Causal Analysis of California Biologically Impaired Waters

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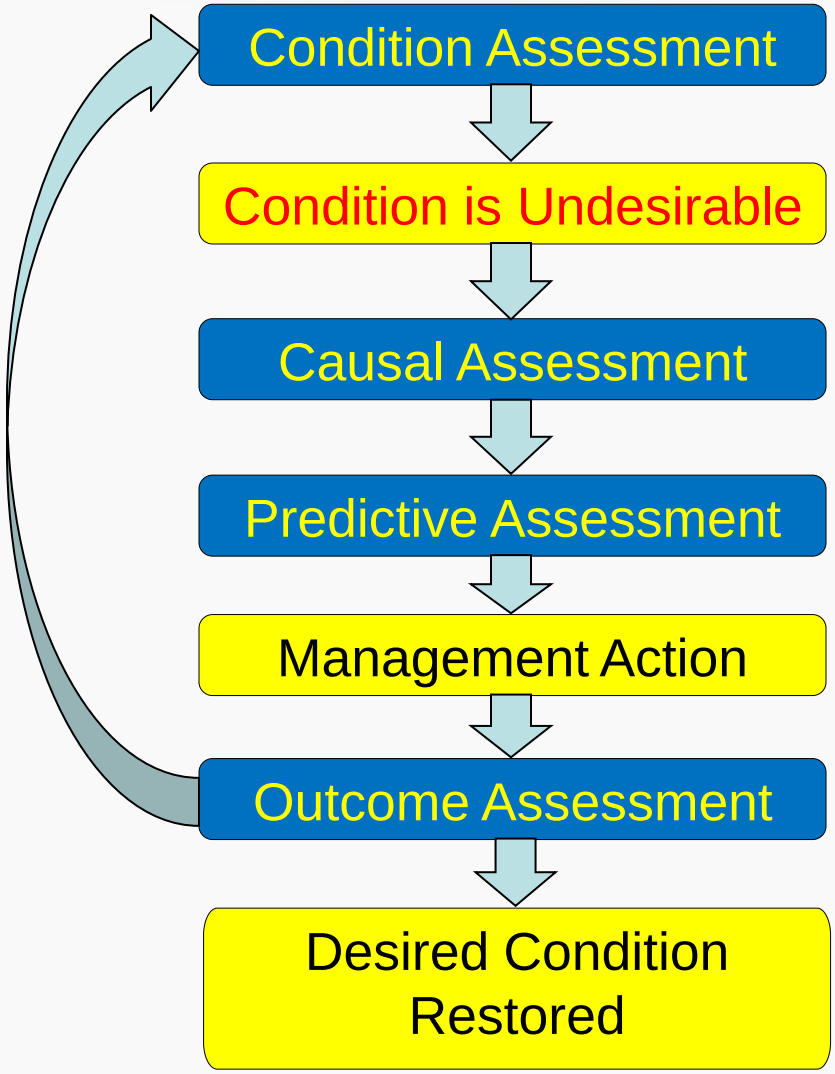
Causal Assessment
Purpose and Motivation

Provide a brief introduction to causal assessment and the California Case Studies

WHY?

- The State of California is setting biological expectations to ensure protection of aquatic life beneficial uses for perennial freshwater streams.
- When biological expectations are not attained and the cause is not readily apparent or obvious, a collaboration between regulated and regulatory agencies is required to identify the cause and remedy the situation.
- ***Causal Assessment*** is a formal method for identifying the probable causes of biological impairment.
  - can be conducted using available information
  - can be a means for engaging stakeholders

Environmental Assessment



Evaluate chemical, biological, or physical state

Identify cause or source

Forecast from causal relationship

Evaluate performance and effect on chemical, biological, or physical state

Why Establish Causation?

- To fix the problem, you have to know what to fix.
- Biological assessments are commonly used to identify if streams are impaired.
- In many cases, causes of impairment are unknown.

General Impairment Name	Causes of Impairment Reported	Percent of Reported
MERCURY	8555	13.45
PATHOGENS	8526	13.41
SEDIMENT	6689	10.52
METALS (OTHER THAN MERCURY)	6389	10.05
NUTRIENTS	5654	8.89
OXYGEN DEPLETION	4568	7.18
PH	3389	5.33
CAUSE UNKNOWN - BIOLOGICAL INTEGRITY	2866	4.51
TEMPERATURE	2854	4.49
HABITAT ALTERATION	2220	3.49
PCBS	2081	3.27
TURBIDITY	2050	3.22
CAUSE UNKNOWN	1356	2.13
PESTICIDES	1322	2.08
SALINITY/TDS/CHLORIDES	996	1.57
FLOW ALTERATION	591	.93
ALGAL GROWTH	510	.80
AMMONIA	415	.65
OTHER TOXIC ORGANICS	339	.53
TOTAL TOXICITY	292	.46
DIOXINS	290	.46
TOXIC INORGANICS	270	.42
FISH CONSUMPTION	260	

Why Establish Causation?

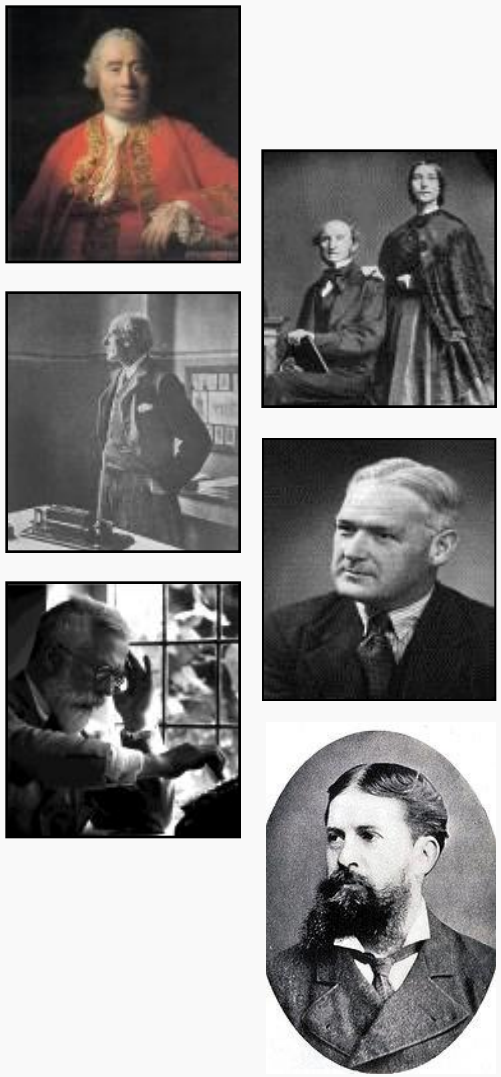
Because we make mistakes about causality

- Overweigh chance events — Every time I wash my car it rains
- Have biases — All pollution is caused by industry
- Are “educationally” predisposed — Hydrologist think hydrology
- Use intuition — I have a hunch it is nitrogen
- Rely on experiences — A flood caused this last time

We are human. We tend to form conclusions quickly and, because we’re smart, we can ably defend them.

Establishing Causation

- Causation is one of the most difficult & controversial concepts in philosophy.
- A **randomized**, **replicated**, **controlled** experiment is the **ONLY** reliable method for establishing causation.
- **THE PROBLEM-** Environmental monitoring designs are rarely randomized, replicated, and controlled.



How to Establish Causation

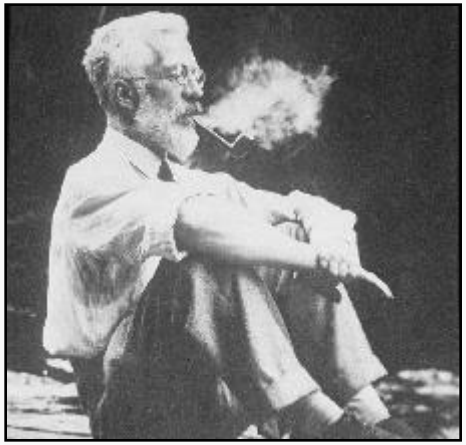
RELY ON A *FORMAL METHOD*

- To provide a defensible & reproducible evaluation
- To identify causal relationships that are not immediately apparent
- To prevent biases and other lapses of logic
- To increase confidence that remedial or restoration efforts can improve biological condition

"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]

How to Establish Causation

Make *SPECIFIC* rather than *GENERAL* statements



- ***AVOID*** *General* – **Does** C cause E?
  - Does smoking cause lung cancer?
  - Does increased water temperature reduce bull trout abundance in rivers?

- ***MAKE*** *Specific* – **Did** C cause E?
  - Did smoking cause lung cancer in Ronald Fisher?
  - Did increased water temperature reduce bull trout abundance in ***my*** stream?

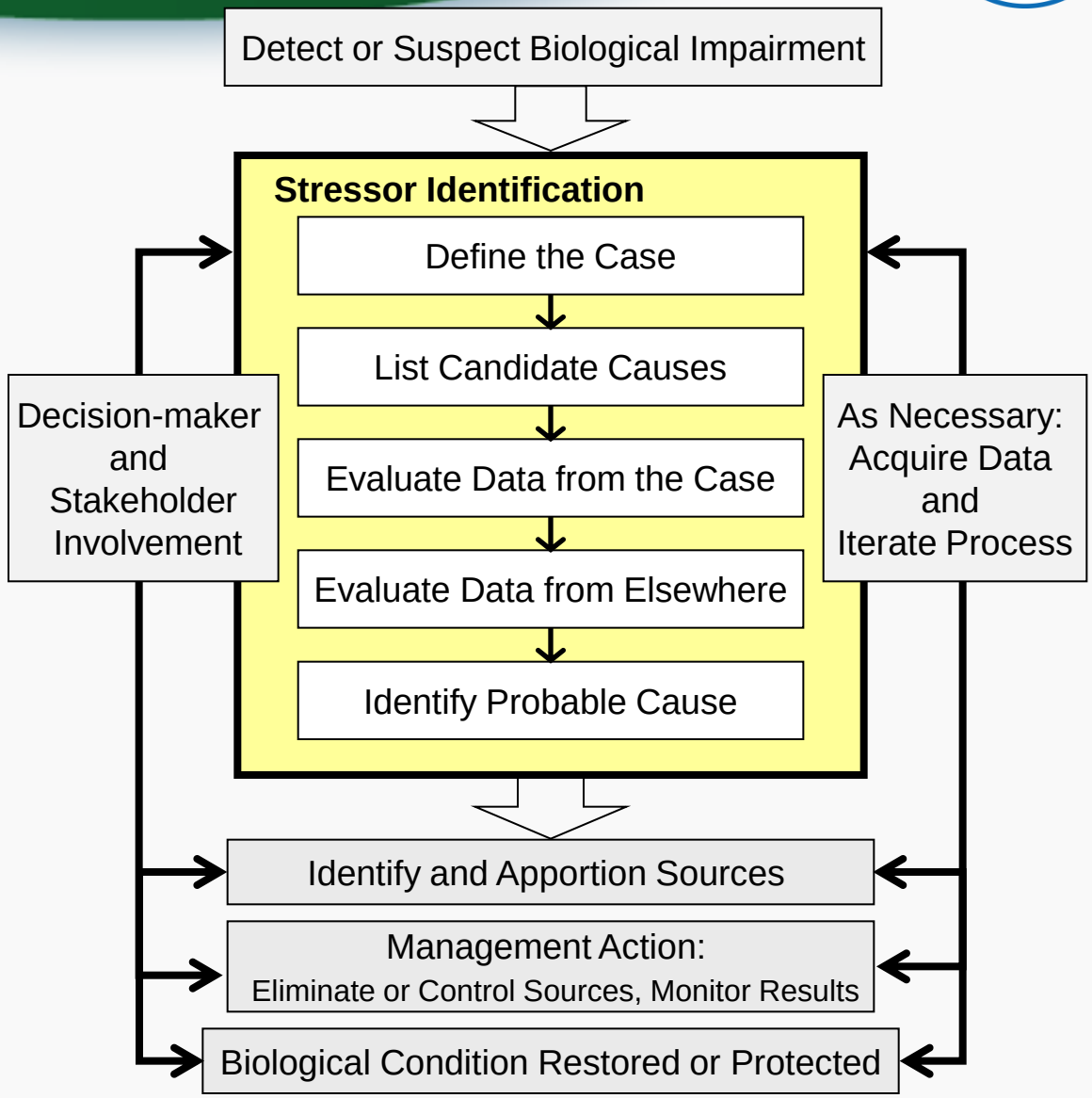
Causal Assessment

- EPA's approach to Causal Assessments is Pragmatic (analysis guides actions).
- Centered on Abductive Inference, where the best hypothesis is identified to explain the available information rather than proving a hypothesis correct or incorrect.
- Aims to establish Specific Causation rather than General Causation (DID *x* cause *y* rather than CAN *x* cause *y*).
- The most likely cause is established by Causal Inference, the interpretation of available evidence:
  - Identify and compare alternative candidate causes
  - Logically eliminate when possible
  - Diagnose when possible
  - Use strength of evidence for remaining
  - Identify most likely cause

Causal Assessment

- The Up-Side…
  - A formal method that provides scientifically defensible results when the stressor is not readily apparent or obvious.
  - The evaluation is reproducible.
  - Prevents biases and other logic lapses.
  - May identify causal relationships that are not readily apparent.
  - Engages stakeholders & decision makers early in the process thereby reducing controversy.
  - Increases confidence in the selected management option.
- …and the Down-Side
  - Conducting Causal Assessments are not necessarily easy or straightforward.
  - Mechanisms of biological impacts can be complex.
  - There is no “one-size-fits-all” methodology.
  - Data are as data do (quantity and quality matter).
  - Net result, a smoking fish may not be found or multiple stressors remain probable causes.

The Causal Analysis Framework



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

CADDIS: The Causal Analysis/Diagnosis Decision Information System

Contact Us Share

Quick Finder

CADLit
CADStat
Case Studies
Causal Assessment Background
Getting Started with Data Analysis
ICD Application
Step-by-step Guide

The **Causal Analysis/Diagnosis Decision Information System, or CADDIS**, is a website developed to help scientists and engineers in the Regions, States, and Tribes conduct causal assessments in aquatic systems. It is organized into five volumes:

- **Volume 1: Stressor Identification** provides a step-by-step guide for identifying probable causes of impairment in a particular system, based on the U.S. EPA's Stressor Identification process. If you are interested in conducting a complete causal assessment, learning about different types of evidence, or reviewing a history of causal assessment theory, start with this volume.
- **Volume 2: Sources, Stressors & Responses** provides background information on many common sources, stressors, and biotic responses in stream ecosystems. If you are interested in viewing source- and stressor-specific summary information (e.g., for urbanization, physical habitat, nutrients, metals, pH and other stressors), start with this volume.
- **Volume 3: Examples & Applications** provides examples illustrating different steps of causal assessments. If you are interested in reading completed causal assessment case studies, seeing how Stressor Identification worksheets are completed, or examining example applications of data analysis techniques, start with this volume.
- **Volume 4: Data Analysis** provides guidance on the use of statistical analysis to support causal assessments. If you are interested in learning how to use data in your causal assessment, start with this volume.
- **Volume 5: Causal Databases** provides access to literature databases and associated tools for use in causal assessments. If you are interested in applying literature-based evidence to your causal assessment, start with this volume.

Basic Information
Recent Additions
Frequent Questions
Publications
Glossary
Related Links
Authors & Contributors
Site Map

Top Three Questions

1. What's new in the 2010 release of CADDIS?
2. How do I cite CADDIS?
3. Where can I view a site map for CADDIS?

CADDIS Navigation

CADDIS Home
Volume 1: Stressor Identification
Volume 2: Sources, Stressors & Responses
Volume 3: Examples & Applications
Volume 4: Data Analysis
Volume 5: Causal Databases

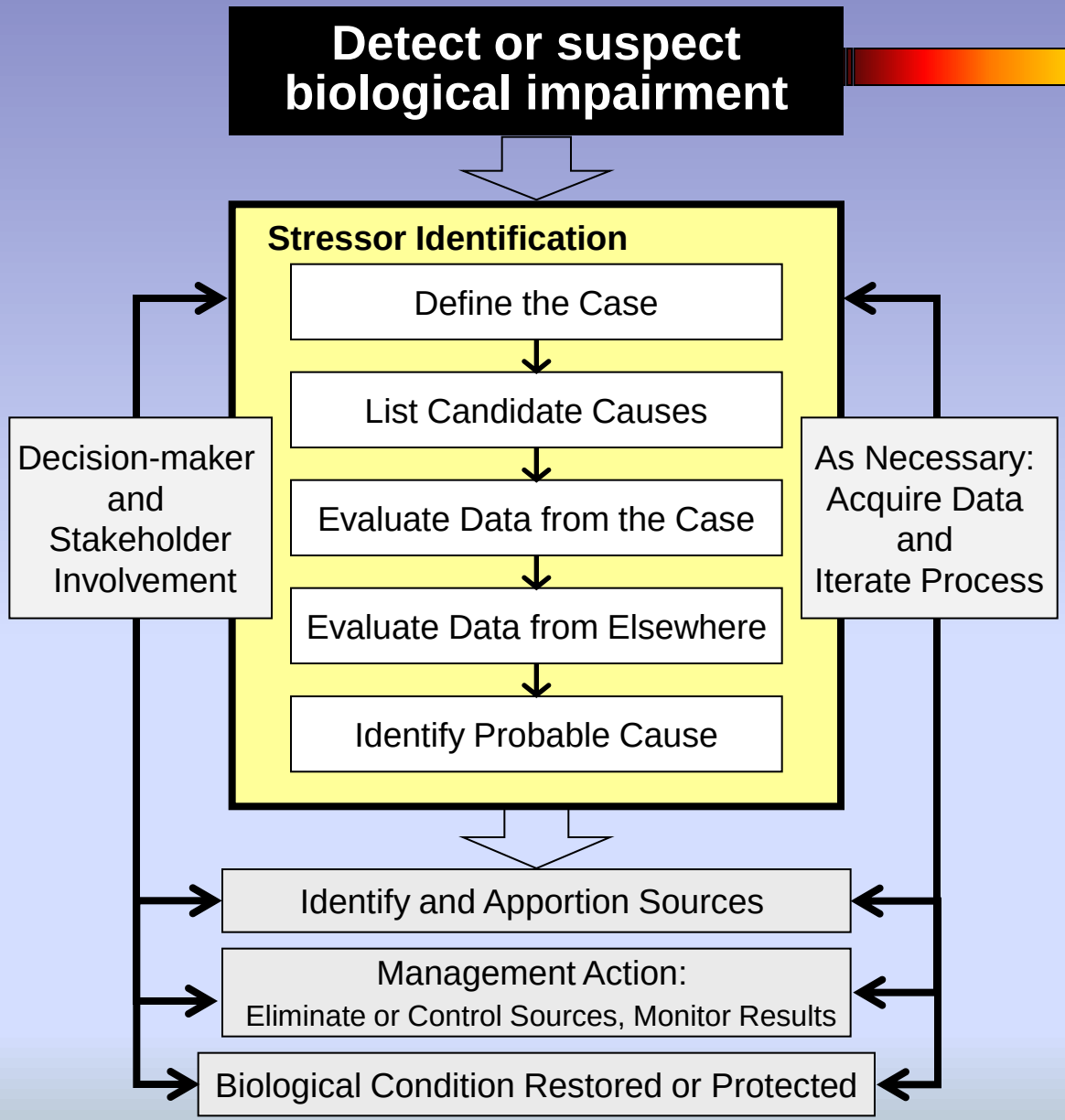
Recent Additions

1. New Causal Assessment Background section
2. New source & stressor modules
   - Urbanization
   - Ammonia
   - Herbicides
   - Insecticides
   - pH
   - Physical habitat
3. New causal assessment Case Studies
4. Revised Data Analysis section
5. Expanded Interactive Conceptual Diagram application

Causal Analysis and California

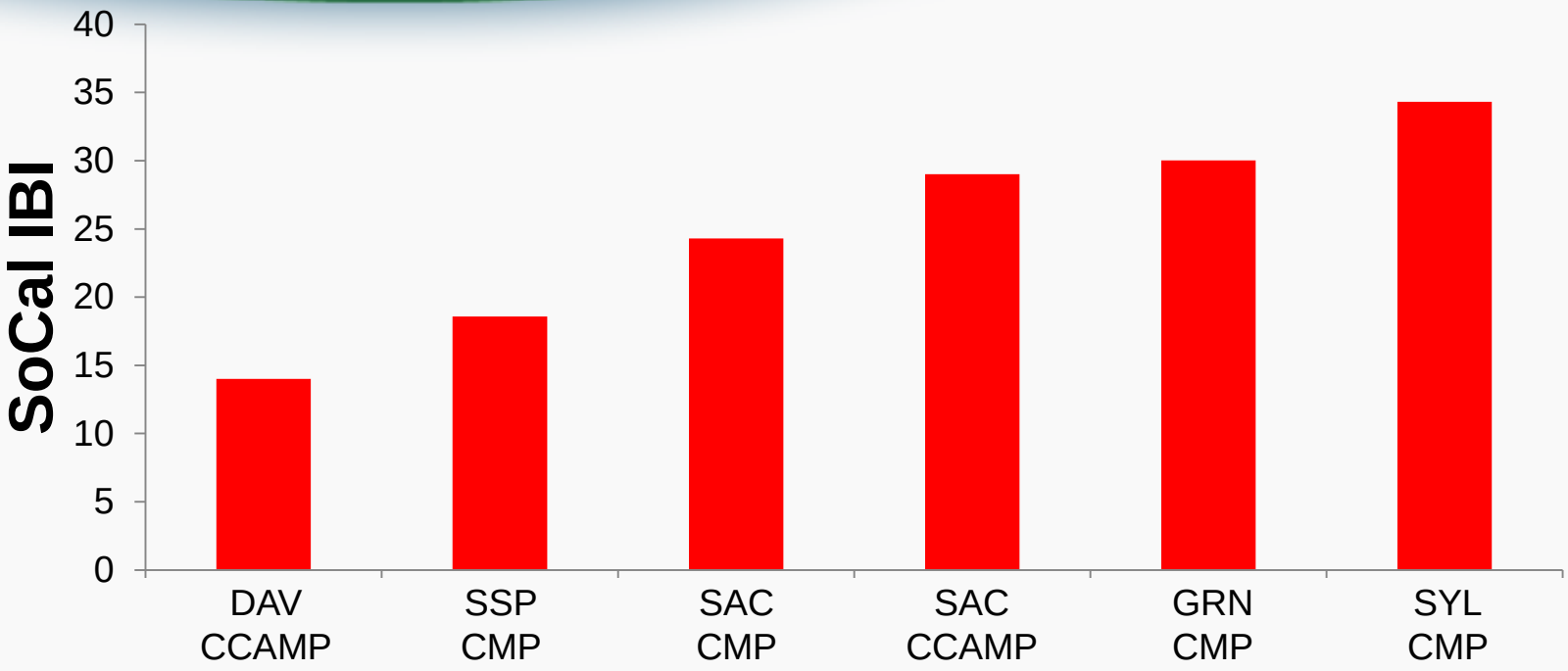
- Not every stream is going to meet biological objectives
- When a stream is non-compliant, causes need to be determined for remediation
- Causal assessment approaches have not been well-vetted in California

- Three (four) case studies
  - Salinas River (agricultural)
  - Garcia River (timber dominated)
  - Santa Clara and San Diego (urban)

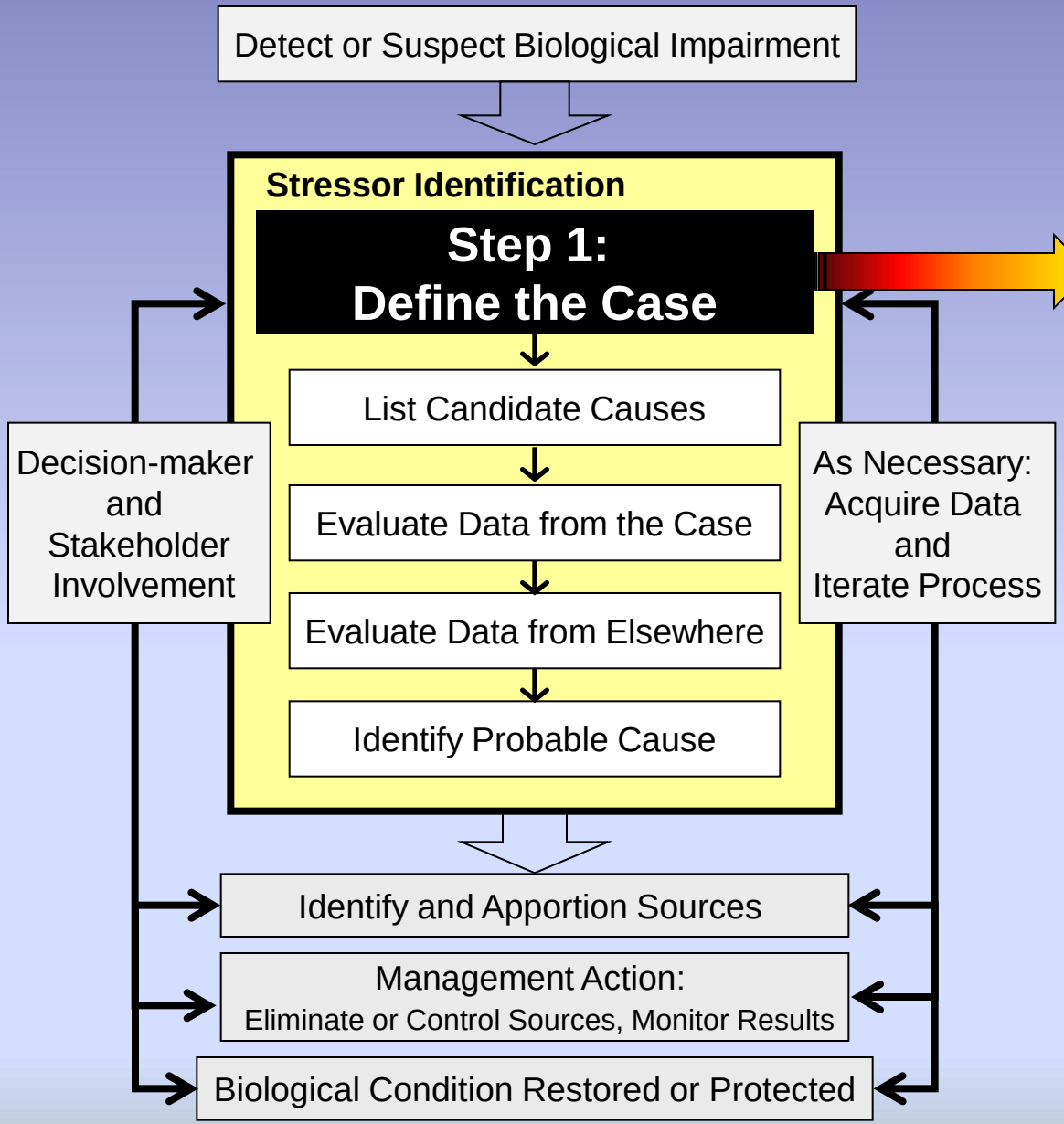


- Fish kills
- Organismal anomalies
- Changes in community structure
- Low biotic index values
- Violation of biocriteria

The Salinas River Impairment Detection



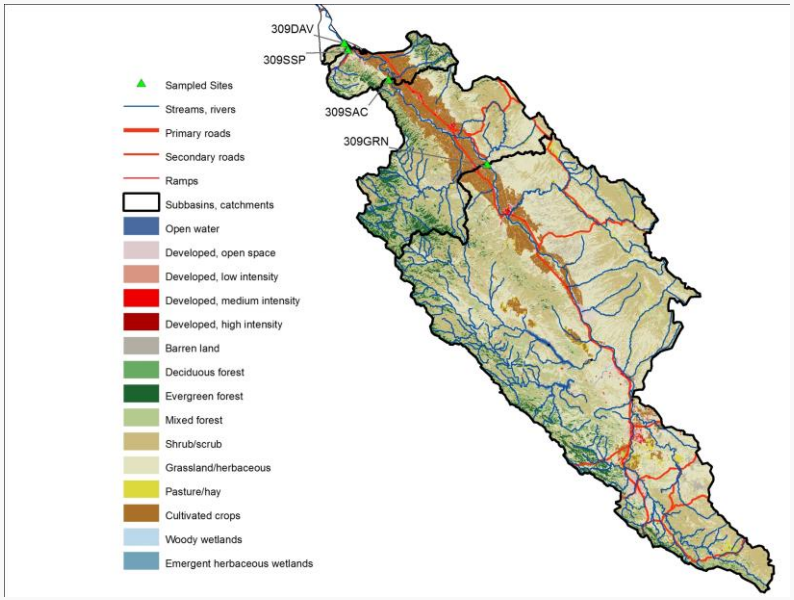
	309DAV	309SSP	309SAC	309SAC	309GRN	309GRN	314SYL
	CCAMP	CMP	CMP	CCAMP	CCAMP	CMP	CMP
SoCal IBI	14	19	24	29		30	34
Sampling Date	6 Jun	26 May	25 May	6 Jun	14 Jun	26 May	14 May



- What biological effects are observed?
- Where & when did they occur?
- Where are comparable comparative sites?

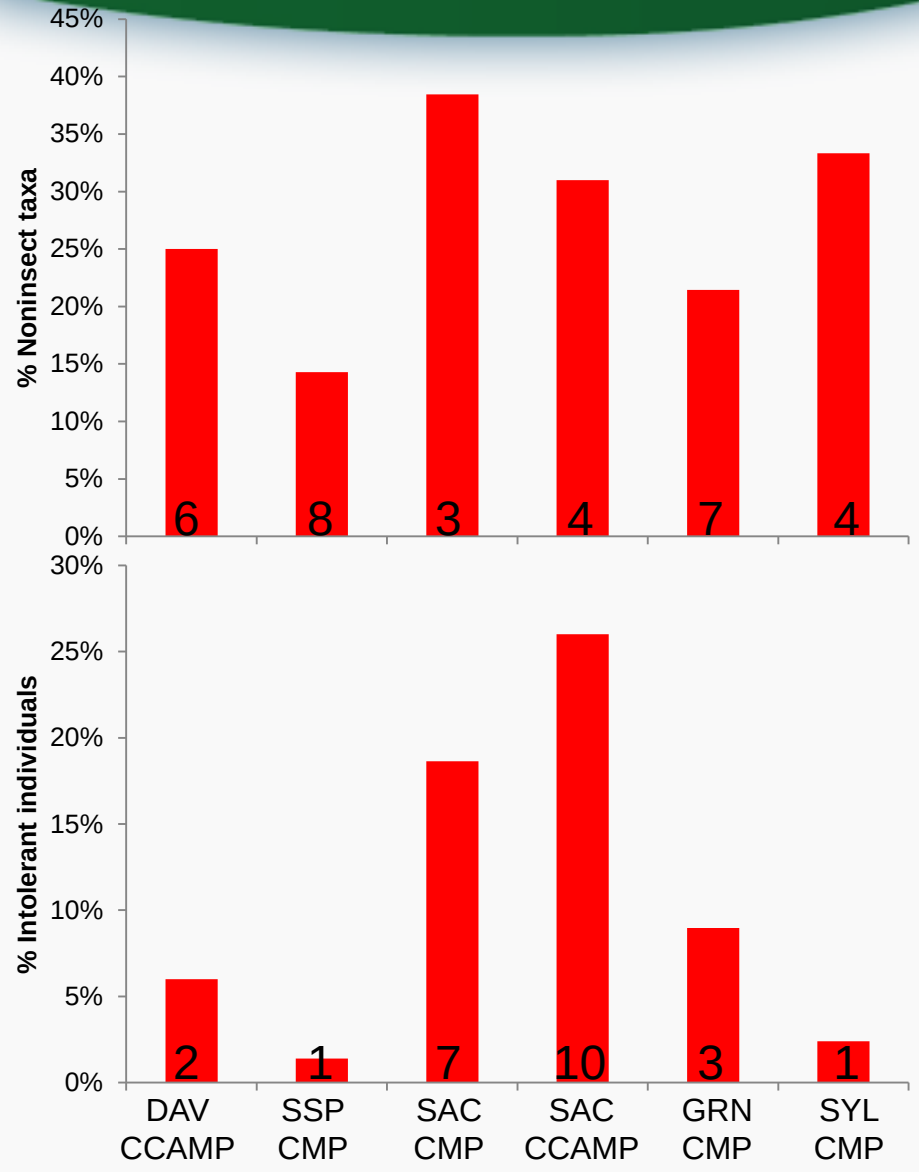
The Salinas River- Step 1 Case Definition

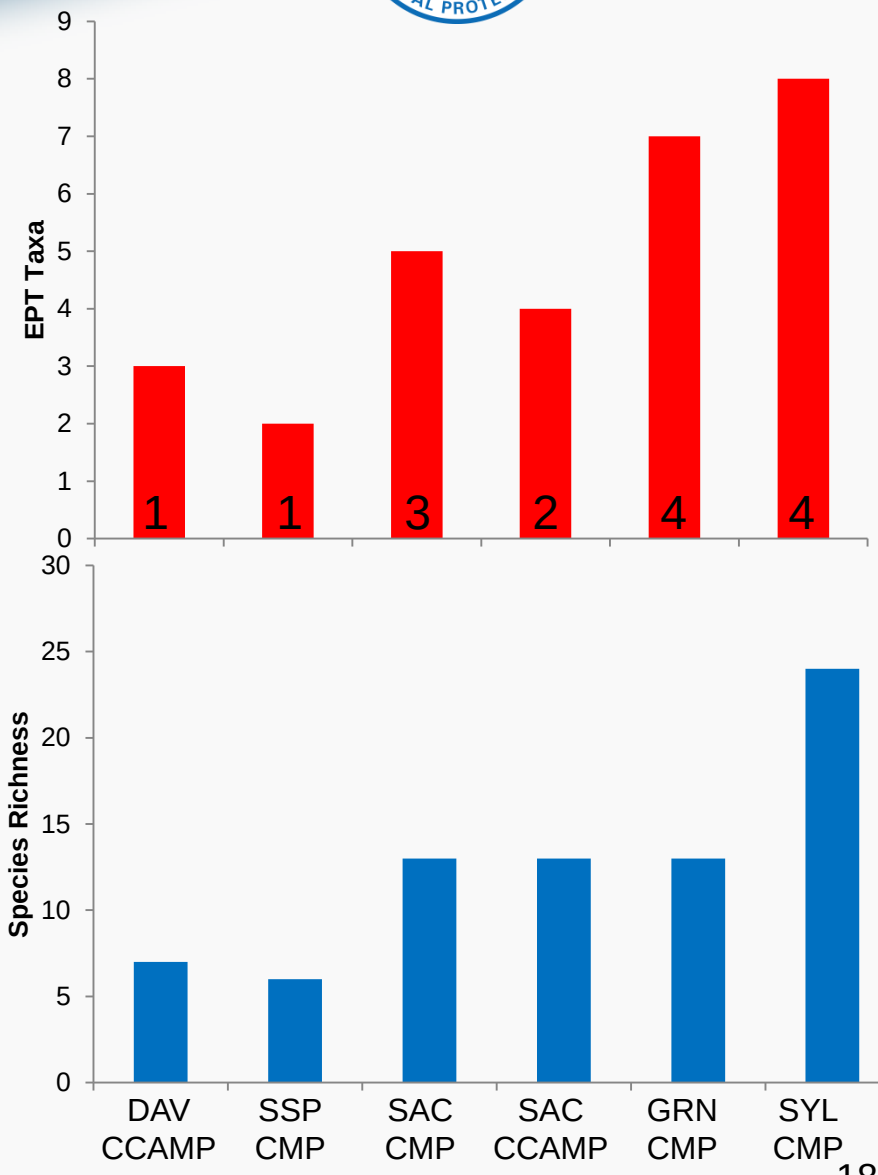
Salinas River	
Length	282 km
Basin	10,774 km^2
Discharge	12 (0-2690) m^3/sec
Mean Annual Discharge	268,699 acre-feet
Precipitation	28-84 cm/yr

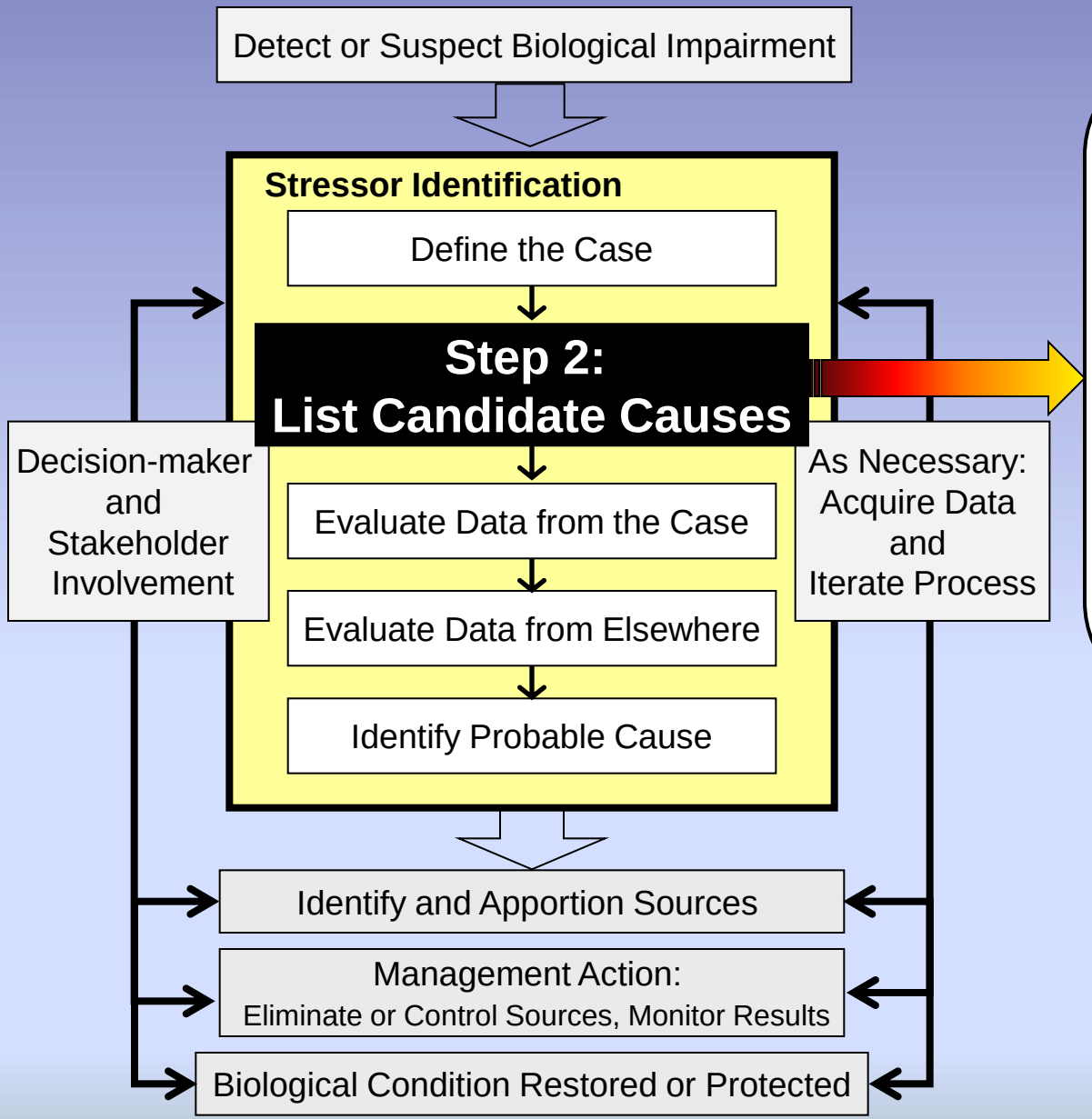


Designated Uses
municipal and domestic water supply
agricultural supply
industrial process supply
industrial process supply
groundwater recharge
water contact recreation
non-contact water recreation
wildlife habitat
cold freshwater habitat
warm freshwater habitat
migration of aquatic organisms
commercial and sport fishing

The Salinas River- Step 1 Case Definition





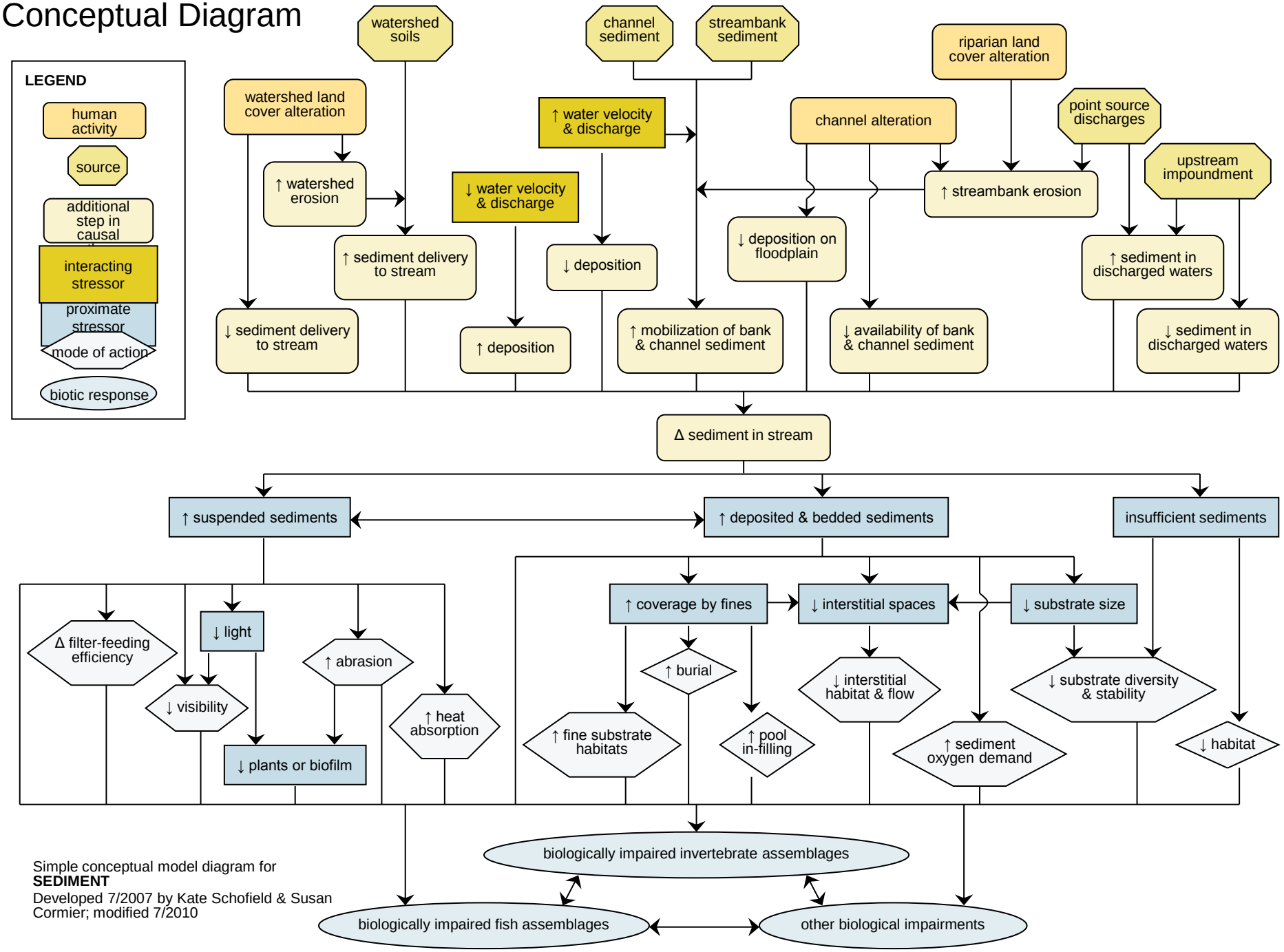


- Make a map
- Gather information on potential sources, stressors, and exposures
- Develop a conceptual diagram
- Engage stakeholders
- Develop “final” list

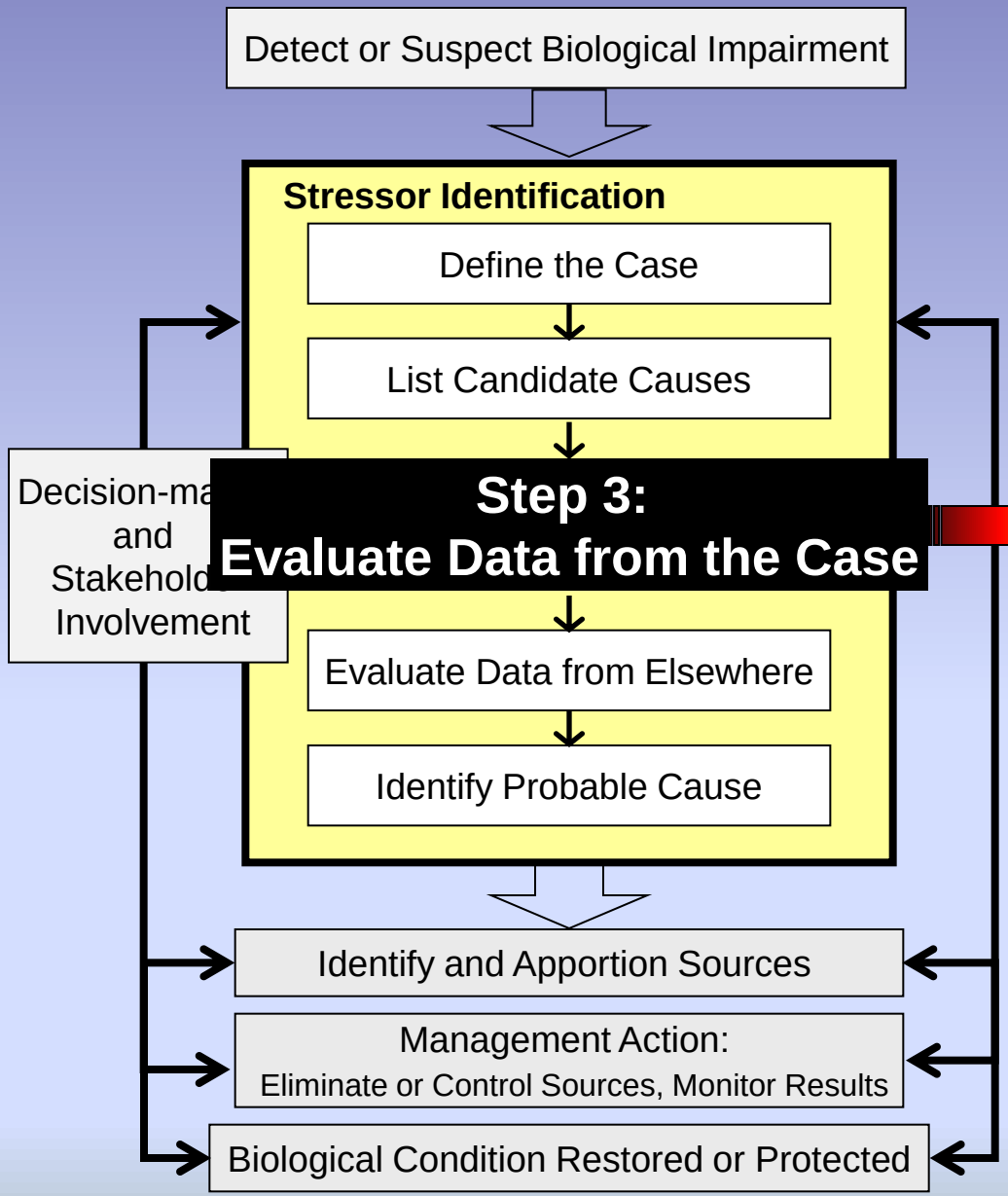
The Salinas River- Step 2
Candidate Causes

- Potential Candidate Causes Identified for the Salinas River
  - Increased Sediments
  - Increased Ionic Strength
  - Increased Pesticides
  - Decreased Dissolved Oxygen
  - Increased Metals
  - Nutrient enrichment & toxicity
  - Flow Alteration
  - Physical Habitat Alteration

Conceptual Diagram



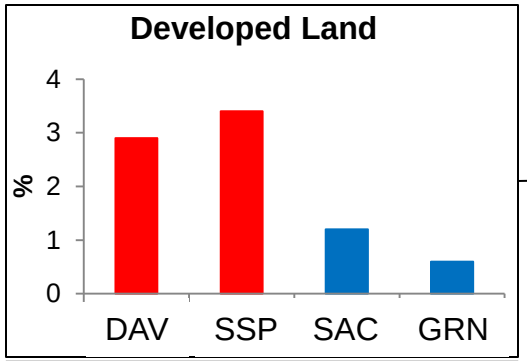
Simple conceptual model diagram for **SEDIMENT**
Developed 7/2007 by Kate Schofield & Susan Cormier; modified 7/2010

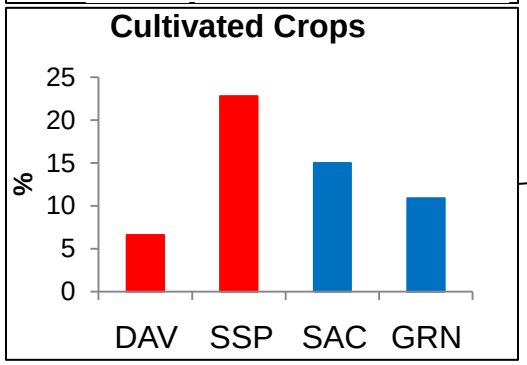


Evidence from the Case

- Co-occurrence (space & time)
- Exposure or mechanism
- Causal pathway
- Stressor-response relationships from field
- Manipulation
- Lab tests of site media
- Temporal sequence
- Verified predictions
- Symptoms

Data From the Case: Step 3
Causal Pathway: Suspended Sediments

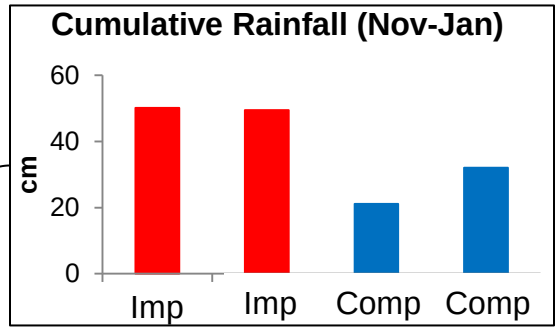


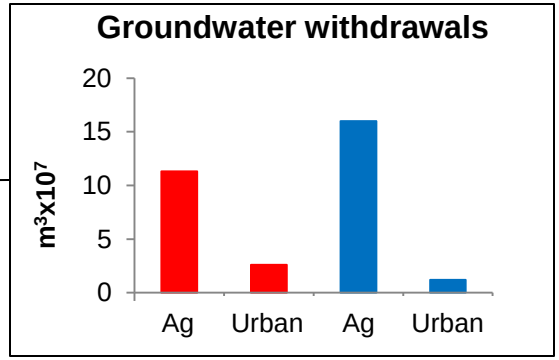


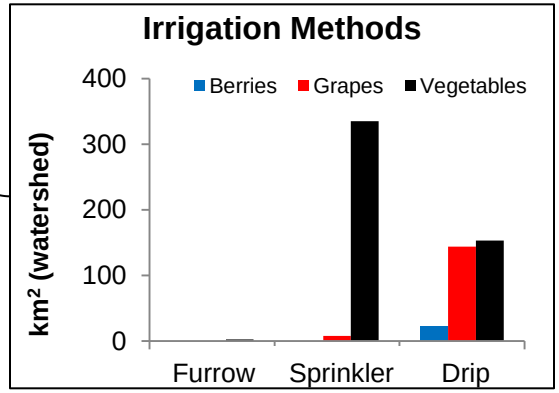
watershed land cover alteration

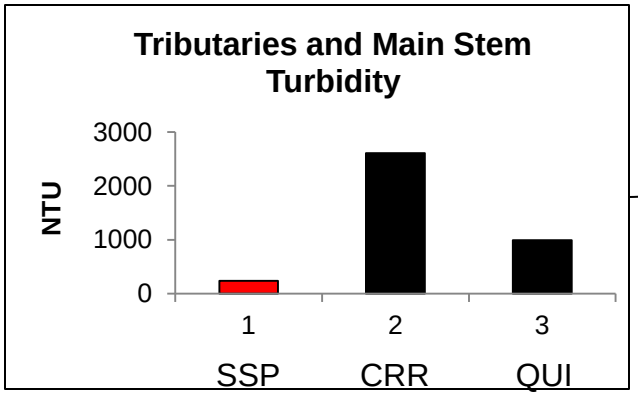
↑ watershed erosion

↑ sediment delivery to stream



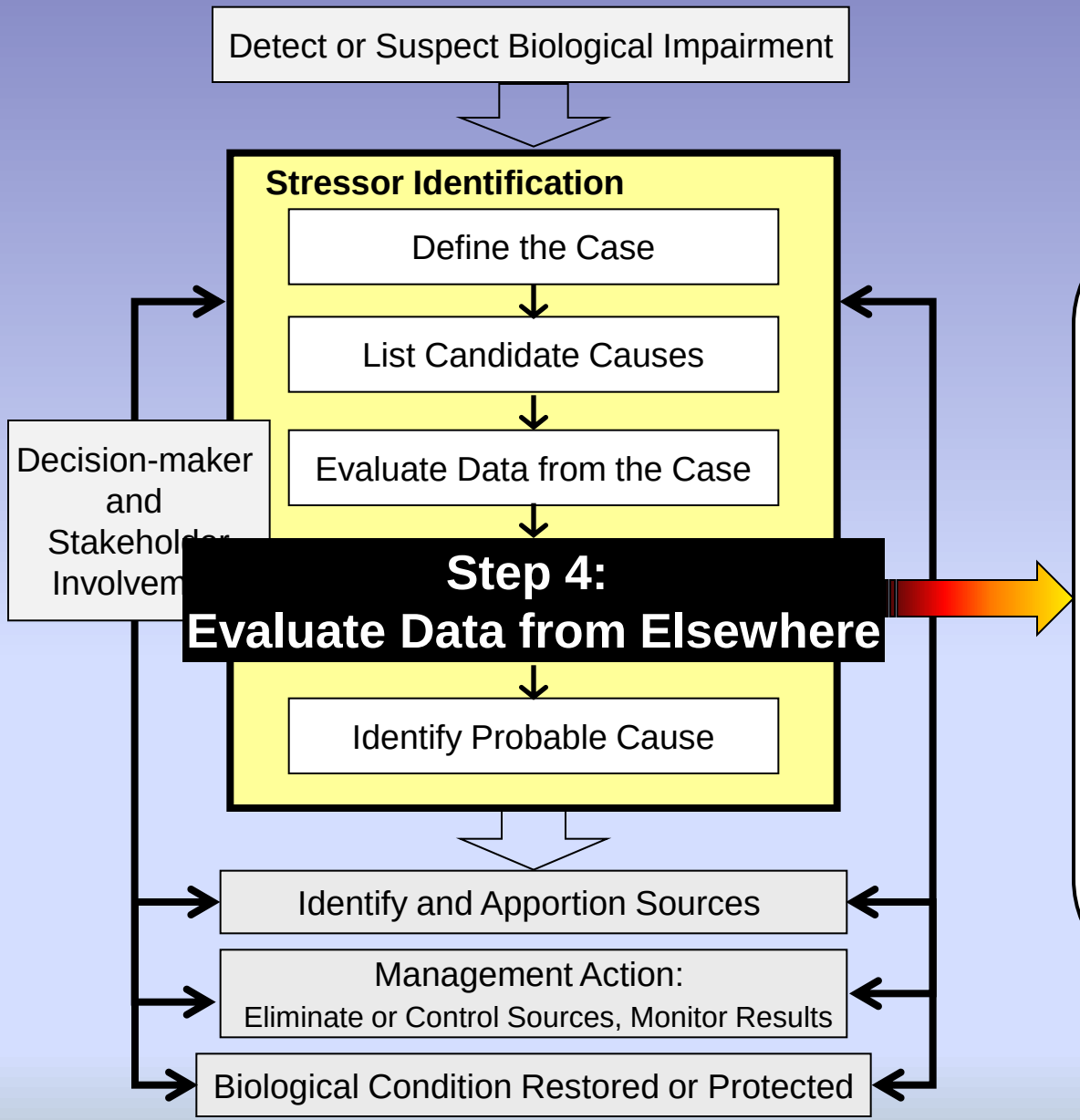






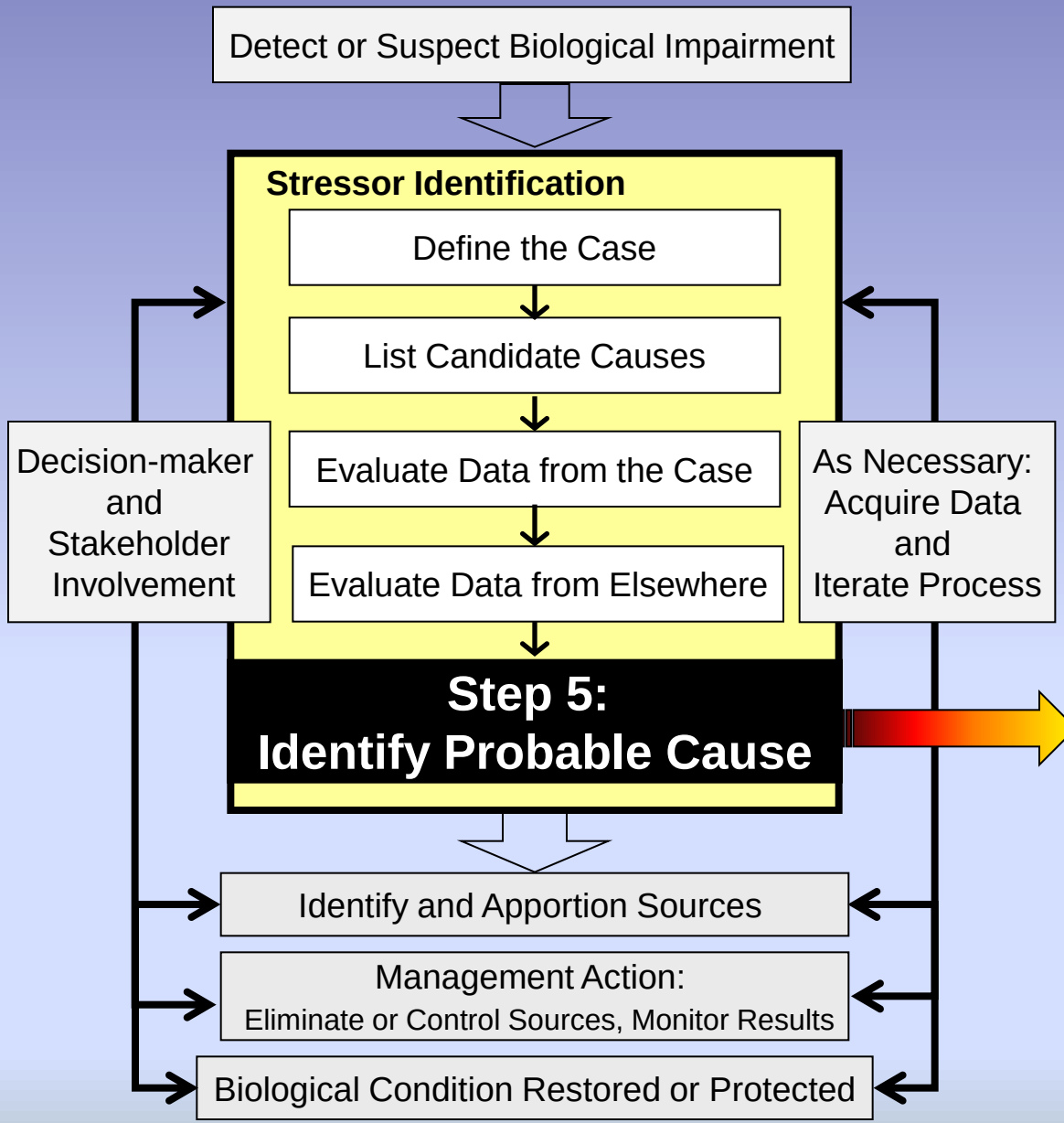
Score: +

Reasoning- Some steps in at least one causal pathway are present



Evidence from elsewhere

- Stressor-response relationships (from lab, other field studies, or ecosystem models)
- Mechanistically plausible cause
- Manipulation at other sites
- Verified predictions
- Analogous stressors



- Weigh strength of evidence for each cause
  - eliminate if possible
  - diagnose if possible
- Compare strength of evidence across causes

Scoring Summary- Step 5

309DAV against 309SAC	Decreased DO	Increased Pesticides	Metals	Increased Nutrients	Increased Ionic Strength	Increased Sediment (Bed)	Increased Sediment (Susp)	Altered Flow Regime	Altered Physical Habitat
Types of Evidence that Use Data from the Case									
Spatial/Temporal Co-Occurrence	-	NE	NE	+	---	---	+	-	-
Causal Pathway	0	+	0	0	0	-	+	0	+
Stressor-Response from the Field	-			-	-	-	++	+	
Laboratory Test of Site Media		-	-						
Temporal Sequence				---	---		+		
Types of Evidence that Use Data from Elsewhere									
Stressor-Response from Other Field Studies							+		
Stressor-Response from Laboratory		+	+						
Evaluating Multiple Types of Evidence									
Consistency of Evidence	-			-	---	-	+	-	-

Final Conclusions: Likely Contributors

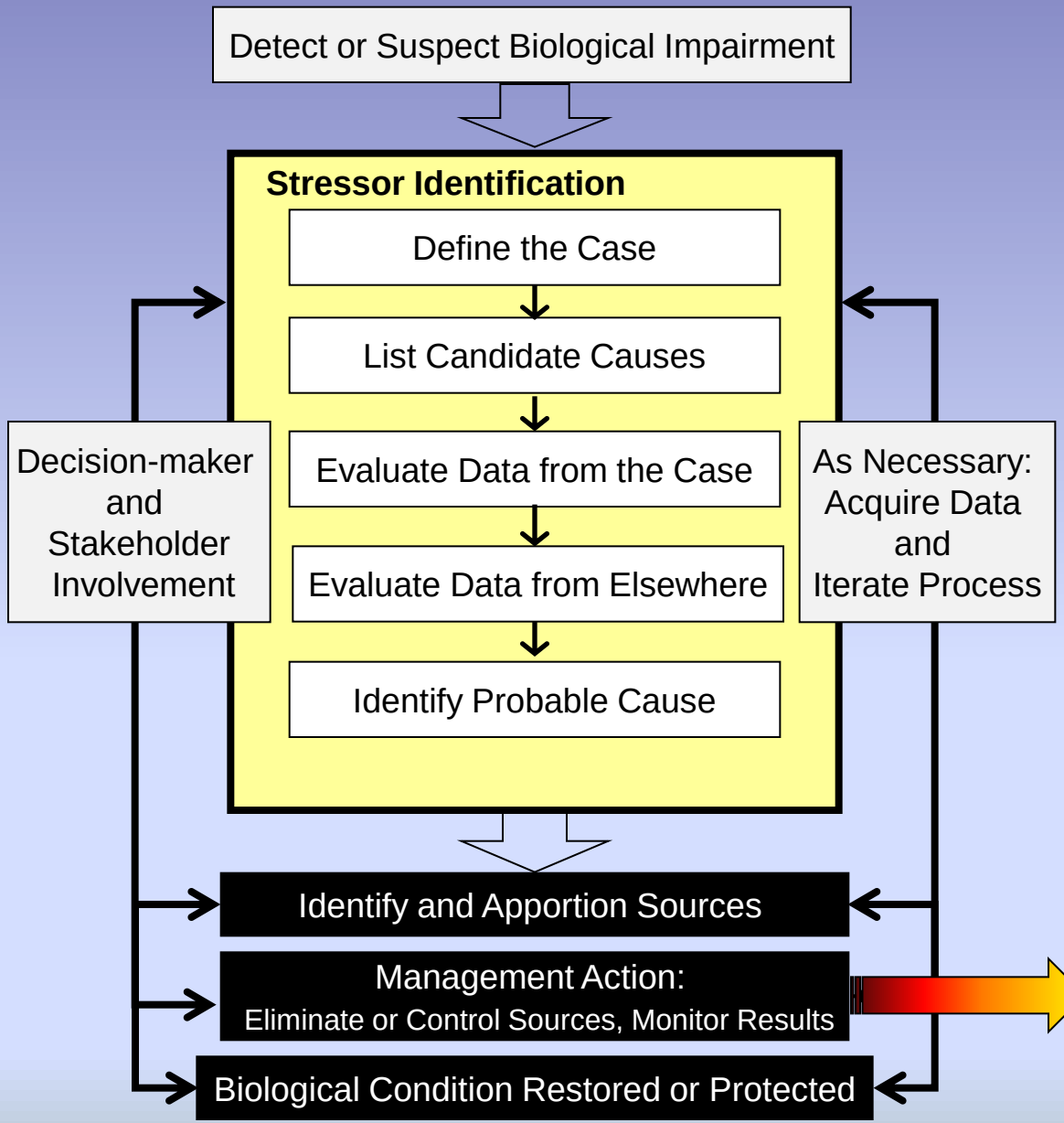
Candidate Cause	Evidence and comments
Suspended sediments	Concentrations consistently higher at subject sites relative to comparator; Concentrations at levels associated with effects in other studies
Physical habitat	Especially as influenced by suspended sediments

Final Conclusions: Unlikely Contributors

Candidate Cause	Evidence and Comments
Dissolved oxygen	Concentrations similar between subject and comparator sites; however, data was limited.
Nutrients	Concentrations peak and differences occur well after invertebrate samples are collected.
Ionic Strength	Concentrations peak and differences occur well after invertebrate samples are collected.
Flow Regime	Flow regimes are similar among the subject and comparator sites.

Final Conclusions: Significant Questions Remain

Candidate Cause	Evidence and Comments
Pesticides	Very limited data available for assessment.
Metals	Very limited data available for assessment.



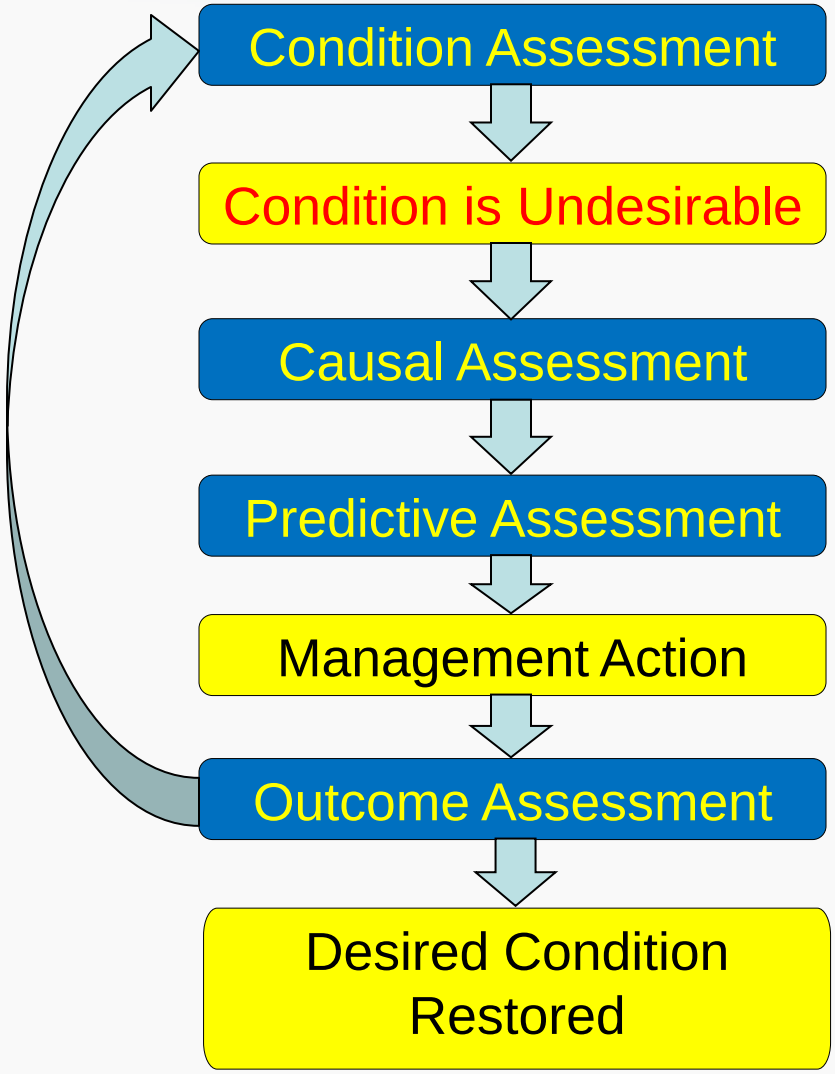
Causal analysis is one step in management process

- After causes identified, sources & management actions must be identified
- Biological monitoring verifies that actions are effective

Causal Assessment- Conclusions

- ***Causal Assessment*** is one step in environmental assessment.
  - The goal is to identify the causes of biological impairment.
  - It is a formal method that engages stakeholders to identify candidate causes of biological impairment.
    - Focuses on Specific Causations (*Did* X *Cause* Y)
    - Based on Available Evidence
    - Centered on the five steps of Stressor Identification

Environmental Assessment



Evaluate chemical, biological, or physical state

Identify cause or source

Forecast from causal relationship

Evaluate performance and effect on chemical, biological, or physical state

Causal Assessment-Lessons Learned California Case Studies

- The formal process, which encourages stakeholder involvement, fostered and focused communication.
- Useful for eliminating candidate causes.
- Recommendations for the existing condition assessment monitoring program to increase causal assessment effectiveness.
- Recommendations for California specific data analysis and support tools.
  - Formalized “comparator” site selection
  - Stressor-response models for pesticides

Acknowledgements

- Partners with the State of California
  - Ken Schiff (SCCWRP)
  - David Gillett (SCCWRP)
  - Peter Ode (DFG)
  - Jim Harrington (DFG)
  - Andy Rehn (DFG)
- The stakeholders (16 in total) representing the three Case Studies
- Michael Paul and his team at Tetra Tech