

Pacific Estuarine Ecosystem Indicator Research (PEEIR)

Integrated Indicators of Salt Marsh Condition



Integrated Indicators of Coastal Condition: A New Paradigm for scientists and managers

1. What was the Pacific Estuarine Ecosystem Indicator Research (PEEIR) program about?
2. Why is approach useful/practical?
3. Is it a paradigm shift?
4. Keeping the concepts alive

A research partnership UCD/UCSB

Acknowledgments: 30 PIs, >70 participants



Thanks Pacific Ecorisk

Problem Statement

Overarching Problem- Techniques used to assess effects of contaminants on estuarine species are outdated

Sediment toxicity- Toxicity tests, chemical analysis, and invertebrate surveys are useful but limited tools

Regional monitoring and wetland restoration- Better knowledge of contaminant effects in resident species is needed

Population Declines in the SF Bay Delta- Large scale interagency efforts have usually not considered contaminants (xc Smelt)

New integrated approach needed linking ecology and toxicology

**Stressor
Characterization**

**Ecosystem
Response**



**Population
Response**



**Individual
Fitness,
Physiological,
Cellular
Responses**



**Exposure
to Stress**

**Ecosystem
Model**

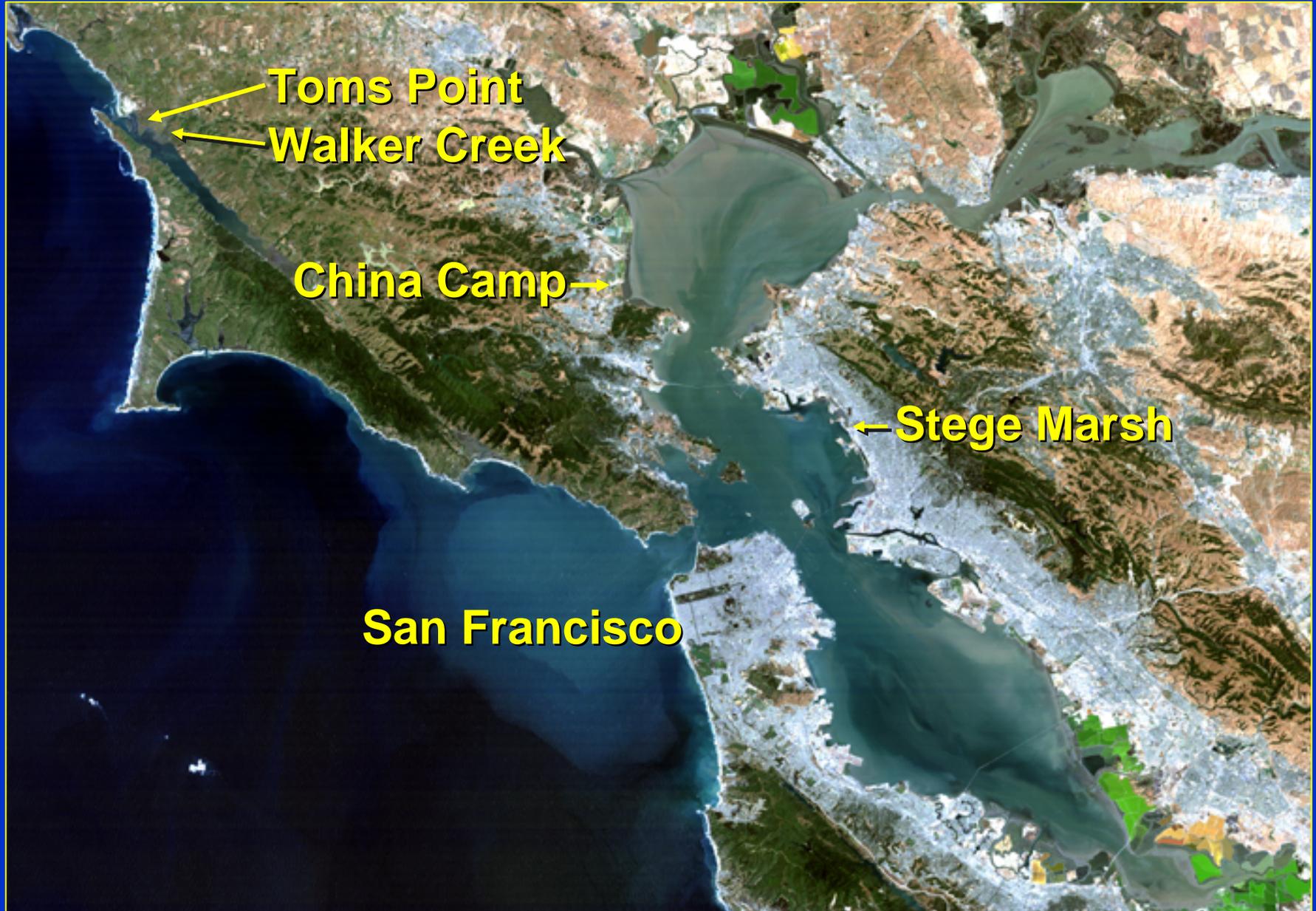
**Overall
PEEIR
Conceptual
Model**

Animal Indicators
Gillichthys (mudsucker)
Pachygrapsus (shore crab)
Macoma (clam)

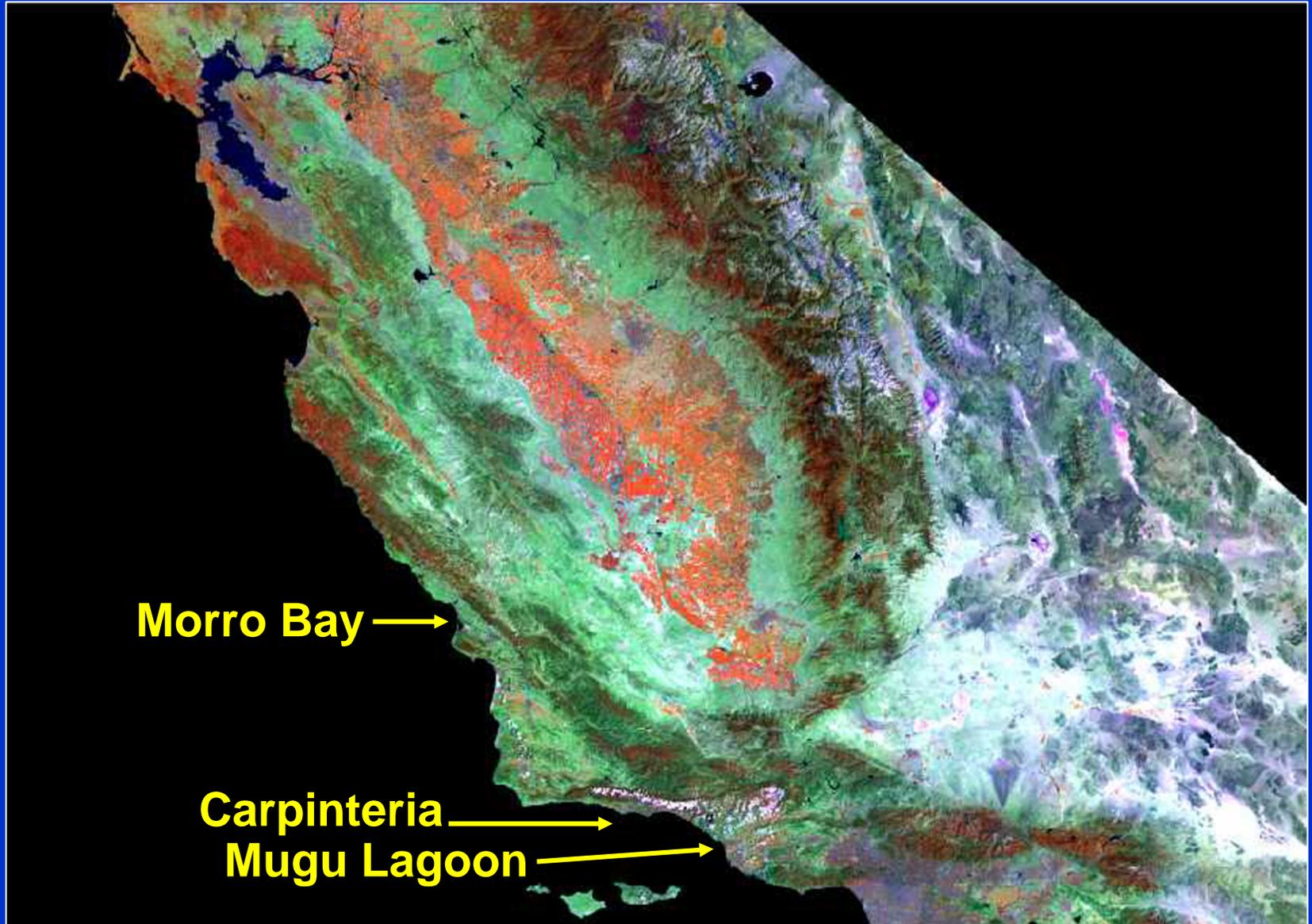
Plant Indicators
Salicornia (pickleweed)
Spartina (cord grass)

Microbial Indicators

Northern Study Sites



Southern Study Sites



General Approach

Integrated sampling with 30 PIs
Six salt marsh sites over 600 km of coast
Fixed stations within sites, three elevations
Integrated laboratory and field experiments
Modelling activities directly linked



Exposure/Effect Indicators

Liver P450
choriogenins
apoptosis
cholinesterase
DNA damage

GSI,
sex ratios,
choriogenins,
ovotestis,
apoptosis in gonad,
tumors

Reproductive Indicators



Fish Condition (energetics/metabolism)

Length/weight,
liver/somatic index,
histology (e.g. glycogen),
otolith growth,
mark-recapture,
DEB models

Strategy for Integration

- Choose biomarkers and develop measures on field fish.
- Describe inter-relationships among biomarkers and their responses in space.
(what are the fish telling us about habitat quality?).
- Diagnose proportions of fish in different "health" categories.
- Extrapolate to the population using abundance estimates.
- Parameterize survival and reproductive rates for population models.

Bennett, Nisbet, Fujiwara

Spartina Salt Exudates and metal bioavailability



Analysis: collect salts in tube of water, analyze by ICP-MS
No sample prep!

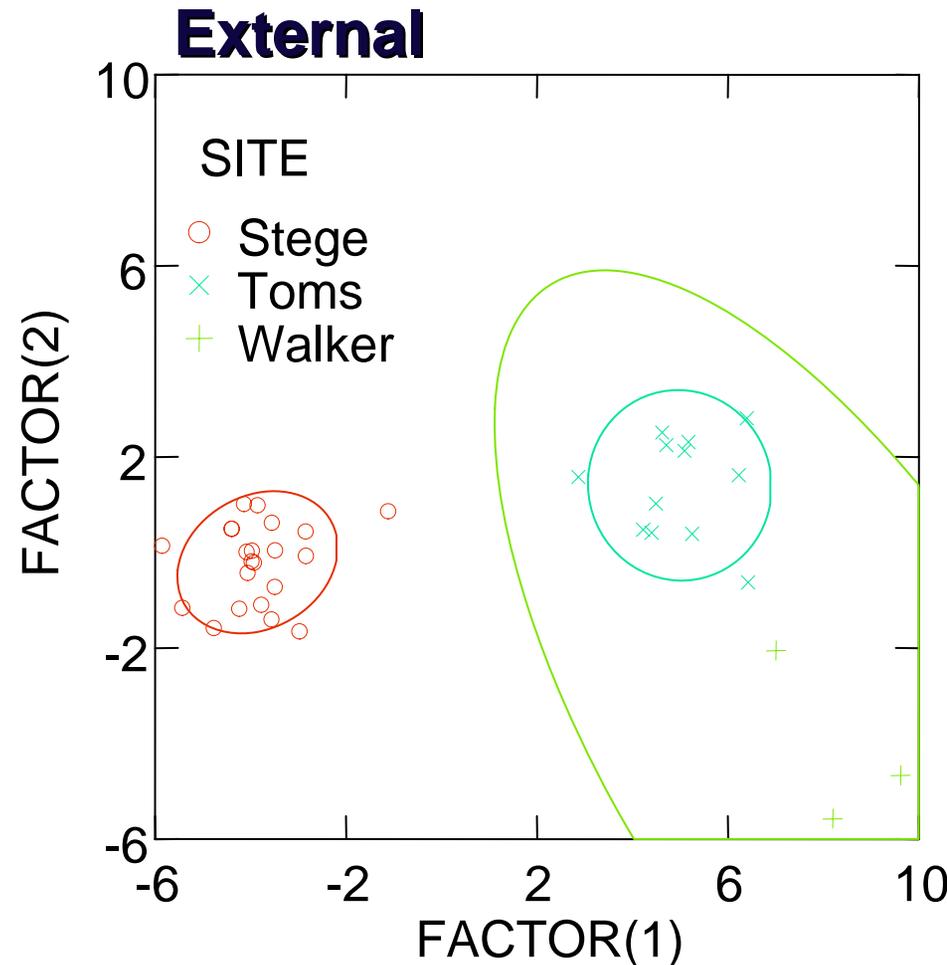
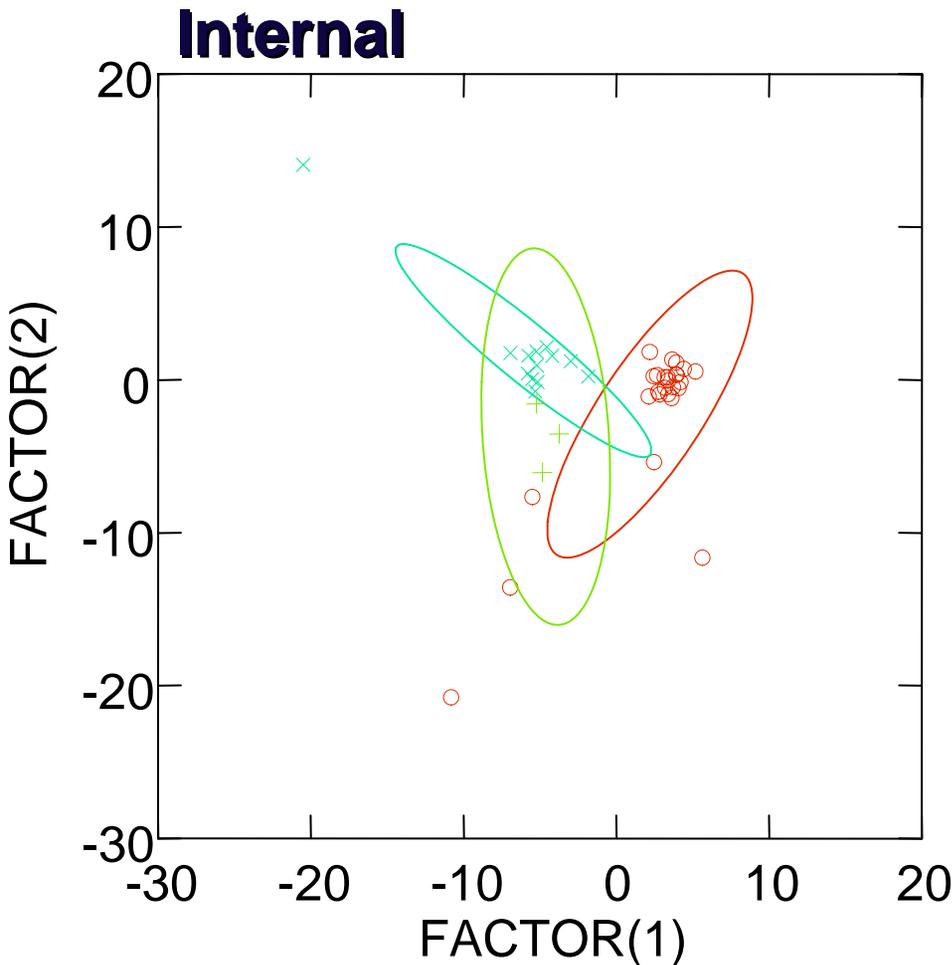
Green, Higashi, Ustin

Crab Indicator- Embryo abnormalities and toxicant burdens

- Measurements of Reproductive Fitness:
 - Fecundity
 - Embryo size & weight
 - Hatching Success
 - Larval Survival
 - Abnormalities*
- Metals and Organics
 - Sediment
 - Haemolymph
 - Embryo *
- Demographics



Discriminant analysis of metals in embryos



Internal: poor discrimination of metals among sites

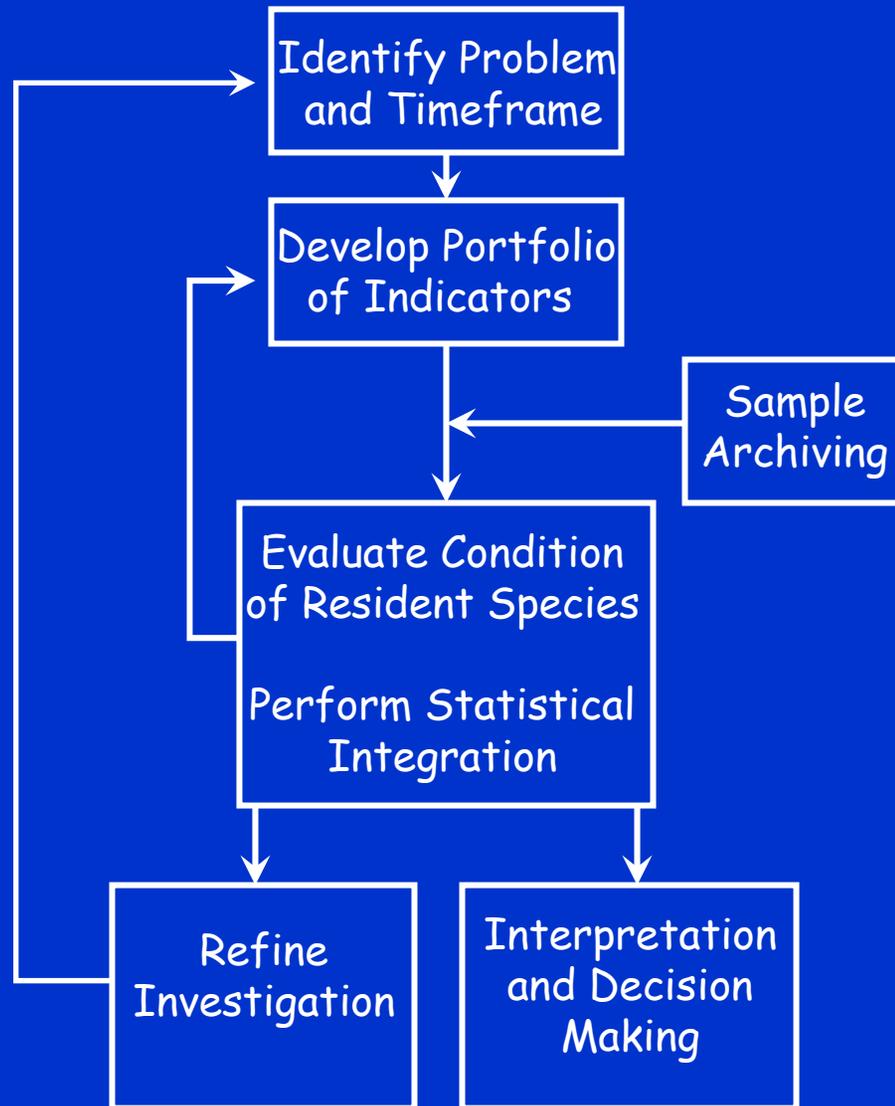
External: Stege is distinct from Tomales sites

Indicates that metals taken up by contacting sediment

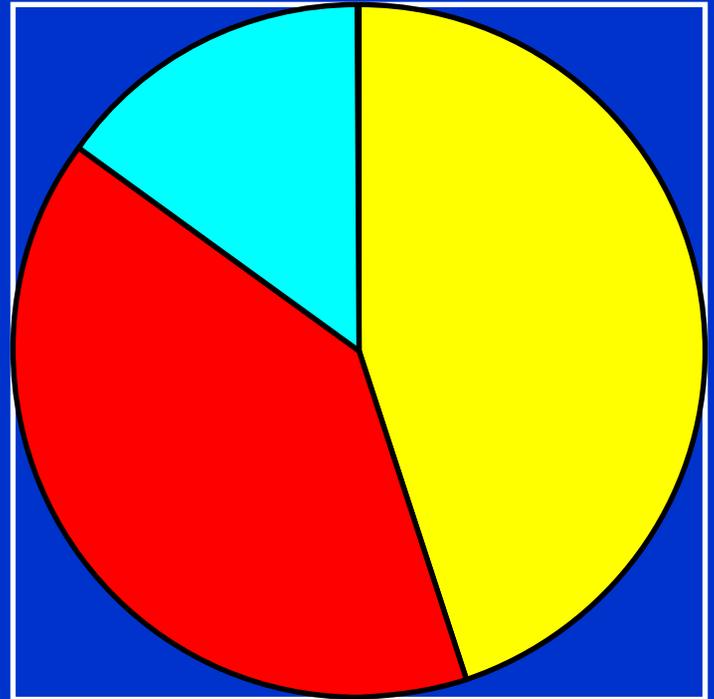
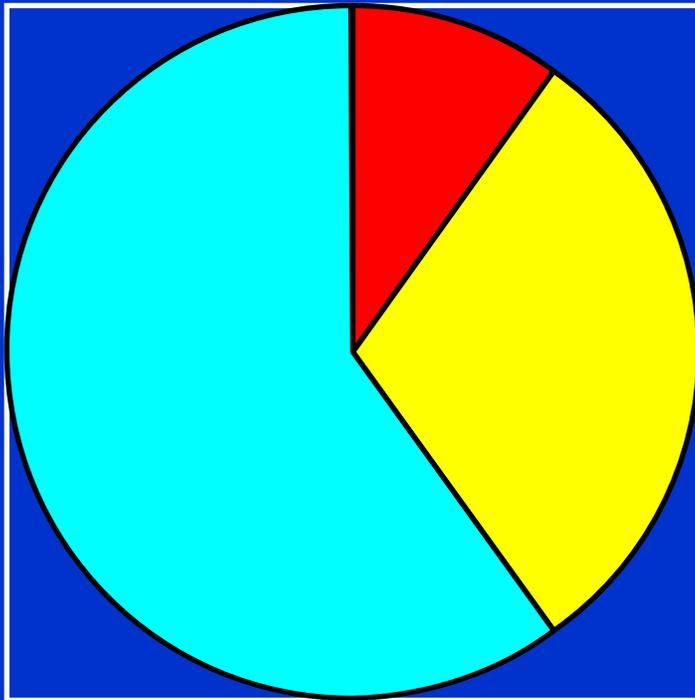
Links metal uptake to external abnormalities

Morgan, Green

Implementing the PEEIR Process



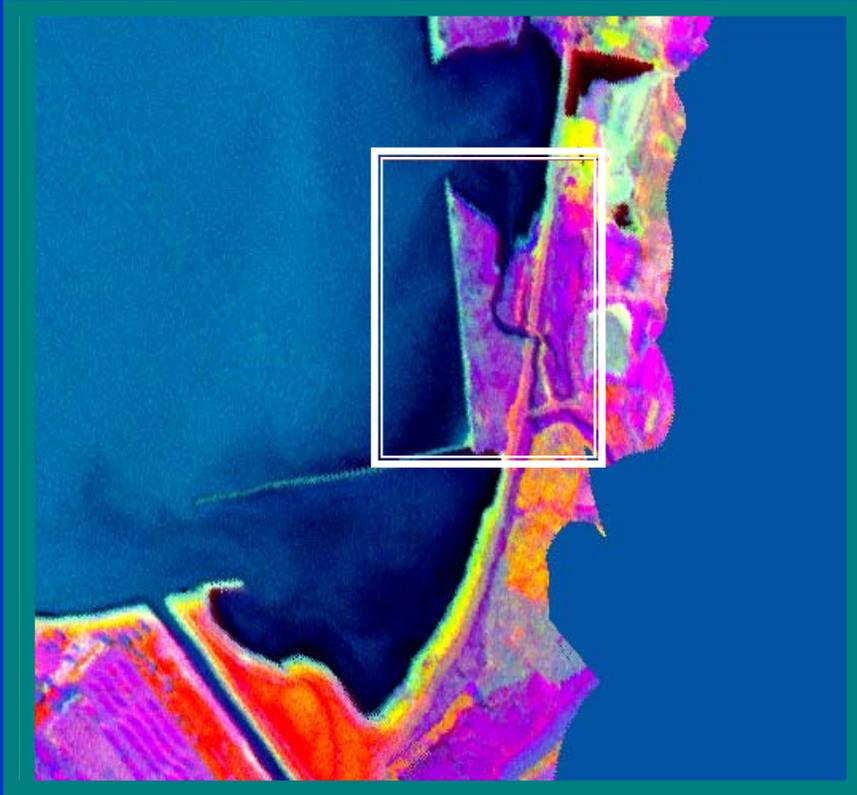
Step 3: Assign level of diversification



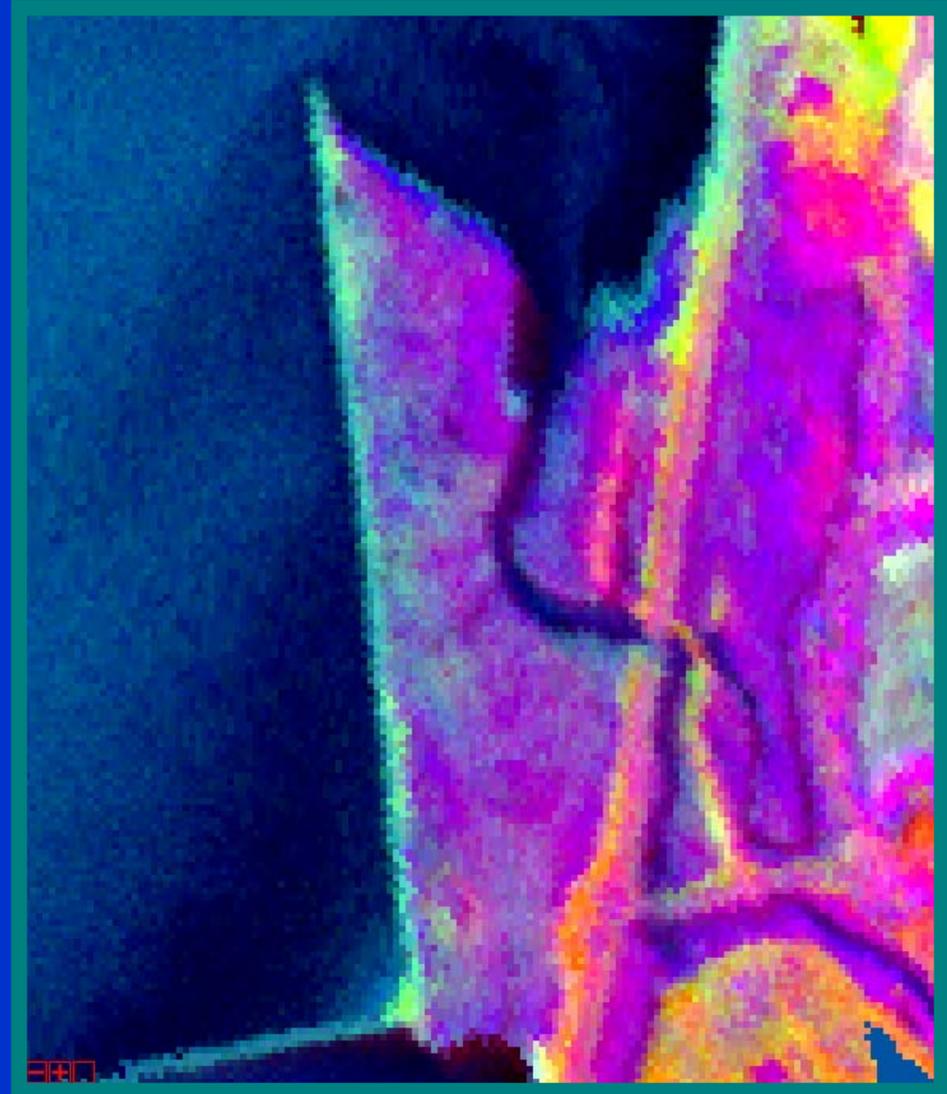
High Risk/High Uncertainty
Long Timeframe
Large Balanced Portfolio

Low/Moderate Risk and Uncertainty
Relatively Short Timeframe
More Modest and Targeted Portfolio

Stege Marsh Restoration



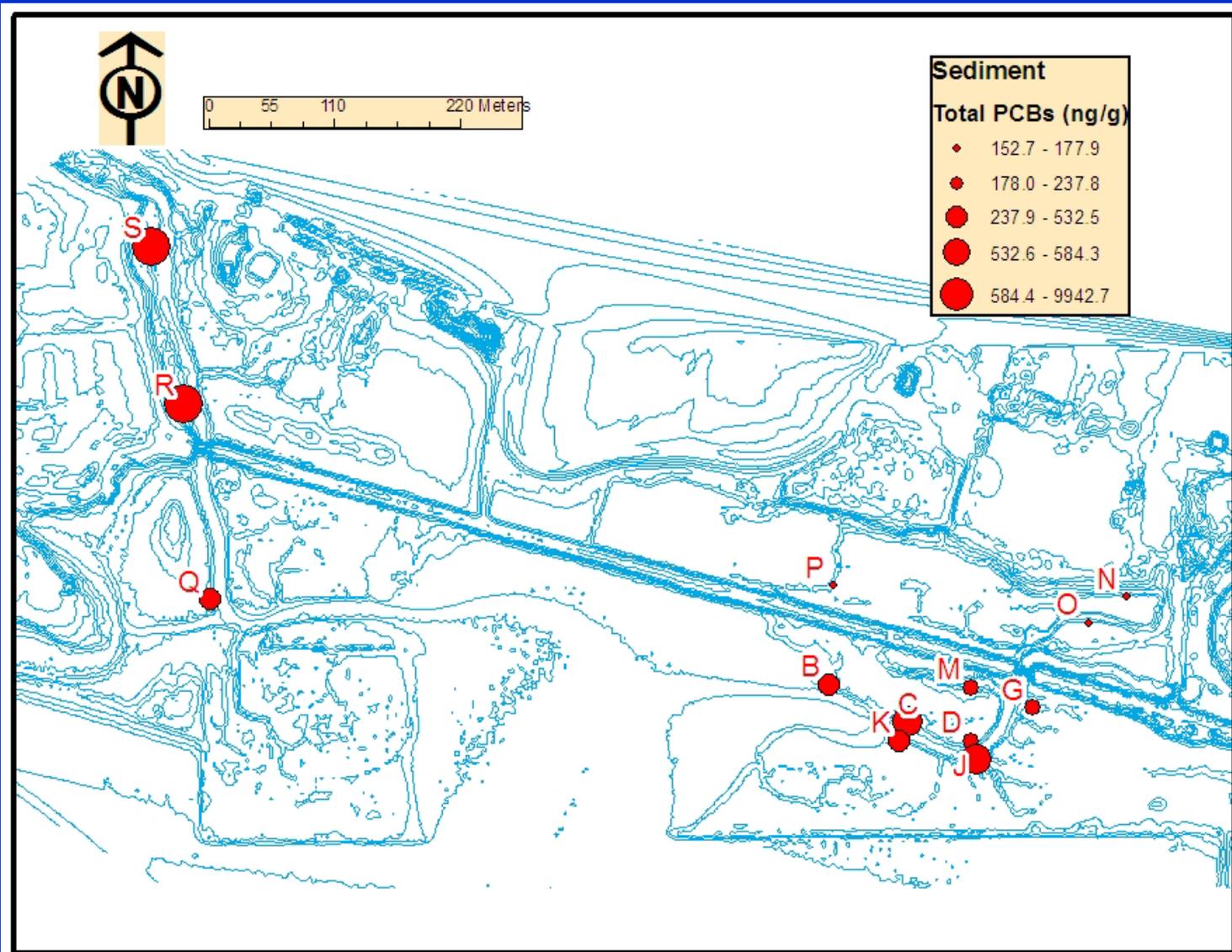
Comparison of Resident
Species Portfolios to
Sediment Quality Triad



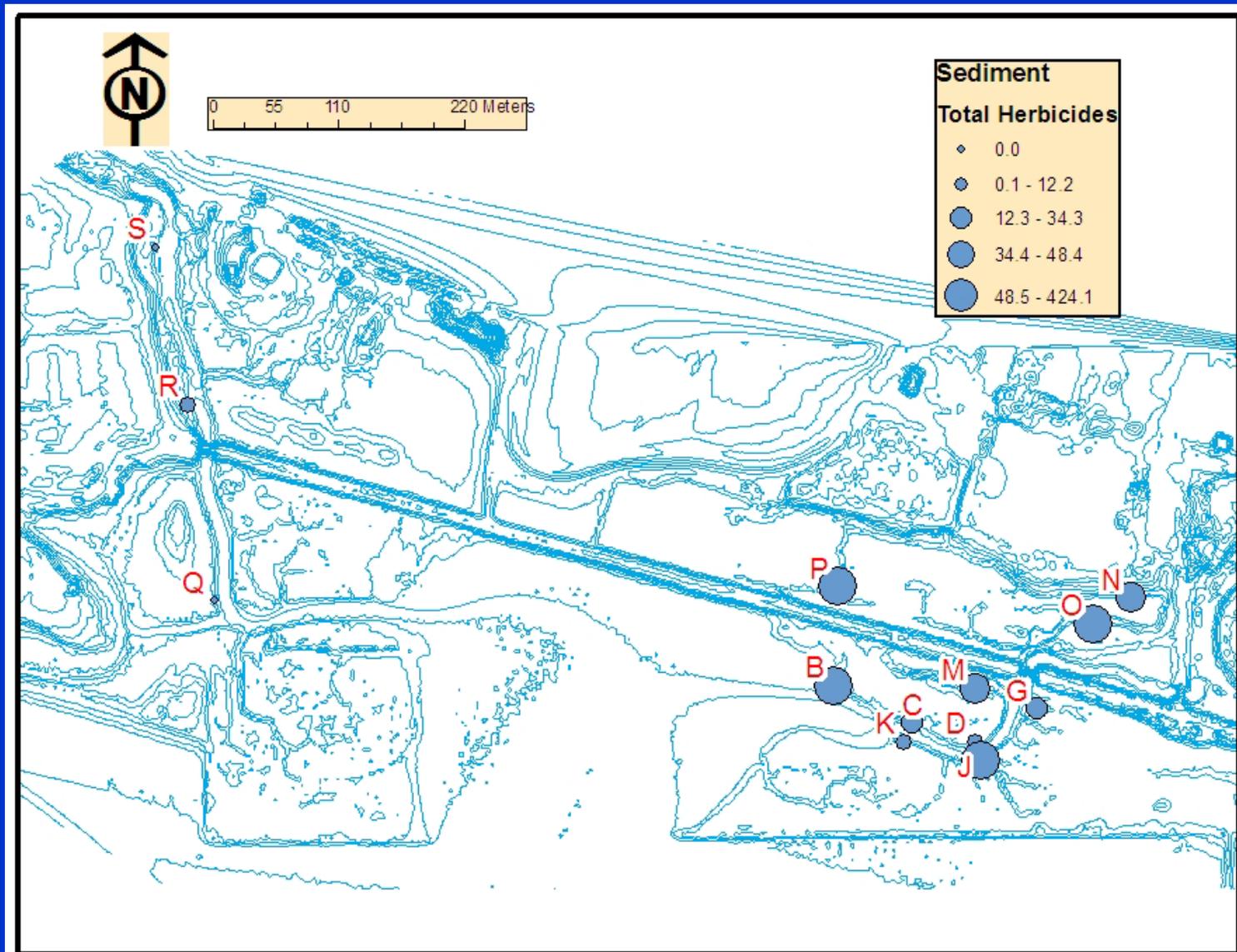
Question: Does an integrated suite of indicators of exposure, effect, and ecological response in wetland plants and animals add value to the currently available toxicity tests and chemical analysis techniques in assessing condition, diagnosing stressor-specific responses and planning restoration of salt marsh habitats

Relevant? Example of integrated approach for sentinel organisms

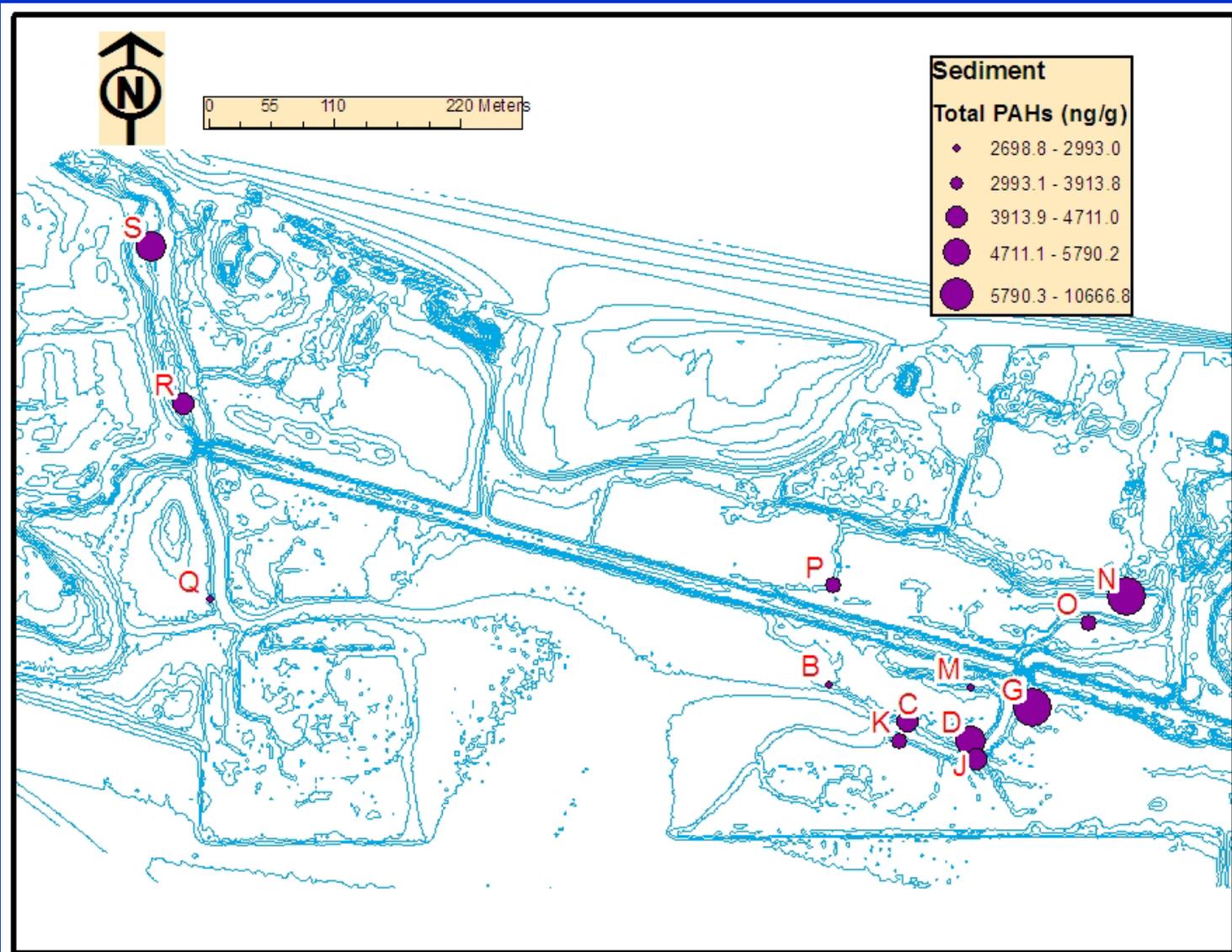
PROBLEMS WITH EXISTING TOOLS: CHEMISTRY - PCBs



PROBLEMS WITH EXISTING TOOLS: CHEMISTRY - HERBICIDES



PROBLEMS WITH EXISTING TOOLS: CHEMISTRY - PAHs



PROBLEMS WITH EXISTING TOOLS

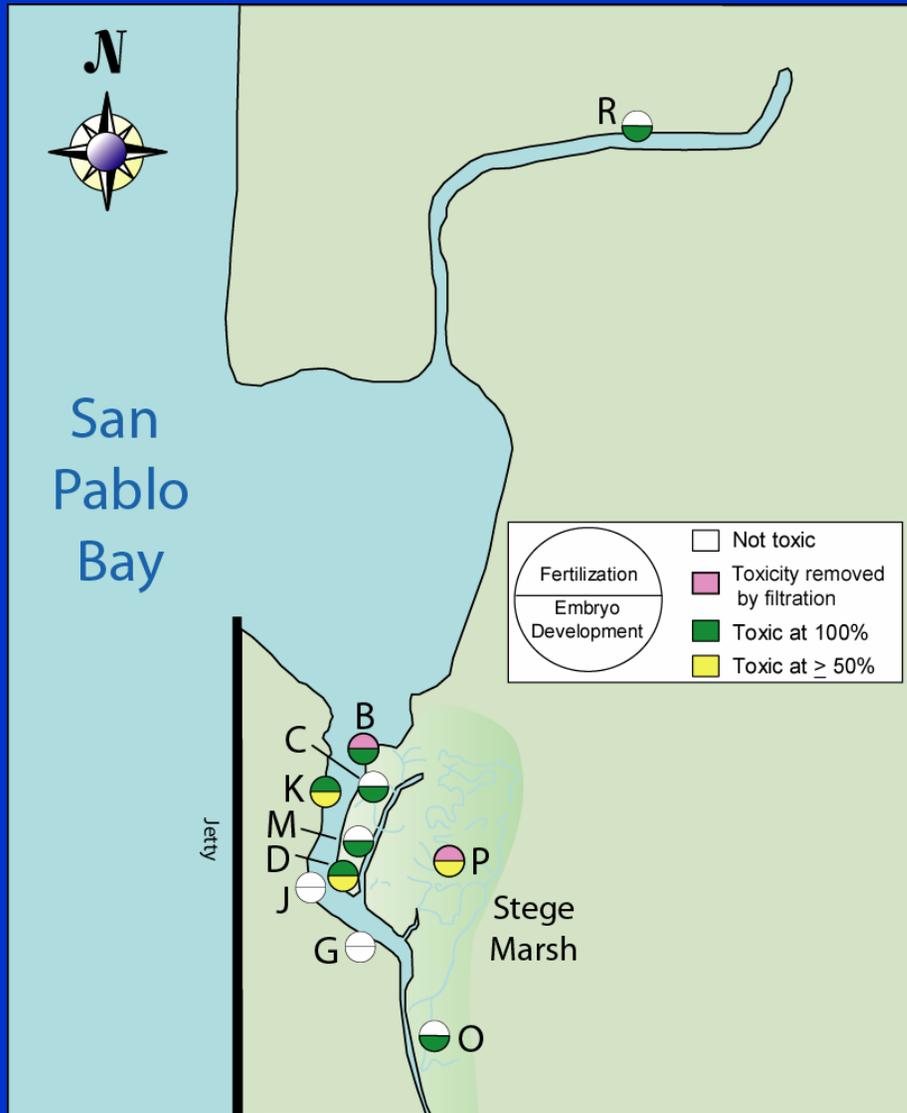


Figure 1. Sea urchin (*Arbacia punctulata*) fertilization and embryological development results for samples from Stege Marsh, near Richmond, California. Color differentiation of circle indicates level of toxicity.

Toxicity Data:

NH₃ interference
Varies with time
Varies by exposure
Extremely patchy
Not realistic for marshes

Chemistry Data:

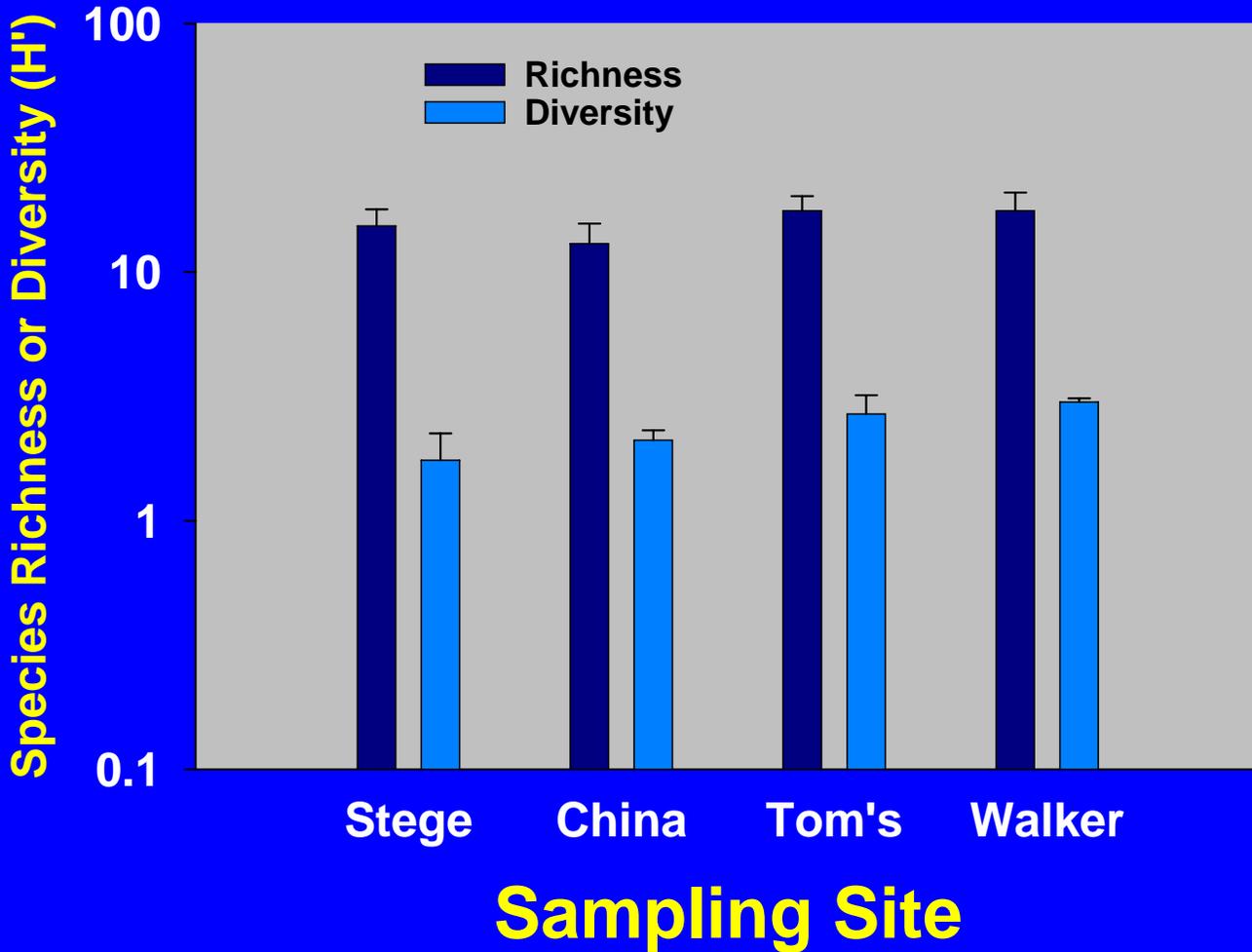
Characterizes metals/organics
Unknown compounds
Effects of mixtures unclear
Varies over time
Costly if done well

PROBLEMS WITH EXISTING TOOLS: BENTHIC INFAUNA

- ❖ Variation in species composition among sites and stations
- ❖ Variation in physical parameters among sites and stations
- ❖ Variation in marsh habitats: channel bottom/marsh plane
- ❖ Variation over time based on seasonal, annual changes
- ❖ Difficulty in establishing causal inferences

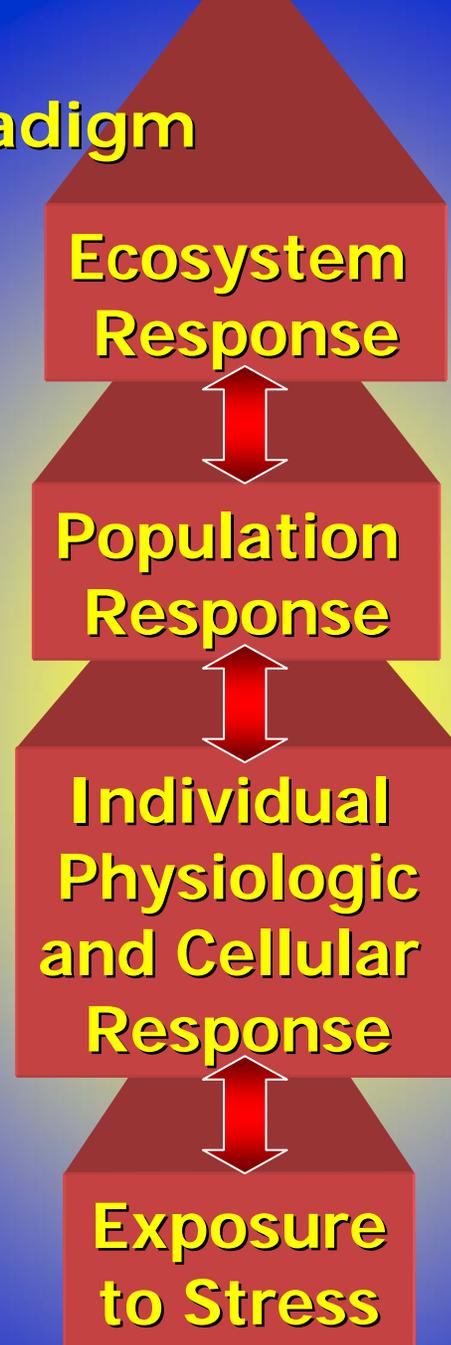


Invertebrate Species Richness and Diversity



Supplementing the Eco-Risk Paradigm

- ❖ Relevant responses without extrapolation
- ❖ Improved information richness
- ❖ Implementation in restoration feasible
- ❖ Truly diagnostic indicators
- ❖ Toxicological and Ecological responses linked
- ❖ Indicator organisms provide framework for scaling
- ❖ Potential utility for regulatory process being evaluated



Paradigm: An important way that ecologists and toxicologists relate is by characterizing dose response relationships then characterizing the composition of communities. This works for simple issues but not for multiple stressors.

PEEIR paradigm is to characterize responses of organisms and then ask why.

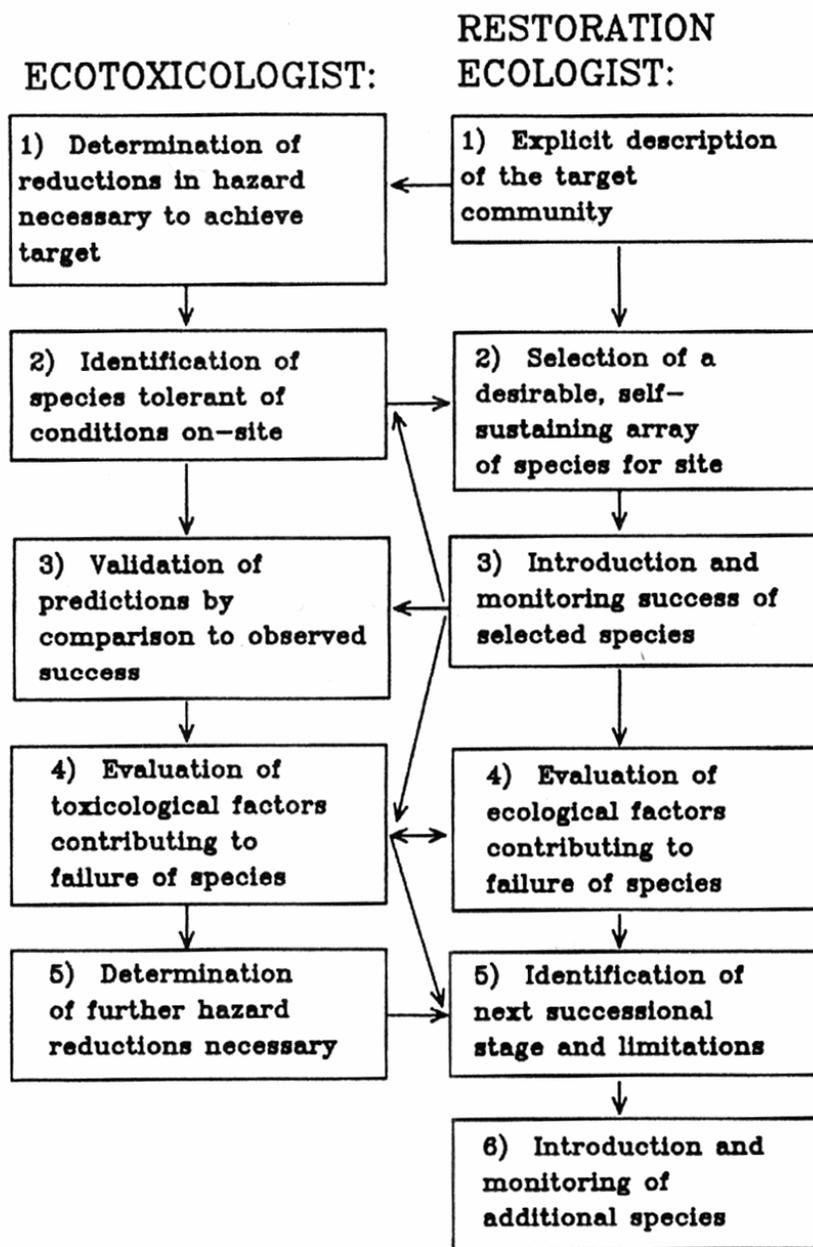


FIGURE 34.4. Interactions between restoration ecologists and ecotoxicologists charged with rehabilitating a hazardous waste site.



Innovative Approach to Coastal Condition Indicators

The Pacific Estuarine Ecosystem Indicator Research (PEEIR) group has developed a new generation of indicators to evaluate the condition of California's estuaries. We have also devised practical methods for their integration and application. An essential feature of the PEEIR approach has been to integrate a range of measurements within a suite of resident aquatic species. This approach was developed and tested in California's salt marshes, but it can be applied to other habitat types and geographic regions. These indicators are primarily applicable for management issues related to contaminant exposure, nutrient enrichment, and microbial contamination and are a useful complement to existing techniques in ecological risk assessment.

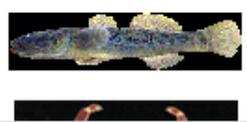
PEEIR Concept and Implementation

Click on these brochures to learn about the integrated PEEIR Approach and how it can be implemented

- ◆ Article or document
- ◆ Article or document
- ◆ Article or document

PEEIR Resident Species Indicators

Click on these images to learn about the integrated indicators developed for the selected salt marsh species



Indicator Interpretation and Policy

Click on these brochures to learn how selected PEEIR findings are interpreted and could influence policy and management

- ◆ Article or document
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PEEIR



Pacific Estuarine Ecosystem Indicator Research Consortium

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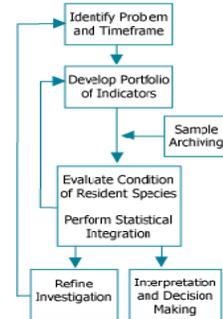


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PEEIR Process



Other PEEIR Accomplishments

- ◆ Article or document

A research partnership between University of California, Davis, Bodega Marine Laboratory and University of California, Santa Barbara

Funded by U.S. EPA Science To Achieve Results (STAR) EAGLE Program Grant No. R82867601





PEEIR



Pacific Estuarine Ecosystem Indicator Research Consortium

Utility of Nitrogen Isotope Measurements as an Indicator of Nutrient Enrichment in Coastal Marshes

Issue

Inputs of anthropogenic nitrogen and perennial freshwater runoff are high priority management concerns for many of the small salt marsh systems in central and southern California. Nutrients are typically monitored through point sampling in the water column; however, in tidal marshes, nutrient concentrations are variable in time and space and there is a need for a time-integrated "indicator" of anthropogenic nutrient inputs. Recent work suggests that stable isotope analysis may be useful in identifying anthropogenic nitrogen subsidies and freshwater inputs to estuarine and marine ecosystems. The overall objective of this study was to develop stable isotope analysis as one tool to indicate anthropogenic inputs into the small Mediterranean coastal wetlands of central and southern California.

Approach and Rationale

Our approach was to examine relationships between nitrogen (N) and carbon (C) isotope values in representatives of 3 trophic groups along presumed gradients of anthropogenic N and freshwater inputs in two salt marshes that differed in land use in the adjoining watershed. We also measured the turnover times of N and C in algal and animal tissues to provide information on the timeframe over which the isotopic signal integrates.



Figure 1. The (a) snail *Cerithidea californica*, and (b) crab *Pachygrapsus crassipes*, are potentially useful bioindicators of nutrient and freshwater inputs. Photo of *P. crassipes* courtesy of K. Lafferty.

Findings and Impact

- The snail, *Cerithidea californica*, and crab, *Pachygrapsus crassipes* (Fig. 1) were more useful as indicator taxa than the macroalga, *Enteromorpha*, because they were less ephemeral in occurrence and more widely distributed across a range of exposure to anthropogenic N and freshwater inputs.



A research partnership between University of California, Davis, Bodega Marine Laboratory and University of California, Santa Barbara
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Take Home Points

Contaminants cause harmful effects on fish and invertebrates

Need to monitor health of the organisms- presence not enough

New methods available to discern contaminant effects in saltmarshes

Methods using resident species are informative- integration

The methods can be used individually or packaged into portfolios

Portfolios vary with the type of problem

These approaches should be applied to wetland restoration/monitoring

Other applications include TMDLs and emerging contaminants

The approach is transferrable to other aquatic ecosystems

Partnerships and policy changes needed for full implementation

Clear goals and vision important to keep concepts alive-ask the fish!

Information from www.bml-ucdavis.ucdavis.edu/peeir/

Integrated science bridging ecology & toxicology is wave of the future

PEEIR Folks:

Susan Anderson, BML

Roger Nisbet, UCSB

Gary Cherr, BML

Stephen Morgan, BML

Bill Bennett, BML

Peter Green, UCD

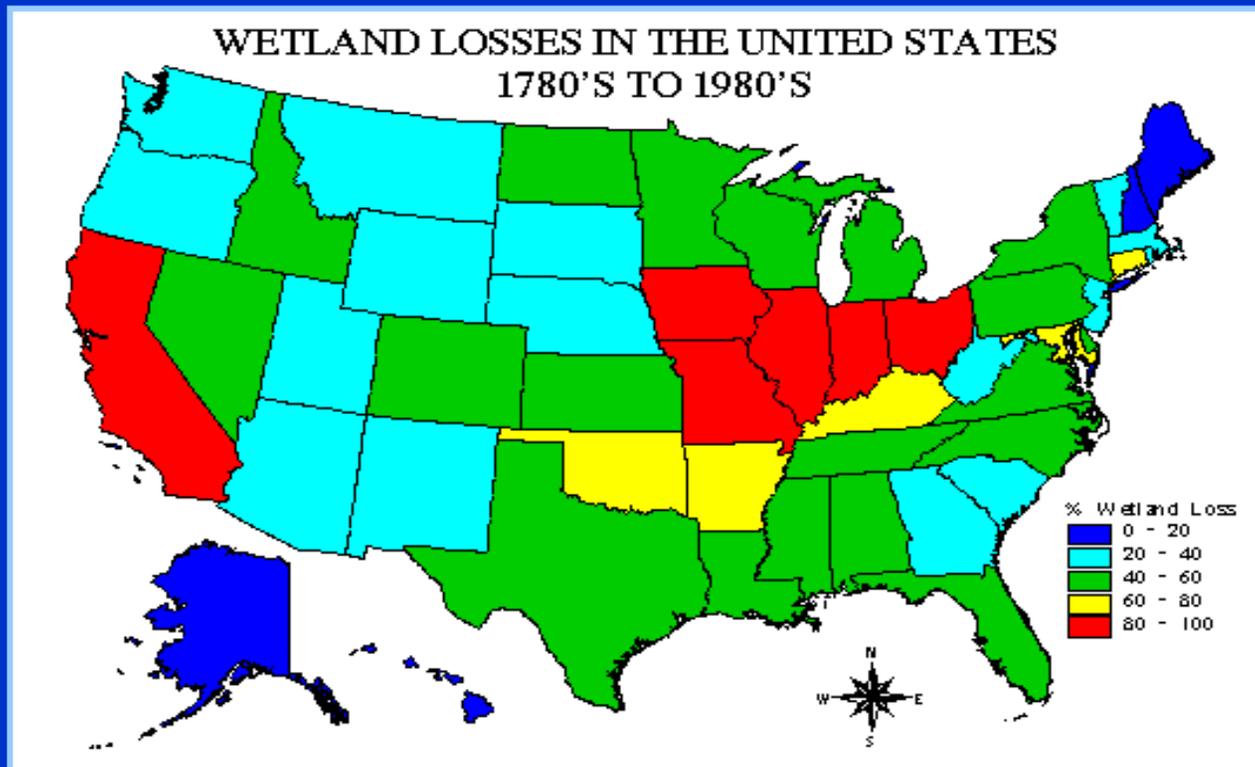
And many others!

Some Guiding Principles

- ❖ West coast estuaries provide a wide range of ecosystem services.
- ❖ West coast estuaries are heavily impacted by multiple stressors.
- ❖ Major concerns include population decline for many species, and loss of biodiversity. Managers need rapid, cheap, effective indicators that anticipate long-term population and community changes.
- ❖ The effects of stressors are typically characterized by effects on *individual organisms*. PEEIR is developing indicators that refine our ability to identify stressors, and characterize their effects on individual physiology.
- ❖ PEEIR aims to develop tools that will allow decisions relating to population and community phenomena to use these *physiologically-based indicators*. The aim is to identify, and test, the key steps connecting physiological responses to ecological processes.
- ❖ The *indicator species* are common organisms in many west coast marshes. Transferability of insight from the indicator species to others requires understanding the biological and ecological mechanisms that link the indicators to the processes of interest.

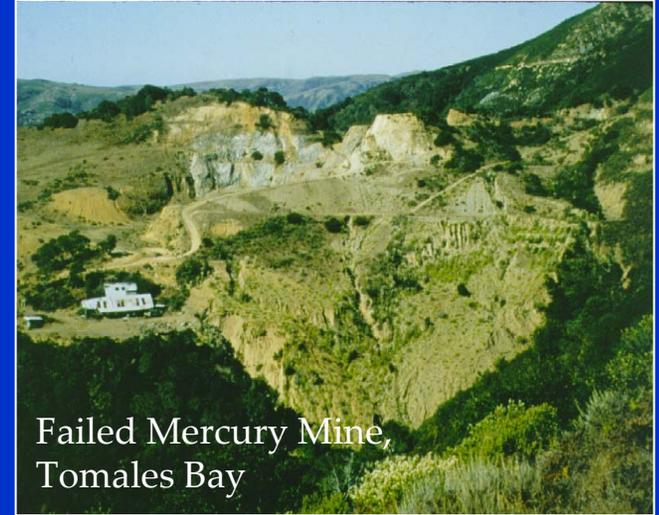
Goal and Scope

To develop indicators of salt marsh condition that can be used to diagnose the significance of specific causes of stress as well as to facilitate restoration and management.



Other Issues

- Wetland degradation
- Fish population declines
- Hg in Tomales Bay- health advisory
- Pathogens and beach closures
- Endocrine disruption
- Restoration activities
- Exotic species
- Pesticides & emerging contaminants



Abnormal fish larvae

