SFEI and SCCWRP Research to Support Nutrient Objectives: Existing Programs and Opportunities for Collaboration

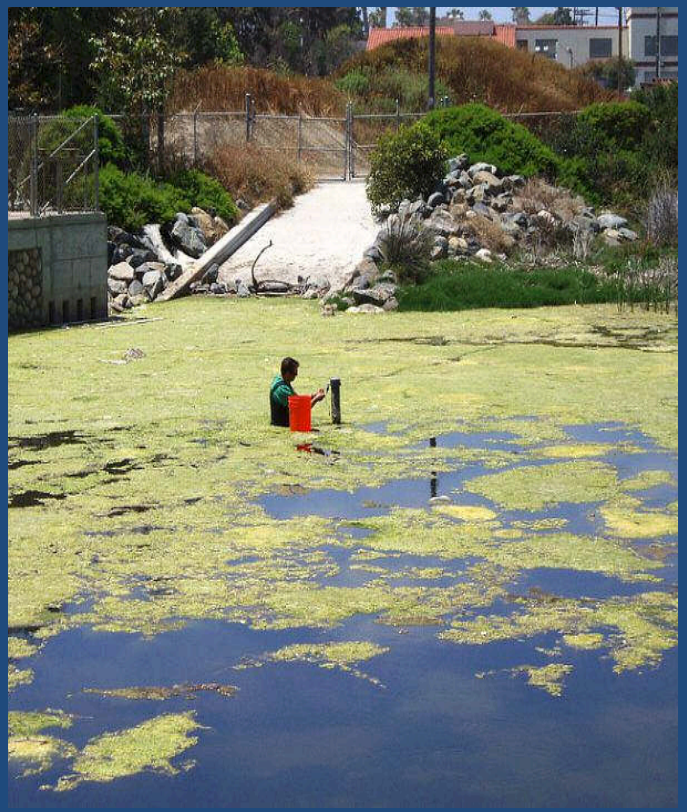
Joint CTG-TRC Meeting

March 28, 2012

Dave Senn (SFEI) and Martha Sutula (SCCWRP)

Approach to Setting Nutrient Objectives Distinct From That Used For Traditional Contaminants

- **Nutrients are required to support life**
  - How much is too much?
- **Toxicity rarely endpoint of interest**
  - Effects occur at much lower levels
- **Using ambient nutrients to diagnose effects can often give a false-negative or false-positive**
  - Need a different approach



EPA Guidance Suggests Three Basic Approaches to Nutrient Objectives

- **Reference**
  - e.g. 75th percentile of reference waterbodies
- **Empirical stress-response models**
  - Correlation between nutrient concentrations & response
- **Mechanistic cause-effect models**
  - Diagnosis is based on response
  - Use model to link back to nutrient loads

SWRCB Staff Favoring Cause-Effect Approach

- **Narrative objective, with numeric guidance**
  - Guidance coined as " Nutrient Numeric Endpoint or NNE"
- **Diagnosis based on response indicators = NNE assessment framework**
  - Assessing eutrophication et al. adverse effects of nutrients
  - Multiple lines of evidence for more robust diagnosis
- **Use of ranges to accommodate uncertainty in science**
- **Models to link response indicators to nutrients et al. factors (e.g. hydrology,, etc.)= NNE load-response models**
  - Nutrient loads rather than ambient concentration

Common Research Program Elements to Support Nutrient Management

- **Science to support nutrient objectives**
  - NNE Assessment Frameworks
- **Assessing extent and magnitude of effects**
  - Regional monitoring
- **Linking effects to nutrients et al. management controls**
  - Numerical modeling and mechanistic studies
- **Quantifying loads and relative contribution of sources**

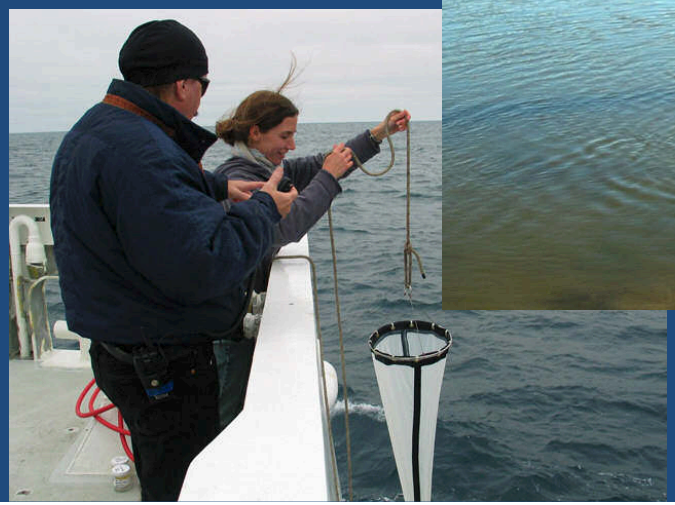
Overview of Joint SCCWRP-SFEI Presentation

- **Comparative presentation on research on common program elements**
  - SCCWRP
  - SFEI
- **Opportunities for leveraging and enhancing collaboration**
  - Roundtable discussion

SCCWRP Research to Support Nutrient Management

Focus of research varies by water body type:

- Streams
- Estuaries
- Marine



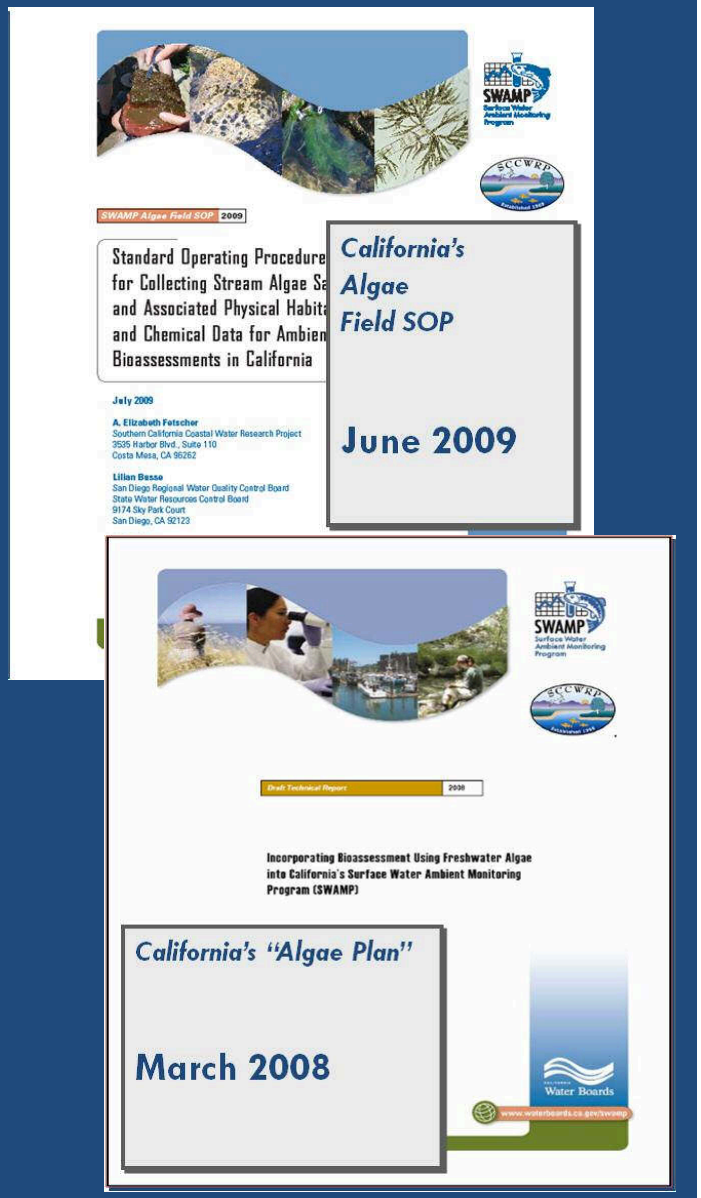
SCCWRP Research to Support Nutrient Management

Focus of research varies by waterbody type:

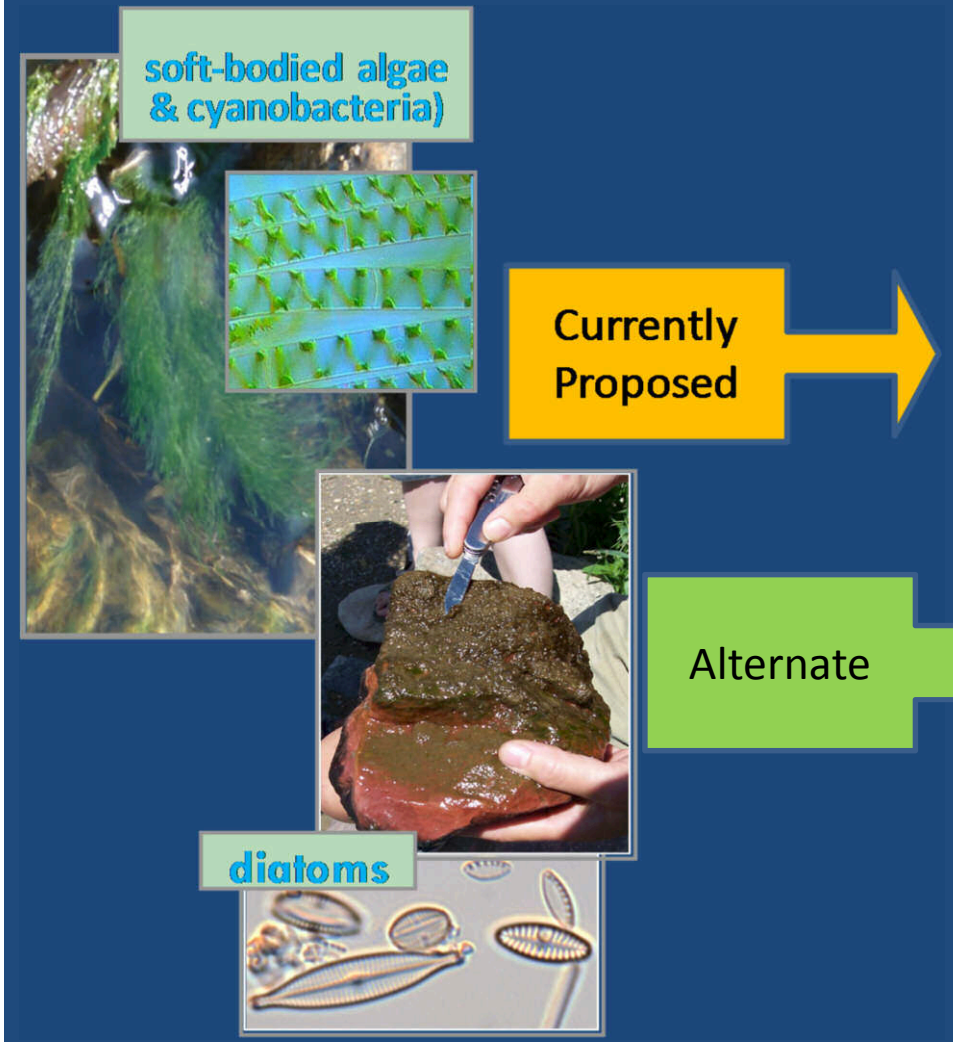
- **Streams**
  - Standard protocols
  - Next generation indicators
  - Extent and magnitude of eutrophication
  - Linkage of algae to aquatic life use
  - Nutrient load-response models
- **Estuarine**
- **Marine**

Stream Algal Sampling Protocols

- **Standard sampling protocols and training**
  - Adopted by SWAMP and SMC
  - Consistent throughout the state
- **Consistent use provides data to**
  - Develop assessment protocols
  - Refine NNE thresholds
  - Build load-response model
  - Investigate alternative indicators



Algal Protocol Includes Next Generation Indicators for Stream Nutrient Objectives



***SWAMP Algal Protocol Includes*:**

Abundance ("quantity")

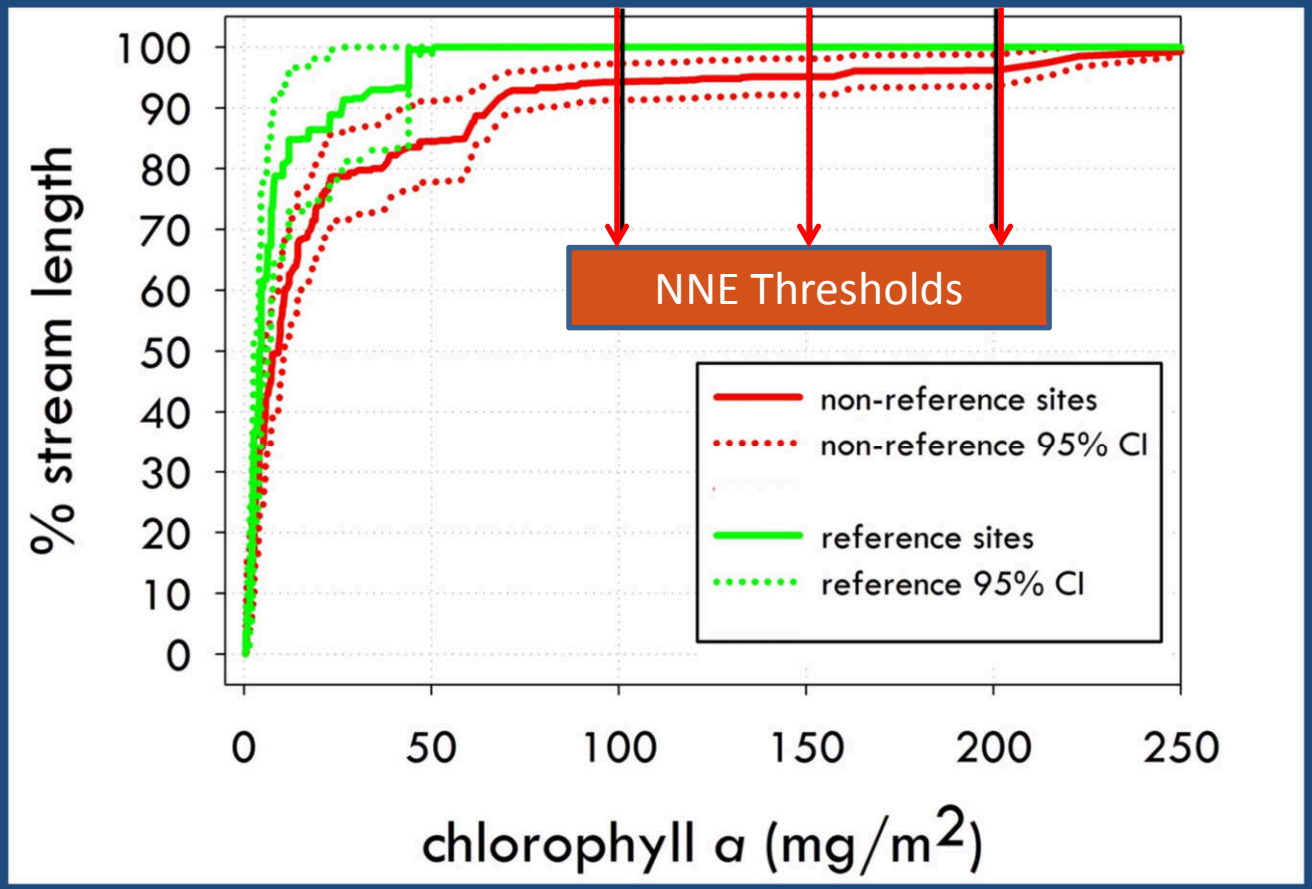
- Biomass (chlorophyll a)
- ash-free dry mass
- algal cover
- algal biovolume

Taxonomic composition

- diatoms
- soft-bodied algae

Magnitude and Extent of Eutrophication

For first time, regional and statewide estimates of % of streams miles adversely effected by stream algal overabundance

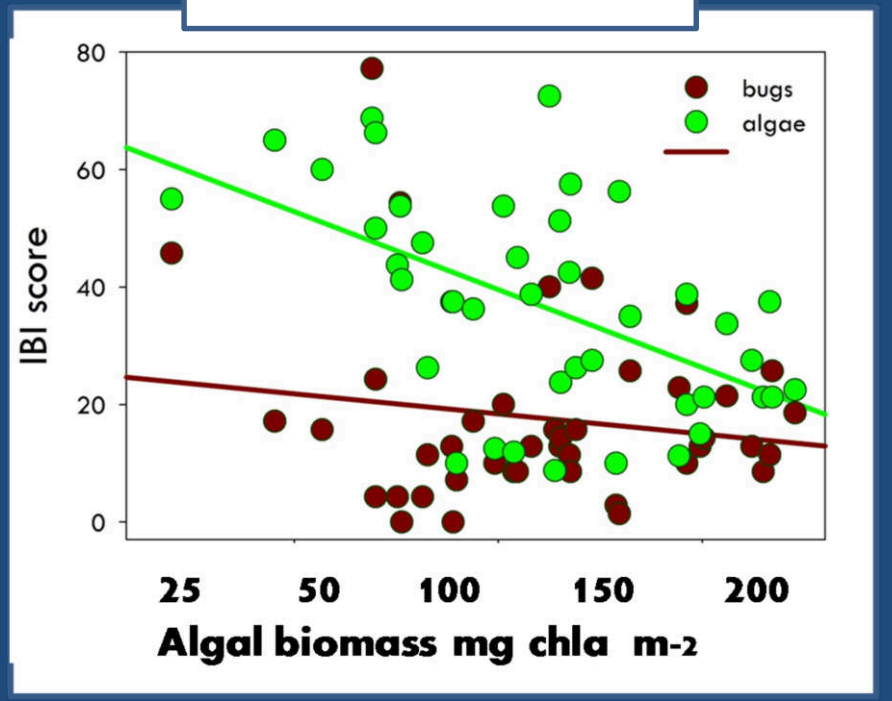


Fetscher et al., unpublished

Are NNE Algal Biomass Thresholds Appropriate? Exploring Links Between Nutrients, Algae, & ALU?

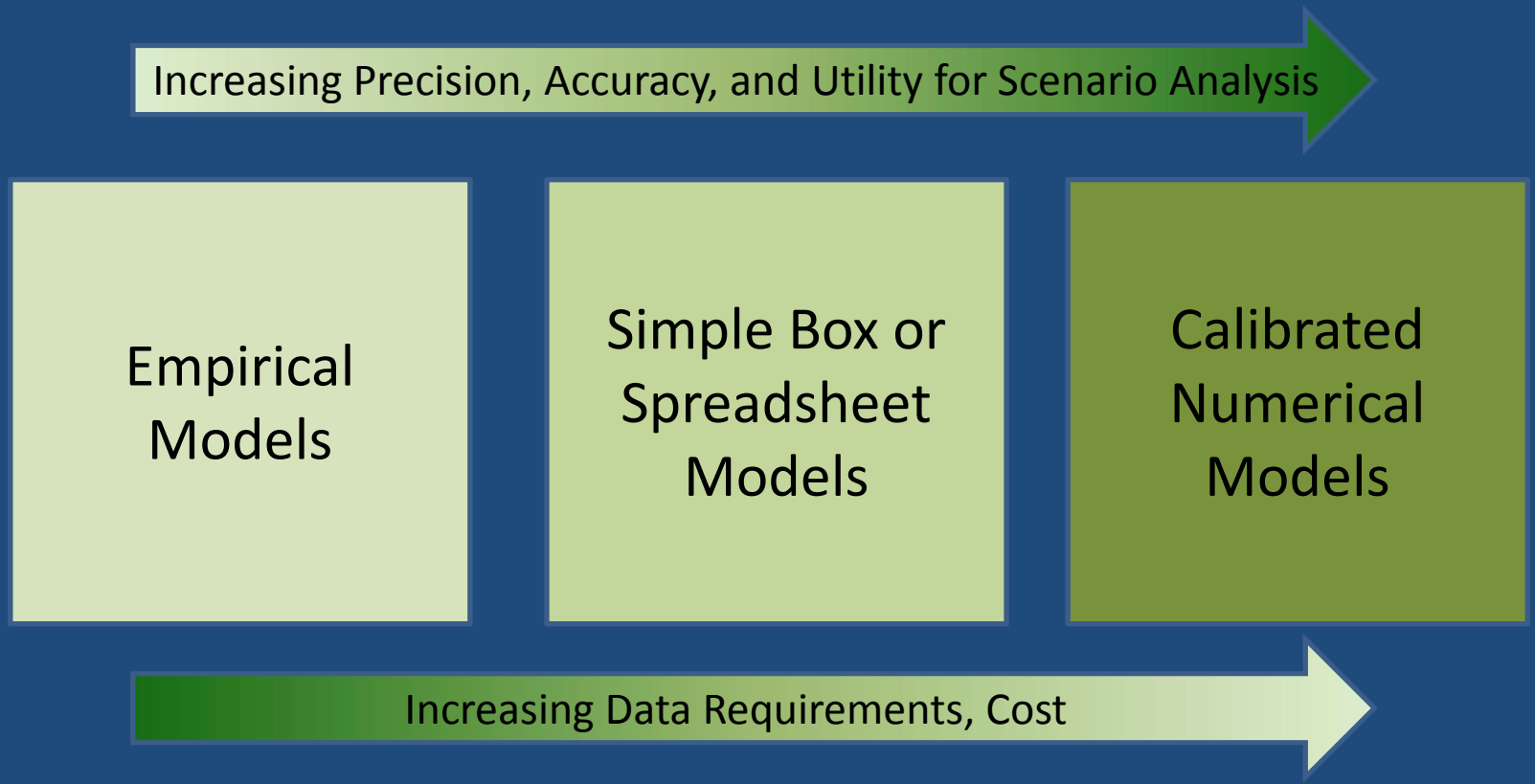
- How much algae is too much?
- NNE algal biomass thresholds developed through best professional judgment
- Does a dose-response relationship exists between nutrients, algal biomass and algal or invertebrate IBIs?

Sample Graphic



Load-Response Models

- **Regulatory approach requires models to convert response thresholds into nutrient goals**
  - —Key to how we manage the problem



Stream Nutrient Load-Response Models

- **SWRCB is offering spreadsheet models**
  - Account for factors that modify response to nutrients
  - Models have not been validated
  - Initial screening – defer to more complete modeling studies
- **SCCWRP focused on building/refining models across spectrum of empirical → spreadsheet→ calibrated numerical**
  - Validating spreadsheet model, identifying sources of error, regional optimization
  - Developing calibrated numeric models with mechanistic studies to quantify key processes

SCCWRP Research to Support Nutrient Objectives

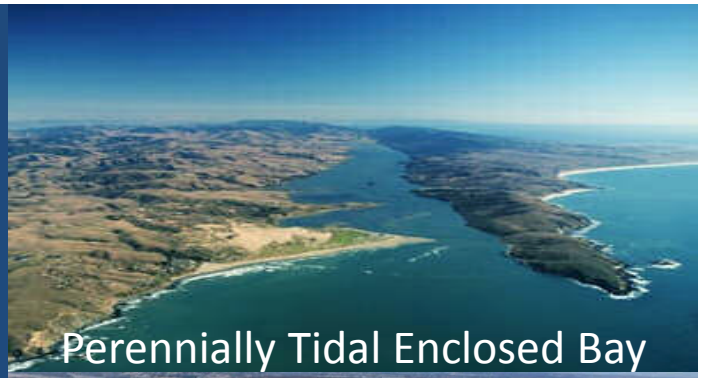
Focus of research varies by waterbody type:

- **Streams**
- **Estuaries- SWRCB Technical Lead**
  - Science to support selection of indicators and thresholds
  - Quantifying nutrient loads
  - Extent of eutrophication
  - Load-response models
- **Marine**

Diversity of California Estuaries

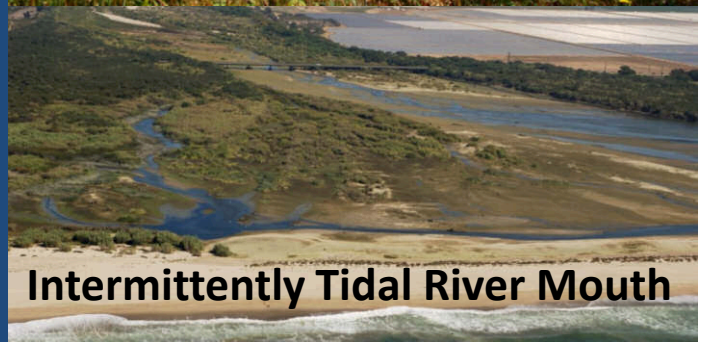
Geoform	Tidal Regime	No.
Enclosed Bay	Perennial	30
Lagoon	Perennial	15
	Intermittent	33
	Ephemeral	46
River mouth	Perennial	11
	Intermittent	270
Total		405

Bar-Built Estuaries


Perennially Tidal Enclosed Bay

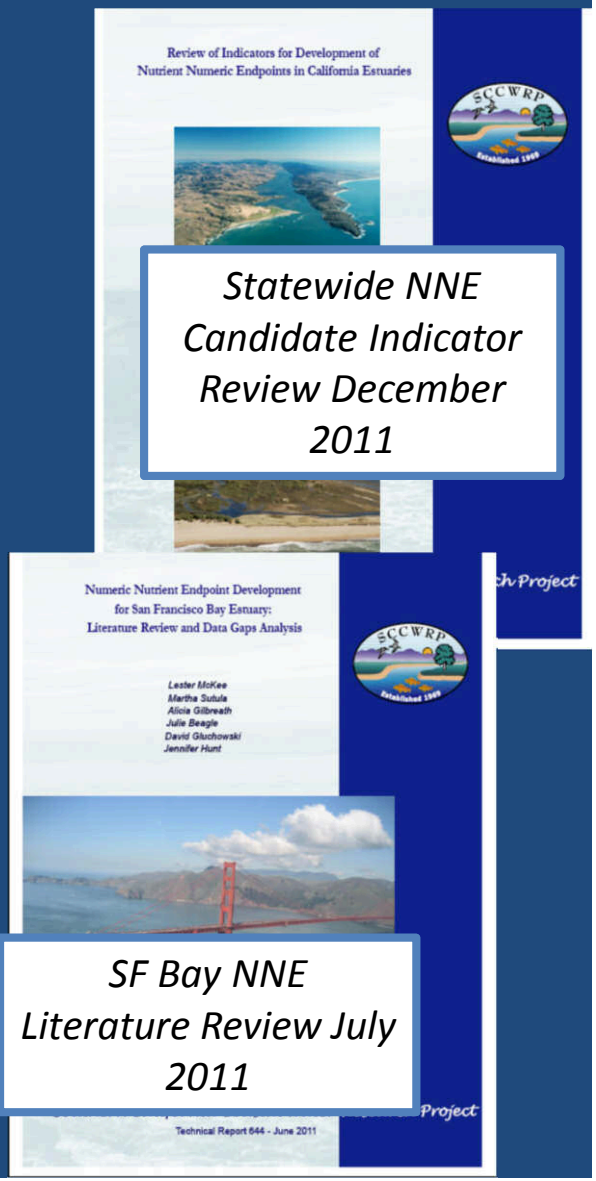

Intermittently Tidal Lagoon


Ephemerally Tidal Lagoon


Intermittently Tidal River Mouth

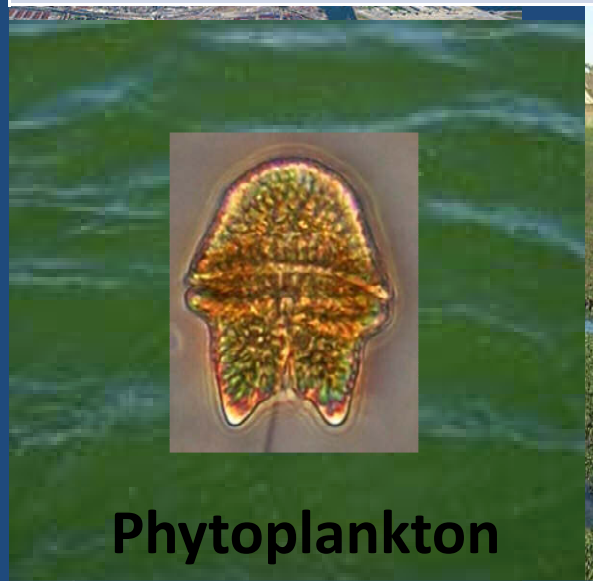
Evaluation of Candidate Response Indicators

- **Evaluated candidate indicators vis-à-vis review criteria**
  - Clear link to beneficial uses
  - Can build model to link to nutrients
  - Scientifically sound & practical measure
  - Reliably use to diagnose eutrophication (signal: noise acceptable)
- **Reviewed studies to establish thresholds**
  - Identifies data gaps and next steps



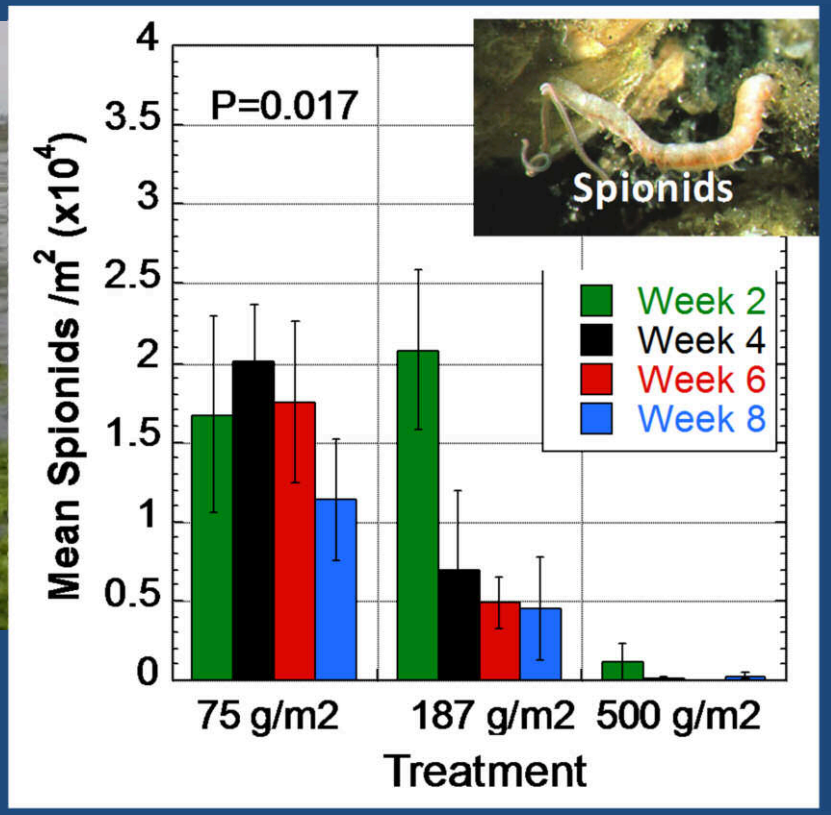
Recommended Indicators

All Subtidal	Intertidal Flats and Shallow Subtidal	Seagrass
Dissolved oxygen Phytoplankton Biomass and Assemblage HAB cell counts & toxin conc. -- Cyanobacteria	Macroalgal biomass/cover	Phytoplankton Biomass Macroalgal Biomass and Cover Light attenuation Epiphyte load



Science to Support Selection of Response Indicator Thresholds: Example of Macroalgae

Caging Studies to Document Dose-Response of Macroalgae on Benthic Infauna

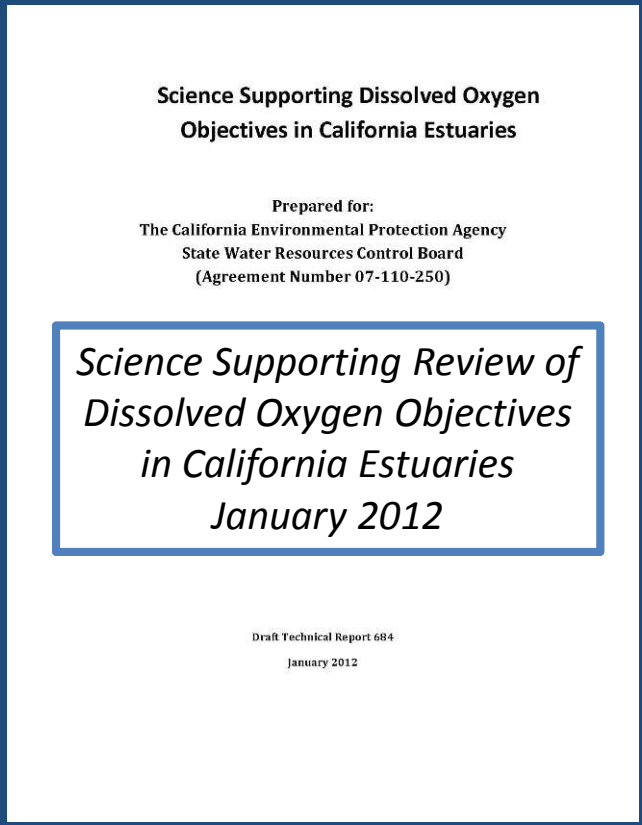


Green et al. (submitted)

Experimental Data Show High Macroalgal Biomass Causes Declines in Benthic Infauna

Synthesis of Science: Review of Science Support Estuarine Dissolved Oxygen Objectives

- **Reviewed basis for deriving DO criteria, utilizing the Virginia Province Approach**
  - Use of fish and invertebrate indicator species linked to beneficial uses
  - Calculation of acute and chronic thresholds based on available data on species



Science Supporting Dissolved Oxygen Objectives in California Estuaries

Prepared for:
The California Environmental Protection Agency
State Water Resources Control Board
(Agreement Number 07-110-250)

Science Supporting Review of Dissolved Oxygen Objectives in California Estuaries January 2012

Draft Technical Report 684
January 2012

Update to Estuarine NNE Science Strategy in Spring 2012

- **Lay out broad vision for assessment framework over 4 yrs**
  - Highlight data gap and identifies studies to support framework development
  - Agree on schedule for assessment framework elements
- **Propose approach for load-response modeling**
- **Specifically identifies SF Bay & Delta tidal freshwater habitat, but these components will be addressed in separate plans**
  - SF Bay Nutrient Strategy (Region 2)
  - Science Plan to Support Nutrient Objectives (Region 5)

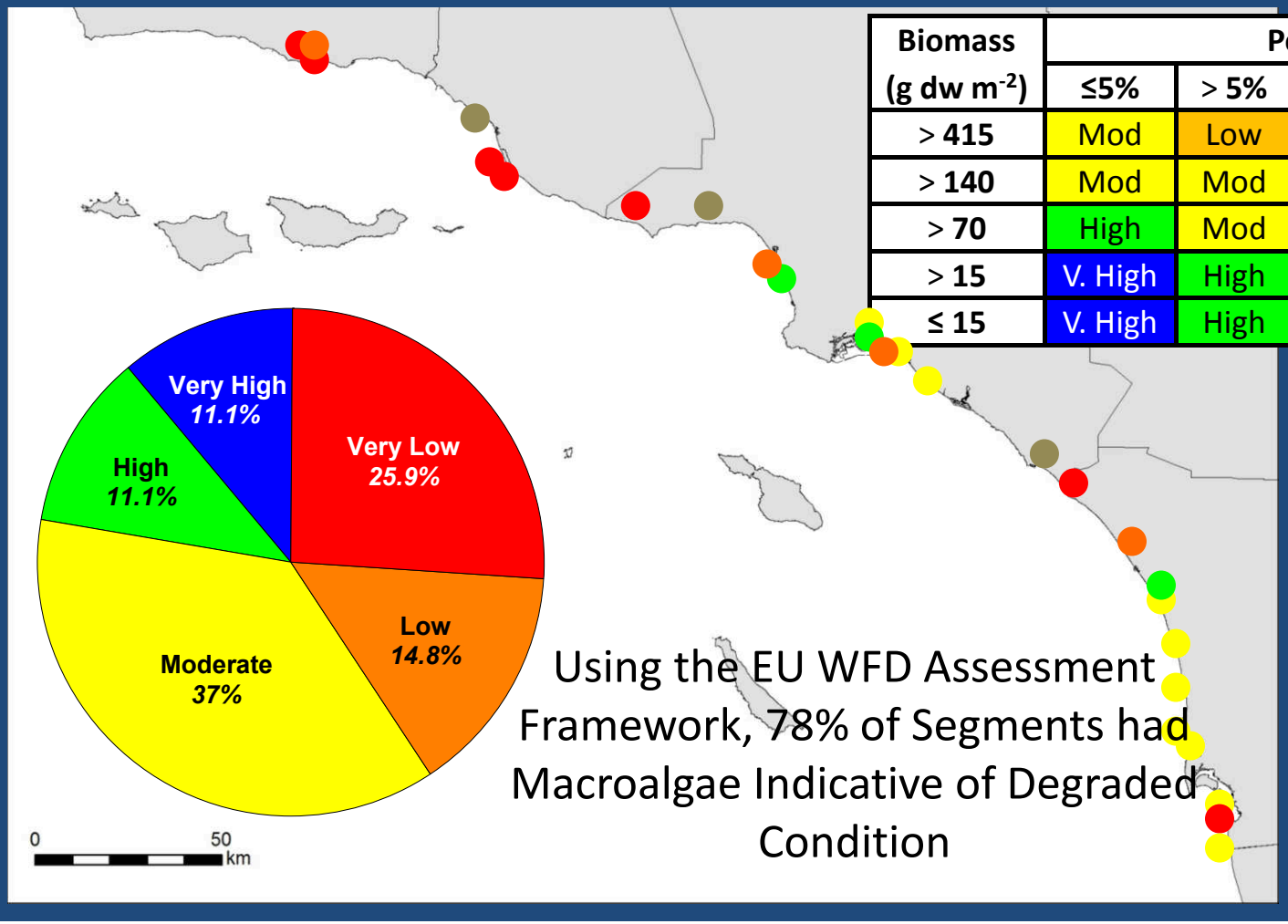
So. Calif. Bight '08 Eutrophication Assessment

- **Eutrophication Assessment collected data on 25 estuaries (27 sites) over a one year period**
- **Major objectives**
  - Estimate magnitude and extent of eutrophication in Bight estuaries
  - Explore the linkage between nutrient loads and ecological response
- **Indicators**
  - Primary producers: Phytoplankton, macroalgae, submerged aquatic vegetation
  - Continuous dissolved oxygen, chlorophyll a fluor., etc.
  - Riverine total nitrogen and phosphorus loads

One Study: Multiple Benefits

- Develop standardized methods
- Pilot approaches for NNE assessment frameworks

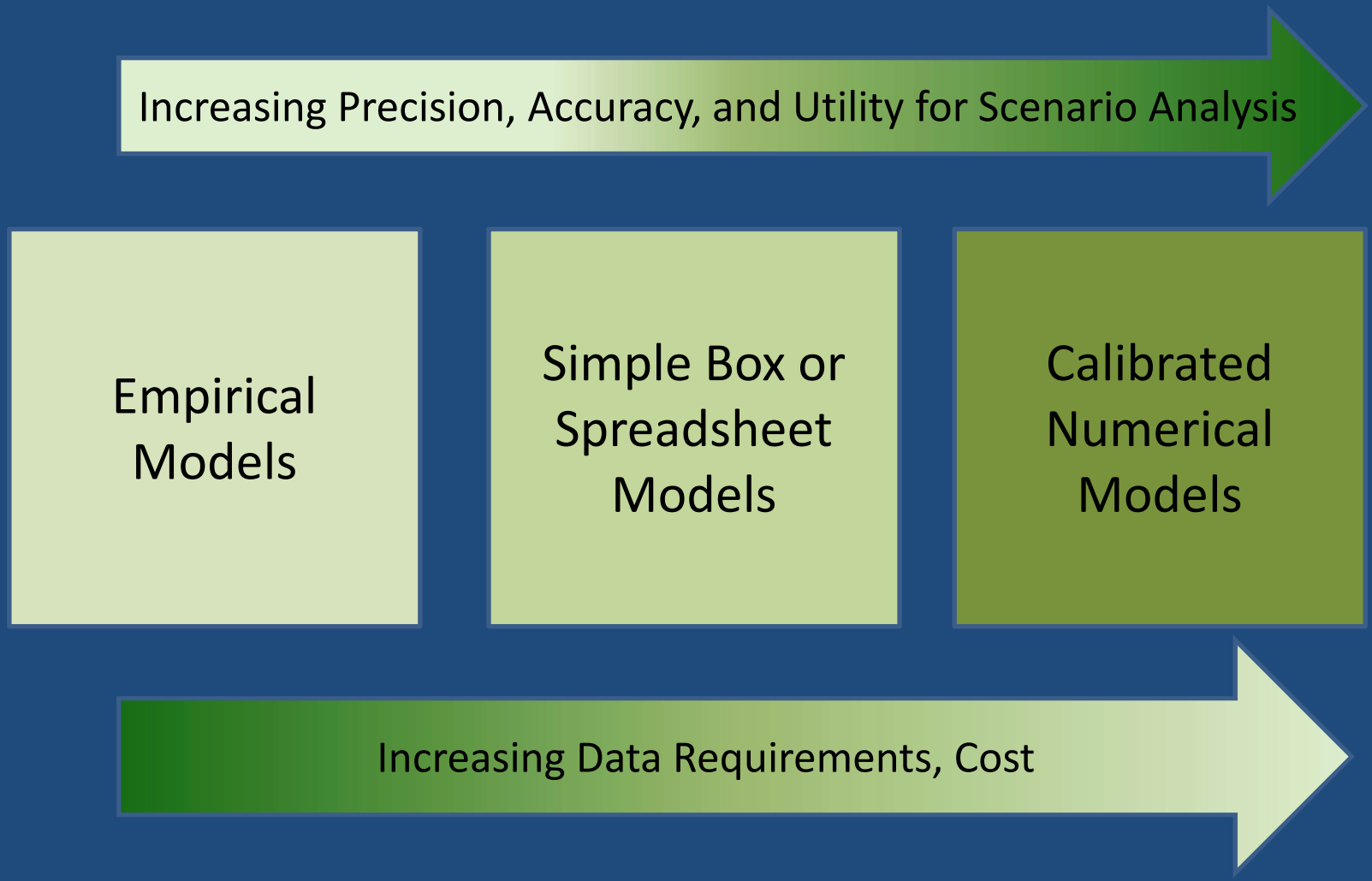
Biomass ($g\ dw\ m^{-2}$)	Percent Cover				
	≤5%	> 5%	> 15%	> 25%	> 75%
> 415	Mod	Low	V. Low	V. Low	V. Low
> 140	Mod	Mod	Low	V. Low	V. Low
> 70	High	Mod	Mod	Low	Low
> 15	V. High	High	High	Mod	Low
≤ 15	V. High	High	High	Mod	Mod



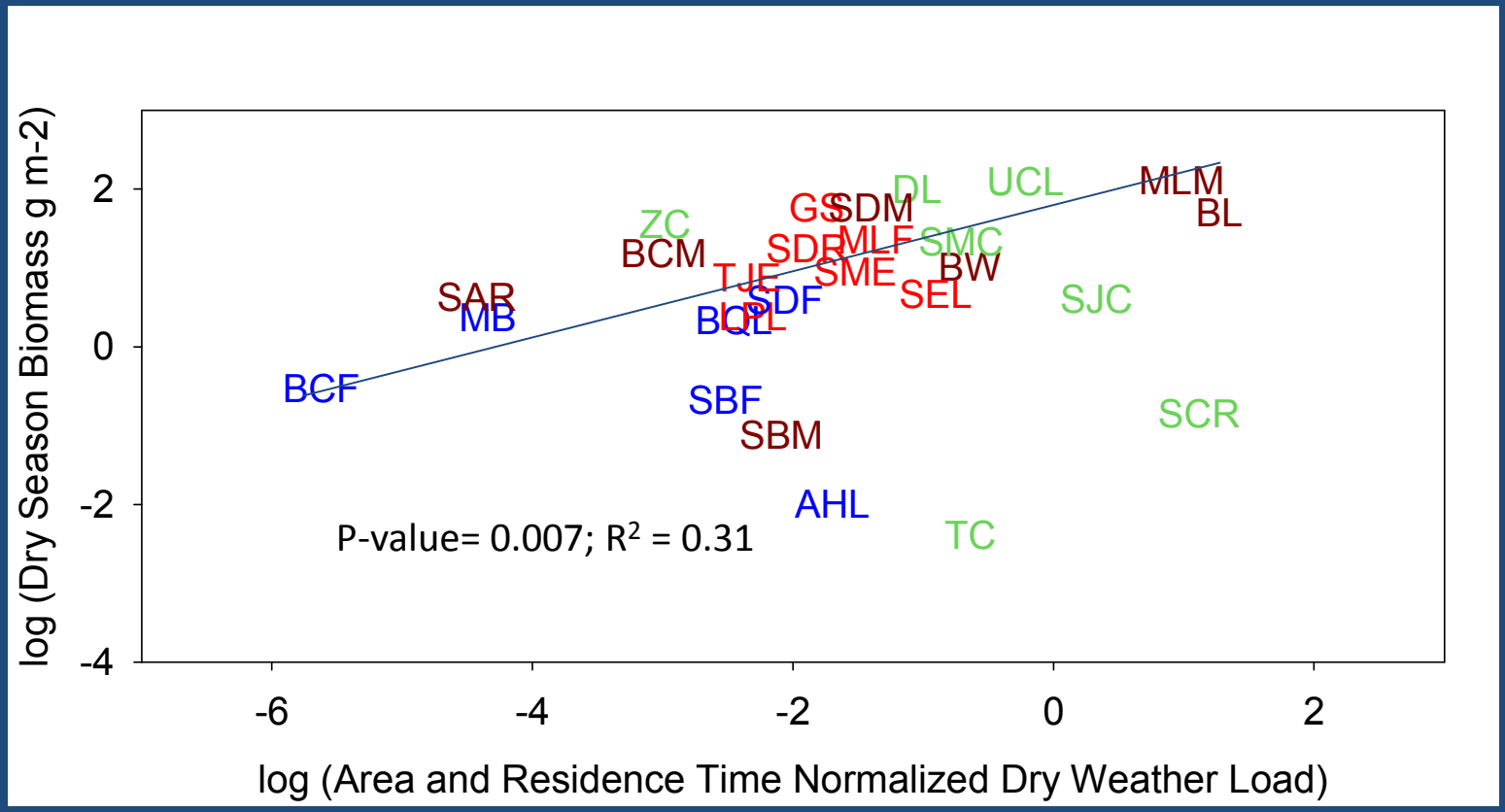
Using the EU WFD Assessment Framework, 78% of Segments had Macroalgae Indicative of Degraded Condition

Ecological Condition Scales
Very High
High
Moderate
Low
Very Low

Load-Response Models



Significant Relationship, But Poor Precision, Between Nitrogen Load and Macroalgal Biomass in 25 Bight Estuaries



Relationship Between Cover Normalized Dry Season Macroalgae Biomass & Area + Residence Time Normalized Dry Weather TN Load

Mechanistic Studies Have Focused On Role of Sediment Nutrient Cycling on Estuary Nutrient Mass Balance

- Benthic flux estimates to estimate net nutrient contribution to surface waters
  - Sediment pore water studies
  - Factors controlling magnitude of exchange
- Rates of macroalgal uptake and release
- Denitrification and nitrogen fixation
- Stable isotopes to identify sources and characterize cycling

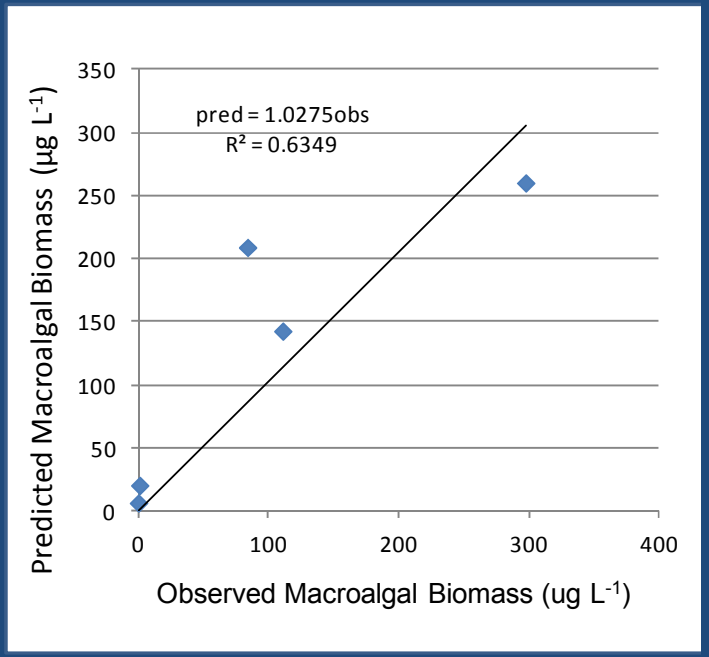
River Mouth Estuaries Are Less Susceptible to Eutrophication Than Lagoons

Fluvial ⟷ Lagoonal

	Fluvial	Lagoonal
Hydrology	Higher water velocity	Lower water velocities
Physical Habitat	Sandy sediments	Fine grained sediments
Biogeochemistry	Low sediment OC & oxygen demand, low algal biomass	High sediment OC & oxygen demand, high algal biomass

Developing Expertise in Calibrated Numeric Models of Nutrient Load-Macroalgal Response

- Algal response models are focused on phytoplankton or stream benthic algae
- Little collective expertise for how to model macroalgae
- Mechanistic studies to improve how we parameterize models
- Some changes in basic code required
  - Collaboration with EPA ORD



Results of dry season validation of EFDC+ WASP 7.0 water quality model in Loma Alta Slough
Wang and Sutula (in prep)

Mechanistic Studies Have Focused On Role of Sediment Nutrient Cycling on Estuary Nutrient Mass Balance

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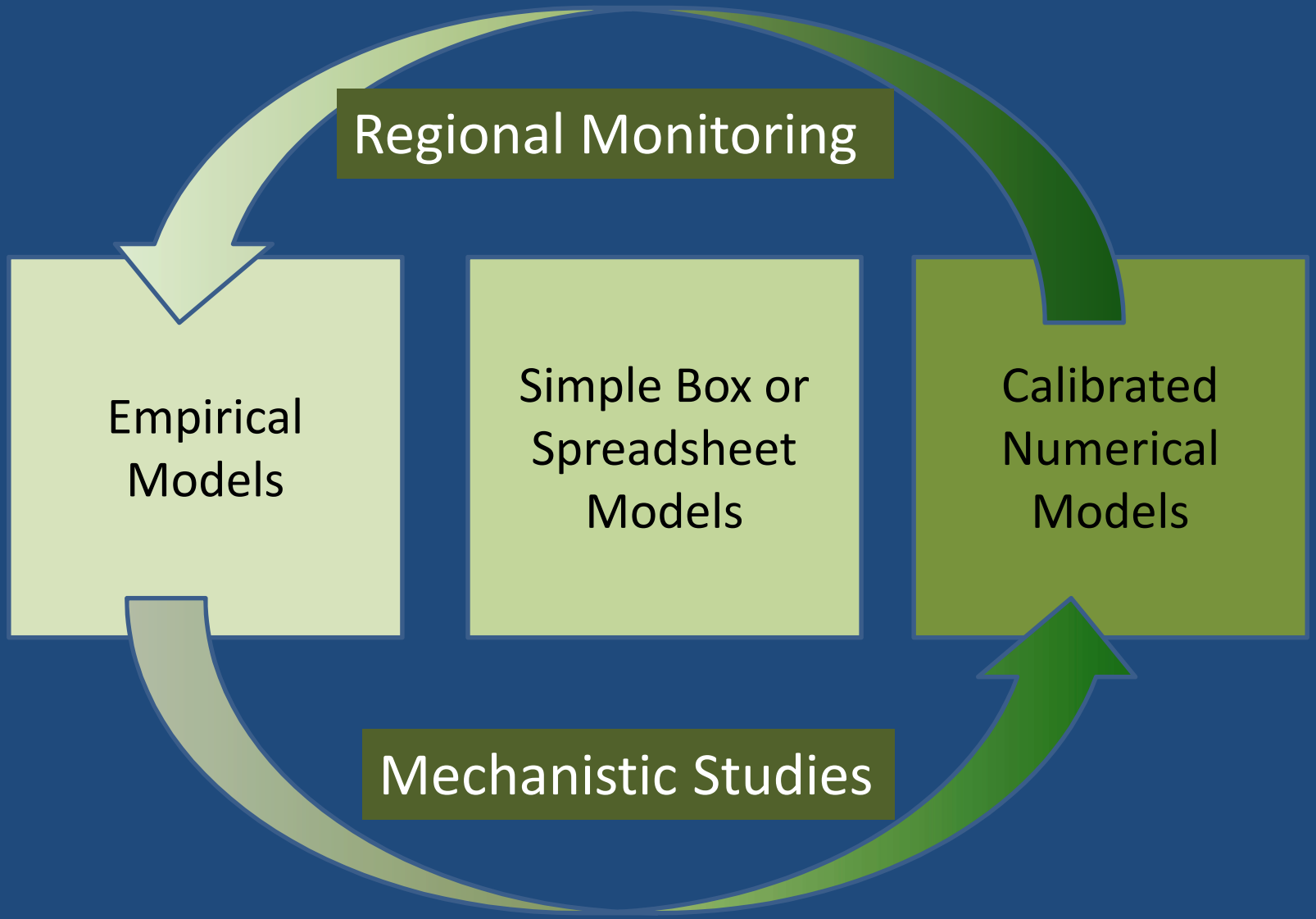
Work on Calibrated Numeric Models Helps to Clarify Validity of Assumptions for Simpler Models



SCCWRP Research to Support Nutrient Objectives

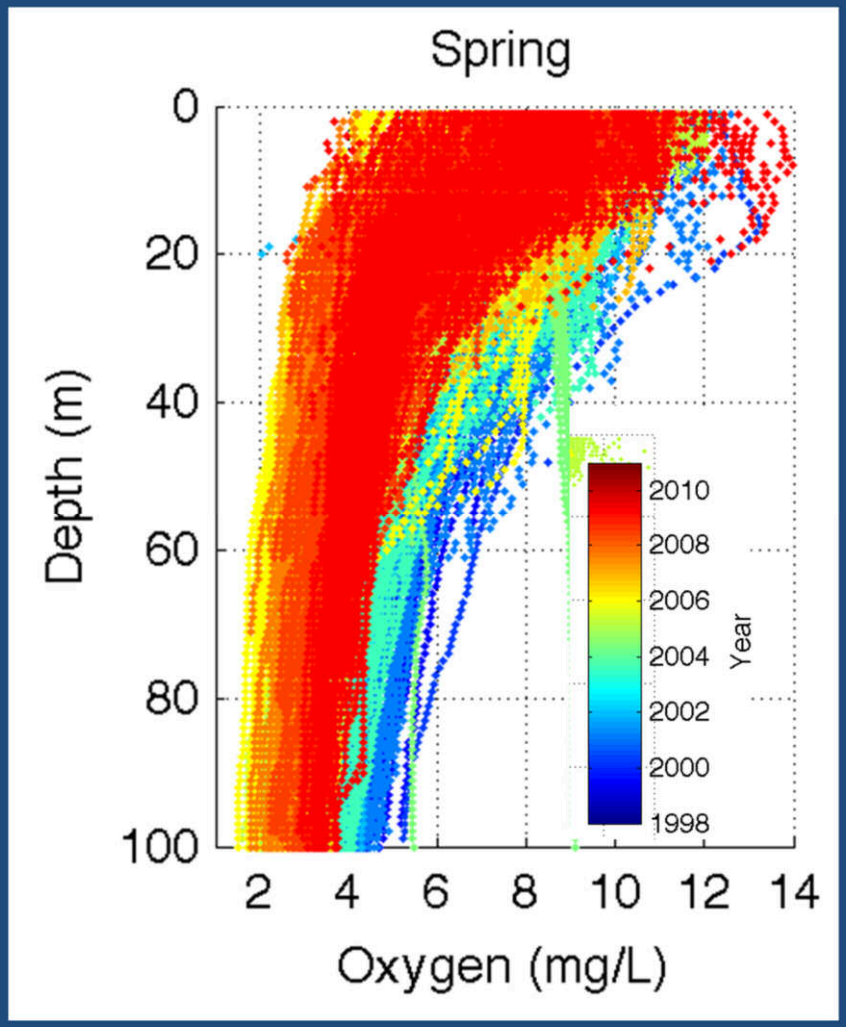
Focus of research varies by waterbody type:

- **Streams**
- **Estuarine**
- **Marine**
  - Defining the problem and assessing magnitude and extent
  - Quantifying nutrient loads
  - Load-response models

SCCWRP Part of a Multi-disciplinary Team Studying Effects of Nutrients on Nearshore Habitat

- **Multiple programs and projects**
- **Interdisciplinary**
  - Physical, biological and chemical oceanographers
  - Fish and invertebrate ecologists and physiologists
  - Numerical modelers
  - Remote sensing
- **Multi-institutional**
  - Universities (USC, UCLA, UCSC, Stanford, Naval Postgraduate School, Moss Landing Marine Labs)
  - SCCWRP Commission agencies
  - Center for Ocean Solutions
  - MBARI
  - NOAA Fisheries
  - JPL

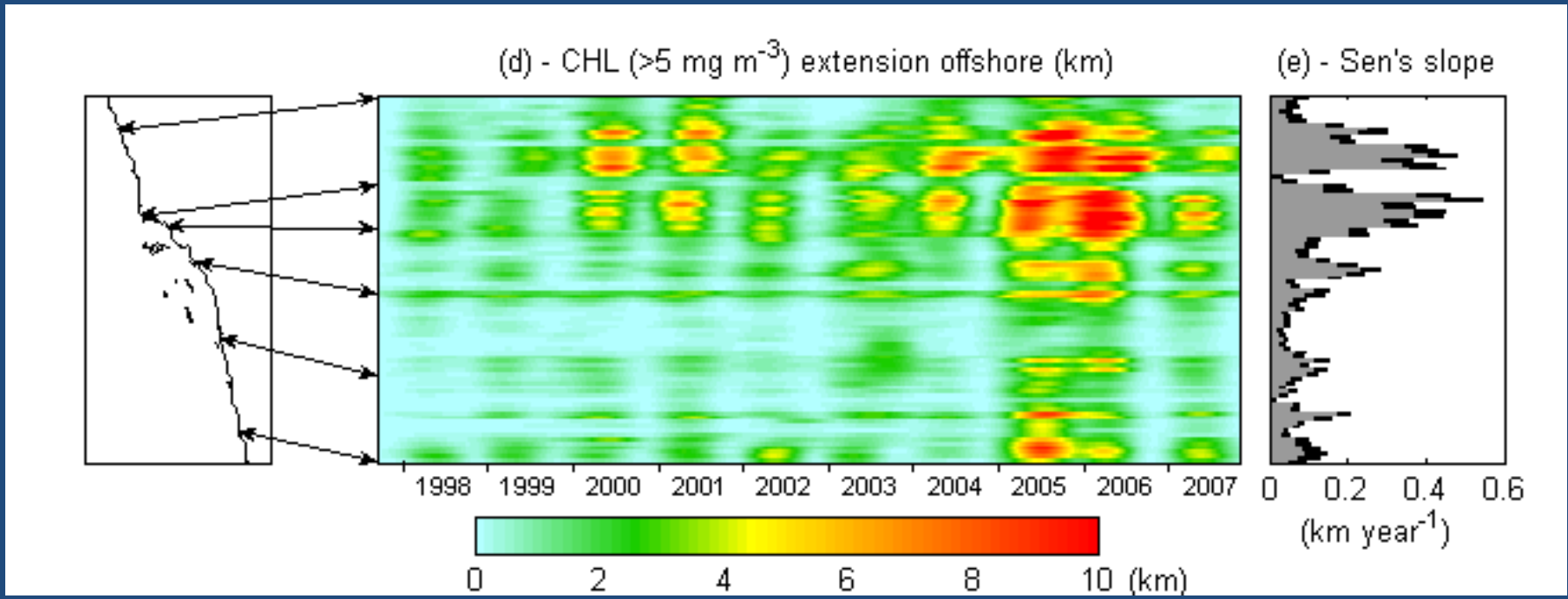
Extent and Magnitude of Eutrophication: DO Concentrations Has Declined 8-45% Over the Past Decade in the SCB



Trends are significant across SCB sub-regions, at all depths, during all seasons

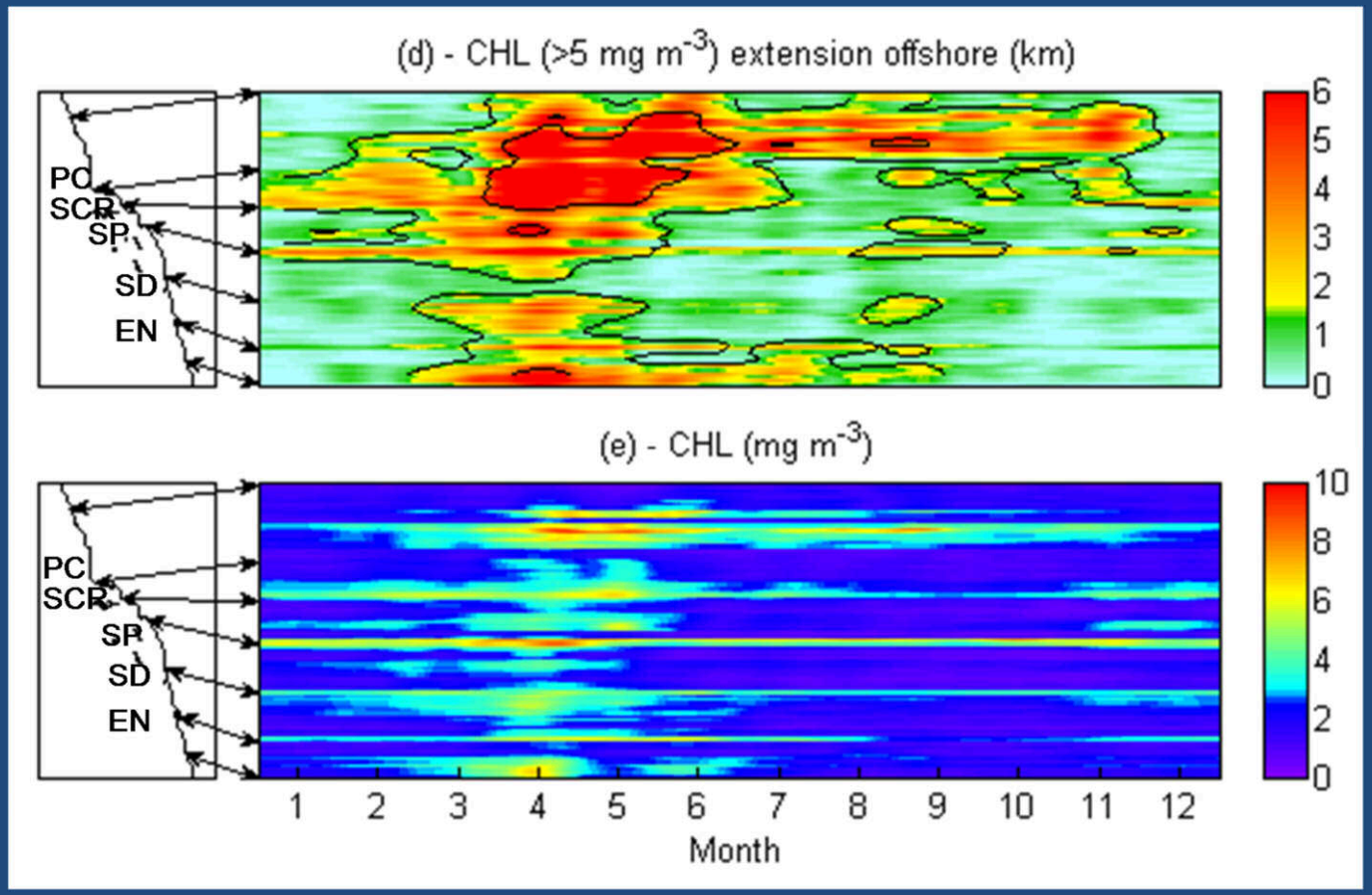
(COS Coastal Hypoxia Working Group, unpublished data)

Significant Increases in Extent of Remotely Sensed Phytoplankton Blooms over 1998-2008



Nezlin et al, Submitted to Journal of Geophysical Research, component of Bight Offshore Water Quality Study

Chronic Algal Blooms Year Round in Santa Barbara Channel, San Pedro and San Diego Bay

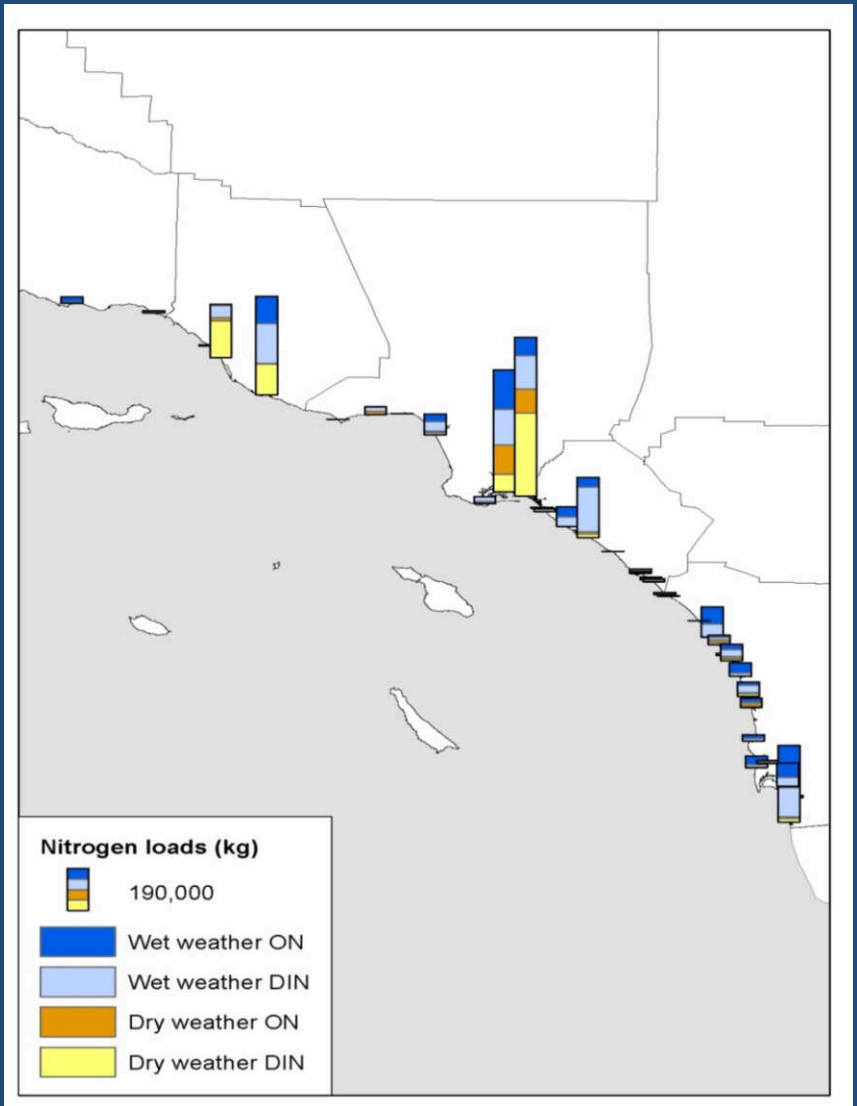


Nezlin et al., Submitted to Journal of Geophysical Research, component of Bight Offshore Water Quality Study

DO Declines and Increased Primary Productivity from Anthropogenically-Enhanced Nutrient Loads?

- **What are the relative contribution of nutrient sources?**
  - — POTW Effluent
  - — Terrestrial nutrient loads
  - — Atmospheric Deposition
  - — Upwelling
- **What are the trends in nutrient sources?**
  - —Changes in riverine and POTW nutrient inputs over time
- **What proportion of productivity or hypoxia is attributable to anthropogenic inputs?**

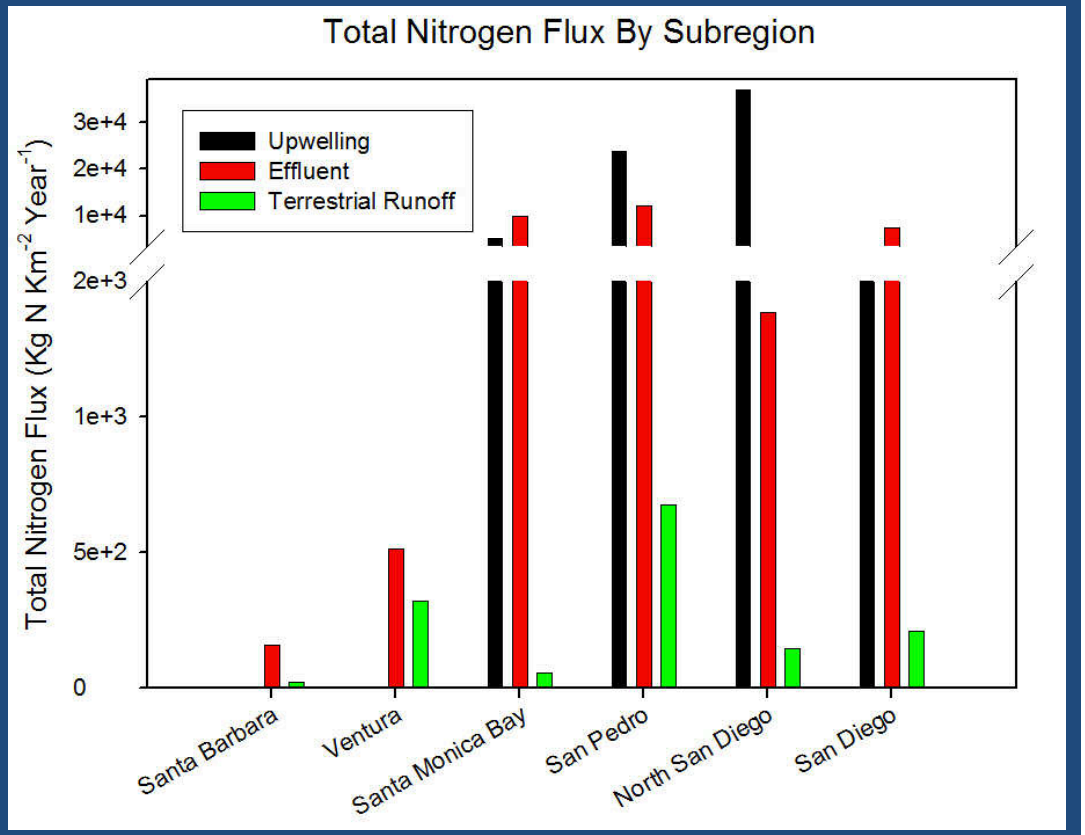
Developed Spreadsheet Models and Used In Combo With Field Data to Estimate Stormwater Loads to SCB



- Loading hotspots in San Pedro and Santa Barbara Channel
- Across Bight, Wet Weather Loads Dominate, With Exceptions in San Pedro Bay, Santa Barbara Channel
- Model predicts 4 to 8-fold increase TN and TP riverine loads to SCB from urbanizing land use

Comparison of Annual Total Nitrogen Loads Among Major Sources

- **Effluent characterization**
  - **New nutrient forms (e.g. urea)**
- **Modeling of upwelling using numeric model (ROMs+ NPZ)**
- **Atmospheric deposition**
  - Developed methods to measure dry deposition



What Proportion of Productivity or Hypoxia is Attributable to Anthropogenic Inputs?

- **Numeric models are an important tool in quantifying effects of anthropogenic nutrients on phytoplankton and hypoxia**
  - Key in estimating upwelling contribution
  - Synthesize net effect of anthropogenic nutrients on primary productivity and hypoxia
- **Same modeling community shared between SCB & SF Bay**
  - SF Bay: using ROMS+ SUNTANS to quantify exchange of nearshore with SF Bay
  - SCB: Using ROMS, but interested SUNTANS
- **Common thought process on adapting monitoring programs**

Looking Forward: SCCWRP Nutrient Research

- **Continued focus on developing assessment frameworks**
  - Standardizing methods and alternative indicators
  - Science supporting refinement of thresholds
- **Factors controlling harmful algal blooms occurrence and toxin production**
  - Cyanobacteria
  - Marine HABs
- **Strong emphasis on developing nutrient load response models**
  - Spanning the range from streams, estuaries, nearshore
  - Improved estimates of nutrient loads
  - Mechanistic studies to support model development