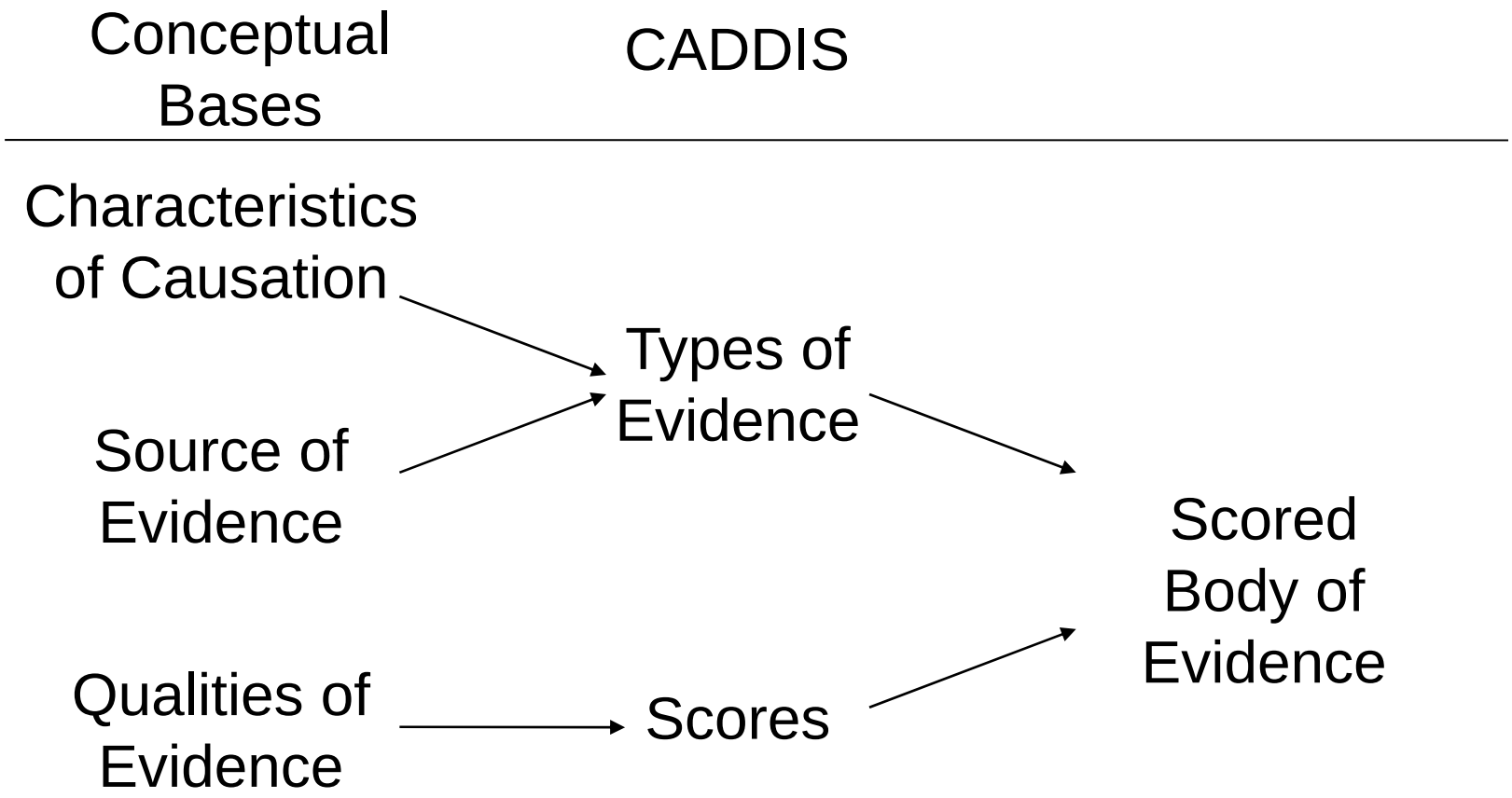
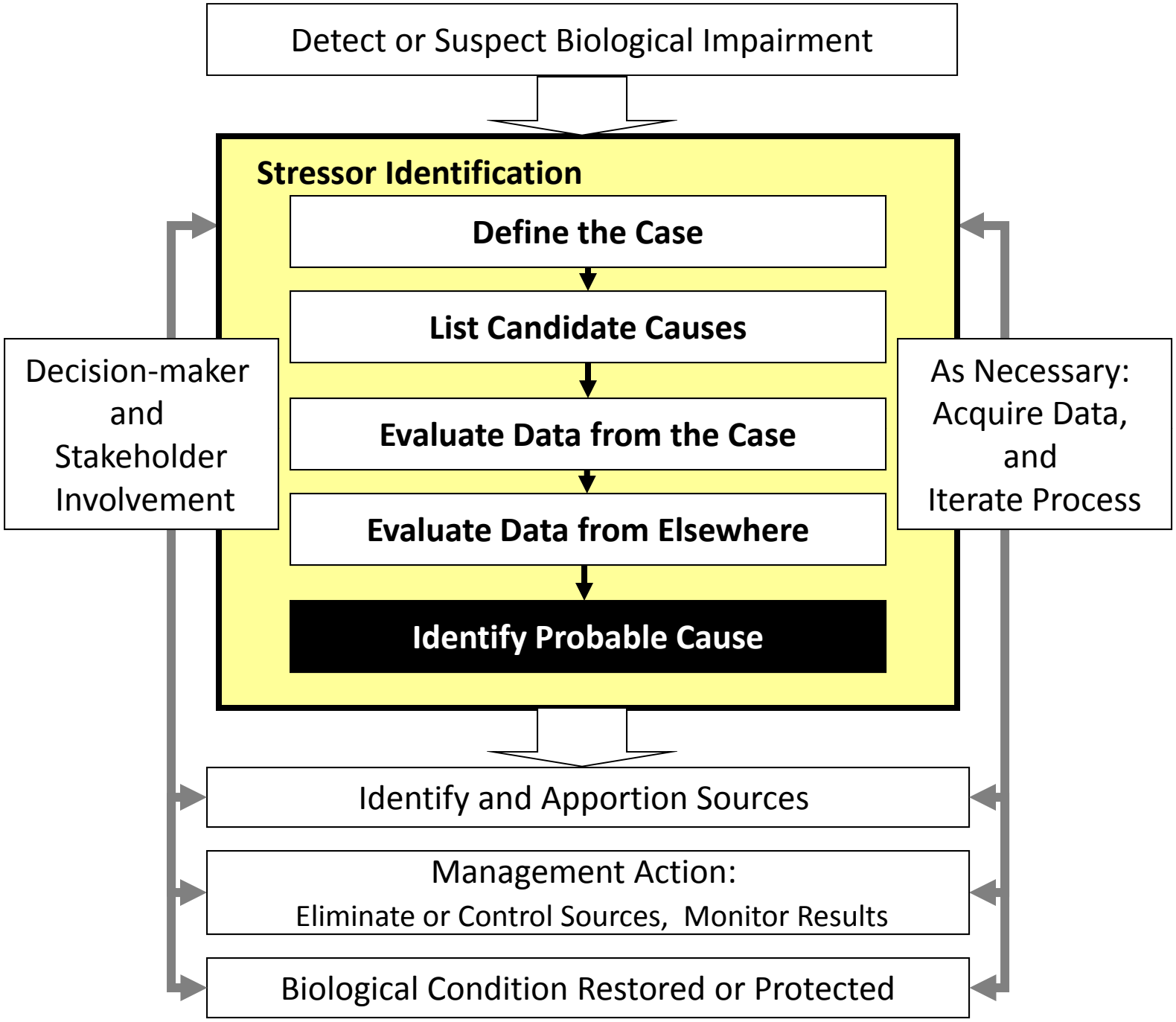
Step 5:

Identifying probable causes


Conceptual Bases
CADDIS
Characteristics of Causation
Source of Evidence
Qualities of Evidence
Types of Evidence
Scores
Scored Body of Evidence


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
Biological Condition Restored or Protected

Quality of the Body of the Evidence

- **Credibility**—The body or evidence is based on relevant and high quality information.
- **Strength**—The body of evidence includes pieces of evidence that are logically compelling or that present quantitatively strong relationships
- **Diversity**—Many sources of evidence and characteristics of causation are represented in the body of evidence.
- **Coherence**—The body of evidence is internally consistent, consistent with scientific knowledge and theory, and logically explains the facts in the case.

Weighing the evidence for each candidate cause

- Consider the source of information
- Evaluate the quality of the body of evidence
- Summarize the compelling evidence

Evaluate quantity & quality of evidence

- Quality & quantity of data influence scores
- Now evaluate overall quality of evidence
- Lots of consistent evidence reduces quality concerns for any 1 type of evidence
- Poor quality data may be discounted
- Consider study designs, methods, relevance, variability, & other QA issues

Evaluate consistency & credibility

- Prepare summary table of scores
- Do **not** add up scores!
- Evaluate consistency of evidence
- Look for compelling evidence
- If evidence is inconsistent, consider mechanistic explanations
  - e.g., lab data not consistent with field conditions due to differing bioavailability

Summarize compelling evidence

- Make an overall evaluation of strength of evidence for each candidate cause
  - what evidence compels belief that candidate cause induced effect?
  - what evidence strongly casts doubt?
- Consider the principle characteristics of causal relationships
  - these are what you're trying to show
  - they summarize the 15 types of evidence

There is no magic formula…

All candidate causes must be compared to determine:

- if there is more than 1 probable cause
- the level of confidence in the results

Comparing evidence among causes: best-case scenario

You have compelling evidence for 1 candidate cause; others are weak or refuted...

TYPE OF EVIDENCE	CANDIDATE CAUSE		
	1	2	3
A	++	-	R
B	+	--	
C	+	-	
Consistency	+	-	

…celebrate, then remediate for Candidate Cause 1

Comparing evidence among causes: more (likely) scenarios

You have uneven evidence across candidate causes...

TYPE OF EVIDENCE	CANDIDATE CAUSE		
	1	2	3
A	++	–	
B	+		–
C	+	+	
Consistency	+	–	NA

- Strong evidence for one candidate cause may be sufficient
- Consider if weakness is due to lack of data

You have unsatisfying evidence across all candidate causes…

TYPE OF EVIDENCE	CANDIDATE CAUSE		
	1	2	3
A	+	–	
B	–		–
C		+	
Consistency	–	–	–

- Reconsider the impairment
- Consider additional candidate causes
- Consider episodic events
- Consider gathering more data

You have insufficient data…

TYPE OF EVIDENCE	CANDIDATE CAUSE		
	1	2	3
A	NE	NE	–
B	+	NE	NE
C	NE	NE	NE
Consistency	0	0	0

- Gather data if possible
- Consider other bases for remediation (e.g., BMPs, chemical criteria) and monitor biological responses
- Use professional judgment as last resort

You have evidence suggesting multiple causes…

TYPE OF EVIDENCE	CANDIDATE CAUSE		
	1	2	3
A	++	+	+
B	+	+	++
C	++	++	+
Consistency	+	+	+

- Consider disaggregating indices or metrics
- Combine causes if they share causal pathways, modes of action, sources and routes of exposure, or if they interact
- Remediate dominant cause
- Design remediation to address multiple causes

Combining stressors

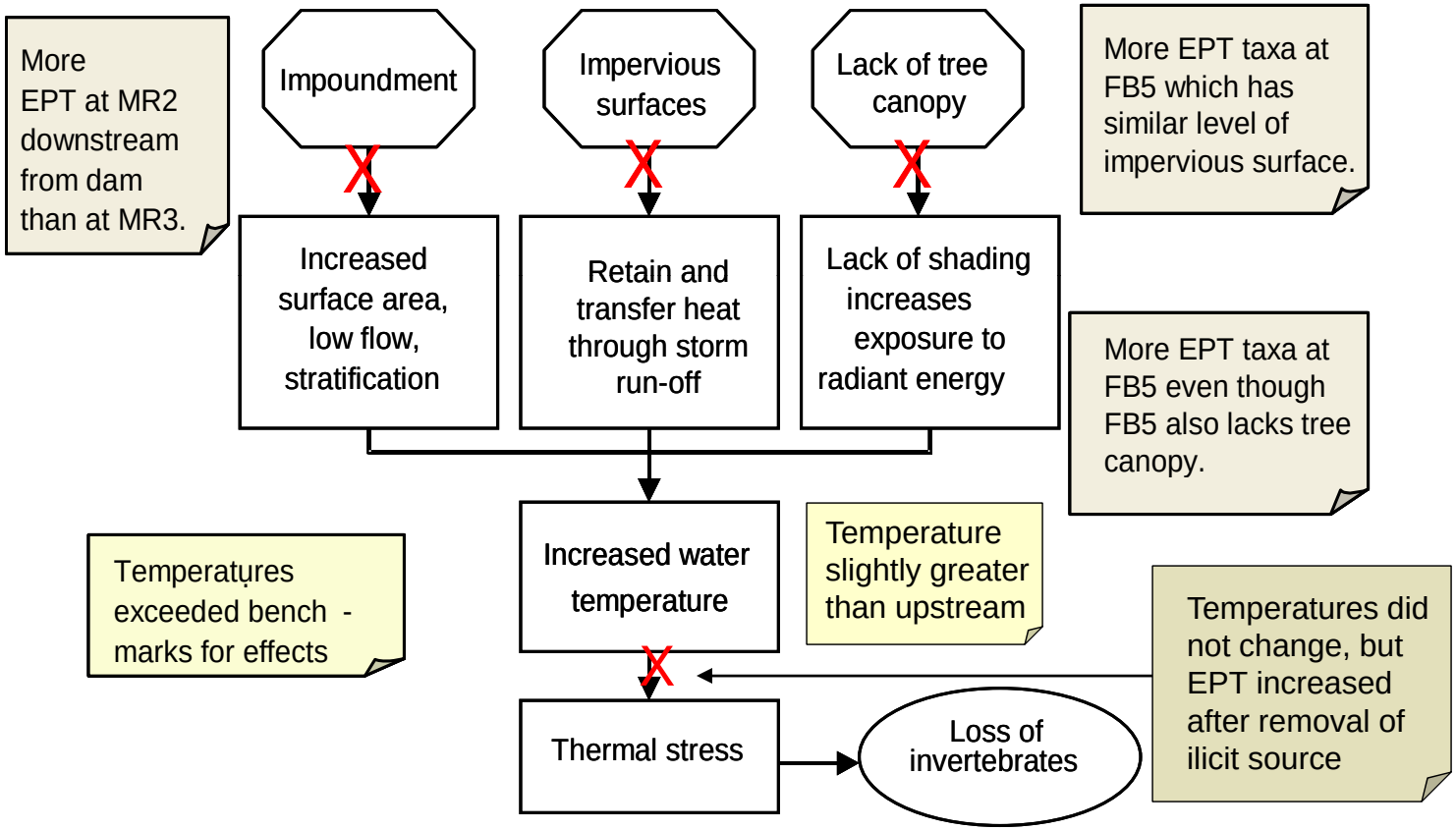
- Strategies
  - Combine if they share causal pathways, modes of action, sources & routes of exposure, or if they interact
  - Re-aggregate stressors that have been unnecessarily disaggregated
  - Identify independently acting stressors that cause the same effect
  - Define effects more specifically
- Warnings
  - Avoid combining causes without an underlying model
  - Avoid broad candidate cause definitions
  - Don’t lose independent effects of individual causes

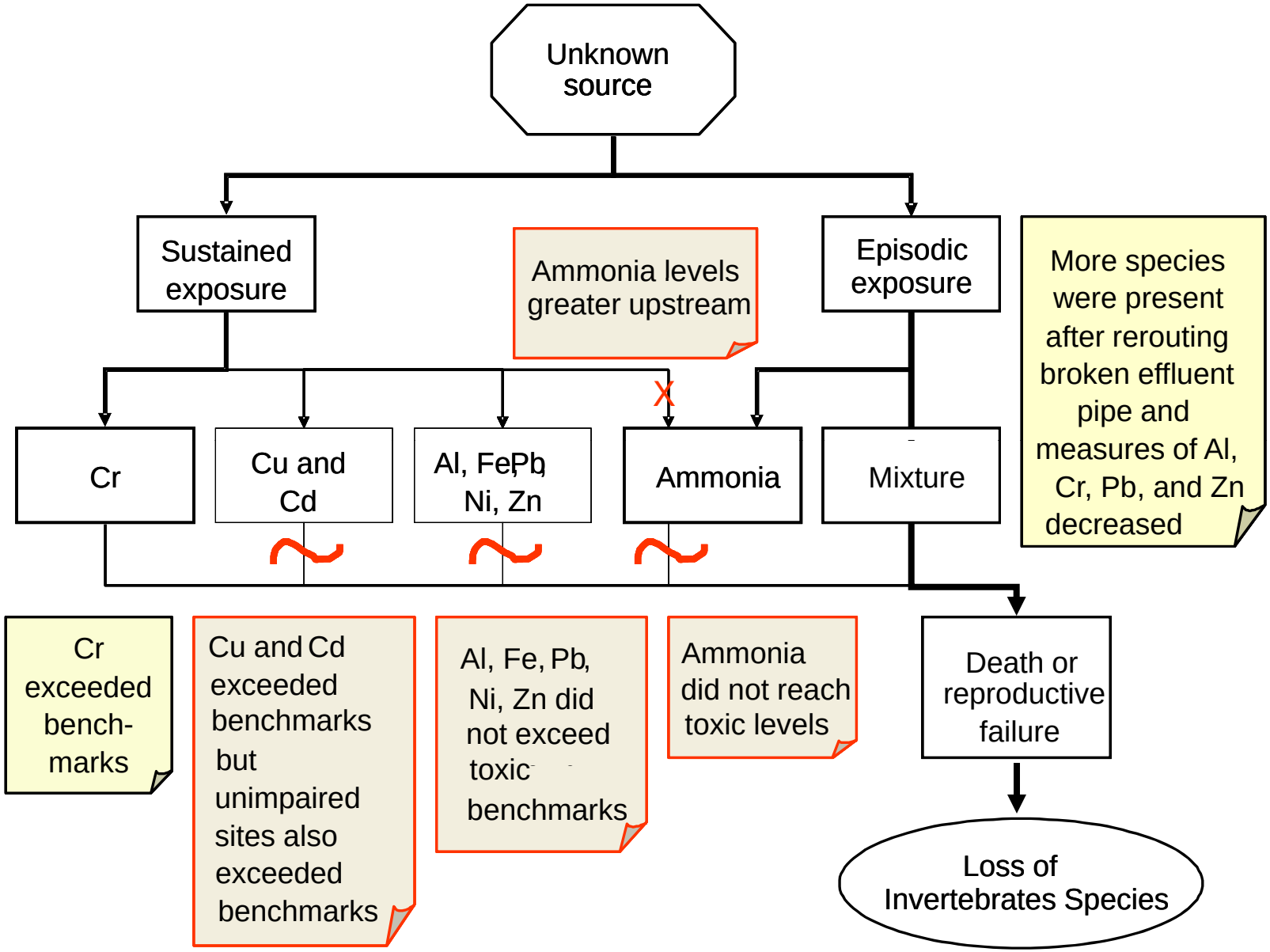
How do I communicate results?

- Make your logic clear
- Present the critical evidence
- Reveal uncertainties
- Fit communication to your audience
- For technical reviewers, include text & tables
- For decision makers, may be helpful to use annotated conceptual model

Willimantic case study		Metals	NH_3	Flow	Silt	Low DO	Temp	Food	Episodic Mix
Types of Evidence that Use Data from the Case									
Preceding Causation	Causal Pathway		-	+	-	-	+	-	+
	Verified Predictions								+ + +
Co-Occurrence	Spatial/Temporal Co-Occurrence	+	-		+	- - -	+		+
	Manipulation of Exposure								+ + +
Sufficiency	Stressor-Response from the Field/Case	+	-		-	+	+		
Alteration	Evidence of Biological Mechanism	+	+	+	-	+	+	-	+
Types of Evidence that Use Data from Elsewhere									
Sufficiency	Stressor-Response from Other Field	- -	+						
	Stressor-Response from Laboratory	+ +	-			-	+		
Evaluating Multiple Types of Evidence									
Consistency of Evidence		-	-	+	-	-	+	-	+ + +

What could we have used here? WET test. TIE.


More EPT at MR2 downstream from dam than at MR3.
Impoundment
Impervious surfaces
Lack of tree canopy
More EPT taxa at FB5 which has similar level of impervious surface.
Increased surface area, low flow, stratification
Retain and transfer heat through storm run-off
Lack of shading increases exposure to radiant energy
More EPT taxa at FB5 even though FB5 also lacks tree canopy.
Temperatures exceeded bench - marks for effects
Increased water temperature
Temperature slightly greater than upstream
Temperatures did not change, but EPT increased after removal of ilicit source
Thermal stress
Loss of invertebrates


Unknown source
Sustained exposure
Ammonia levels greater upstream
Episodic exposure
More species were present after rerouting broken effluent pipe and measures of Al, Cr, Pb, and Zn decreased
X
Cr
Cu and Cd
Al, Fe, Pb, Ni, Zn
Ammonia
Mixture
Cr exceeded bench-marks
Cu and Cd exceeded benchmarks but unimpaired sites also exceeded benchmarks
Al, Fe, Pb, Ni, Zn did not exceed toxic benchmarks
Ammonia did not reach toxic levels
Death or reproductive failure
Loss of Invertebrates Species

What comes after causal analysis?

- If confidence in results is low…
  - plan studies to obtain critical evidence
  - experimental studies most likely to be convincing
- If confidence in results is high…
  - identify sources
  - take action
  - monitor results