Causal Assessment in California

Concepts, Case Studies, and a Vision for its Future Application

David Gillett
Southern California Coastal Water Research Project

Why Causal Assessment?

- As bio objectives are implemented, some sites will invariably be out of compliance
  - i.e., degraded biology
- Causal assessment can be used to figure out what to "fix"
- Causal assessment has not been widely vetted in California
  - Specifically, US EPA's CADDIS tool

Our Goals

- To test the utility of CADDIS in California
- Make recommendations for its use in Bio Objectives
- If successful, create a guidance manual
  - Help regulated stakeholders and RWQCB staff with future causal assessments

The Outcome

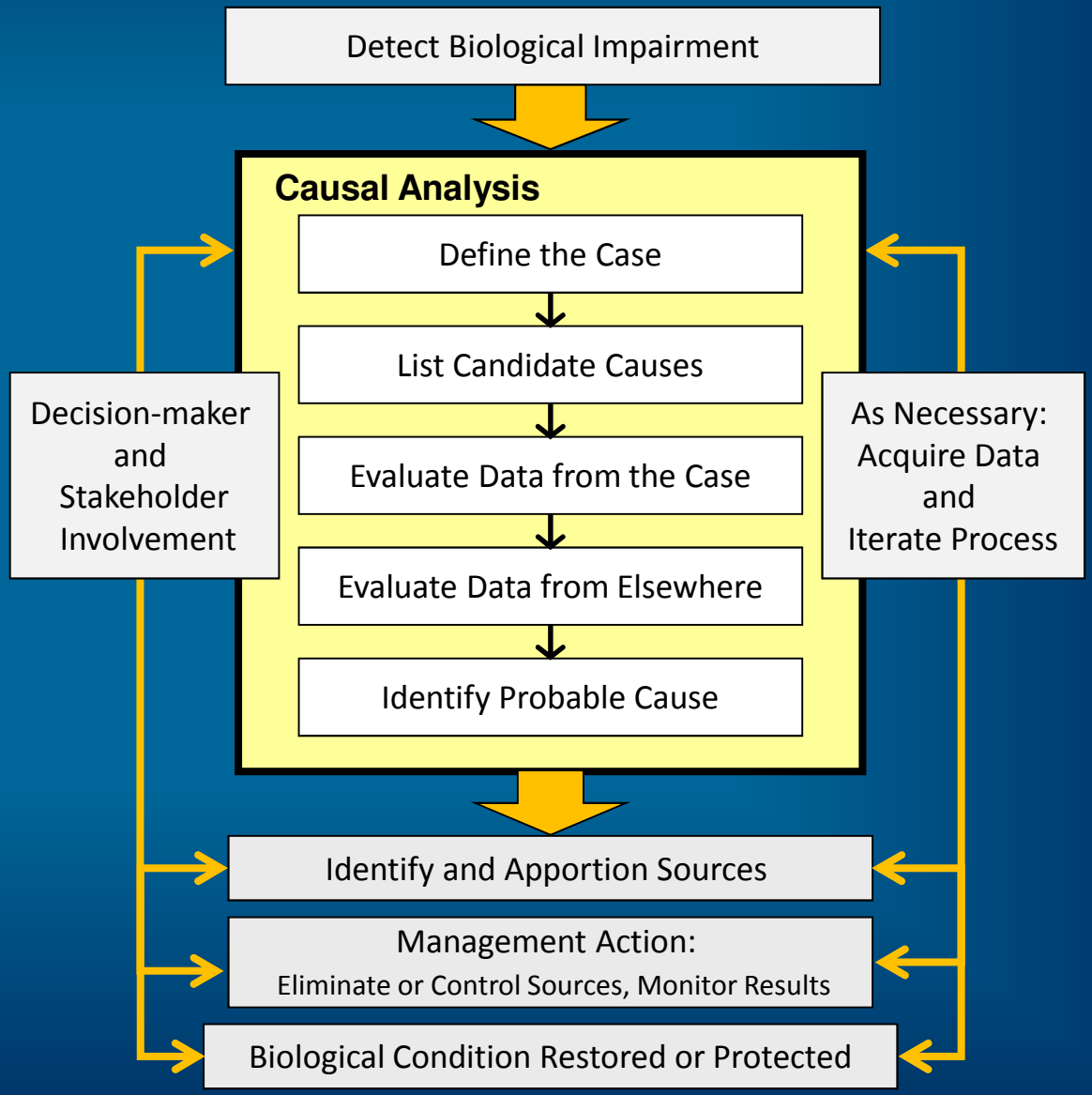
- Across our four case studies, CADDIS performed reasonably well
  - We were able to identify some causes and eliminate others
- CADDIS was not well designed for the non-point, chronic stressors that dominate CA
  - This is where new tools and modifications will be needed

Today's Talk

- What is the CADDIS approach?
- Applying CADDIS in California
- Snapshots of our test cases in California
- Summary
- User perspectives
- Producing a guidance document

What is CADDIS?

- This is CADDIS:



What is CADDIS?

- The Up-Side…
  - A formal method that provides scientifically defensible results when the stressor is not readily apparent or obvious.
  - 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.
- …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.

Applying CADDIS in CA


Garcia River
Partners with North Coast Regional Board and The Nature Conservancy


Salinas River
Partners with Central Coast Regional Board and Central Coast Water Preservation, Inc.

Santa Clara River

Partners with Los Angeles Regional Board and LA County Sanitation District

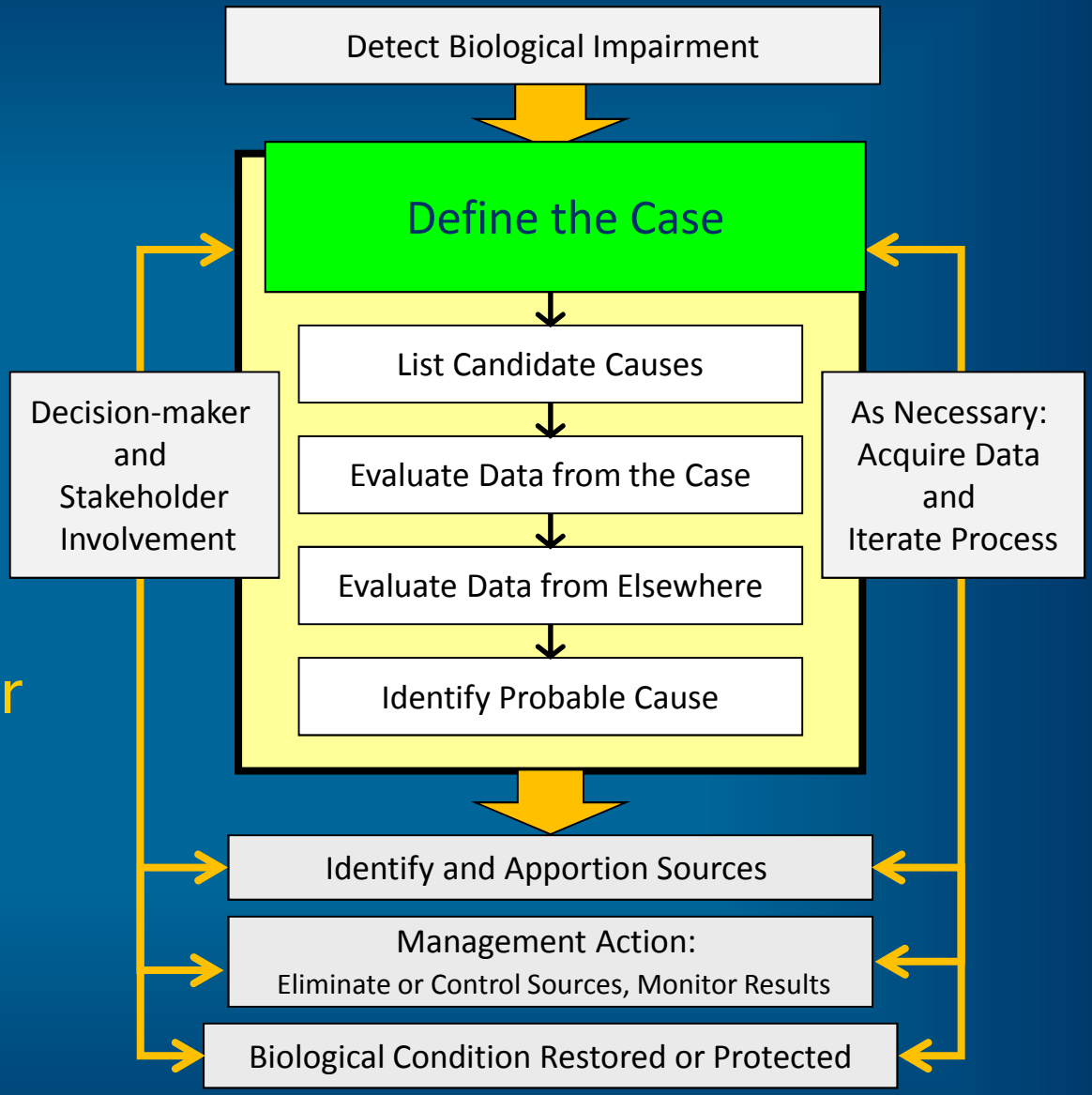
San Diego River

Partners with San Diego Regional Board, City of San Diego, and County of San Diego

Case Study Snapshots

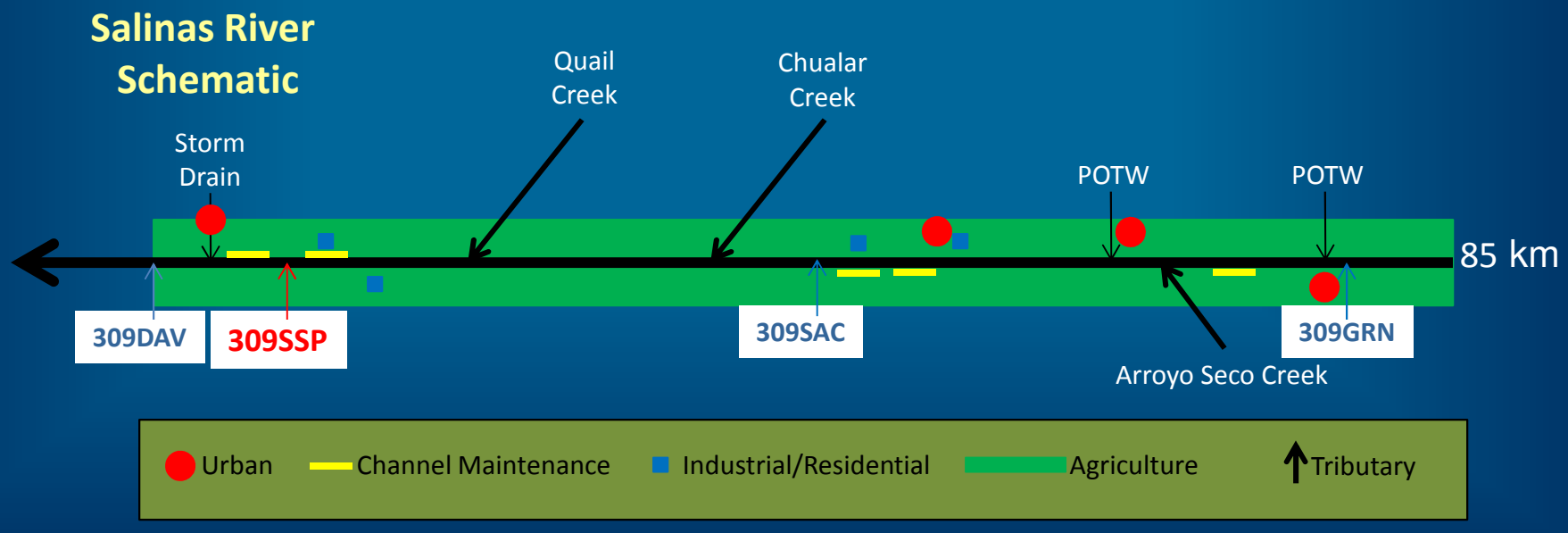
What was done and how it could be done in the future

- Case Definition
  - 3 Parts
    - Impacted site
    - Comparator sites
    - Biological endpoints

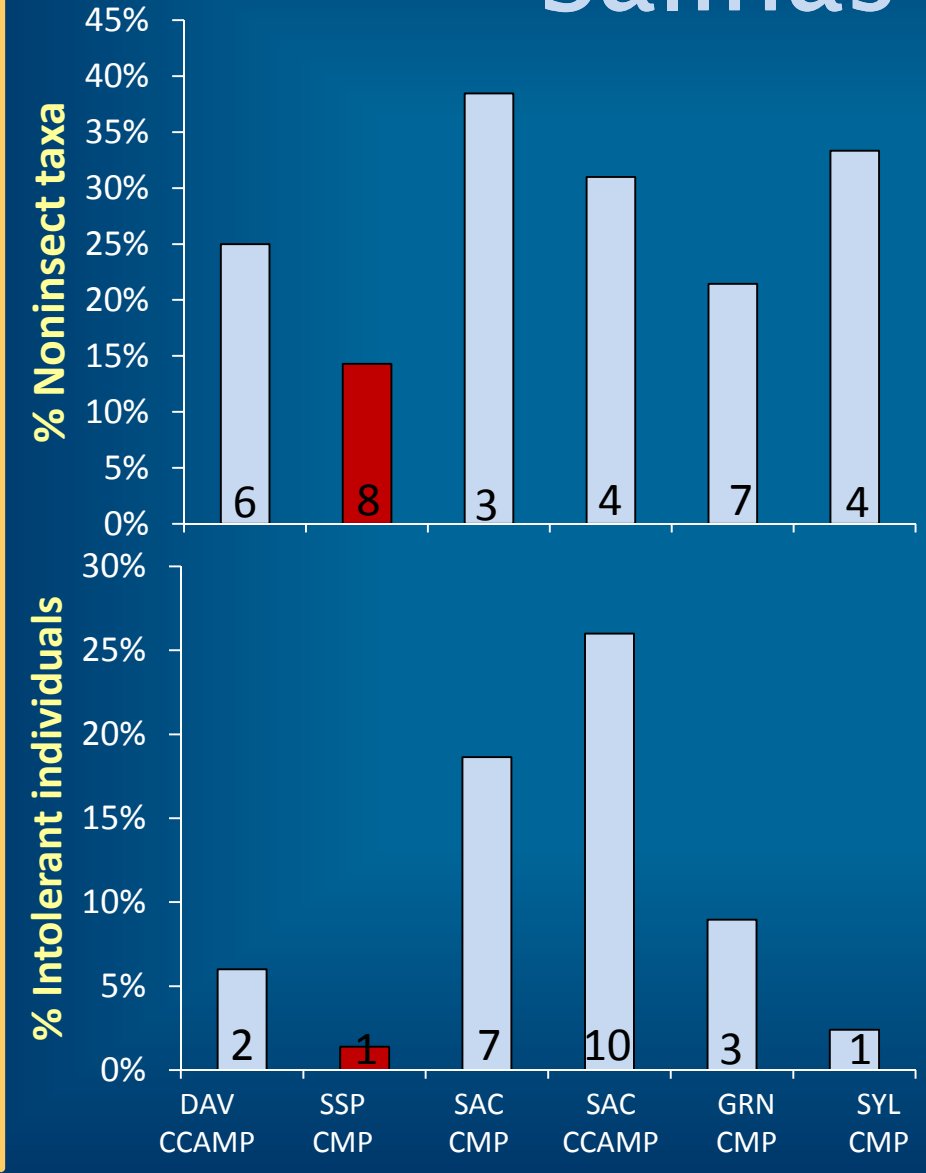


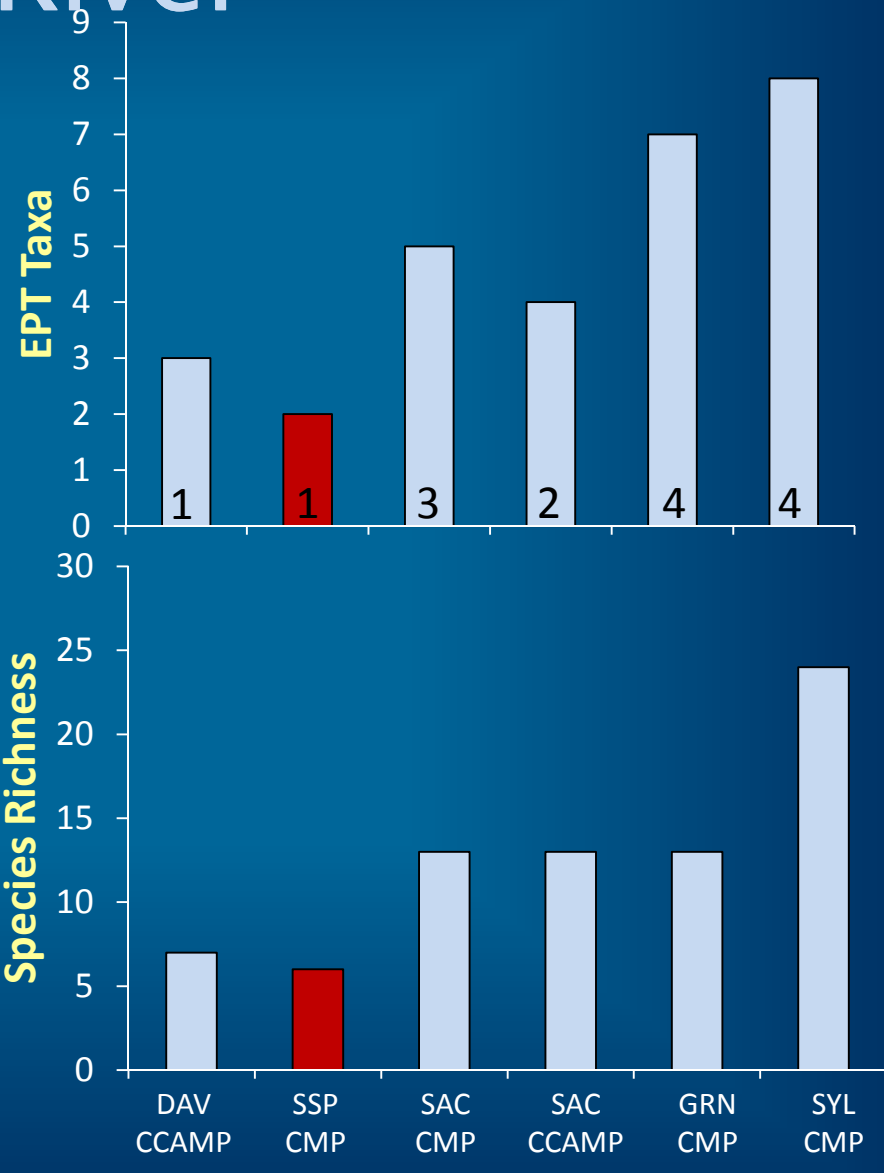
Defining the Case
Salinas River

- Example of an agricultural system
- Case centered around Spring 2006 sampling event



Biological Endpoints
Salinas River



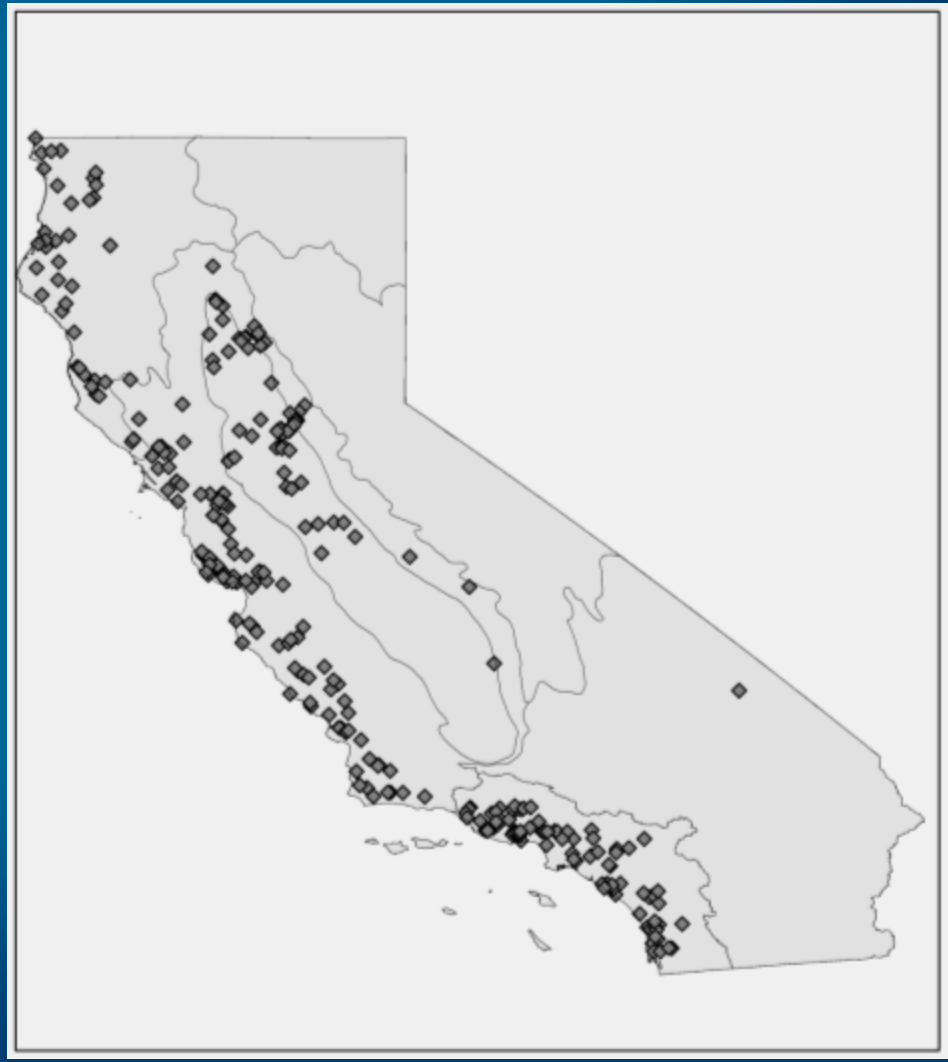


Case Definition: The Future

- Remove the distinction between inside- and outside the case sites
- Select sites with better or equivalent biology from other locations
- Many different approaches
  - All filter sites based on environmental/geographic similarities

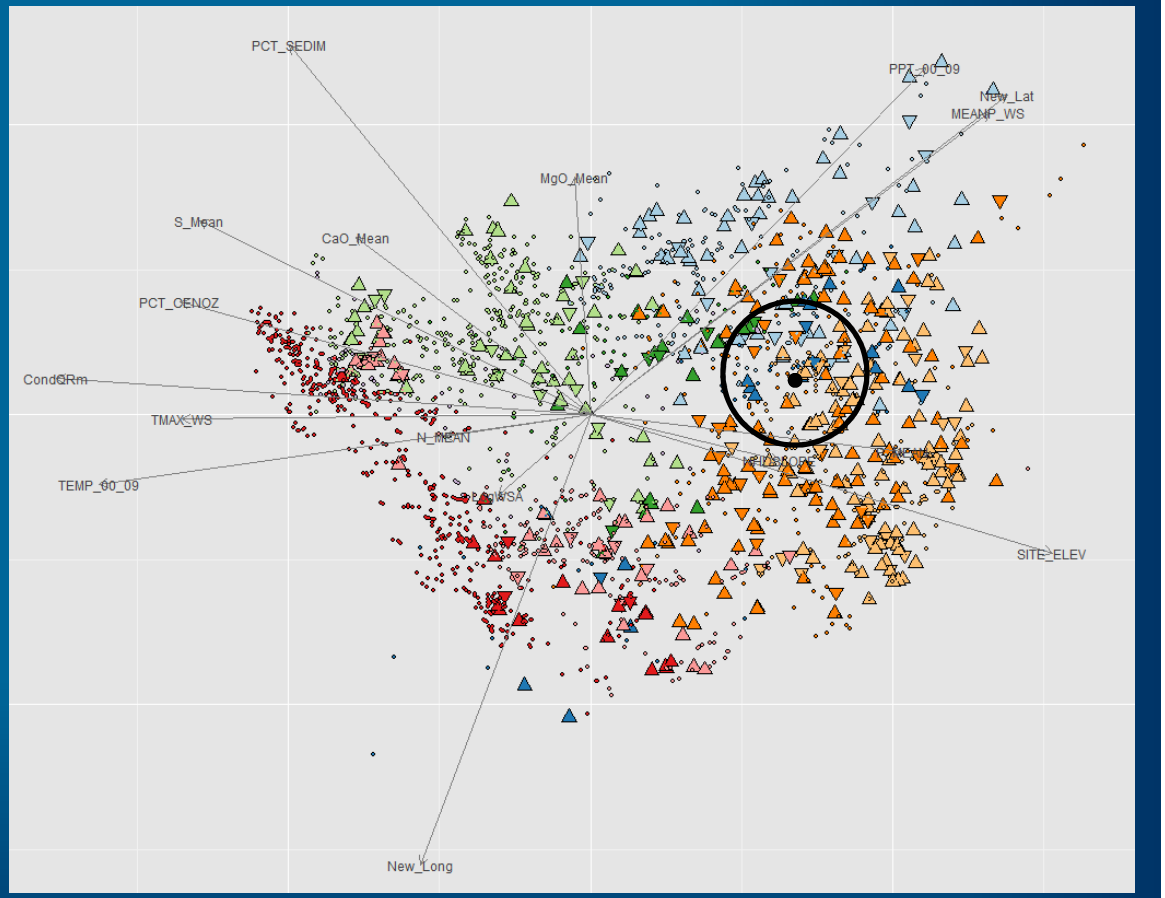
Selecting Comparator Sites

- Selected based on elevation and slope
  - <333m and 1.5% slope
- 540 samples across 515 sites



Selecting Comparator Sites

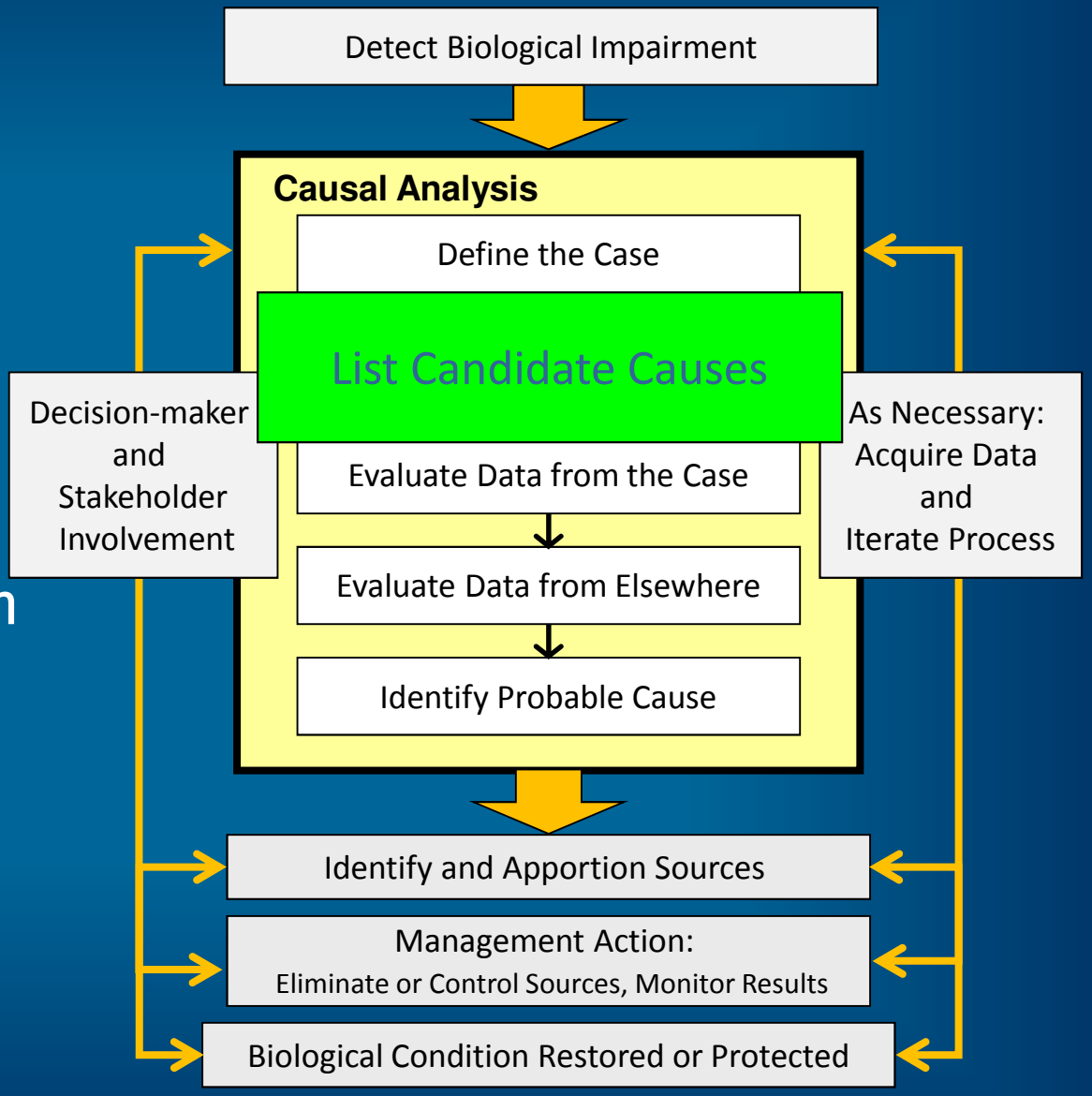
- Selection based upon environmental similarity



Case Definition: The Future

- Use missing taxa or modeled metrics as biological endpoints
  - Ties the assessment into the other parts of bio objectives
- This approach links the assessment to potential remediation action
  - How to get back in compliance

- Candidate Causes
  - The stressors impacting the biota
  - Each cause can have multiple proximate stressors
    - Dissolved metals
    - Not Urban Development



Candidate Causes
Salinas River

- Candidate Causes
  - Increased Sediments
  - Increased Ionic Strength
  - Increased Pesticides
  - Decreased Dissolved Oxygen
  - Increased Metals
  - Nutrient enrichment & toxicity
  - Flow Alteration
  - Physical Habitat Alteration

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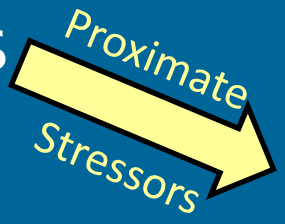
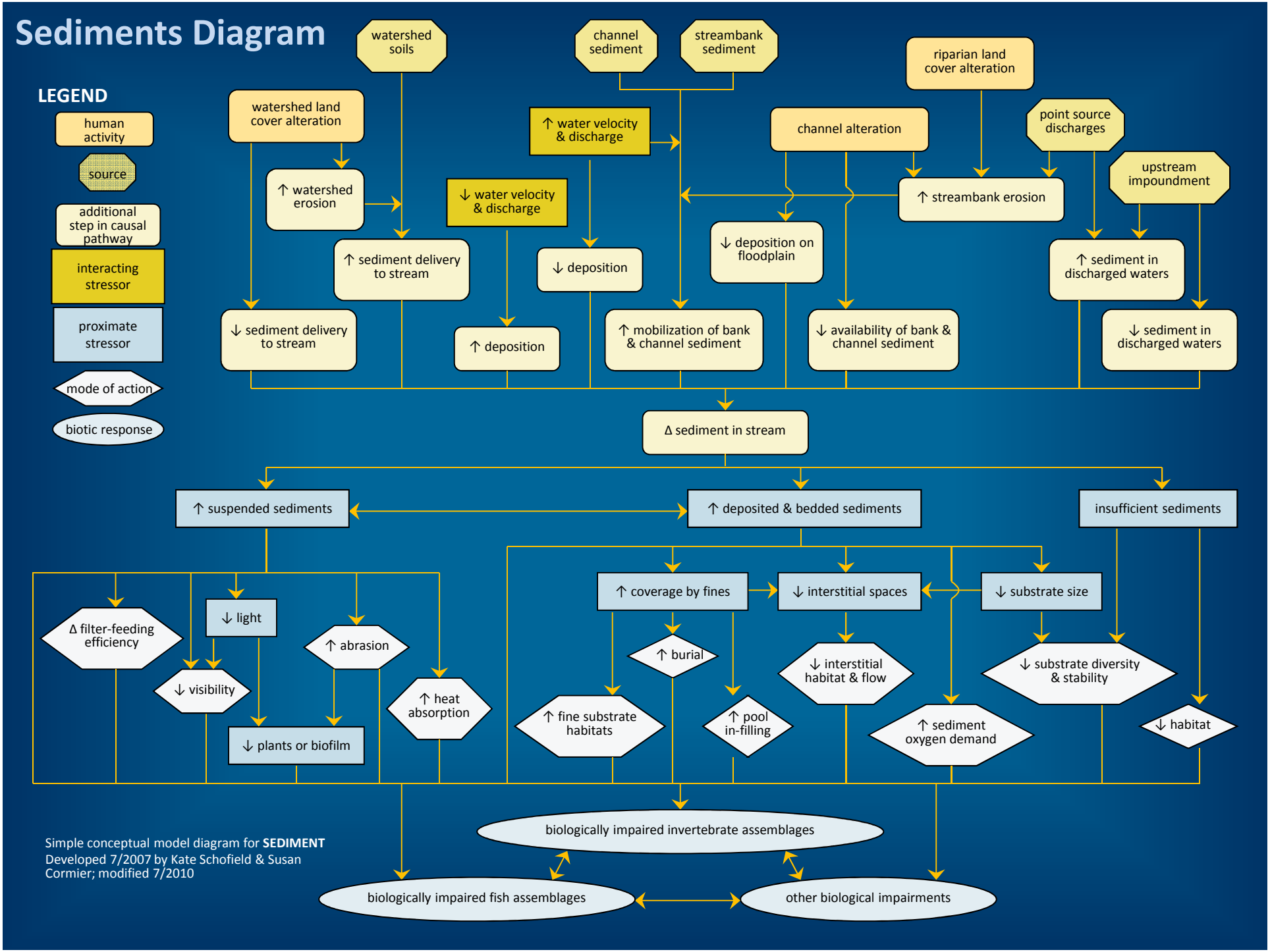


- Increased suspended sediments
- Increase in deposited/bedded sediments
- Insufficient sediments
- Decreased light
- Loss of interstitial space
- Decreased substrate size
- Increased smothering


Sediments Diagram
LEGEND
human activity
source
additional step in causal pathway
interacting stressor
proximate stressor
mode of action
biotic response
watershed soils
channel sediment
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riparian land cover alteration
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↑ mobilization of bank & channel sediment
↓ availability of bank & channel sediment
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Δ sediment in stream
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insufficient sediments
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↓ light
↑ abrasion
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↑ heat absorption
↓ plants or biofilm
↑ coverage by fines
↓ interstitial spaces
↓ substrate size
↑ burial
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↓ substrate diversity & stability
↑ fine substrate habitats
↑ pool in-filling
↑ sediment oxygen demand
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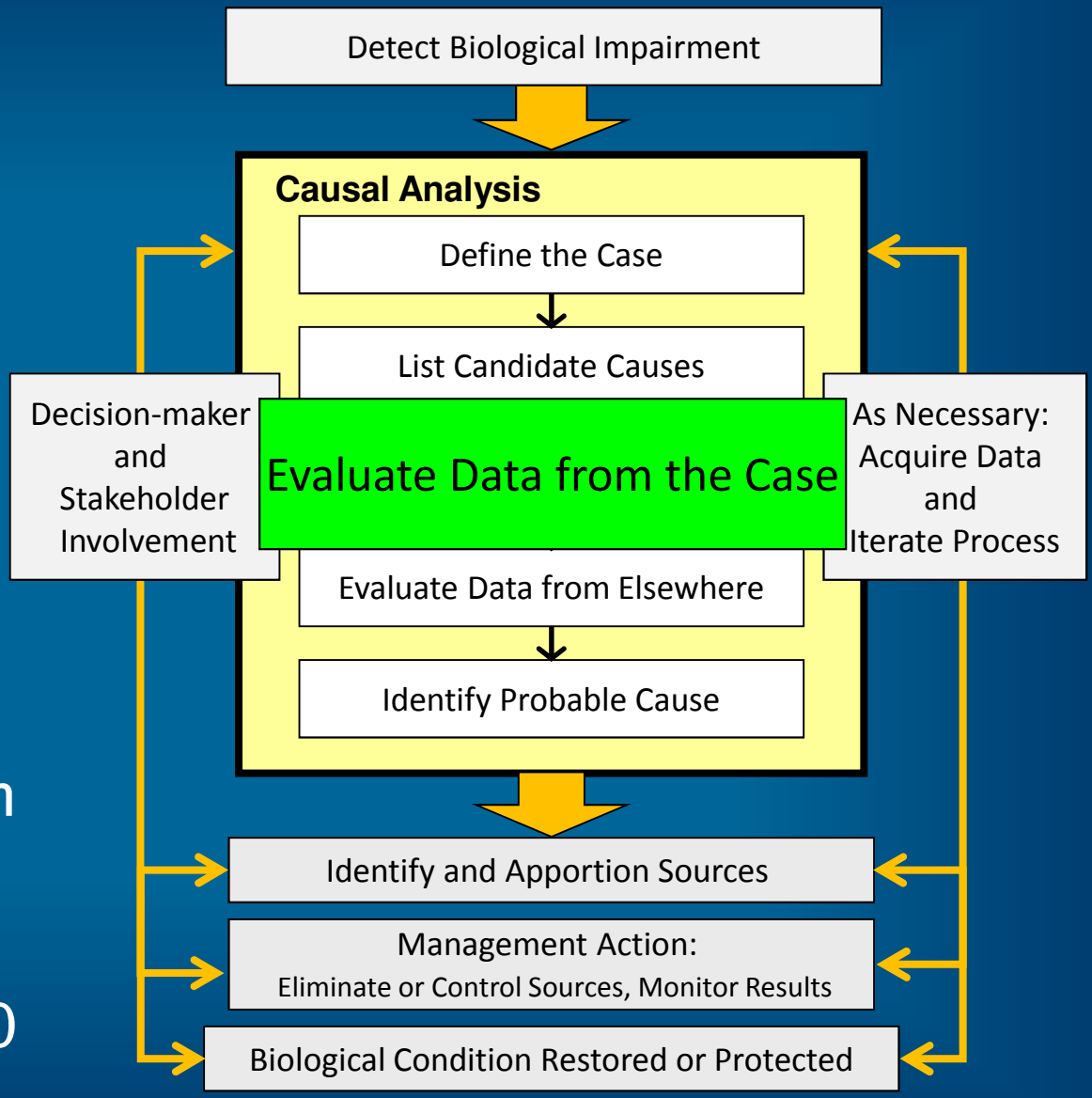
biologically impaired invertebrate assemblages
biologically impaired fish assemblages
other biological impairments
Simple conceptual model diagram for SEDIMENT
Developed 7/2007 by Kate Schofield & Susan Cormier; modified 7/2010

Candidate Causes: The Future

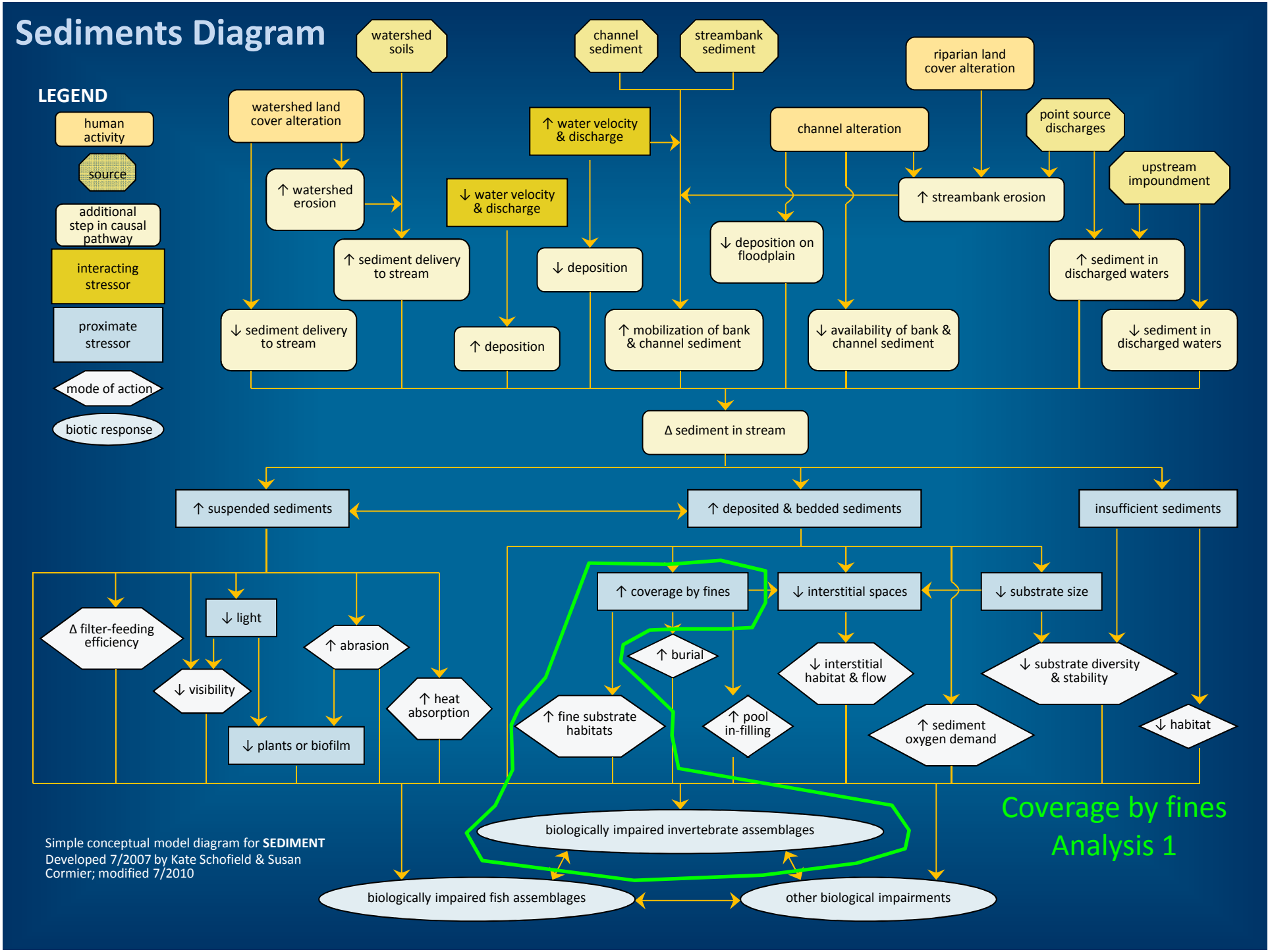
- Creating the diagrams fosters communication
- The diagrams created in our studies will go to CADDIS as resources
  - Can be modified for future assessments
- As more assessments are done, more California-specific diagrams will be available

- Data from the Case
  - Contrasts of impacted/ comparator sites
  - Primary data accumulation step
  - Results are scored: +,–,0



Data from the Case

- Types of Evidence
  - *Spatial/Temporal Co-occurrence*
  - Evidence of Exposure or Biological Mechanisms
  - *Causal Pathway*
  - *Stressor-Response Relationships from the Field*
  - Manipulations of Exposure
  - *Laboratory Tests of Site Media*
  - Temporal Sequence
  - Verified Predictions
  - Symptoms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Coverage by fines Analysis 1
Simple conceptual model diagram for SEDIMENT
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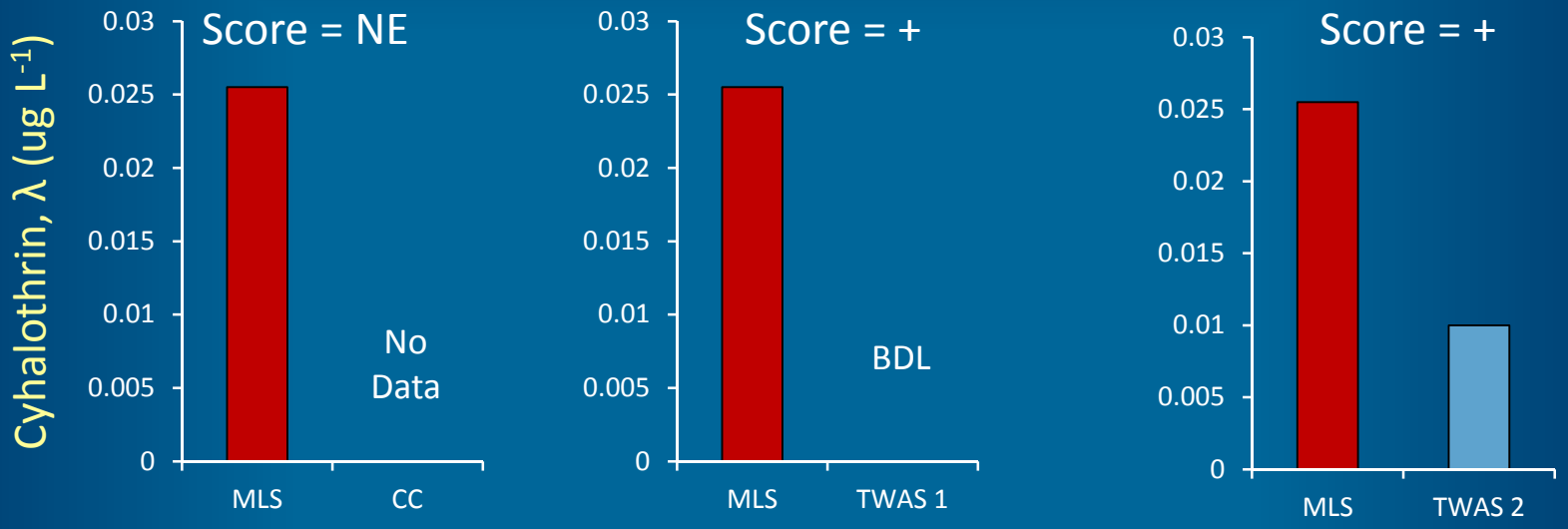
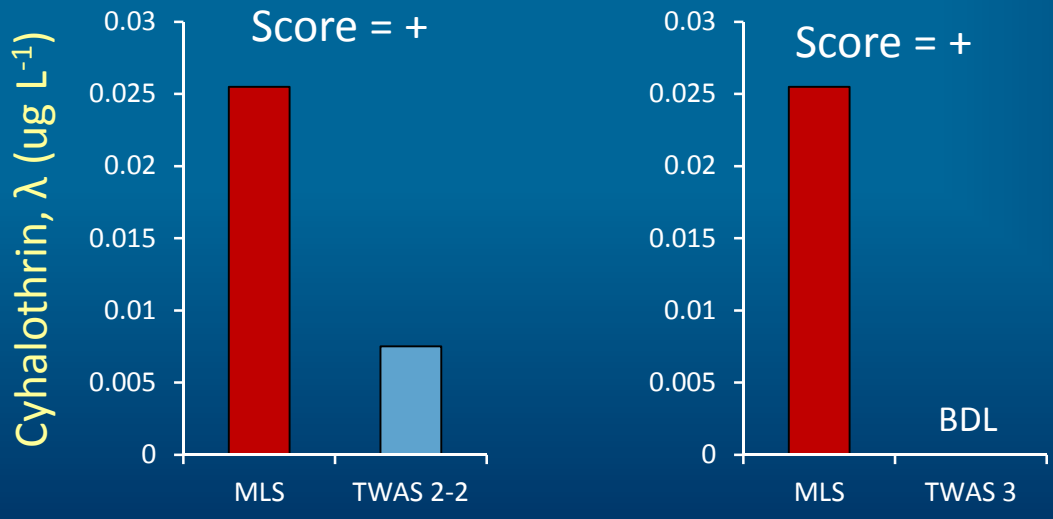
Data From the Case

- Scores are used to keep track of evidence patterns
  - Not additive
- Supporting Evidence (+, ++, or +++)
- Weakening Evidence (–, ––, or –––)
- Indeterminate Evidence (0)

Spatial-Temporal Co-Occurrence
San Diego River





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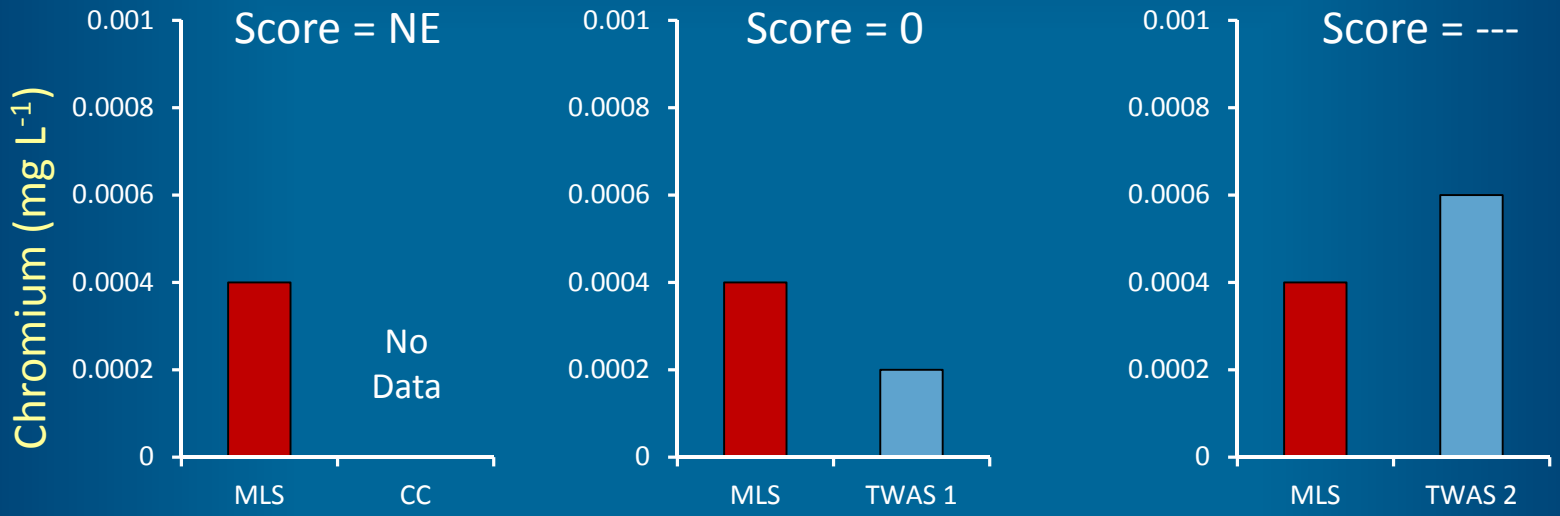
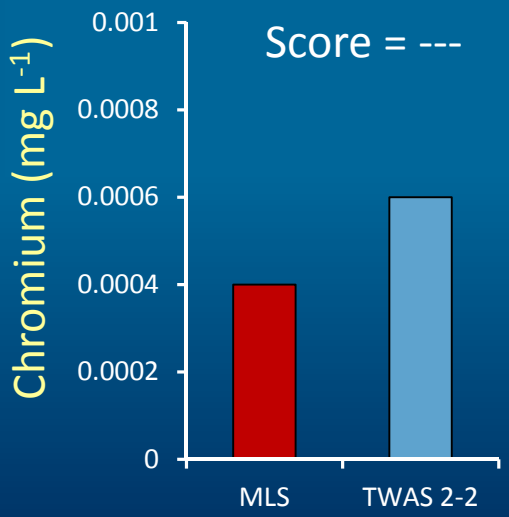
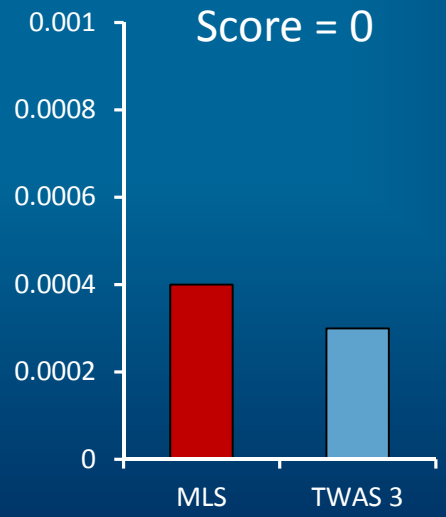
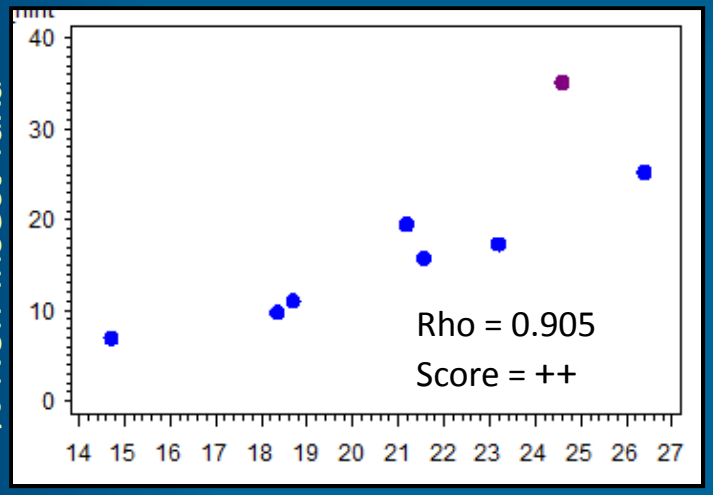


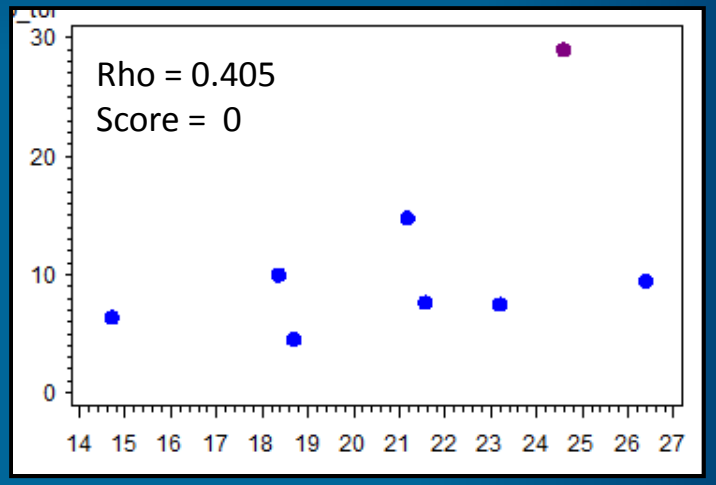


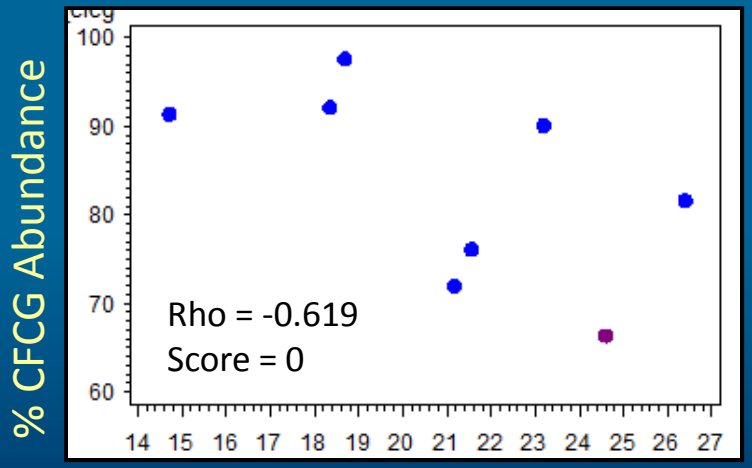


X

Stressor Response
Santa Clara River







TDS (mg L^{-1})

Sites Other RD

Stressor Response
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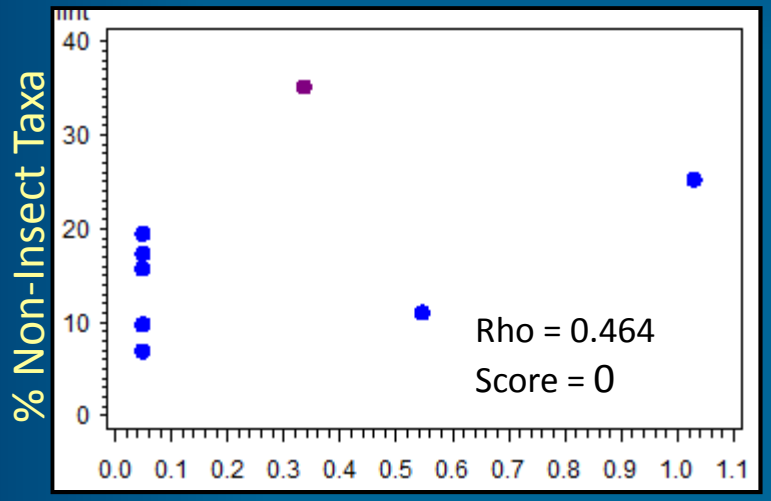
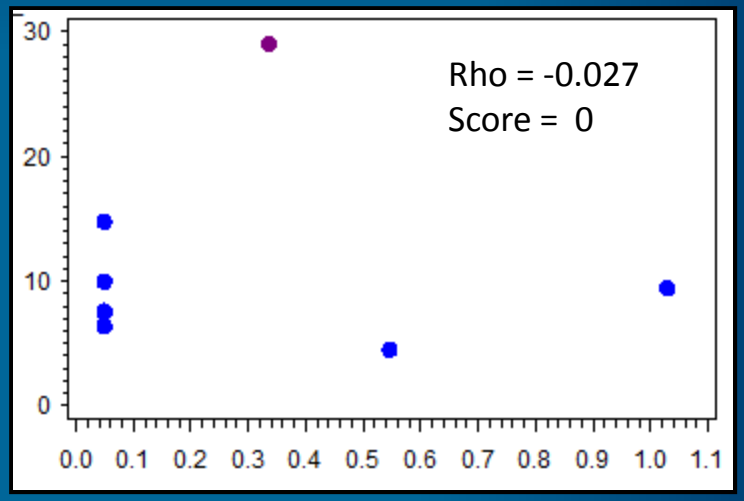
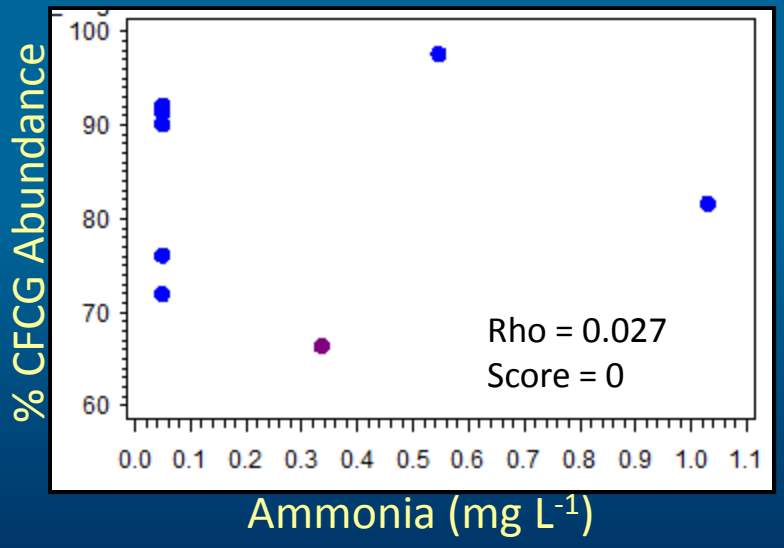
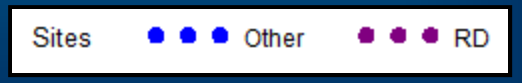
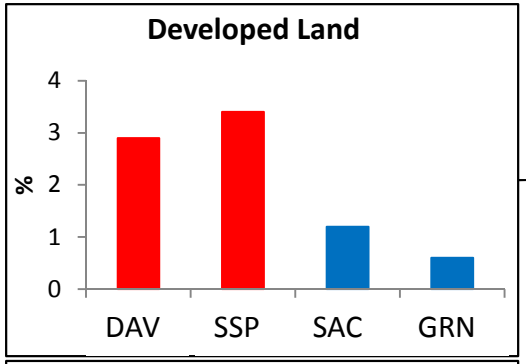


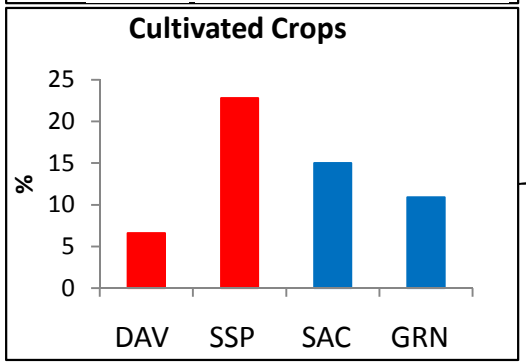






Causal Pathway
Salinas River

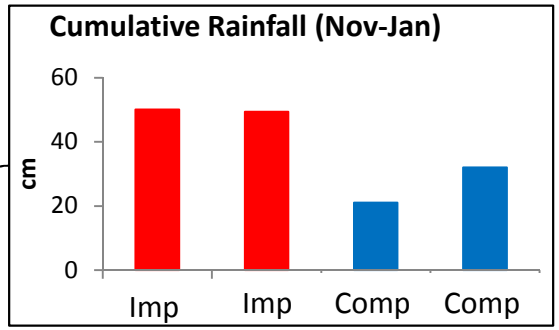


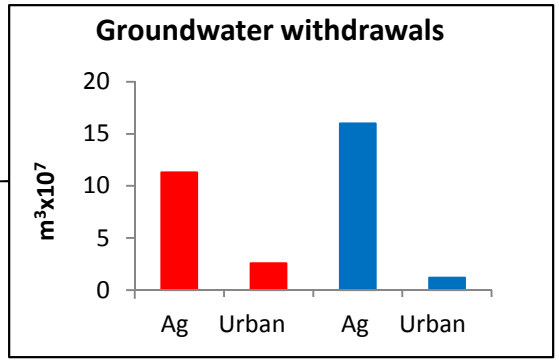


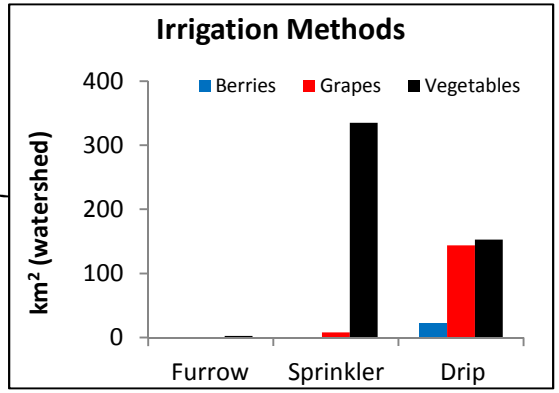
watershed land cover alteration

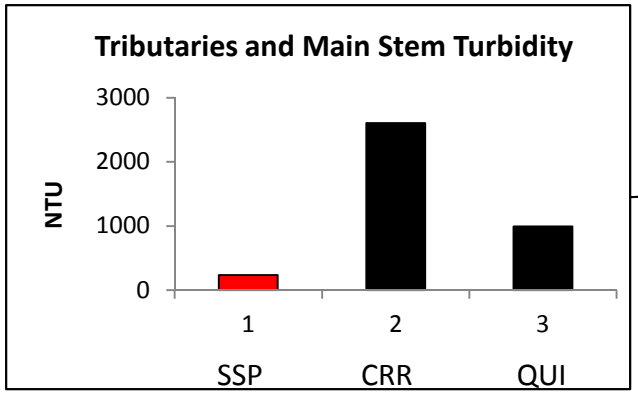
↑ watershed erosion

↑ sediment delivery to stream



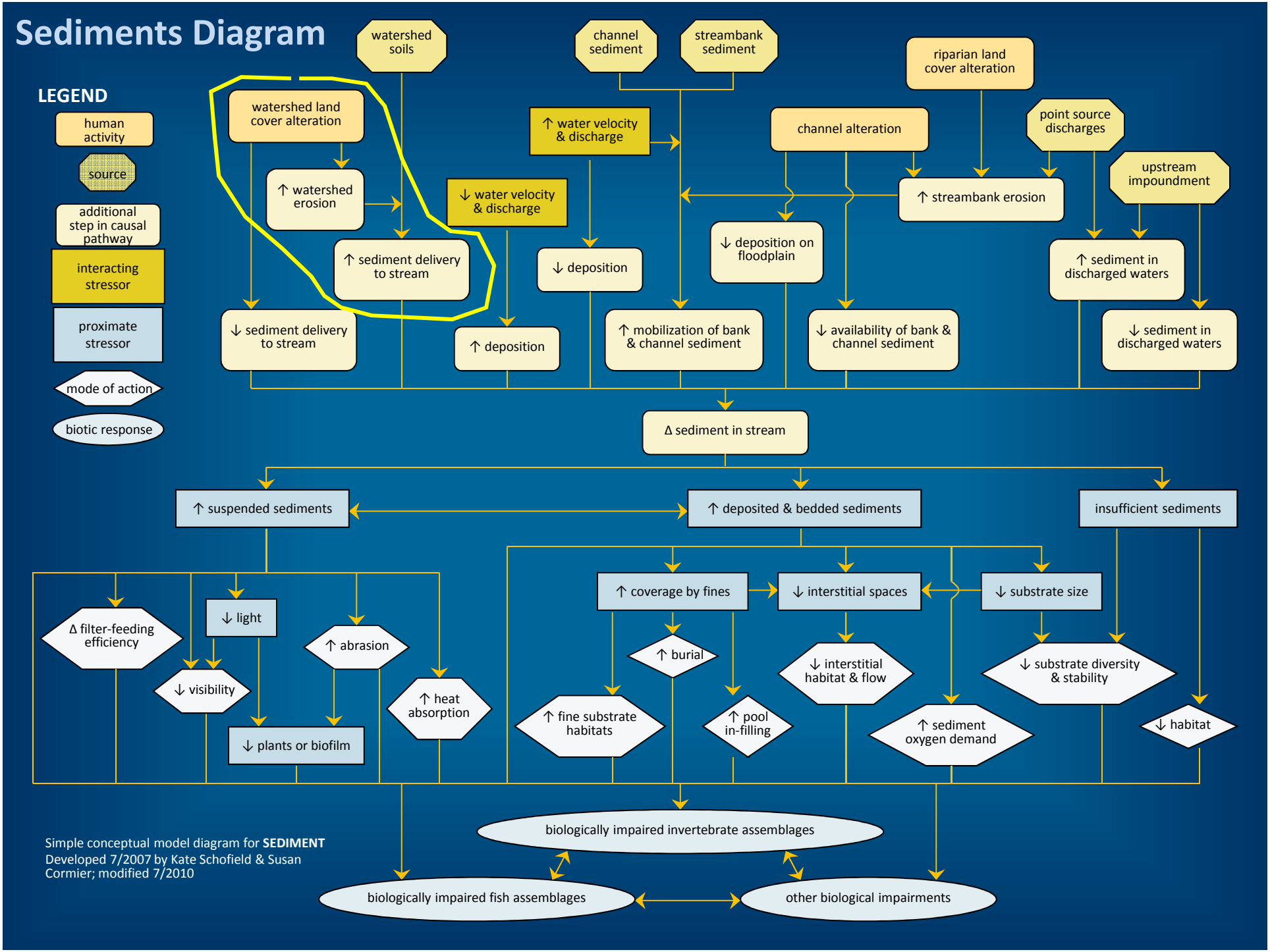






Score: +

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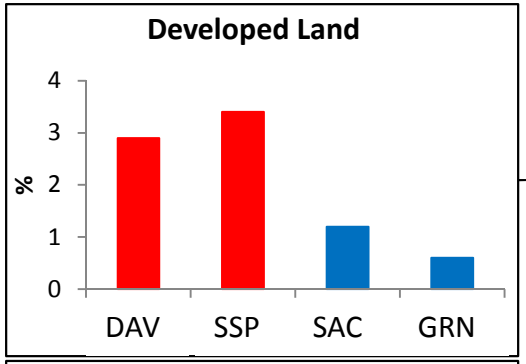

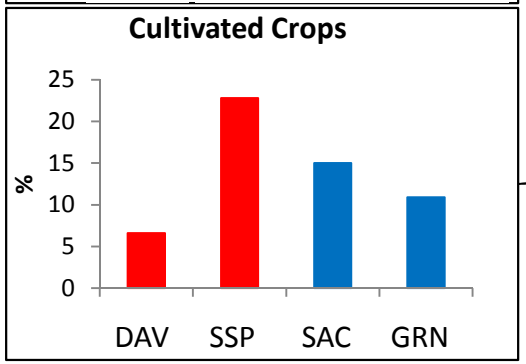

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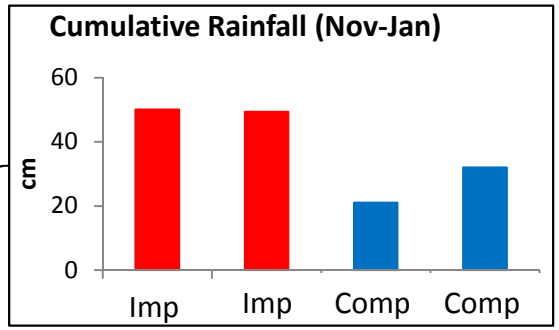

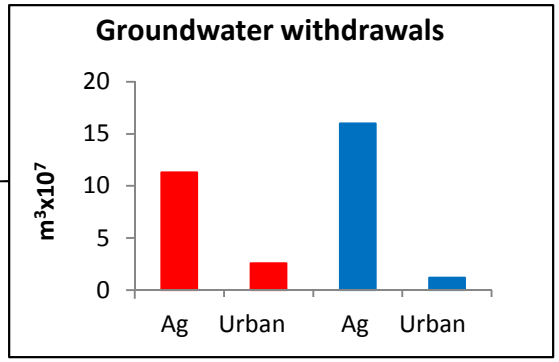

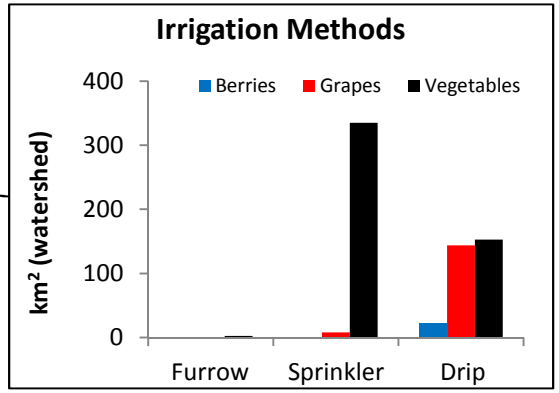

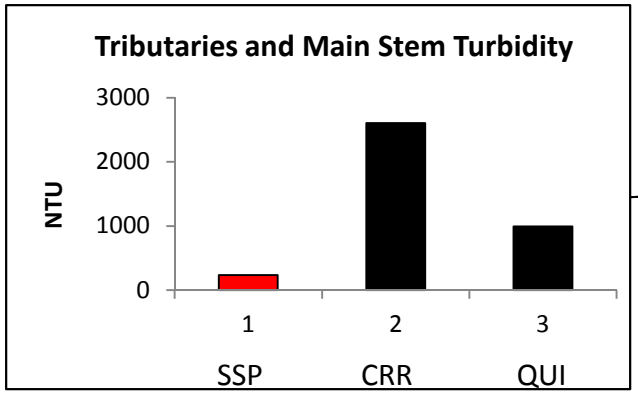

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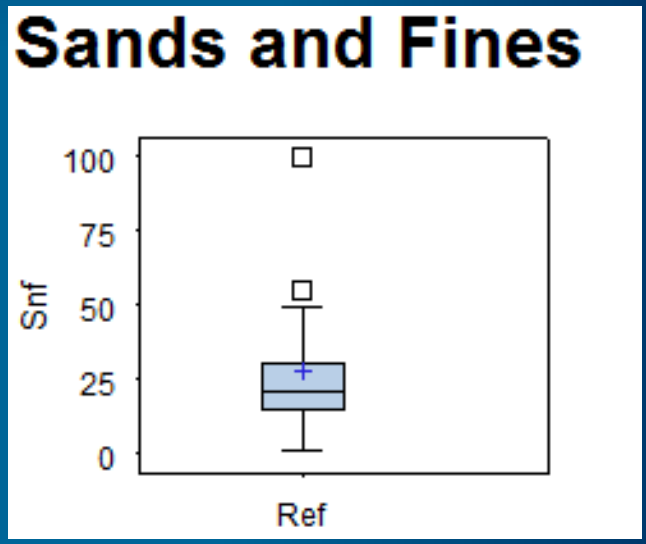
Reasoning- Some steps in at least one causal pathway are present

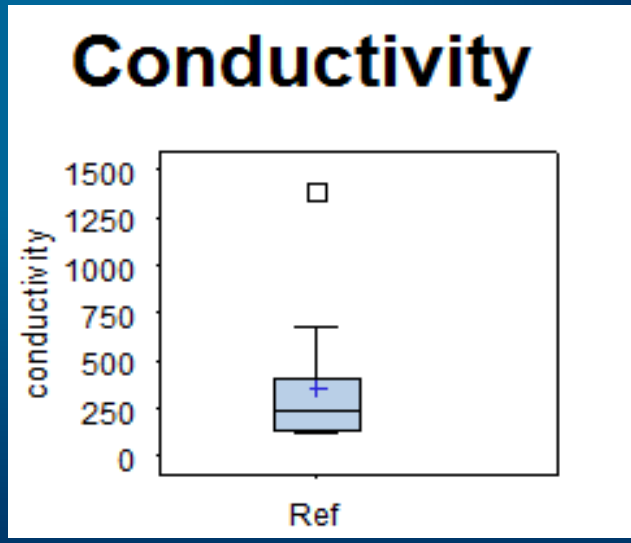
Data From the Case: The Future

- Most significant change will come from redefining comparator sites
  - The utilization of the state's biomonitoring dataset
- Develop new assessment tools
  - Relative risk, reference distribution, etc
- Guidance towards establishing scoring "rules"

Data From the Case: The Future

- Co-Occurrence
- Use a subset of comparator sites that pass reference screens
- Provides context for stressor levels





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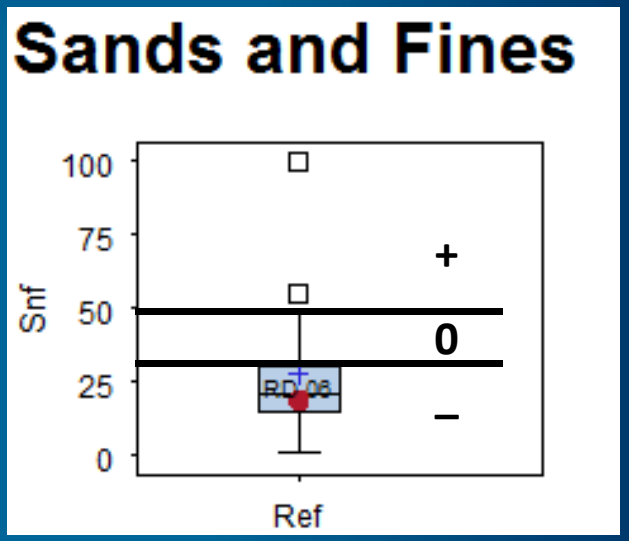
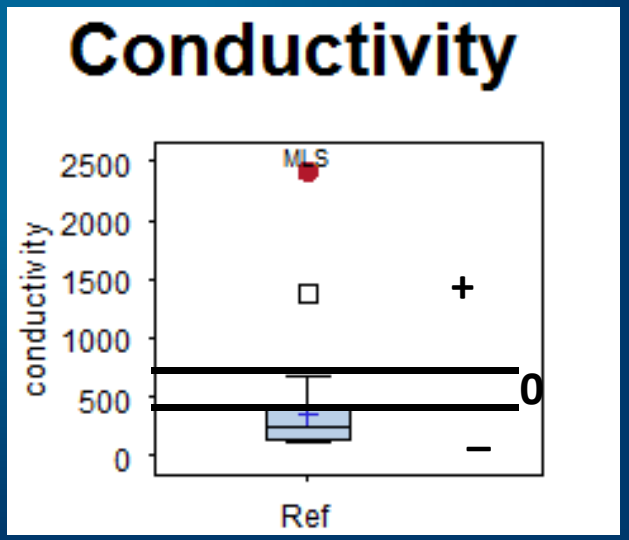
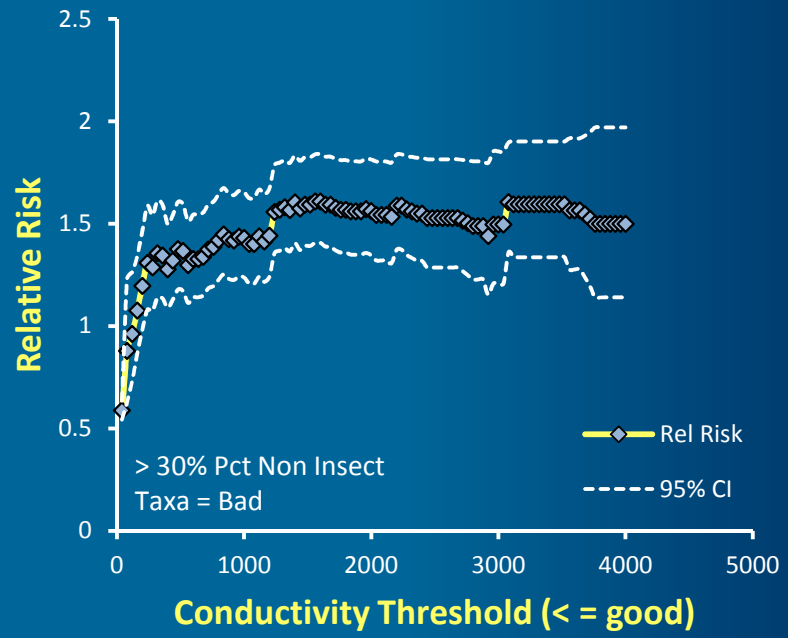




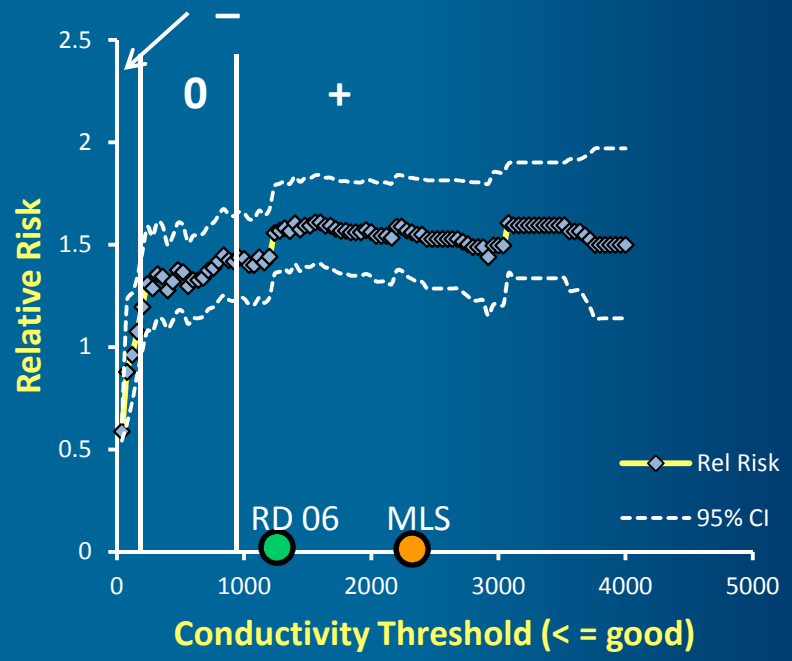
Data From the Case: The Future

- Stressor-Response
- Use a relative risk approach to evaluate probability of stressor-biology relationships
  - Subset sites again
  - Set biological threshold and incrementally change stressor threshold

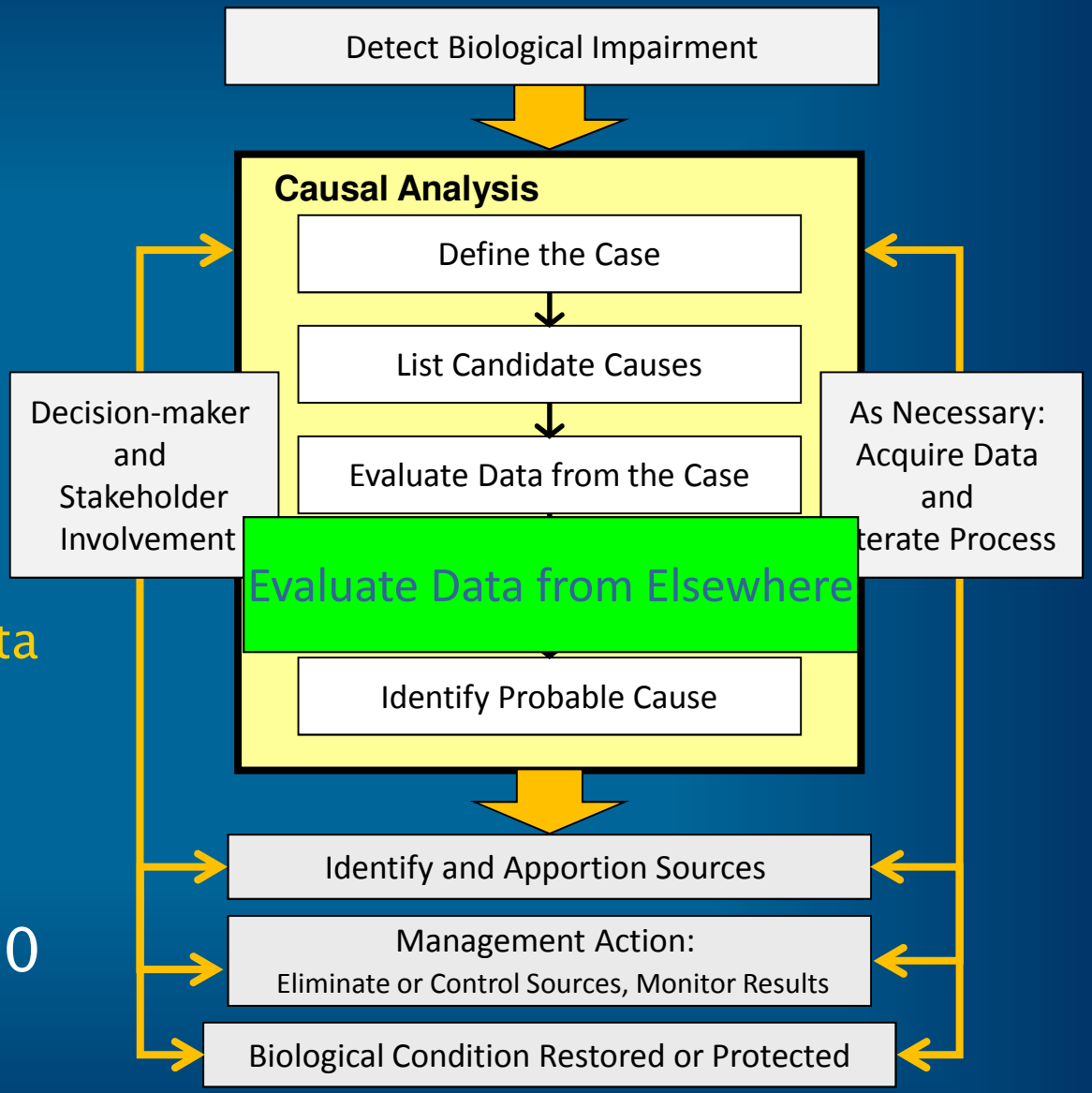


Data From the Case: The Future

- Stressor-Response
- Use a relative risk approach to evaluate probability of stressor-biology relationships
  - Subset sites again
  - Set biological threshold and incrementally change stressor threshold



- Data from elsewhere
  - Compare impacted site to other places
    - Field or lab data
  - Provides context for the stressors
  - Scored +,–, or 0

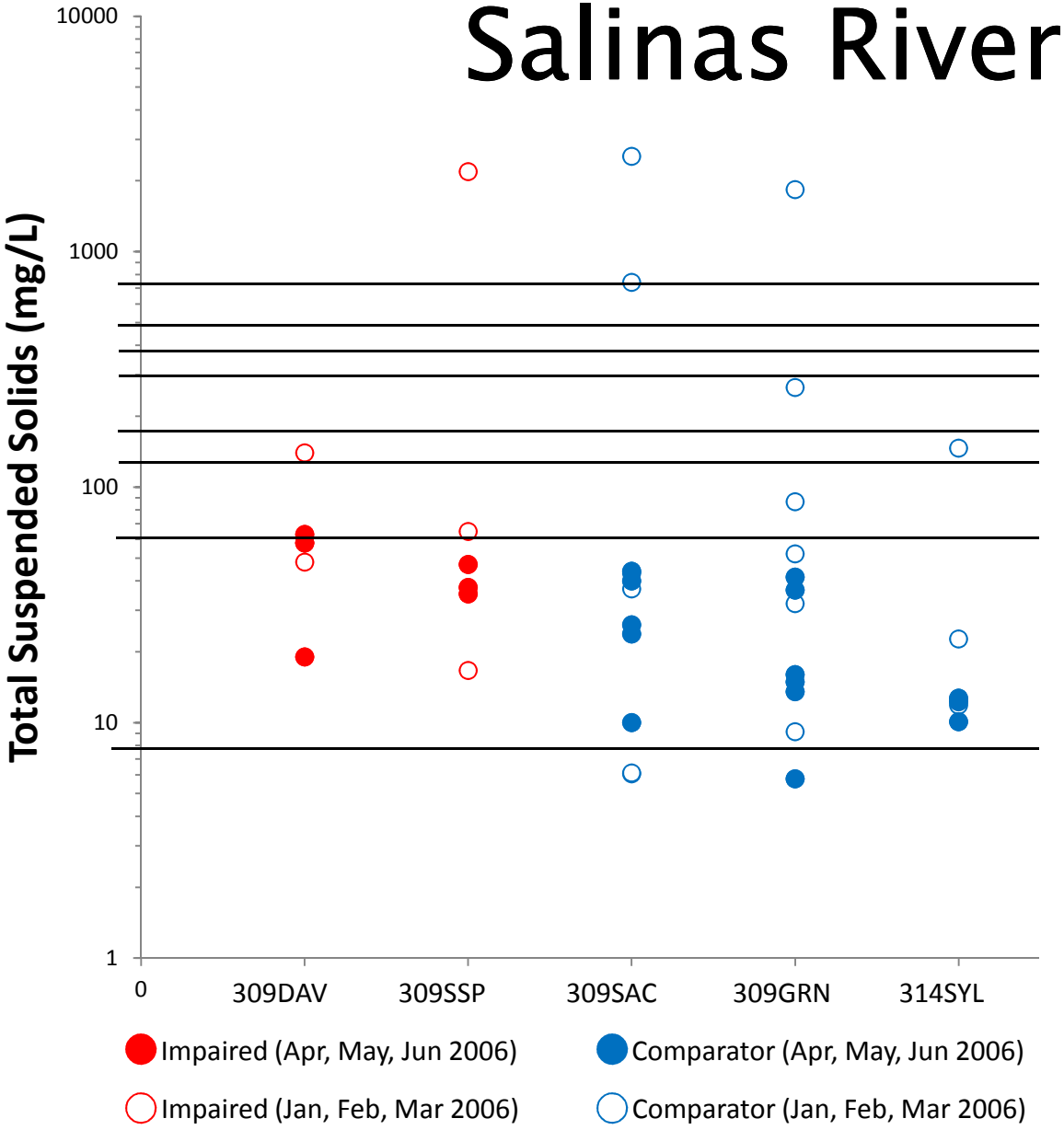


Data From Elsewhere

- Types of Evidence
  - *Stressor-Response Relationships from Other Field Studies*
  - *Stressor-Response Relationships from Laboratory Studies*
  - Stressor-Response Relationships from Ecological Simulation Models
  - Mechanistically Plausible Causes
  - Manipulations of Exposure at Other Sites
  - Analogous Stressors

Data From Elsewhere

Salinas River



Ecological Effects of Suspended Sediment*

85% reduction benthic invertebrate population

Cladocera and copepoda gill and gut clogging
90% reduction chironomid population

7-fold increase in drifting invertebrates
40% reduction stream invertebrate diversity

Cladocera survival and reproduction harmed

Benthic invertebrate Increased drift
& reduced density

Score: +

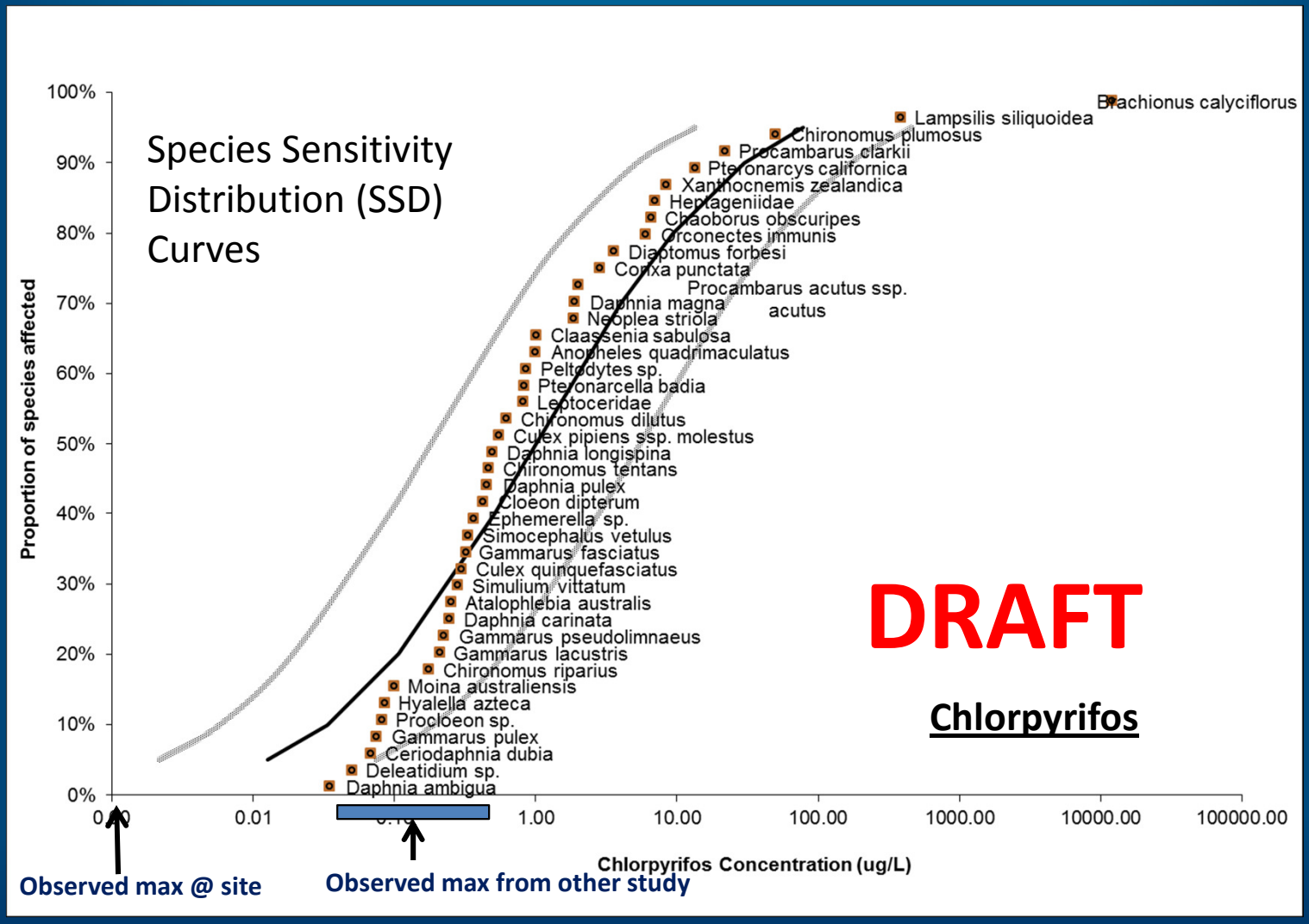
Reasoning- observed values consistently with ranges reported as having negative effects

*From Bilotta and Brazier (2008)

Data From Elsewhere: The Future

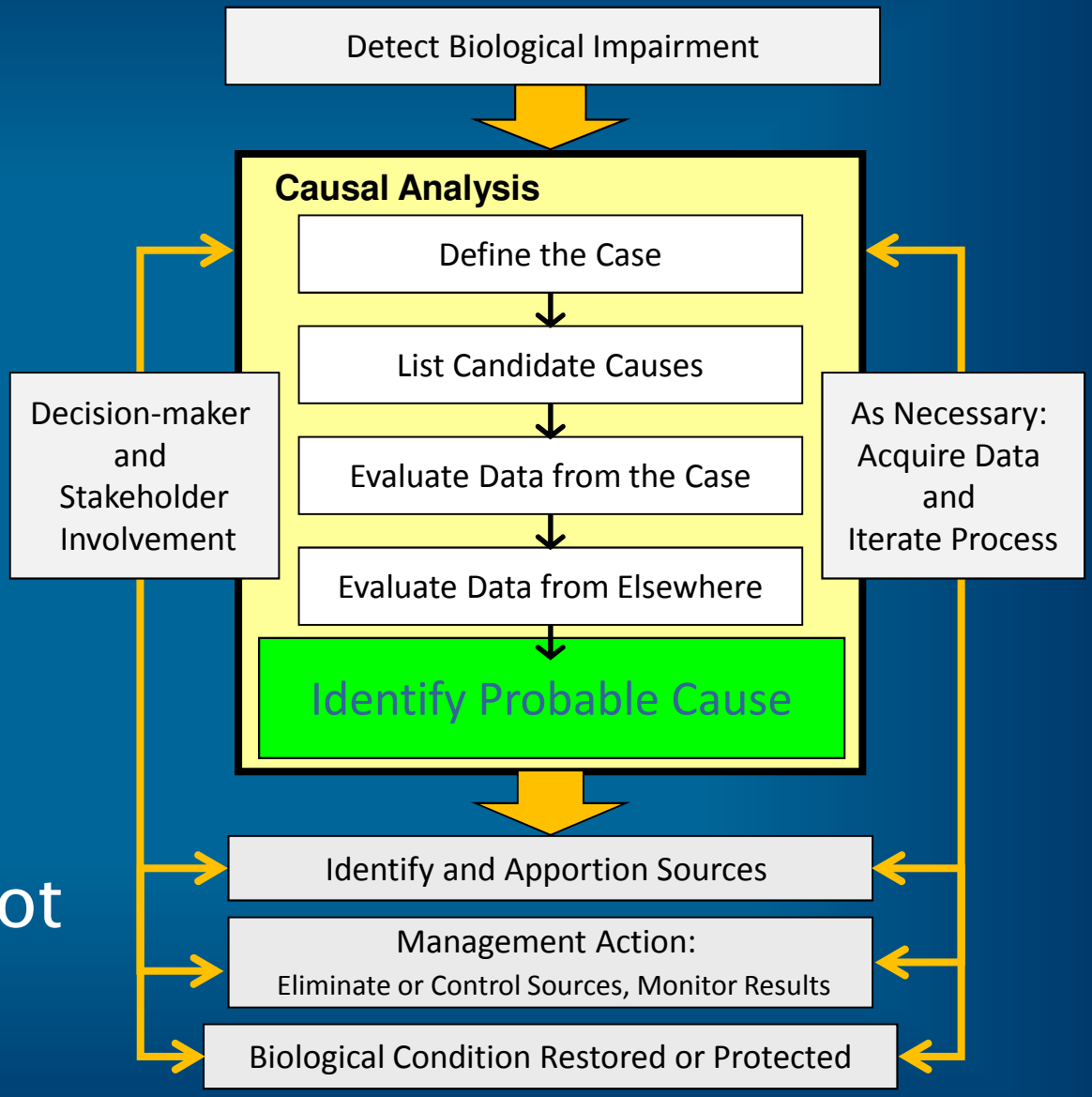
- If comparator sites are redefined, then "other field" data will get wrapped into Data From the Case
  - Data from lab studies and predictive models will take a central role
- Toxicity and tolerance experiments
- Identification of stressor-specific taxa

Data From Elsewhere: The Future



Anderson et al. 2003. Integrated assessment of the agricultural drainwater in the Salinas River (California, USA). Env. Poll. 124: 523-532

- Identify cause(s)
  - Based upon consistent scores across all evidence types
  - Narrative, not additive summary



Identifying Probable Cause

- The most problematic part of CADDIS
- The summary of scores are not additive and the narrative statement is the true end product
- The transition from score sheet to narrative can be prone to bias

Identifying Probable Causes

	Low DO	pH	Temp	Cond-uctivity	PHAB	Sediment (bed)	Flow	Increased Pesticides	Increased Nutrients	Increased Petroleum
Types of Evidence That Use Data From the Case										
Spatial/Temporal Co-Occurrence	---	---	+	---	+	+	---	---	0	0
Causal Pathway	-	-	+	-	+	+	-	-	0	0
Stressor Response From the Field	--	-	+	-	+	+	-	--	0	0
Types of Evidence That Use Data From the Elsewhere										
Stressor Response From Other Field Studies	-	-	+	-	+	+	-	-	0	0
Evaluating Multiple Types of Evidence										
Consistency of Evidence	-	-	+	-	+	+	-	-	0	0

Identifying Probable Causes
Garcia River

	Low DO	pH	Temp	Cond-uctivity	PHAB	Sedim (Geo)	Flow	Increased Pesticides	Increased Nutrients	Increased Petroleum
Types of Evidence That Use Data From the Case										
Spatial/Temporal Co-Occurrence	+	0	0	+/---- overall: ---	+	+ overa +	---	NE	NE	NE
Causal Pathway	0	-	0	-	+		+	0	0	0
Stressor Response From the Field	-	-	-		(we k!)	-	-	NE	NE	NE
Types of Evidence That Use Data From the Elsewhere										
Stressor Response From Other Field Studies	-		-	-	+ (weak!)	+	-	NE	NE	NE
Evaluating Multiple Types of Evidence										
Consistency of Evidence	-	-	-	-	+	+	-	0	0	0

Site 154 against 218/223

Identifying Probable Cause
Garcia River

Candidate Cause	Evidence and Comments
Physical habitat	Greater habitat diversity observed at comparator sites (especially site 223) than at case sites, including more instream cover, more fastwater (riffle) habitat, less glide habitat, greater variation in depth, etc.
Sedimentation	Comparator sites (especially 223) less embedded and with less sand + fines + fine gravel. Differences consistent with legacy effects from historical timber harvest affecting the entire inner gorge, and site 223 being a higher gradient, more constrained reach that transports sediment downstream

Identifying Probable Cause: The Future

- Continue developing a more direct scoring and identification framework
- Codify rules for scoring individual evidence types and score-summary
  - Should allow for more consistent and reproducible results
- Develop framework to prioritize stressors based on confidence in the causal identification

Bringing It to a Close

Summary and Participant Perspectives

Summary

- The CADDIS framework provides a great base to build upon
  - We have started making modifications to better suite California's problems
- Impacted sites will be better diagnosed using the state-wide dataset
- Causal assessment works best when analysts, regulators, and regulated parties work together

Science Panel Thoughts

- Causal Assessment is important for progress in bio-objectives development
  - Panel recognizes that CADDIS is an imperfect tool and needs refinement
- CA needs to take advantage of its large data set to streamline causal assessment
  - This unique opportunity should reduce future costs
- CA needs to improve comparator site selection
  - Incorporate comparators outside the watershed
- CA needs to improve diagnostic tools
  - Regional response models (i.e., Relative risk)
  - Species specific response models
  - Laboratory based species sensitivity distributions

Stakeholder Thoughts

- "[We like that it is] based on the multiple lines line of evidence approach that uses the scientific method and available data"
- "[A weakness is that it is] designed for point sources and acute problems, the San Diego region seems to suffer from chronic pollution throughout the watershed"
- "…need to be able to demonstrate with … scientific certainty that controlling the identified causal stressor has a decent chance of bringing a stream back into compliance."

Guidance Document

- It will be oriented towards the regulated and regulating audience
- It will not be a collection of SOPs
  - CADDIS website is a resource for that
- Document will be more about the approach, supplemented with examples
- It will include recommendations for future improvements

Acknowledgements

- Science Advisory Panel
- Science Team
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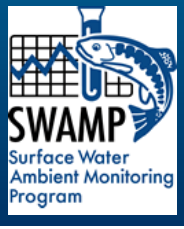
  - David Paradies
  - Mary Adams
  - Sarah Lopez
  - Jonathan Warmerdam
  - Jennifer Carah



Thank You For Your Time

Questions?

davidg@sccwrp.org

www.epa.gov/caddis

Spatial-Temporal Co-Occurrence "Rules"

Score= +

Score= 0

Score= ---

Score= ---

Score= ---

X