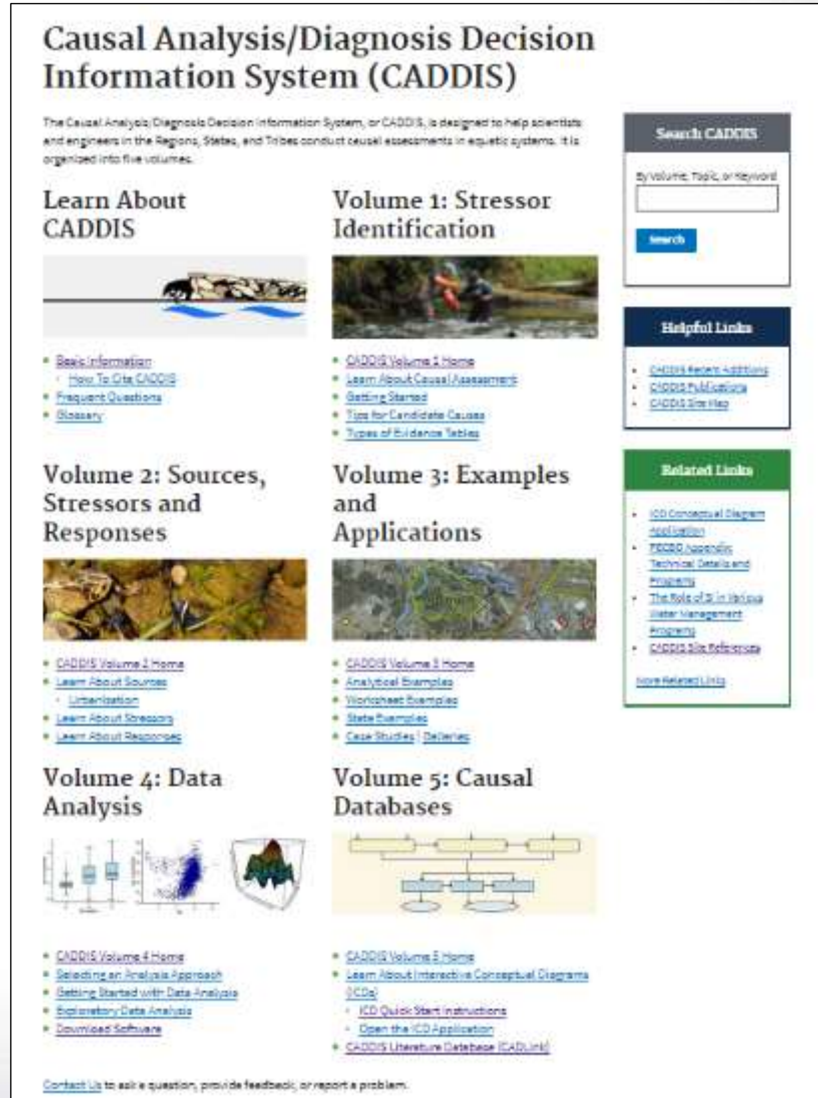
Causes of Impairment for 303(d) Listed Waters

Rank	Impairment Group
1	Pathogens
2	Sediment
3	Nutrients
11	Cause unknown
12	Cause unknown: impaired biota
33	Cause unknown: fish kills

What's in CADDIS? (www.epa.gov/caddis)

CADDIS

- Provides guidance, tools, and useful information for identifying causes of biological degradation of streams, rivers, and other bodies of water
- Organized in five volumes
- Developed and maintained by EPA ORD's National Center for Environmental Assessment
  - Material contributed by over 42 scientists from across EPA



Volume 1: Stressor Identification

Volume 1 of CADDIS

- A step-by-step procedure for identifying likely causes of biological degradation

- The process is derived from the **Stressor Identification Guidance Document**, published jointly by EPA's Office of Water and ORD (US EPA 2000)

Why use a Formal Method?

Because we make mistakes about causality…

First: We form initial impressions quickly, based on readily available information; for example, we might…

Overweight memorable events	*Every time I cross this bridge, the stream is dry.*
Have biases	*All fish kills are caused by toxic chemical spills.*
Be "educationally" predisposed	*Hydrologists think altered flow.*
Rely on intuition and past experiences	*I have a hunch that it's nutrients.* *Last time I saw this, it was nutrients.*

Why use a Formal Method?

Because we make mistakes about causality…

Second: We gather information that supports our initial impression

HYPOTHESIS TENACITY

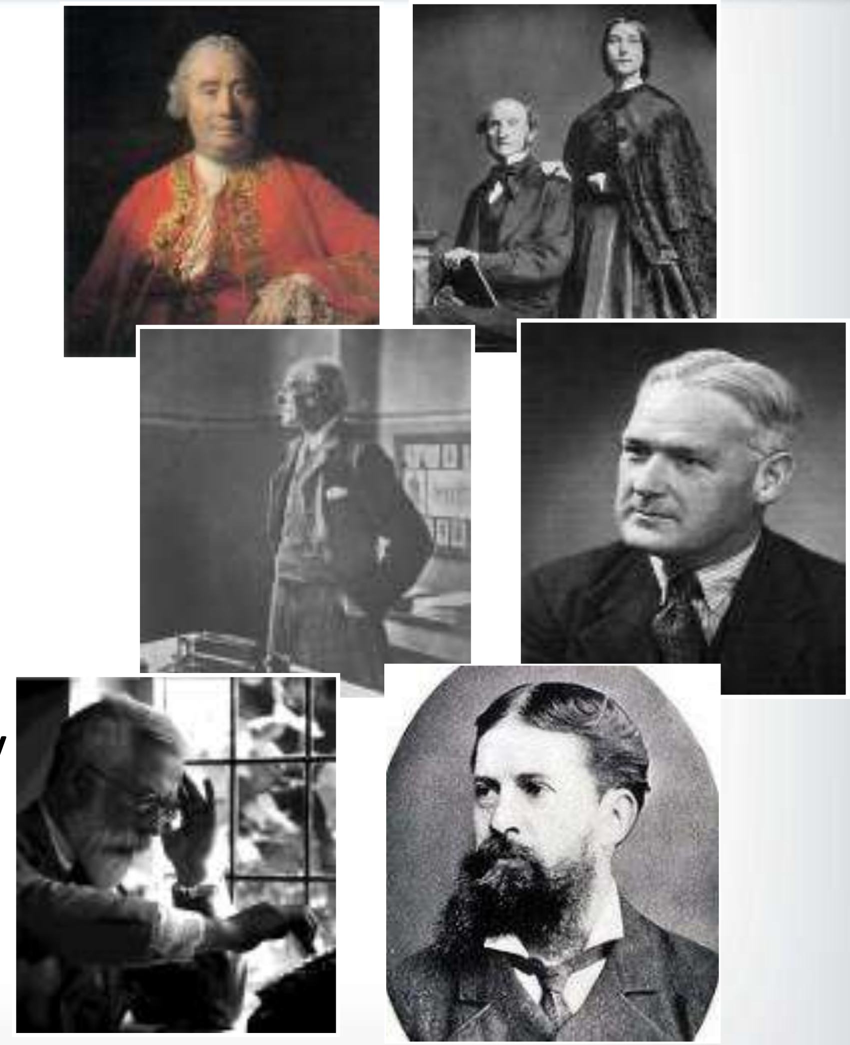
Third: We confidently reach conclusions based on incomplete information

WYSIATI
"what you see is all there is"

"Science is a way of trying not to fool yourself. The first principle is that you must not fool yourself – and you are the easiest person to fool." [Feynman 1964]

Establishing Causation

- Causation is one of the most difficult and controversial concepts in philosophy
- A **randomized, replicated, controlled** experiment is the most reliable method for establishing causation...
- ...but environmental studies rarely randomize, replicate or control exposures



Stressor Identification in a Nutshell

5 Step Process for Identifying Causes

Step 1. Define the case under investigation

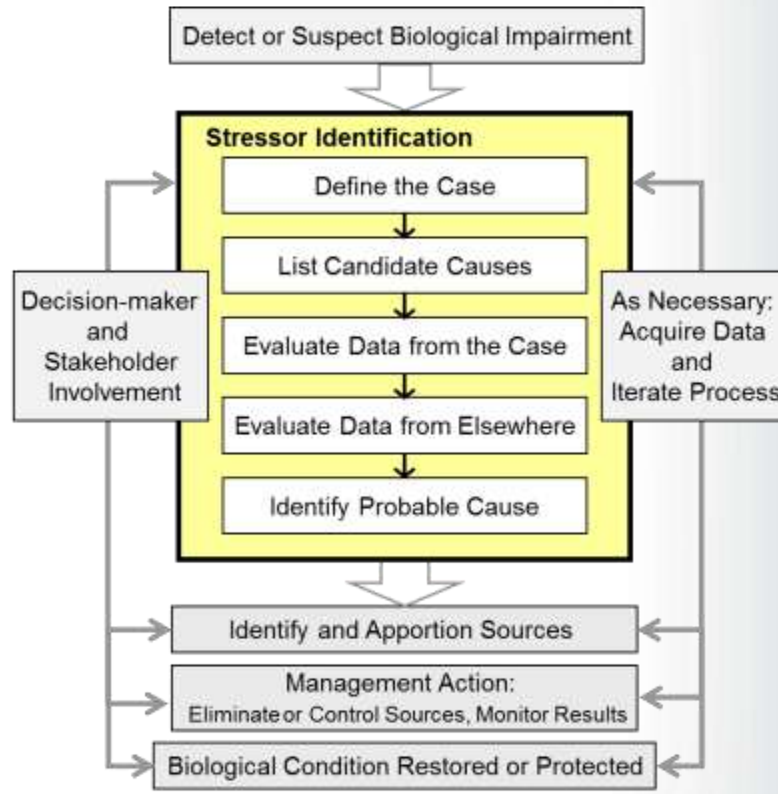
- Where effects are occurring
- Where effects are not occurring

Step 2. Identify a set of candidate causes (i.e., alternative hypotheses) that might explain how the adverse effect occurred

Steps 3 and 4. Derive evidence relevant to each candidate cause

- Field observational studies
- Laboratory experiments

Step 5. Identify the candidate cause(s) that is best supported by the evidence



Our Causal Assessment Approach

THE GOOD…

- Provides formal method that supports transparent, defensible conclusions
- Identifies causal relationships that may not be immediately apparent
- Minimizes biases and other lapses of logic
- Helps identify all available evidence
- Increases confidence that remedial or restoration effects can improve biological condition

Our Causal Assessment Approach

…THE BAD…

- Conducting causal assessments is not necessarily easy or straightforward
- Mechanisms driving biological impacts can be complex
- The method relies on data – quantity and quality matter
- Ultimately, a "smoking fish" may not be found, or multiple stressors may remain as likely causes

Our Causal Assessment Approach

…AND BACK TO THE GOOD

- Even when one likely cause is not identified, a causal assessment can narrow the universe of possible causes and point to promising data and analyses

1. ~~Low dissolved oxygen~~
2. Gill damage
3. Nitrate exposure
4. Infections
5. ~~High pH~~
6. ~~pH fluctuations~~
7. ~~Ammonia toxicity~~
8. Other, unspecified toxic substances
9. ~~Inadequate food resources~~

Volume 2: Sources, Stressors and Responses

Problem: Causal assessment asks that investigators know something about all the possible stressors that are capable of causing effects in their systems

Volume 2: Provides background information on commonly encountered aquatic stressors

- Ammonia
- Dissolved Oxygen
- Flow Alteration
- Herbicides
- Insecticides
- Ionic Strength
- Metals
- Nutrients
- pH
- Physical Habitat
- Sediments
- Temperature
- Unspecified Toxic Chemicals

Volume 2: Sources, Stressors and Responses

Each stressor module includes

- Introduction
- When to Consider it as a Candidate Cause
- Ways to Measure
- Conceptual Diagrams
- References

Site Evidence and Biological Effects
mmonia as a Candidate Cause
uting, Modifying and Related Factors as Candidate

ng (Eliminating) Ammonia as a Candidate Cause

When to
List

Ways to
Measure

Conceptual
Diagrams

Literature
Reviews

References

nmon toxicant derived from wastes (see Figure 1), rocesses. Ammonia nitrogen includes both the m, NH_4^+) and the unionized form (ammonia, NH_3). formation of the more toxic unionized form (NH_3), the ionized (NH_4^+) form. Temperature also affects to aquatic life.

cause of fish kills. However, the most common th ammonia relate to elevated concentrations ll condition, organ weights and hematocrit sure duration and frequency strongly influence Milne et al. 2000).

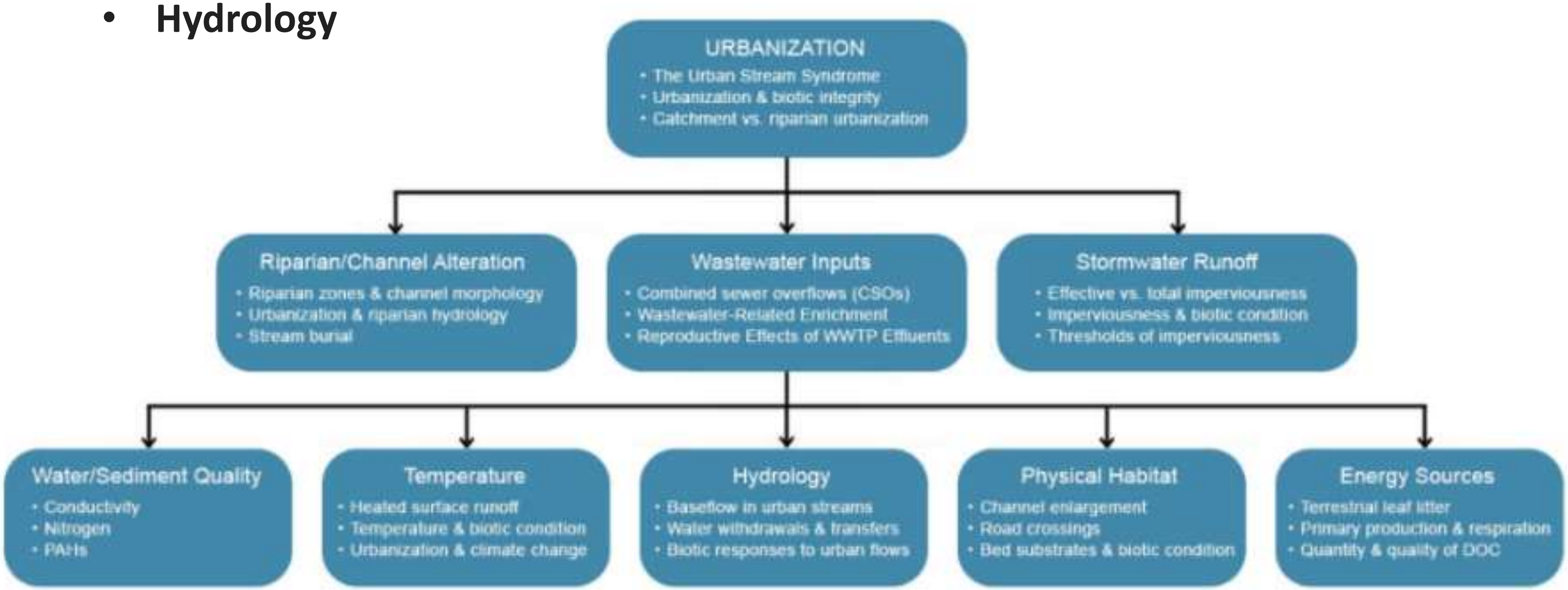
Figure 1. Landfill settling pond.

typically results from bacterial decomposition ccumulates in sediment. Sediment microbiota gen or (less commonly) produce ammonia by dissimilatory nitrate reductio prevalent in anoxic sediments because nitrification (the oxidation of ammon rate [NO_3^-]) is inhibited. Ammonia generated in sediment may be toxic to r biota (Lapota et al. 2000).

Volume 2: Urbanization module

Describes typical pathways through which urbanization may affect stream ecosystems

- **Riparian/channel alteration, wastewater inputs and stormwater runoff** associated with urbanization can lead to changes in 5 general stressor categories:
  - **Water/sediment quality**
  - Water **temperature**
  - **Hydrology**
  - **Physical habitat** within the channel
  - Basic **energy sources** for the stream food web

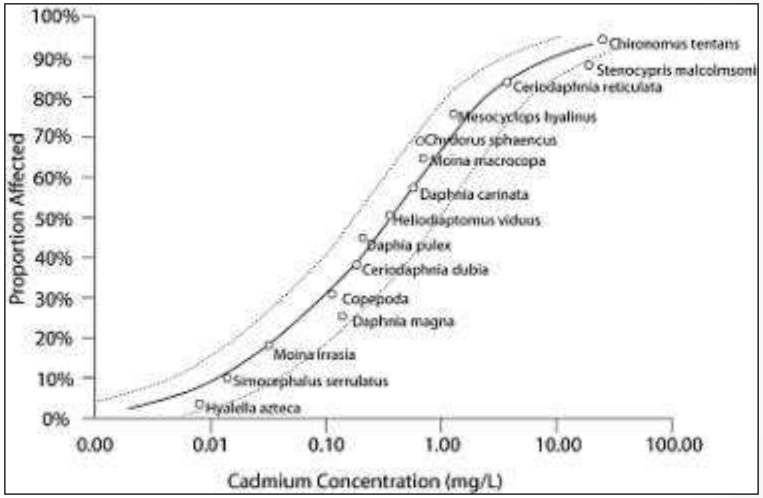


Volume 4: Data Analysis

Volume 4: Describes **statistical analyses** useful for deriving different types of evidence for causal assessment

Major sections:

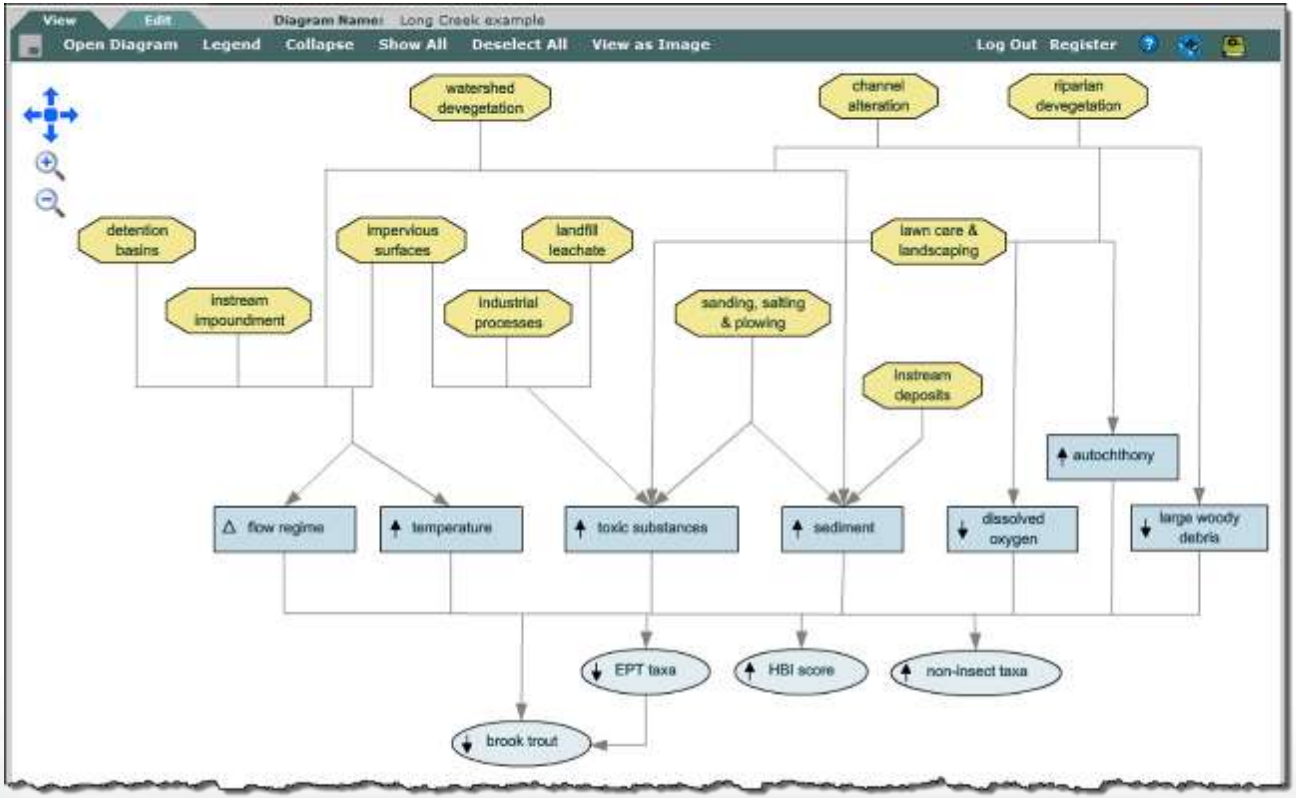
- Selecting an Analysis Approach
- Getting Started and Basic Principles
- Exploratory Data Analysis
- Basic Analyses
- Advanced Analyses
- Download Software
  - CADStat: A point-and-click add-on to the R Statistical program
  - Species Sensitivity Distribution builder (in Excel)



Species sensitivity distribution for cadmium

Volume 5: Causal Databases

Volume 5 includes an interactive **conceptual diagram tool** and supporting **literature database** designed to help users access and apply literature-based evidence in their causal assessments.



Volume 3: Examples and Applications

State Applications

State	Example of Stressor Identification Use
Arizona	Biocriteria Implementation Procedures
Idaho	Hellroaring Creek Stressor Identification
Indiana	Stressor Identification Process for the Limberlost Watershed (Morris et al. 2006)
Iowa	Total Maximum Daily Load For Sediment and Nutrients Camp Creek Polk County, Iowa
Maine	Urban Streams Project Report
Maryland	TMDL Elements to Review Prior to Implementation Planning
Minnesota	2007 Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment
Mississippi	Phase 1 Total Maximum Daily Load Organic Enrichment/Low Dissolved Oxygen and Ammonia Nitrogen Little Tangipahoa River South Independent Basin
New Jersey	The Use of Benthic Macroinvertebrate Assessments in the Stressor Identification Process to Reduce Chemical Analytical Costs
North Carolina	DRAFT Total Maximum Daily Load for Addressing Impaired Biological Integrity in the Headwaters of Swift Creek Watershed, Neuse River Basin
Virginia	Benthic TMDL Development: Stressor Identification for the Jackson River, Virginia; Potomac/Shenandoah River Fish Kill

Case Studies

Arkansas River, CO
Willimantic River, CT
Little Floyd River, IA
Long Creek, ME
Presumpscot River, ME
Groundhouse River, MN
Bogue Homo, MS
Little Scioto River, OH
Touchet River, WA
Lake Washington, WA
Clear Fork Watershed, WV
Elk Hills, CA (terrestrial)
Upper Arkansas River, CO (terrestrial)
Birds of prey (terrestrial)

Case Study: Long Creek, ME

Partners: Maine Department of Environmental Protection
Challenge: Poor biological assessment scores and lack of brook trout in an urban watershed

- The primary goals of the Long Creek case study included: (1) to serve as an example EPA Stressor Identification (SI) case study, whereby the report may help future assessors understand the SI process for other biologically impaired ecosystems, (2) use the specific case to better understand urban-related stressor interactions and (3) to provide useful information for the improvement of the Long Creek watershed and recovery of the stream.
- Likely causes were consistent with the urban stream syndrome, including decreased dissolved oxygen, altered flow regime, decreased large woody debris, increased temperature, and increased toxicity due to dissolved salts.
- Impacts:
  - Provides input to the watershed restoration plan
  - Contributed to the development of the CADDIS urbanization module and EPA Region I's approaches to managing and improving urban watersheds

www.youtube.com/watch?v=K2x20Q1df48

Case Study: Susquehanna River Basin, PA

Partners: Pennsylvania Department of Environmental Protection (PA DEP), Pennsylvania Fish and Boat Commission (PFBC)
Challenge: Smallmouth Bass population declines

- Since 2005, mortality and disease outbreaks were observed in Smallmouth Bass in the Susquehanna River Basin.
- In 2012, the PA DEP initiated a large study of the river. PA DEP, PFBC and their partners looked to EPA ORD's expertise and innovative tool CADDIS to help organize and synthesize the data.
- EPA assisted PA DEP, PFBC and their partners in implementing the CADDIS causal assessment process, providing a means to utilize the study data collected to date; to winnow the long list of hypothesized causes of the Smallmouth Bass health issue; and to optimize further data collection and analysis efforts.

"I am confident that our science-based partnership with EPA ORD and the Pennsylvania Fish and Boat Commission will help us determine the causes of impacts to aquatic health in the Susquehanna. Science guides our work in assessing the overall health of the river, and in partnership with these agencies, we will be able to create a strategy that matches our challenges to conserve and protect this river, which is important to the recreational vitality and economic prosperity of Pennsylvania."

– John Quigley,
PA DEP (former Secretary)

Case Study: Southern CA

Partners: Southern California Coastal Water Research Project in collaboration with CA Department of Fish and Wildlife, San Diego Water Quality Control Board, The Nature Conservancy, Central Coast Preservation Inc., Central Coast Regional Water Quality Control Board, Los Angeles County Sanitation District, Central Coast Regional Water Quality Control Board, City of San Diego, County of San Diego

Challenge: Adapting and applying CADDIS causal assessment process to land uses typical of CA watersheds

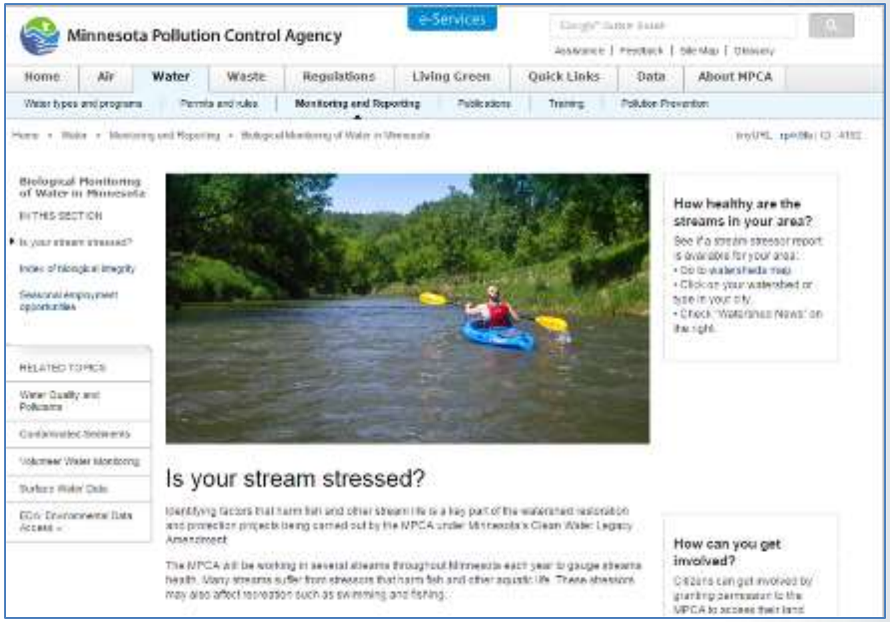
- Likely causes were successfully identified for all case studies (e.g., suspended sediments in the agricultural watershed, salts and toxic substances in the urban watershed). However, some candidate causes remained uncertain, typically because of lack of information.
- Simple modifications to monitoring requirements were identified that could improve the information available for causal assessments.
- The selection of comparator sites was identified as a key technical challenge. It could be solved by using and taking advantage of California's robust biological assessment database and is the subject of follow-on research.

"[We like that the process is] based on the multiple lines of evidence approach that uses the scientific method and available data"– Los Angeles County Sanitation District

States adapt the approach and tools for their own stream systems: MN example

Minnesota Pollution Control Agency

- Developed State-Specific Stressor Identification Guidance
- Applied process systematically to watersheds across the state
- Developed the Aquatic Biota Stressor and Best Management Practice Selection Guide
  - Reference table linking the common stressors to aquatic biota with best management practices that can positively affect them



Who uses CADDIS?

- **Page Visits**
  - 150,000 in 2016; 180,000 in 2015
- **83 Countries, all 50 states**
  - **Most frequent users:** California, Texas, Florida, New York, Massachusetts, North Carolina, Colorado, Virginia, Ohio, Washington
- **Top search engine keywords leading to CADDIS**
  - What is urbanization?
  - Herbicide(s), glyphosate, insecticides, fungicides
  - Ionic strength, conductivity
  - Sources of metals in waste
  - Interpreting statistics
  - Ammonia

EPA

Future Plans

Enhance readability on phones and tablets

- Migrate to Drupal content management system

Update tools and modules

- Add new or revise modules on symptoms, conductivity, fungicides, pathogens
- Update examples and case studies pages
- Upgrade diagramming tool linking literature-based evidence to conceptual diagrams that depict causal pathways

Make causal assessments faster, cheaper and routine

- Develop Rapid Causal Assessment methods utilizing biomonitoring databases

Questions? Suggestions?

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www.epa.gov/caddis