

National Biological Assessment
and Criteria Workshop

Advancing State and Tribal Programs



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

SI 201

THE STRESSOR IDENTIFICATION (SI) PROCESS: CASE STUDY

Course Presenters and Contributors

Susan Cormier, Susan Norton, Glenn Suter II, Jeff Varricchione,
Charlie Holderman, Trish MacPherson, Darren Brandt,
Chris Bellucci, Ed Rankin

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SI 201

Introduction & Expectations for the Day

Stressor Identification 201

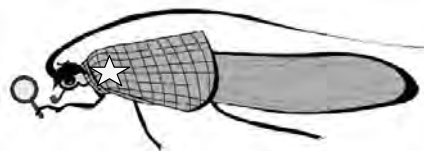
What it says in the Workshop Agenda

- Using a detailed case study, participants will become proficient in applying the stressor identification process to determine the cause(s) of a biological impairment and to organize the information into compelling lines of evidence.

Stressor Identification 201

What we really want to do

- Turn you into *SI SENIOR Super Sleuths* who
 - Have worked through a case study in detail
 - Are ready to apply the method to new cases.
 - Are the foundation of a community of investigators who will share experiences, and data.



So, how we gonna do that?

- Delve deeply into the Little Scioto case study
- Discuss some knotty issues
- Solicit views on the Causal Analysis/Diagnosis Decision Information system (CADDIS)



Who are your trusted guides?

USEPA ORD

Susan Cormier, Glenn Suter II, Susan Norton

State Agencies

Jeff Varricchione, Maine

Charlie Holderman, Kootenai Tribe

Trish MacPherson, North Carolina

Darren Brandt, Idaho

Chris Bellucci, Connecticut

Ed Rankin, Ohio

Outline for Stressor Identification 201

1:30 Expectations for the Day

1:45 Intro to the Little Scioto Case Study

2:00 List Candidate Causes

3:00 Appropriate Use of Statistics

3:15 Eliminate

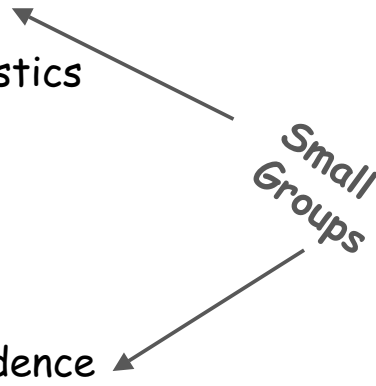
3:35 BREAK

3:50 Diagnose

4:00 Compare Strength of Evidence

5:00 Identify Probable Cause and Iteration Options

5:15 Discuss CADDIS



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*Case Study: Little
Scioto River*

*Step 1 - List
Candidate Causes*

STEP 1

List Candidate Causes

a: Develop Initial List

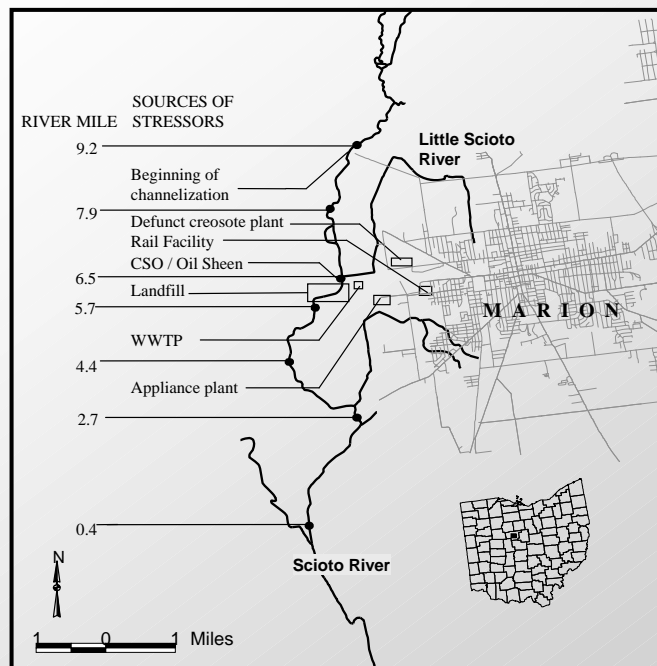
Develop Initial List of Candidate Causes

Candidate Cause	Notes

STEP 1

List Candidate Causes

b: Draw a Map



Map of the Little Scioto River, Ohio, showing sites where fish were sampled. Approximate locations of significant physical features, tributaries and point source inputs are noted. The small inset shows the location of the study area in the state of Ohio.

STEP 1

List Candidate Causes

c: Gather Information

Types of Data Available for the Little Scioto River, Ohio, 1992

Sample Medium	Measurements	Site designation and sample locations (RM upstream from confluence with Scioto River)							Number of samples per location
		Upstream Site	Site A	Site B	Downstream sites				
Fish	IBI and Miwb metrics	9.2	7.9	6.5	5.7	4.4	2.7	0.3	2-3
Macroinvertebrates	ICI metrics	9.2	7.9	6.5	5.7	4.4	2.1	0.4	1
Sediment	Volatile chemicals, semivolatile chemicals, metals and cyanide, PCBs and pesticides	9.5	7.9	6.5	5.8	4.4	2.7	0.4	1-3
Water	Metals, phenolic compounds, ammonia, nitrates and nitrites (NO _x), total phosphorus (P), hardness, and BOD	9.2	7.9	6.5	5.8	4.4	2.7	0.4	1
Water	Dissolved oxygen 1992 1987	9.2 NA	7.9 7.9	NA 6.5	5.8 5.8	4.4 4.4	2.7 2.7	0.4 0.4	measured continuously over 3 days (1987)
Physical Habitat	Qualitative Habitat Evaluation Index (QHEI) Metrics (ordinal scores)	9.2	7.9	6.5	5.7	4.4	2.7	0.3	1
Fish tissue	Pesticides, PCBs, metals, semivolatile compounds, and percent lipid	9.2		6.5			2.7		2-5 composite samples
White sucker bile	PAH metabolites		7.9	6.5	5.7	4.4	2.7	0.3	5-7

Average sediment concentrations (mg/kg) of selected PAHs¹ and metals. Samples were taken from the upper 15 cm.

Chemical	Upstream Site	Site A	Site B	Downstream sites (RM)			
				5.8	4.4	2.7	0.4
Anthracene	ND	ND	ND	27.1	7.9	ND	3.3
Benzo[a]anthracene	ND	ND	8.2J	16.5	6.9	2J	15.8
Benzo[ghi]perylene	ND	ND	49.5	11.2	4.9	ND	6.9
Benzo[a]pyrene	ND	ND	14.8J	15.8	7.2	ND	11.5
Chrysene	ND	ND	16.5	20.8	9.9	1.6J	ND
Fluor-anthene	ND	ND	8.2J	37.6	13.5	ND	22.4
Fluorene	ND	ND	ND	7.0	4.0	ND	ND
Cr	7.34	13.6	208	60.9	302	71.2	48.6
Cu	7.44	17.2	79	56	76.8	42.4	24.5
Pb	12.1	19.1	172	84.6	93.4	108	38
Zn	3.06	79	173	141	226	408	96.8
Hg	ND	ND	0.33	0.24	0.79	0.12	ND

¹ PAHs shown were either significantly correlated with biological responses, or exceeded sediment quality guidelines.

ND: Not detected. J: estimated value (below quantitation limit)

**Concentrations of chemicals in water.
Units are mg/l except where noted.**

Chemical	Upstream Site	Site A	Site B	Downstream sites (RM)			
				5.8	4.4	2.7	0.4
BOD	1	1	2.3	4.7	4.2	3.5	2.2
Nitrate and nitrite	1.22	1.44	0.81	8.1	6.6	4.5	4.47
Ammonia	ND	ND	0.12	1.16	1.44	2.1	0.58
Total phosphorus	0.06	0.07	0.09	2.17	1.96	1.8	1.34
Dissolved oxygen (minimum)	8.8	5.7	NA	4.2	4.3	3.0	4.4
	NA	2.8	1.9	4.2	3.2	2.0	2.5
Copper *	ND	ND	15	ND	ND	ND	ND
Lead *	ND	ND	3	3	ND	ND	ND
Zinc *	ND	ND	ND	18	12	13	ND

* Units are ug/l

NA: No data collected

ND: Not detected

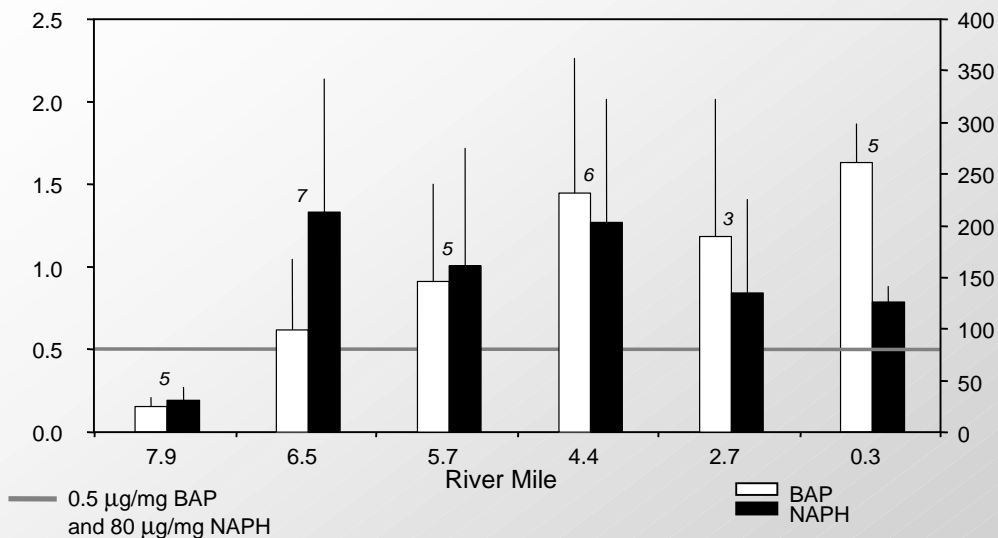
All data from 1992, except for DO, collected in 1987 over 3 days with continuous Datasonde continuous monitors

Selected physical habitat quality scores

Parameter	Upstream Site	Site A	Site B	Downstream sites (RM)			
				5.7	4.4	2.7	0.4
Channel	17	10	10	10	10	10	7
Substrate embeddedness ¹	2	1	1	1	1	1	1
Silt ²	2	1	1	1	1	1	1

¹ Levels of embeddedness were scored from most to least 1=Extreme, 2=Moderate, 3=Low, 4=None.

² Levels of silt were scored from most to least 1=Heavy, 2=Moderate, 3=Normal, 4=Free.



Bile metabolites ($\mu\text{g}/\text{mg}$ protein) of benzo[a]pyrene (BAP) and naphthalene (NAPH) type metabolites measured in white suckers from the Little Scioto River in 1992. Median levels of PAH metabolites below RM 7.9 were up as much as 4 times the Exposure Criteria, levels above background for the state of Ohio. The numbers above the bars equal number of fish sampled. Vertical lines are standard error.

STEP 1

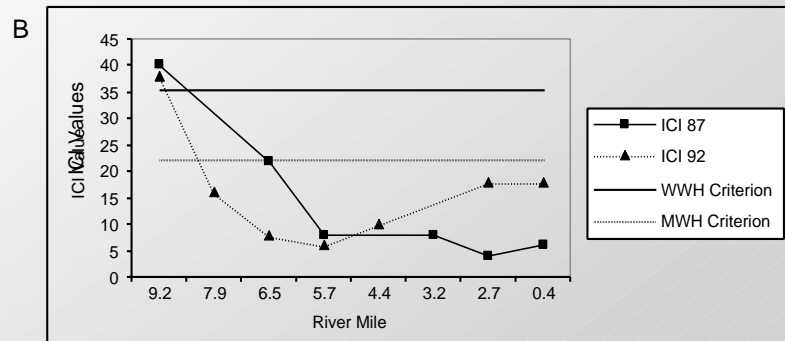
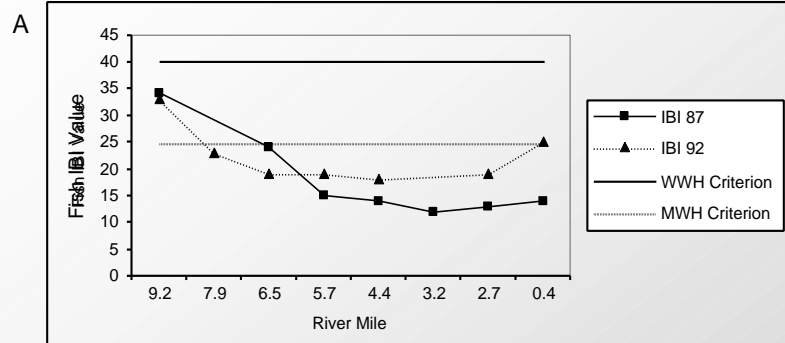
List Candidate Causes

d: Examine Effects

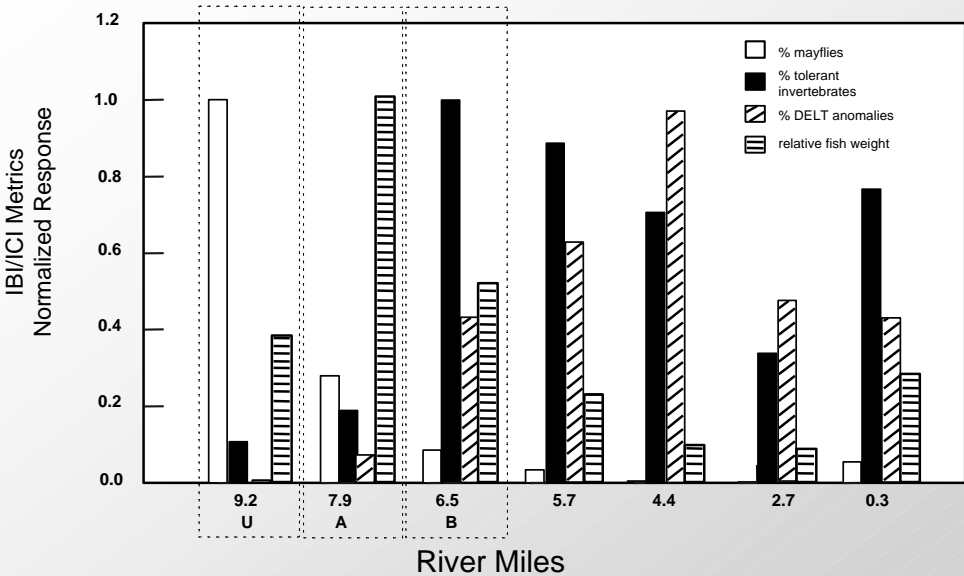
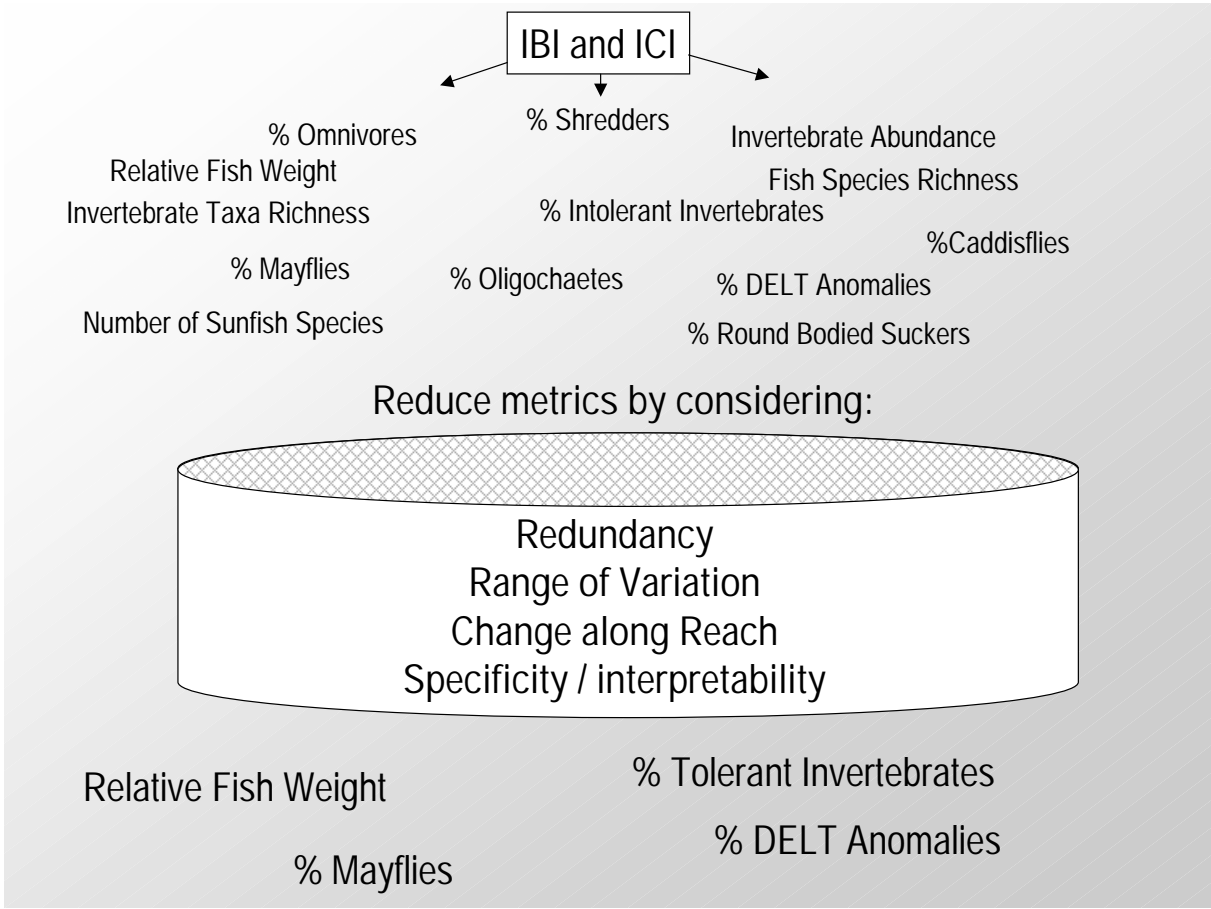
March 31 – April 4, 2003

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Spatial changes in fish IBI, (A) and benthic macroinvertebrate ICI (B) values in the Little Scioto River in 1987 (OEPA 1988) and 1992 (OEPA, 1994)



Changes in fish and macroinvertebrate metrics in the lower 15 km of the Little Scioto River, 1992. Normalized values were calculated by dividing the value at each site by the highest value for all sites.

Summary of the three impairments that were considered in the Little Scioto River. The location is scored relative to the location immediately upstream.

Response	Impairment A: Change in assemblage at Site A Relative to Upstream Site
<i>Fish</i>	
Relative Weight	increased
% DELT Anomalies	increased
<i>Invertebrates</i>	
% Mayflies	decreased
% Tolerant taxa	increased

STEP 1

List Candidate Causes

e: Engage Stakeholders

Stakeholder Engagement

Great for:

- Local knowledge
- Buy-in on results
- Reaching the ultimate customer

BUT

- Time consuming
- May raise concerns outside the scope of investigation
- Gaming

STEP 1 **List Candidate Causes**

f: Construct a Conceptual Model

STEP 1

List Candidate Causes

g: Finalize list and

h: Crosswalk available
measurements relevant to each
candidate cause

Crosswalk available measurements relevant to
each candidate cause.

Candidate Cause	Relevant Measurements
1. Habitat alteration	
2. PAH toxicity	
3. Metal toxicity	
4. Ammonia toxicity	
5. Low dissolved oxygen/high biological oxygen demand	
6. Nutrient enrichment	



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Appropriate Use of Statistics

Presented by

Glenn Suter II, USEPA,
Office of Research & Development

What is the Problem?

- Correlation does not prove causation
 - Except in experiments
- Practitioners often attempt to test causal hypotheses with observational data
 - t tests, ANOVA, etc. are experimental stats.
- Practitioners often mistake statistical significance for biological significance
 - Which can produce misleading results
- Practitioners often believe that regression, ordination, etc. demonstrate causation

Lessons

- Statistics cannot derive causation from observational data
 - The correlation of C and E is not the probability that C causes E
 - You can not test the hypothesis that C causes E
- Statistics can help to identify and quantify
 - Associations
 - Magnitudes of differences
 - Gradients and other patterns

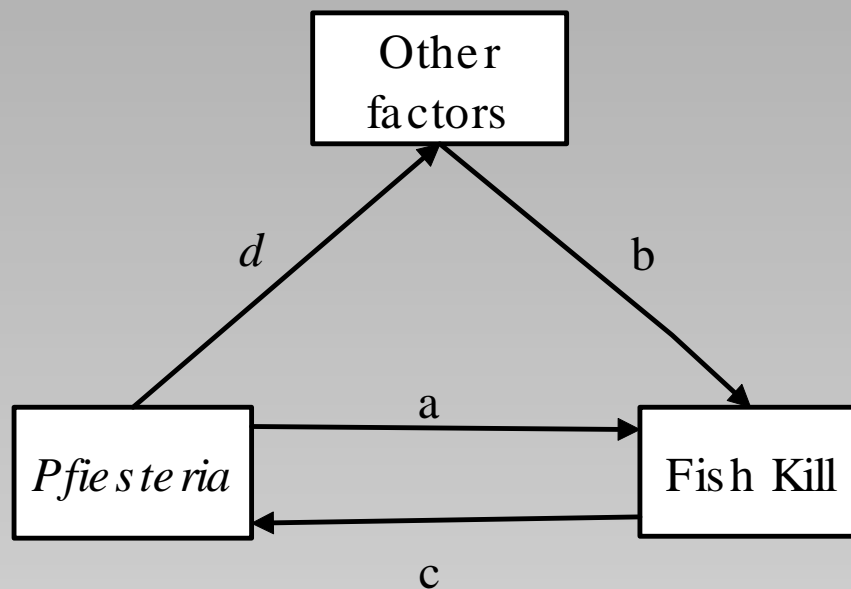
Uses for Statistics in SI

- Summarize data using descriptive statistics
 - Mean, range, variance, recurrence rates, etc.
- Explore data sets
 - Multivariate correlations
- Quantification of associations
 - Correlation, regression, etc.
- Statistical modeling
 - Exposure-response relationships
- Comparison of models
 - Goodness of fit, maximum likelihood

Pitfalls for Statistics

- Few samples at few times and locations
- No replication
- No randomization
- No control of treatments
- Many confounding variables
 - Flow augmentation
 - Stream gradient
 - Julian day (seasonality)
 - Habitat structural attributes

Pfiesteria Conceptual Model



Conclusions

- Statistics can not determine the cause
 - but it can help a lot
- Define needed inference first
 - then statistics
- Use statistics like a drunk uses a lamp post
 - more for support than enlightenment



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Case Study: Little Scioto River

Analyze Evidence & Characterize Cause

Step 2: Eliminate

Step 3: Diagnose

Step 4: Compare Strength of Evidence

Step 5: Identify Probable Cause

STEP 2: Eliminate

- a: Analyze Evidence
- b: Characterize Cause by Eliminating Candidates

Step 2a: Analyze Evidence for Elimination:

1. Spatial co-location of candidate causes with Impairment A
2. Analysis of Exposure Pathway

Candidate Cause	Detected at Site A?	Decreased quality at Site A compared with Upstream Site?	Exposure pathway complete at Site A?
Habitat alteration			
PAHs			
Metals			
Ammonia			
Low-dissolved oxygen/BOD			
Nutrient enrichment			

Uncertainties: Measurement methods, sample size, data/time of sample, other?

Step 2b: Characterize Cause by Eliminating Candidates

Which candidate causes remain?

	RM 7.9 Impairment A
#1 Habitat alteration	
#2 PAH Contamination	
#3 Metal Contamination	
#4 Ammonia	
#5 Low DO/BOD	
#6 Nutrient Enrichment	

STEP 3: Diagnose

- a: Analyze Evidence for Diagnosis
- b: Characterize Cause by Diagnosis

Step 3a: Analyze Evidence for Diagnosis

Are Causes Subject to Diagnosis?

Candidate Cause	Symptom or suite of measures specific to cause?	Observed at site?
Habitat Alt.		
Metal Contamination		
Nutrient Enrichment		

STEP 4: Strength of Evidence

- a: Analyze Evidence for SOE comparisons
- b: Characterize Cause by Comparing Strength of Evidence

4a. Analyze Evidence from the Case

- Co-occurrence
 - Use analysis conducted for elimination
- Temporality
 - No measurements available prior to the impairment
- Consistency
 - Used biological gradient instead, because variables are continuous
- Biological Gradient
 - Analyze correlations from the reach
- Exposure Pathway
 - Use analysis conducted for elimination
- Experiment
 - No experiments relevant to the remaining causes

4b: Compare strength of evidence for the three candidate causes of Impairment A

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Case-Specific Considerations</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Co-occurrence						
Temporality	No evidence	NE	No evidence	NE	No evidence	NE
Consistency of Association	No evidence	NE	No evidence	NE	No evidence	NE

NE = no evidence; NA = not applicable/not available

Step 4a: Analyze Evidence from the Case for SOE: Biological Gradient

Correlations between selected measurements and biological responses.

Uncertainties: Sample size, Covariation, Other?

	Relative weight of fish	DELTA	Percent mayflies	Percent tolerant invertebrates
Cr ¹	-0.50	0.75*	-0.71*	0.61
Cu ¹	-0.29	0.64	-0.54	0.81*
Pb ¹	-0.39	0.54	-0.64	0.68
Zn ¹	-0.71*	0.75*	-0.89*	0.43
Nitrate and Nitrite ²	-0.75*	0.86*	-0.75*	0.14
Total Phosphorus ²	-0.75	0.96*	-0.86*	0.54
Minimum DO ^{2,3}	0.89*	-0.77*	0.94*	-0.6

¹Concentrations measured in sediment. ²Concentrations measured in water. ³n=6

Correlations denoted with an asterisk are greater than 0.70.

All correlations for Channel, Silt, and Embeddedness scores, were less than 0.70 are not shown. N=7 except where noted.

4b: Compare strength of evidence for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Case-Specific Considerations</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Biological Gradient	Increased relative weight:		Increased relative weight:		Increased relative weight:	
	Increased %DELT:		Increased %DELT:		Increased % DELT:	
	Decreased % mayflies:		Decreased % mayflies:		Decreased % mayflies:	
	Increased % tolerant organisms:		Increased % tolerant organisms:		Increased% tolerant organisms:	
Complete Exposure Pathway	Not applicable: No known intermediate steps.	NA	No evidence: Internal concentrations of metals were not measured.	NE	No evidence: concentrations of algae or chlorophyll <i>a</i> were not measured.	NE
Experiment	No evidence.	NE	No evidence.	NE	No evidence.	NE

NE = no evidence; NA = not applicable/not available

Step 4a. Analyze Evidence Using Other Situations or Biological Knowledge

Is Causal Mechanism Plausible?

- Habitat Alteration
- Metals
- Nutrient enrichment

4b. Compare strength of evidence for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Considerations Based on Other Situations or Biological Knowledge</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Plausibility: Mechanism	Increased Relative Weight:		Increased Relative Weight:		Increased Relative Weight:	
	Increased DELT:		Increased DELT:		Increased DELT:	
	Decreased % Mayflies & Increased % Tolerant Organisms:		Decreased % Mayflies & Increased % Tolerant Organisms:		Decreased % Mayflies & Increased % Tolerant Organisms: Plausible:	

NE = no evidence; NA = not applicable/not available

**Step 4a. Analyze Evidence for SOE
Using Other Situations or Biological Knowledge
Plausibility: Stressor-Response**

**Uncertainties: Sample size, Covariation,
Relevance of Test Endpoint, Other?**

Chemical		Upstream Site	Site A
TEL	PEL		
Cu			
28	101.2		
Pb			
37.2	81.7		
Zn			
98.1	544		
Cumulative Toxic Units based on PEL			

**TEL and PEL values are for *Hyaella azteca* and are
normalized to sediment dry weight.**

**Step 4a. Analyze Evidence for SOE
Using Other Situations or Biological Knowledge
Plausibility: Stressor-Response**

**Comparison of the reported concentration of water quality
parameters (mg/L) with available criteria.**

Uncertainties: Sample size, Covariation, Relevance of Test Endpoint, Other?

Criterion	Site A
Dissolved Oxygen ^b 3.0 mg/L for MWH	
Nitrate-nitrite ^c 1.6 mg/L	
Total phosphorus ^d 0.28 mg/L	

NA = No data for that year.

ND=not detected.

^b OEPA (1994) dissolved oxygen criterion.

^c Rankin et al. (1999) proposed nitrate-nitrite criterion

^d Rankin et al. (1999) proposed total phosphorus criterion

^e minimum dissolved oxygen concentrations from continuous monitoring over three days in 1987

**Step 4a. Analyze Evidence for SOE
Using Other Situations or Biological Knowledge
Plausibility: Stressor-Response**

Comparison of the reported concentration of water quality parameters (ug/L) with available criteria.

Uncertainties: Sample size, Covariation, Relevance of Test Endpoint, Other?

Chemical AWQC (ug/l) @ 200 mg/L hardness	Upstream Site	Site A
Copper 21		
Lead 7.7		
Zinc 190		

4b. Compare strength of evidence for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Considerations Based on Other Situations or Biological Knowledge</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Plausibility: Stressor-Response	Increased Relative Weight: No evidence.	NE	Increased Relative Weight: Not applicable: Implausible mechanism.	NA	Increased Relative	
	Increased DELT: No evidence.	NE	Increased DELT:		Increased DELT:	

NE = no evidence; NA = not applicable/not available

4b. Compare strength of evidence analysis for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Considerations Based on Other Situations or Biological Knowledge</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Plausibility: Stressor-Response cont.	Decrease % Mayflies & Increased % Tolerant Organisms: No evidence.	NE	Decrease % Mayflies & Increased % Tolerant Organisms:		Decrease % Mayflies & Increased % Tolerant Organisms:	
Consistency of Association	No Evidence	NE	No Evidence	NE	No Evidence	NE

NE = no evidence; NA = not applicable/not available

Step 4a: Analyze Evidence for SOE

➤ Specificity – How many causes produce the effect?

➤ Note: the score is the same across all candidates unless NA, but the score differs for each effect

Other evidence that would be nice to have:

➤ Temporality -- Historical or intermittent exposures

➤ Consistency of Association -- How consistently are these levels of stress associated with these effects?

➤ Experiment -- At the case, or elsewhere (e.g. mitigation of effects post-dredging)

➤ Predictive performance -- e.g., look at type of fin erosion

4b. Compare strength of evidence analysis for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Considerations Based on Other Situations or Biological Knowledge</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Specificity of Cause	Increased Relative Weight:		Increased Relative Weight:		Increased Relative Weight:	
	Increased DELT:		Increased DELT:		Increased DELT:	
	Decrease % Mayflies & Increased % Tolerant Organisms:		Decrease % Mayflies & Increased % Tolerant Organisms:		Decrease % Mayflies & Increased % Tolerant Organisms:	
Analogy	Not applicable	NA	Not applicable	NA	Not applicable	NA
Experiment	No evidence	NE	No evidence	NE	No evidence	NE
Predictive Performance	No evidence	NE	No evidence	NE	No evidence	NE

NE = no evidence; NA = not applicable/not available

4b. Compare strength of evidence for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Considerations from Multiple Lines of Evidence</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Consistency of Evidence	Increased Relative Weight:		Increased Relative Weight:		Increased Relative Weight:	
	Increased DELT:		Increased DELT:		Increased DELT:	
	Decrease % Mayflies & Increased % Tolerant Organisms:		Decrease % Mayflies & Increased % Tolerant Organisms:		Decrease % Mayflies & Increased % Tolerant Organisms:	
Coherence of Evidence	Not applicable	NA	Increased Relative Weight, Increased DELT, Decrease % Mayflies & Increased % Tolerant Organisms:		Increased Relative Weight, Increased DELT, Decrease % Mayflies & Increased % Tolerant Organisms:	

NE = no evidence; NA = not applicable/not available

Step 4b: Causal Characterization: Strength of Evidence Summary Impairment A

Causal Consideration	Habitat	Metals	Nutrient
<i>Case-Specific Considerations</i>			
Co-occurrence			
Temporality	NE	NE	NE
Consistency of Association	NE	NE	NE
Biological Gradient			
Increased relative weight			
Increased % DELT			
Decreased % mayflies			
Increased % tolerant			
Complete Exposure Pathway	NA	NE	NE
Experiment	NE	NE	NE
<i>Considerations Based on Other Situations or Biological Knowledge</i>			
Plausibility: Mechanism			
Increased relative weight			
Increased % DELT			
Decreased % mayflies and Increased % tolerant			
Plausibility: Stressor-Response			
Increased relative weight	NE	NA	
Increased % DELT	NE		
Decreased % mayflies and Increased % tolerant	NE		
Consistency of Association	NE	NE	NE
Specificity of Cause			
Increased relative weight		NA	
Increased % DELT			
Decreased % mayflies and Increased % tolerant			
Analogy			
Experiment	NE	NE	NE
Predictive Performance	NE	NE	NE
<i>Considerations from Multiple Lines of Evidence</i>			
Consistency of Evidence			
Increased relative weight			
Increased % DELT			
Decreased % mayflies and Increased % tolerant			
Coherence of Evidence			
	NA	0	0

STEP 5: Identify Probable Cause

Step 5: Identify Probable Cause of Impairment A Confidence?

Increased fish weight?

Increased % DELT?

Increased % mayflies?

Increased % tolerant inv.?

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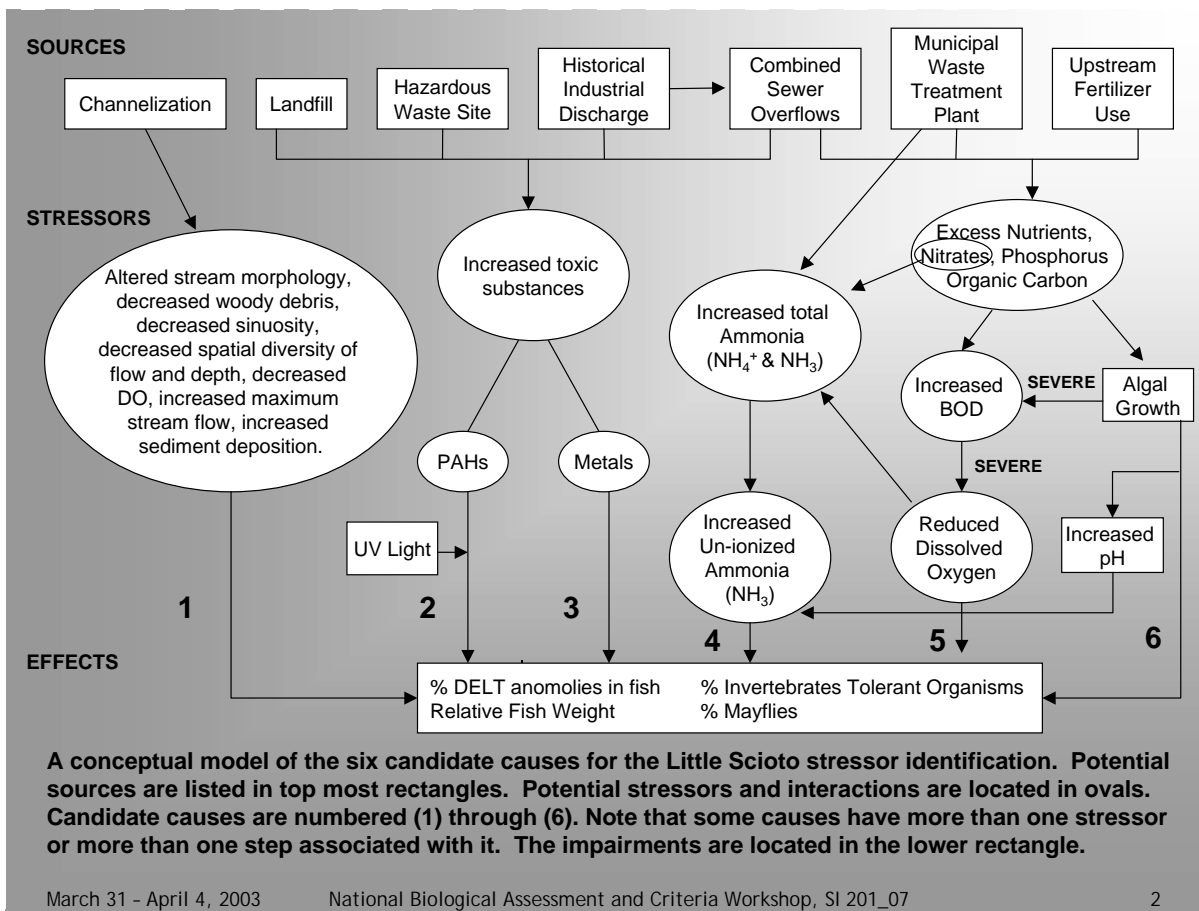


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SI 201

Case Study: Little Scioto River

Answers



Step 1: List Candidate Causes g: Refine List of Candidate Causes

Candidate Cause	Notes
1. Habitat alteration	Includes altered stream morphology, decreased woody debris, decreased sinuosity, decreased spatial diversity of flow and depth, decreased DO, increased maximum stream flow, and increased sediment deposition.
2. PAH toxicity	Historically, the river has provided a means of waste disposal for various industries, whose effluents have contained metals, PAHs, and creosote. Exposure of fish and macroinvertebrates to these contaminants could occur through food, water, and direct contact with sediment. Exposure to UV light enhances the toxicity of PAHs in sediment and water to both fish and invertebrates.
3. Metal toxicity	
4. Ammonia toxicity	Ammonia is directly discharged into streams by point sources. Ammonia also can be formed as the result of nutrient enrichment. When DO levels are low nitrates are reduced to ammonium ion.
5. Low dissolved oxygen/ high biological oxygen demand	Potential sources of excess organic matter within the study area include a wastewater treatment plant and several combined sewer outfalls, as well as upstream, nonpoint sources. Since depletion of dissolved oxygen commonly occurs from organic enrichment, BOD alone is not considered as a candidate cause.
6. Nutrient enrichment	Mild nutrient enrichment results in increased primary production and organic matter loading to the sediments, but does not reduce DO. This can cause changes in fish and macroinvertebrate assemblages, including changes in dominant species, and greatly increased abundance and biomass. This form of nutrient enrichment is also associated with DELT anomalies. Since the effects from nitrate and phosphorus enrichment can not be teased out, these were considered together as nutrient enrichment.

Step 1: List Candidate Causes
h: Cross walk available measurements relevant to each candidate cause

Candidate Cause	Relevant Measurements
1. Habitat alteration	Channel score, embeddedness subscore, siltation subscore, dissolved oxygen
2. PAH toxicity	PAH concentrations in sediments, bile metabolites in fish
3. Metal toxicity	Metal concentrations in sediments, water and fish tissue
4. Ammonia toxicity	Ammonia concentrations in water
5. Low dissolved oxygen/high biological oxygen demand	Dissolved oxygen, biological oxygen demand of water
6. Nutrient enrichment	Nitrate and nitrite concentrations in water, total phosphorus concentrations in water

Step 2a: Analyze Evidence for Elimination

Spatial co-location of candidate causes with Impairments A and B

Candidate Cause	Detected at Site A?	Decreased quality at Site A compared with Upstream Site?	Exposure pathway complete at Site A?
Habitat alteration	Yes	Yes	Yes
PAHs	No	No	No
Metals	Yes	Yes	Yes
Ammonia	No	No	No
Low-dissolved oxygen/BOD	Yes	DO: Yes BOD: No ¹	
Nutrient enrichment	Yes	Yes	Yes

¹Although dissolved oxygen was not measured at Site B, BOD was measured and was elevated compared with Site A.

Step 2b: Candidate Causes Remaining after Elimination

	RM 7.9 Impairment A
#1 Habitat alteration	X
#2 PAH Contamination	
#3 Metal Contamination	X
#4 Ammonia	
#5 Low DO/BOD	
#6 Nutrient Enrichment	X

4b. Compare strength of evidence for the three candidate causes of Impairment A

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Case-Specific Considerations</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Co-occurrence	Compatible: At and below site A the habitat of the Little Scioto is altered as a result of channelization. The degree of habitat alteration remains about the same to the mouth of the river. Substrate scores and DO are lower than upstream. The Upstream Site is not channelized and habitat is good.	+	Compatible: All sediment metal concentrations were slightly higher at site A compared to upstream	+	Compatible: NO _x was elevated by 0.2mg/L in 1992 compared to upstream. Total P was elevated compared to upstream by 0.01 mg/L .	+
Temporality	No evidence	NE	No evidence	NE	No evidence	NE
Consistency of Association	No evidence	NE	No evidence	NE	No evidence	NE

NE = no evidence; NA = not applicable/not available

4b. Compare strength of evidence for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Case-Specific Considerations</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Biological Gradient	Increased relative weight: None for channel, sediment, low DO was weakly correlated, but relative weight decreases with decreasing DO	-	Increased relative weight: Weak correlation with zinc, but relative weight decreases with increasing Zn	-	Increased relative weight: Clear association but wrong sign: Weak correlations with NO _x and total P, but relative weight decreases with increasing nutrient concentrations.	-
	Increased %DELT: None for channel, sediment, but low DO was weakly correlated	+	Increased %DELT: Weak correlations with chromium and zinc.	+	Increased % DELT: Weak correlation with NO _x , Strong with total P.	+++
	Decreased % mayflies: None for channel, sediment, but low DO was strongly correlated	+++	Decreased % mayflies: Weak correlations with chromium and zinc.	+	Decreased % mayflies: Weak: correlations with both NO _x and total P	+
	Increased % tolerant organisms: Ambiguous	0	Increased % tolerant organisms: Weak correlation with copper.	+	Increased% tolerant organisms: Ambiguous	0
Complete Exposure Pathway	Not applicable: No known intermediate steps.	NA	No evidence: Internal concentrations of metals were not measured.	NE	No evidence: concentrations of algae or chlorophyll <i>a</i> were not measured.	NE
Experiment	No evidence.	NE	No evidence.	NE	No evidence.	NE

NE = no evidence; NA = not applicable/not available

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4b. Compare strength of evidence for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Considerations Based on Other Situations or Biological Knowledge</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Plausibility: Mechanism	Increased Relative Weight: Plausible: Artificially deepened channel allows larger sized fish to survive.	+	Increased Relative Weight: Implausible: No known mechanism for metals. Metals usually cause a decrease in the relative weight of fish (Eisler 2000a, USEPA, 1985a, 1985b, 1985c, 1987).	-	Increased Relative Weight: Plausible: NO _x and total P are nutrients that can increased algal growth. Greater production of algae could provide additional food, increasing fish growth.	+
	Increased DELT: Plausible: No obvious mechanism other than stress due to low DO. DO decreased by 3.1 mg/l (Austin & Austin 1993).	+	Increased DELT: Plausible: Metals cause fin erosion and lesions (Hinton et al. 1993). Pb, Cu, Zn cause deformities (Eisler 2000a, USEPA 1985a, 1985b, 1985c 1987).	+	Increased DELT: Plausible: Nutrients may create conditions that favor opportunistic pathogens and fungi that cause lesions, fin erosion and interfere with wound healing.	+
	Decreased % Mayflies & Increased % Tolerant Organisms: Plausible: Fine sediments provide poor forage, reproductive, and cover habitats for benthic invertebrates including many mayflies. Low DO is not tolerated by many species (Karr and Schlosser 1977, Yount and Niemi 1990, Rankin 1995).	+	Decreased % Mayflies & Increased % Tolerant Organisms: Plausible: metals are known to cause lethal and sublethal effects to invertebrates (Eisler 2000a, USEPA, 1985a, 1985b, 1985c, 1987).	+	Decreased % Mayflies & Increased % Tolerant Organisms: Plausible: Switching to an autochthonous energy source could alter species survival and community composition of invertebrates.	+

NE = no evidence; NA = not applicable/not available

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Step 4a. Analyze Evidence for SOE
Using Other Situations or Biological Knowledge
Plausibility: Stressor-Response

Metals concentrations (mg/kg) at the Upstream Site, and Site A.
(TEL and PEL values are for *Hyaella azteca* and are normalized to sediment dry weight.)

Chemical		Upstream Site	Site A
TEL	PEL		
Cu		7.4	17.2
28	101.2		
Pb		12.1	19.1
37.2	81.7		
Zn		3.06	79
98.1	544		
Cumulative Toxic Units based on PEL		0.28	0.66

(*) exceeds PEL and TEL; (#) exceeds TEL.

Step 4a. Analyze Evidence for SOE
Using Other Situations or Biological Knowledge
Plausibility: Stressor-Response

Comparison of the reported concentration of water quality parameters (mg/L) with available criteria.

Criterion	Site A
Dissolved Oxygen ^b 3.0 mg/L for MWH	2.8 ^{e*}
Nitrate-nitrite ^c 1.6 mg/L	1.4
Total phosphorus ^d 0.28 mg/L	0.07

^b OEPA (1994) dissolved oxygen criterion.

^c Rankin et al. (1999) proposed nitrate-nitrite criterion

^d Rankin et al. (1999) proposed total phosphorus criterion

^e minimum dissolved oxygen concentrations from continuous monitoring over three days in 1987

* Violates criteria

Step 4a. Analyze Evidence for SOE Using Other Situations or Biological Knowledge Plausibility: Stressor-Response

Comparison of the reported concentration of water quality parameters (ug/L) with available criteria.

Chemical AWQC (ug/l) @ 200 mg/L hardness	Upstream Site	Site A
Copper 21	ND	ND
Lead 7.7	ND	ND
Zinc 190	ND	ND

4b. Compare strength of evidence analysis for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Considerations Based on Other Situations or Biological Knowledge</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Plausibility: Stressor-Response	Increased Relative Weight: No evidence.	NE	Increased Relative Weight: Not applicable: Implausible mechanism.	NA	Increased Relative Inconcordant: NO _x does not limit algal growth in most Ohio streams (Rankin et al 1999, Allan 1995). Magnitude of nutrient change too small to cause effect.	-
	Increased DELT: No evidence.	NE	Increased DELT: Inconsistent: Deformities including lordoscoliosis are reported at water hardness greater than 200 mg/l for 850ug/l lead and 160 ug/l zinc at (USEPA 1987). No metals were detected in water at site A.	-	Increased DELT: Inconcordant: The magnitude of nutrient change was too small to account for the dramatic shifts in invertebrate metrics. NO _x does not limit algal growth in most streams (Allan 1995, Rankin et al 1999). Ohio's proposed criteria nitrogen and phosphorus were not exceeded. Criteria are protective of fish (Rankin et al. 1999).	-

NE = no evidence; NA = not applicable/not available

4b. Compare strength of evidence analysis for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Considerations Based on Other Situations or Biological Knowledge</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Plausibility: Stressor-Response cont.	Decrease % Mayflies & Increased % Tolerant Organisms: No evidence.	NE	Decrease % Mayflies & Increased % Tolerant Organisms: Inconcordant: No metals exceeded <i>Hyalella azteca</i> PEL values. Cumulative toxic index was not exceeded (USEPA 1996b). Hickey and Clements (1998) reviewed invertebrate species richness, particularly of mayflies, which declined in association with metals in water column; however, concentrations at site A were probably less than concentrations reported by Hickey and Clements.	-	Decrease % Mayflies & Increased % Tolerant Organisms: Inconcordant: Magnitude of nutrient change too small to account for change of invertebrate metrics. NO ₃ does not limit algal growth in most streams (Allan 1995). Virginian streams are associated with algal growth that decrease numbers of EPT taxa, but at higher concentrations than at site A (Lemly 1998). Ohio's proposed nitrogen and phosphorus criteria were not exceeded (Rankin et al. 1999).	-
Consistency of Association	No Evidence	NE	No Evidence	NE	No Evidence	NE

NE = no evidence; NA = not applicable/not available

4b. Compare strength of evidence analysis for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
<i>Considerations Based on Other Situations or Biological Knowledge</i>						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Specificity of Cause	Increased Relative Weight: One of a few.	++	Increased Relative Weight: Not applicable: Implausible mechanism.	NA	Increased Relative Weight: One of a few.	++
	Increased DELT: One of many.	0	Increased DELT: One of many.	0	Increased DELT: One of many.	0
	Decrease % Mayflies & Increased % Tolerant Organisms: One of many.	0	Decrease % Mayflies & Increased % Tolerant Organisms: One of many.	0	Decrease % Mayflies & Increased % Tolerant Organisms: One of many.	0
Analogy	Not applicable	NA	Not applicable	NA	Not applicable	NA
Experiment	No evidence	NE	No evidence	NE	No evidence	NE
Predictive Performance	No evidence	NE	No evidence	NE	No evidence	NE

NE = no evidence; NA = not applicable/not available

4b. Compare strength of evidence analysis for the three candidate causes of Impairment A (continued)

Causal Consideration	Evidence	Score	Evidence	Score	Evidence	Score
Considerations Based on Other Situations or Biological Knowledge						
	Habitat Alteration		Metals Contamination		Nutrient Enrichment	
Consistency of Evidence	Increased Relative Weight: Most Consistent. Biological gradient direction is in the wrong direction for DO.	+	Increased Relative Weight: Multiple Inconsistencies: Implausible mechanism.	---	Increased Relative Weight: Multiple Inconsistencies: Biological gradient is in the wrong direction, implausible stressor response.	---
	Increased DELT: All consistent.	+++	Increased DELT: Most consistent: Stressor response unlikely.	+	Increased DELT: Most Consistent: Magnitude of change inconsistent with magnitude of effect.	+
	Decrease % Mayflies & Increased % Tolerant Organisms: All consistent	+++	Decrease % Mayflies & Increased % Tolerant Organisms: Most consistent: Although metals are present, the concentrations are unlikely to be toxic.	---	Decrease % Mayflies & Increased % Tolerant Organisms: Most consistent: Magnitude of change inconsistent with magnitude of effect.	+
Coherence of Evidence	Increased relative weight of fish likely associated with channelization rather than DO	+	Increased Relative Weight, Increased DELT, Decrease % Mayflies & Increased % Tolerant Organisms: No explanation.	0	Increased Relative Weight, Increased DELT, Decrease % Mayflies & Increased % Tolerant Organisms: No explanation.	0

NE = no evidence; NA = not applicable/not available

Step 4b. Causal Characterization: Strength of Evidence Summary Impairment A

Causal Consideration	Habitat	Metals	Nutrient
<i>Case-Specific Considerations</i>			
Co-occurrence	+	+	+
Temporality	NE	NE	NE
Consistency of Association	NE	NE	NE
<i>Biological Gradient</i>			
Increased relative weight	-	-	-
Increased % DELT	+	+	+++
Decreased % mayflies	+++	+	+
Increased % tolerant	0	+	0
Complete Exposure Pathway	NA	NE	NE
Experiment	NE	NE	NE
<i>Considerations Based on Other Situations or Biological Knowledge</i>			
<i>Plausibility: Mechanism</i>			
Increased relative weight	+	-	+
Increased % DELT	+	+	+
Decreased % mayflies and Increased % tolerant	+	+	+
<i>Plausibility: Stressor-Response</i>			
Increased relative weight	NE	NA	-
Increased % DELT	NE	-	-
Decreased % mayflies and Increased % tolerant	NE	-	-
Consistency of Association	NE	NE	NE
<i>Specificity of Cause</i>			
Increased relative weight	++	NA	++
Increased % DELT	0	0	0
Decreased % mayflies and Increased % tolerant	0	0	0
<i>Analogy</i>			
Experiment	NE	NE	NE
Predictive Performance	NE	NE	NE
<i>Considerations from Multiple Lines of Evidence</i>			
<i>Consistency of Evidence</i>			
Increased relative weight	+	---	---
Increased % DELT	+++	+	+
Decreased % mayflies and Increased % tolerant	+++	+	+
Coherence of Evidence	+	0	0

Case Study: Little Scioto River

Identify Probable Cause

Causal Characterization

<i>Causal Characterization</i>
Impairment A - River Mile 7.9
Habitat Alteration
<p>The probable cause of Impairment A is Habitat Alteration.</p> <p>Increase in relative weight of fish is probably caused by an artificially deepened channel that allows larger fish to survive at Site A. The cause of increased DELT anomalies is uncertain, but is likely caused by general stress associated with altered habitat including low dissolved oxygen.</p> <p>Low substrate texture and low DO associated with the habitat alteration are the most likely causes for the decrease percent mayflies and increase in tolerant organisms.</p> <p>Metal contamination is improbable, because laboratory studies indicate decreases in growth rather than increases. Metal concentrations in both sediment and water were below relevant criteria. Nutrient enrichment is an unlikely cause because the increase in nutrient concentrations was minute.</p>



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

CADDIS: Making Stressor ID Easier

The Causal Analysis/Diagnosis Decision Information System Development Workshop

Presented by
Sue Norton, USEPA,
Office of Research & Development


The Causal Analysis/Diagnosis Decision Information System Development Workshop

Mt. Sterling, OH
August 26-28, 2002




Why CADDIS?

Users of the Stressor Identification Guidance Need Help

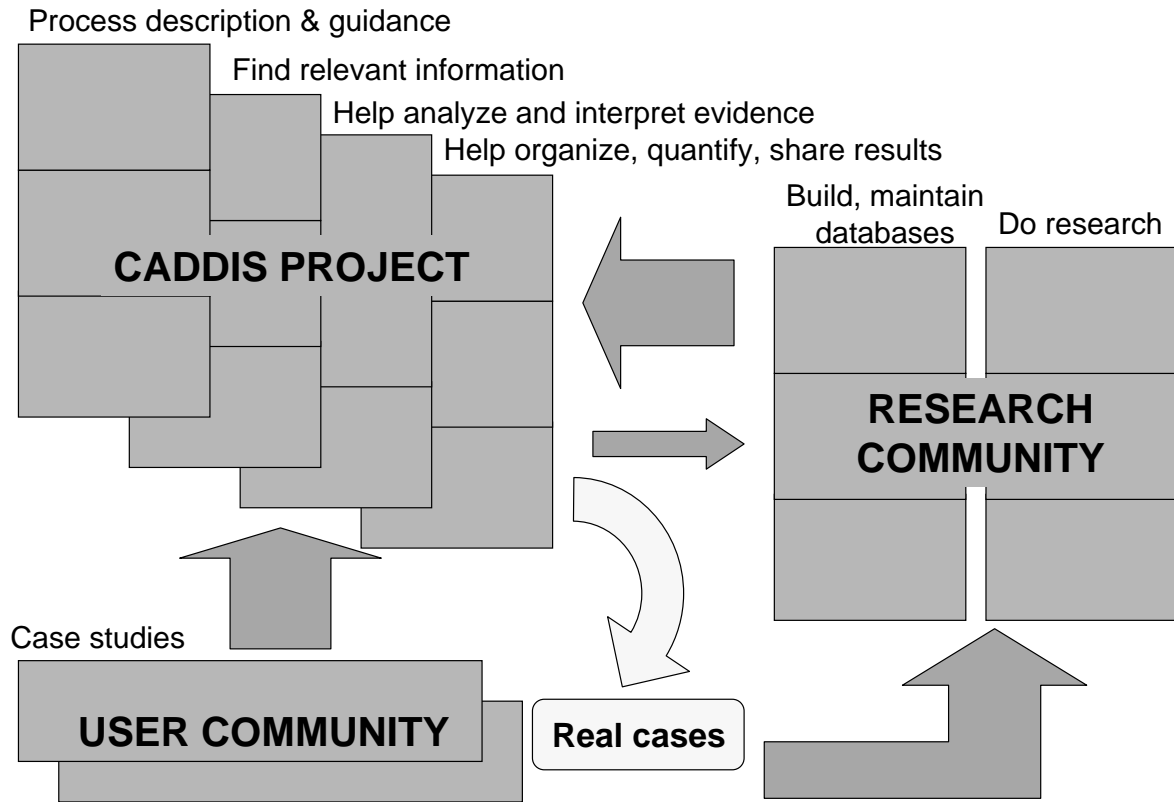


- The Stressor Identification Guidance asks much from investigators:
 - In-depth knowledge of multiple stressors, multiple endpoints
 - Familiarity with different approaches to causal inference
 - Juggling many different lines of evidence
- Documenting the process for presentation to others may be burdensome.
- Research results may need additional development to be directly useful.
- Users need high quality data from field and laboratory studies that are not readily at hand.
- Users would benefit from sharing data, results and experiences.

Workshop Objectives

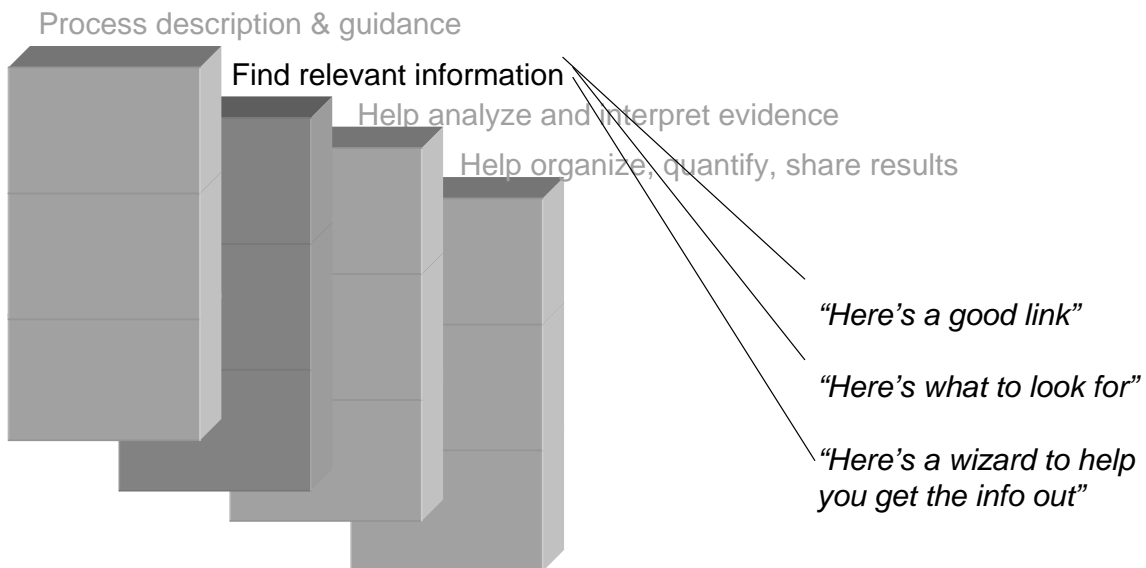
- 
- To conceptualize an information system (decision support system, expert system) that will help investigators find, access, organize and share information useful for causal evaluations in aquatic systems.
 - To identify critical research needs for system implementation and population.
 - 30 participants (most from EPA)

Conceptual Diagram of the CADDIS Project, Research and User Communities

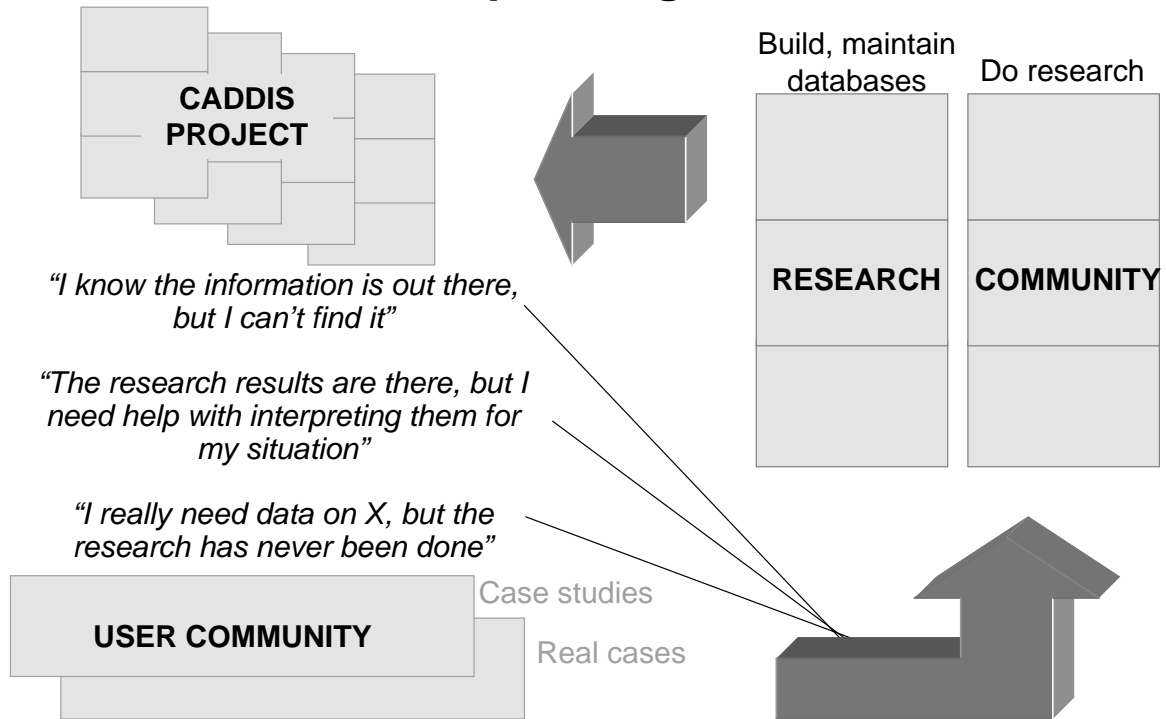


Which functions have the greatest value?

Each of these CADDIS tasks can be implemented in a variety of ways, from simple to complex



Which database and information needs are most pressing?

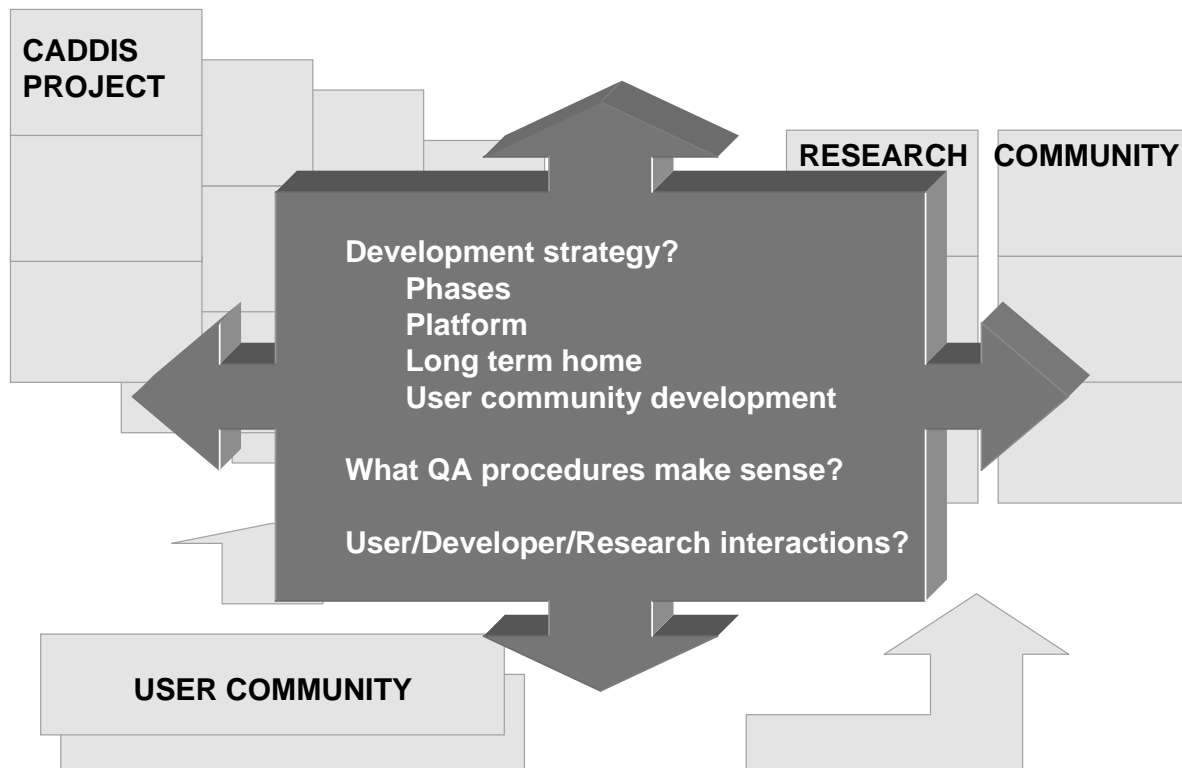


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How should general system development proceed?



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Workshop Results

General Impressions

- Professional judgement can be aided, but not replaced, by a computer system
- CADDIS should focus on providing information
 - a guide through the SI process
 - no statistical analyses

Workshop Results

Major Themes

- System functions should focus on guidance, a knowledge base and user interaction
- System development should be user-focused, modular, and iterative

Workshop Results

Priority Functions

Guidance <ul style="list-style-type: none">– prompt through the process– blank forms and tables– advice on analyses and avoiding pitfalls	Case Studies <ul style="list-style-type: none">– searchable database<ul style="list-style-type: none">• EPA Cases• User Input
Knowledge Base <ul style="list-style-type: none">– stressor-response relationships<ul style="list-style-type: none">• prioritized– organism tolerances– probabilities of association for stressors and impairments	Conceptual Models <ul style="list-style-type: none">– examples from typical situations– modifiable– graphics tool

Workshop Results

System Development

- **Need User Input**
 - participation on development team
 - solicit feedback on SI web site
 - meetings and training
- **Phased, iterative, and modular development process**
 - manage expectations
 - incorporate feedback; keep up with changing needs
 - showcase success quickly and often
- **Build into the system a communication mechanism**
 - facilitate technical support (listserve, online forms)
 - identify research gaps

Workshop Results

Conclusions

- Need to be on fast track -- States are moving forward
 - get development team in place
 - get prototype system out for user feedback
 - start with simple, web-based system; move towards complex system run locally with web components
- Long-term commitment
 - developers
 - users
 - management



Questions for You

- What information or data base needs are the highest priority for your causal investigations?
 - Stressors? Assemblages? Other types of information?
- What system functionality would you find most useful?
 - Step by step guide to SI? Data analysis? Good links?
- What advice would you give us as we make decisions about system platform and home?
 - Web vs. local? Housed at EPA vs. elsewhere? Data security issues? Internet speed/connection issues?
- Are you interesting in serving on the CADDIS development workgroup or as an early reviewer as we build the system?
 - If so provide contact information here, nab Sue, Susan or Glenn later, or follow-up via e-mail: norton.susan@epa.gov