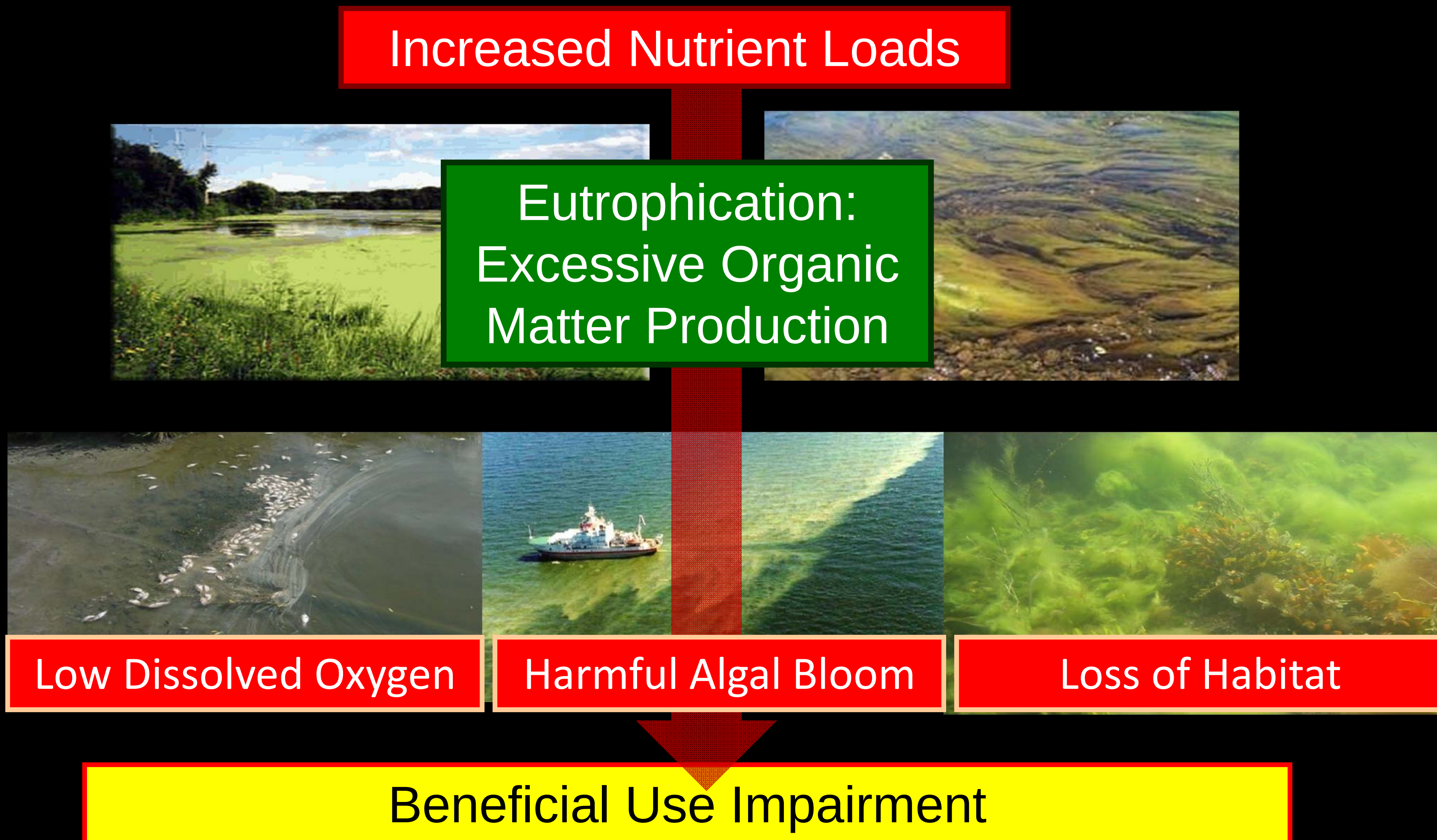
# Riverine Nutrient Inputs and Extent of Estuarine Eutrophication in the Southern California Bight

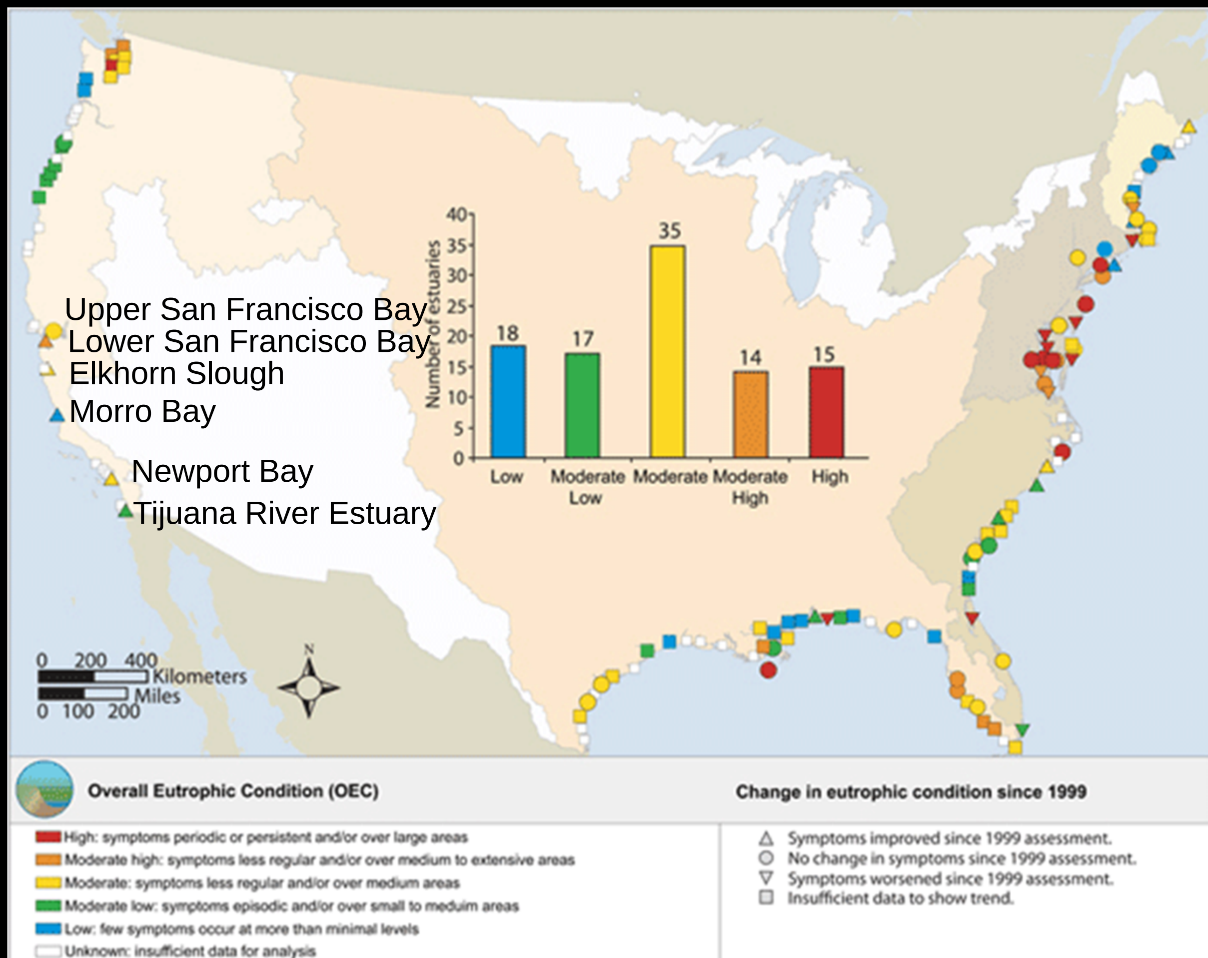
Karen McLaughlin, Martha Sutula, Lilian Busse,
Sean Anderson, Shirley Birosik, Rosi Dagit,
Jeff Crooks, Doug Gibson, Karina Johnston, Lisa Stratton

June 20, 2013

# Eutrophication is a Leading Cause of Impairment in U.S. Waterbodies



# Data on Eutrophication in California Estuaries is Limited




2007 NOAA National Eutrophication Assessment

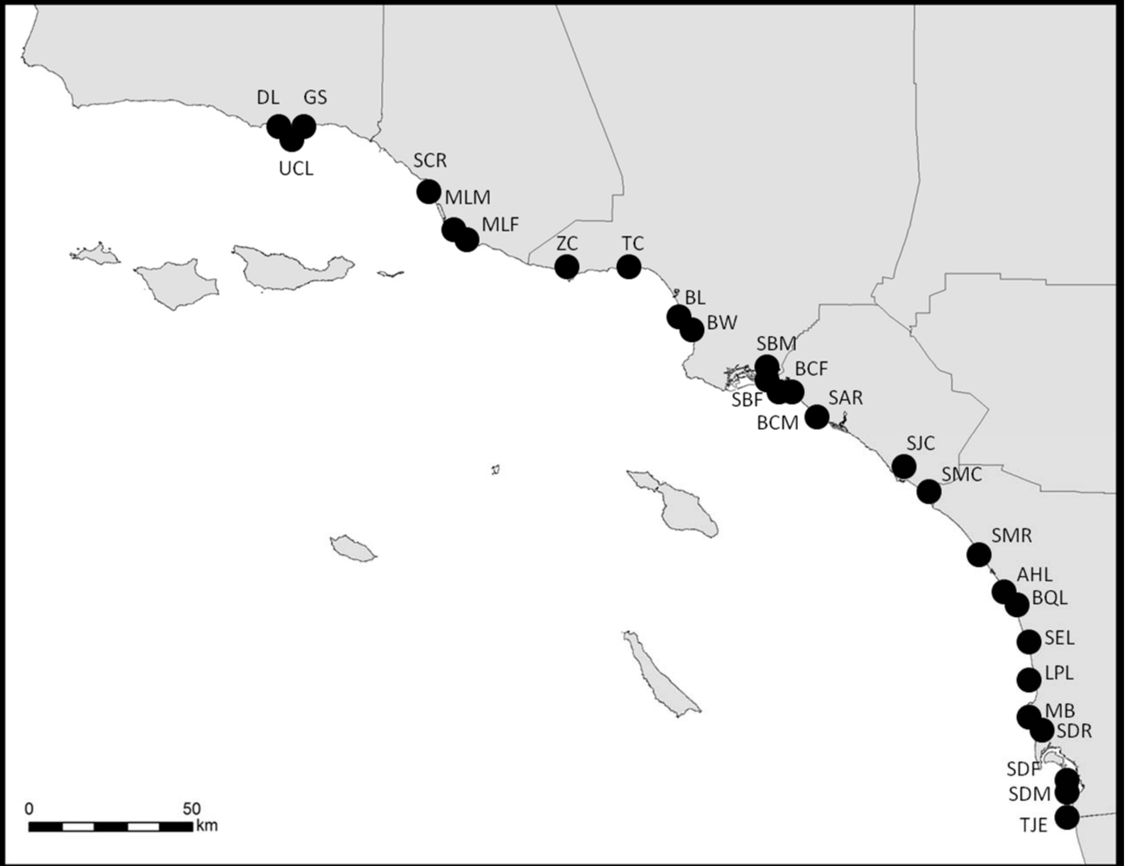
# Bight ‘08 Eutrophication Assessment: Filling in the Data Gap

**Key Questions:**

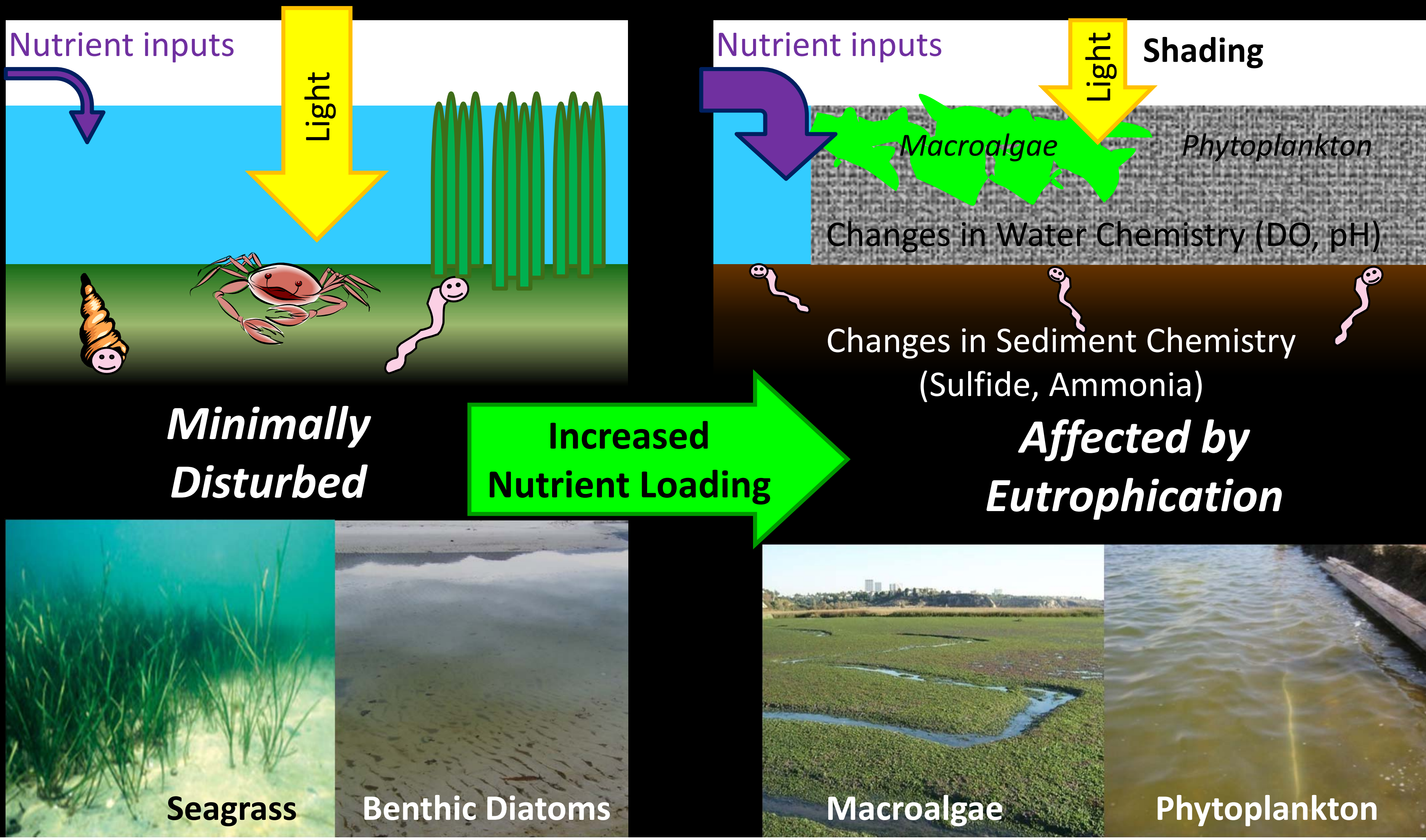
- What is the extent and magnitude of eutrophication in southern California estuaries?
- What is the relationship between expression of eutrophication and nutrient inputs?
- What are the implications for nutrient management?

# Study Design

- 27 Segments from 23 Estuaries; Randomly Selected
- Monitored from Nov 2008 - Oct 2009
- Targeted “index area” within each estuary-- Conservative Answer



# Conceptual Model of Development of Eutrophication



# Approach

Assess Extent and Magnitude Using Indicators of Eutrophication:

- Primary producers – biomass and cover, bimonthly
  - Macroalgae
  - Phytoplankton
- Dissolved Oxygen – continuous in bottom water

Relationship with Nutrient Inputs

- Estuarine ambient nutrients- bimonthly
- Riverine Nutrient Loading
  - Continuous flow
  - Dry weather concentrations- bimonthy
  - MS4 data or modeled (Sengupta et al. in prep)

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**Key Questions:**

- What is the extent and magnitude of eutrophication in southern California estuaries?
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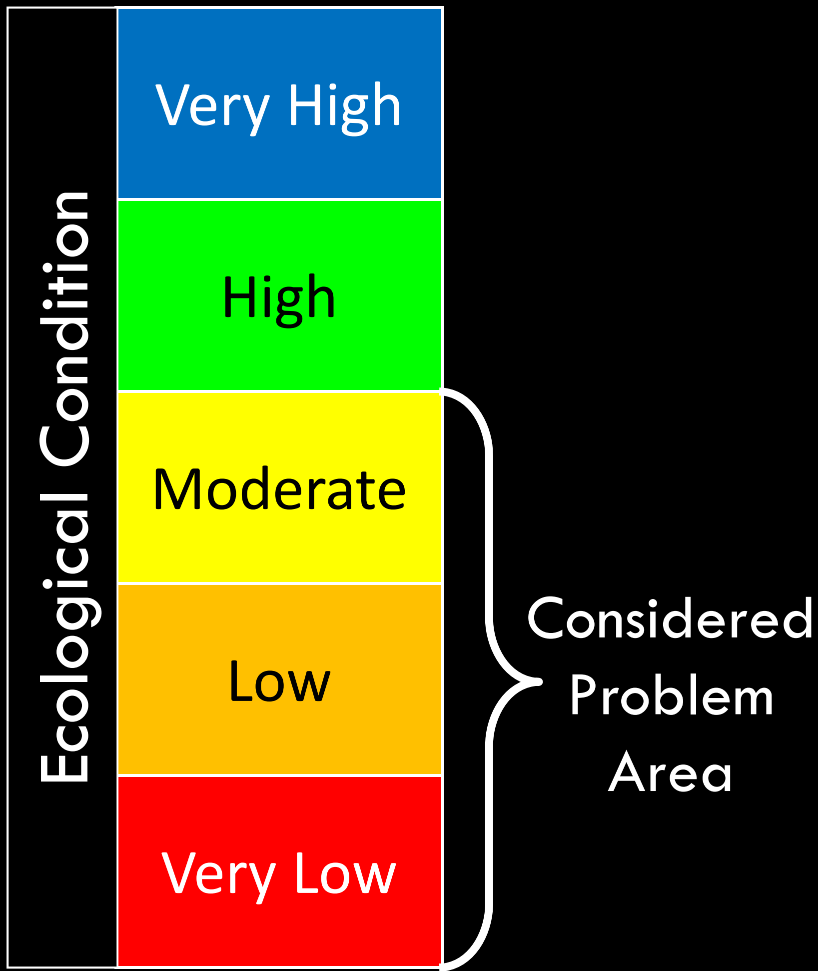
# How Do We Assess Eutrophication?

## *European Union – Water Framework Directive*

- Thresholds for indicators related to biological response to eutrophication
  - Dissolved oxygen
  - Macroalgae
  - Phytoplankton

- Categorize estuaries based on ecological condition

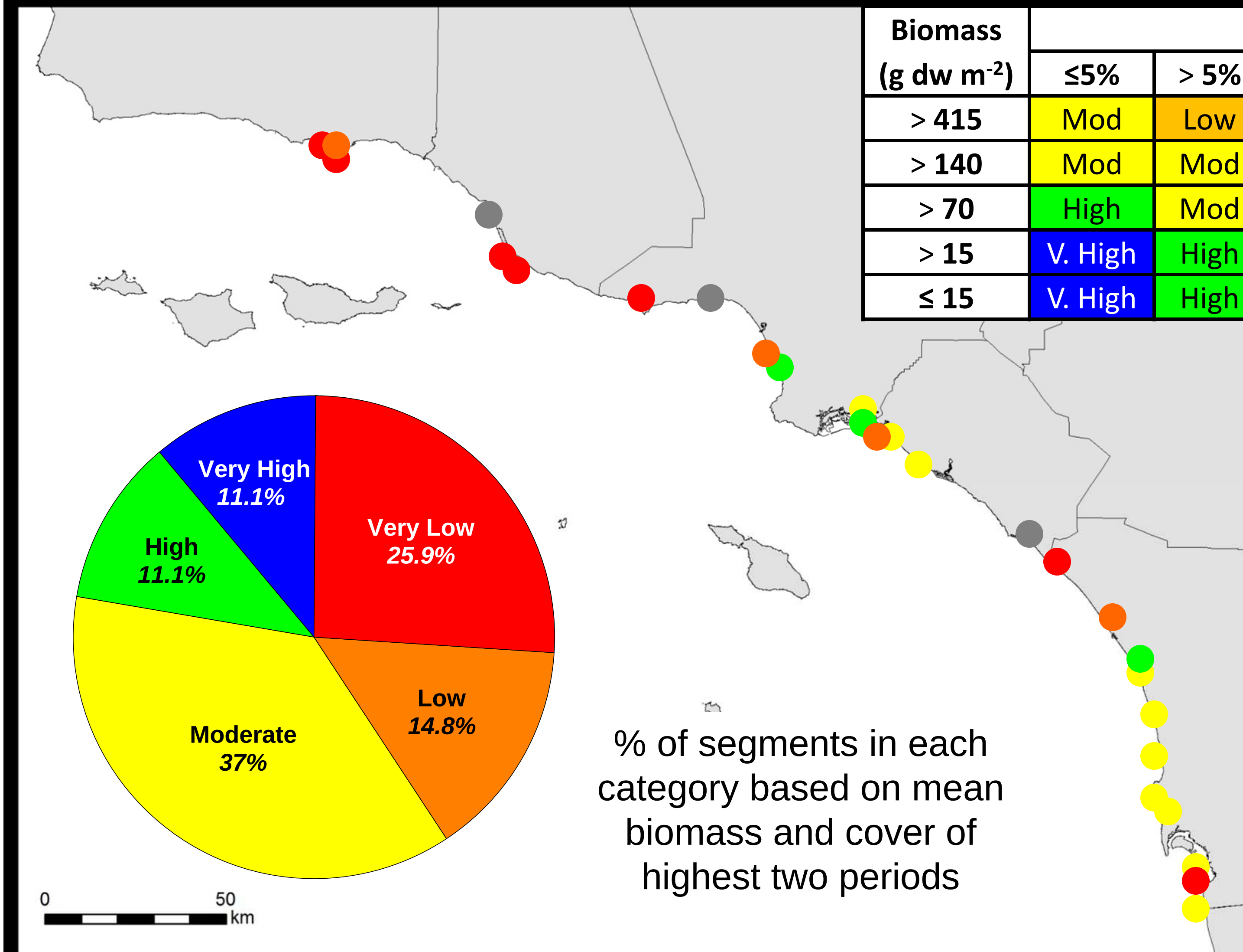


# Macroalgae Assessment

| Ecological Condition Interpreted from WFD Framework | | | | | |
|---|---|---|---|---|---|
| **Biomass ($g\ dw\ m^{-2}$)** | **Percent Cover** | | | | |
| | **≤5%** | **> 5%** | **> 15%** | **> 25%** | **> 75%** |
| **> 415** | Moderate | Low | V. Low | V. Low | V. Low |
| **> 140** | Moderate | Moderate | Low | V. Low | V. Low |
| **> 70** | High | Moderate | Moderate | Low | Low |
| **> 15** | V. High | High | High | Moderate | Low |
| **≤ 15** | V. High | High | High | Moderate | Moderate |

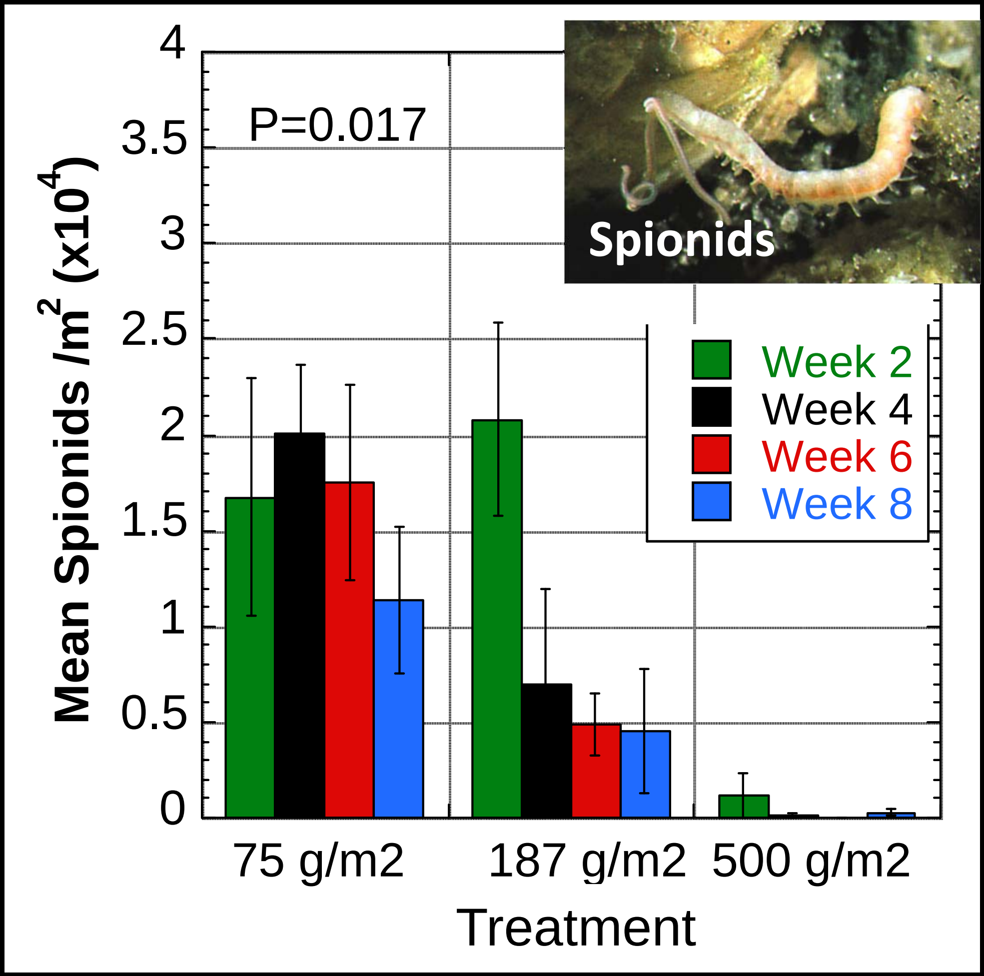
# 78% of Segments had Macroalgae Indicative of Degraded Condition

| 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 |



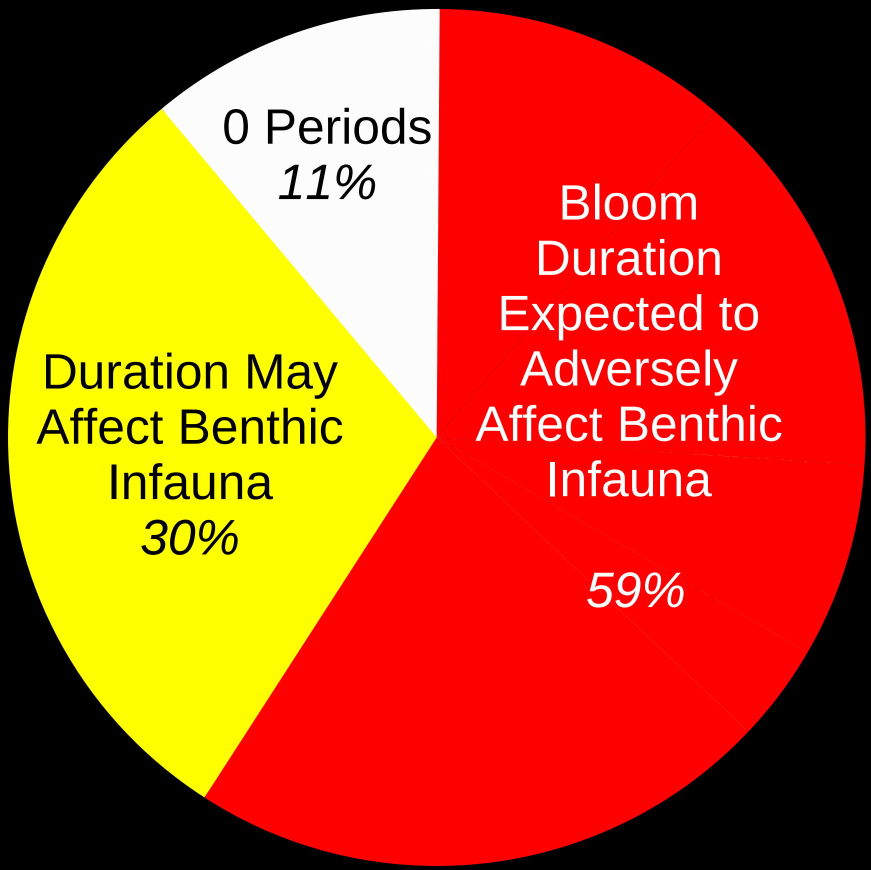

% of segments in each category based on mean biomass and cover of highest two periods

# Biomass AND Duration of Bloom Affect Benthic Infauna in Intertidal Flats




Lauri Green, Ph.D. Dissertation, UCLA Department of Biology (Spring 2010)

# Macroalgae Bloom Duration is a Concern for the SCB Estuaries

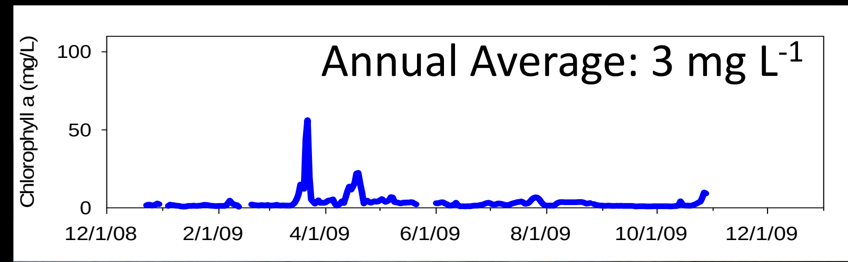



Bloom Duration Interpreted from Consecutive Periods of Moderate or Worse Macroalgae Biomass/Cover

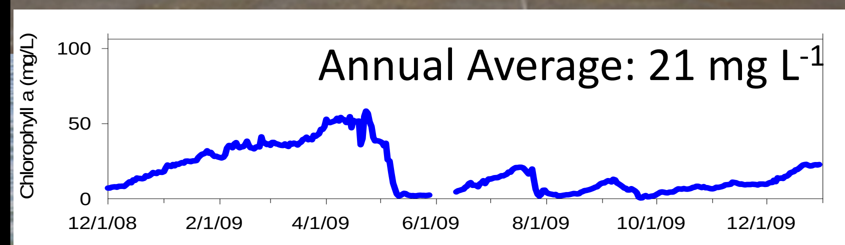
# Phytoplankton Assessment

**Ecological Condition Interpreted from WFD Framework**

| Annual Average of Sonde Chlorophyll a (µg/L) | |
|---|---|
| Very High | < 5 |
| High | 5 - 7 |
| Moderate | 7 - 10 |
| Low | 10 - 30 |
| Very Low | ≥ 30 |

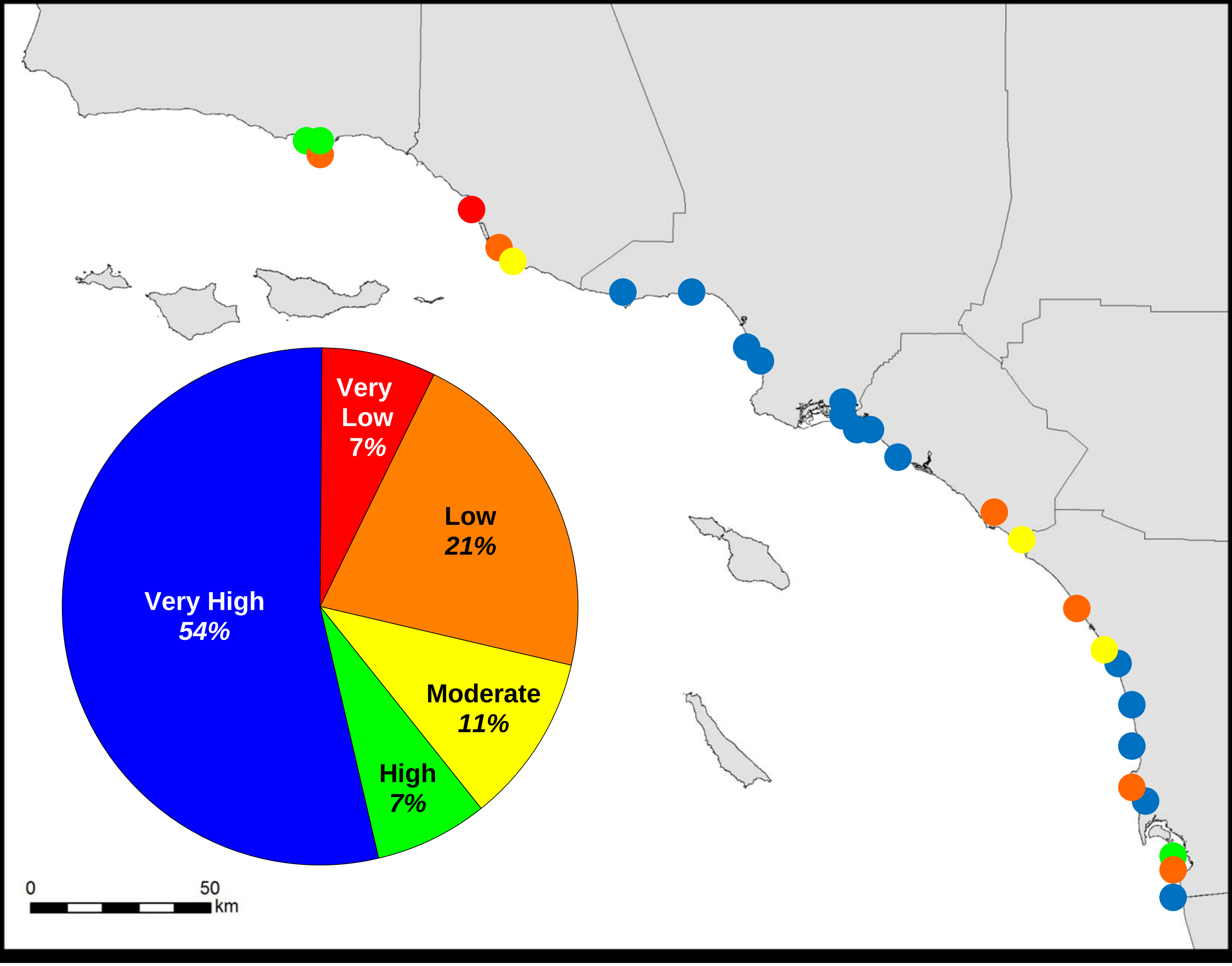




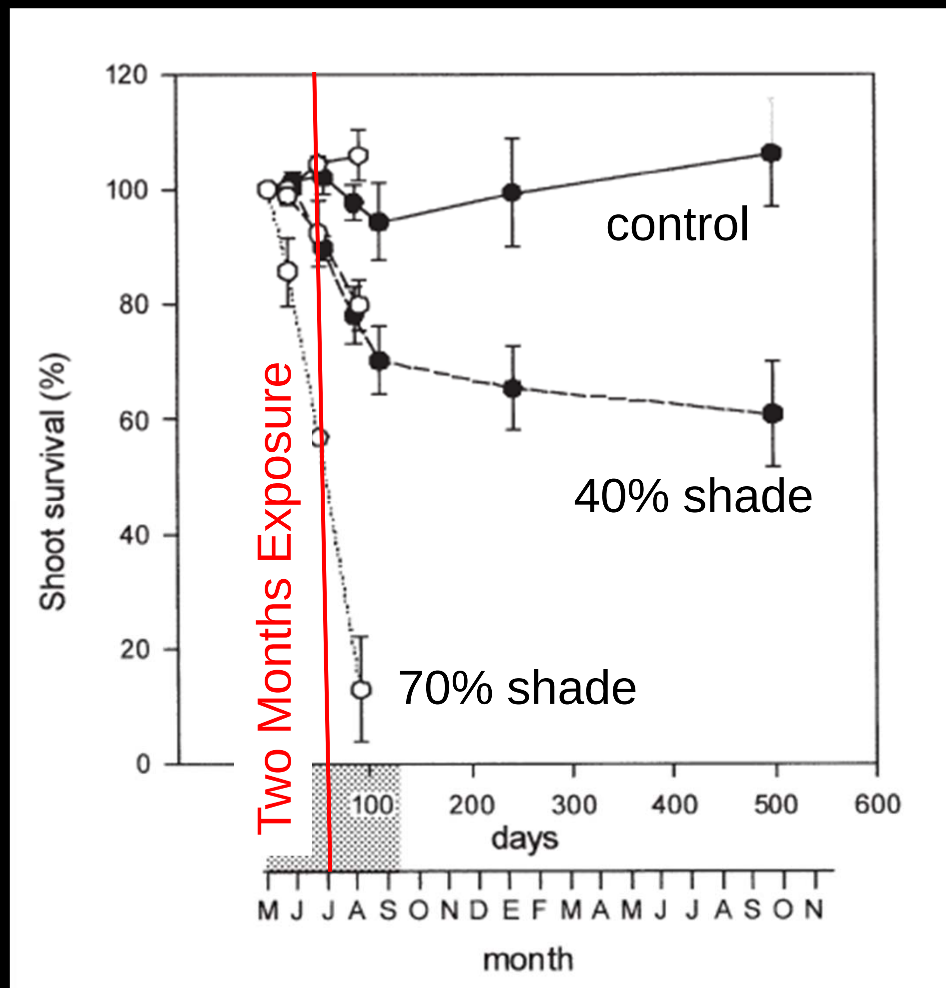



# 39% of Segments had Phytoplankton Biomass Indicative of Degraded Condition

| Annual Average of Sonde Chlorophyll a (µg/L) | |
|---|---|
| Very High | < 5 |
| High | 5 - 7 |
| Moderate | 7 - 10 |
| Low | 10 - 30 |
| Very Low | ≥ 30 |

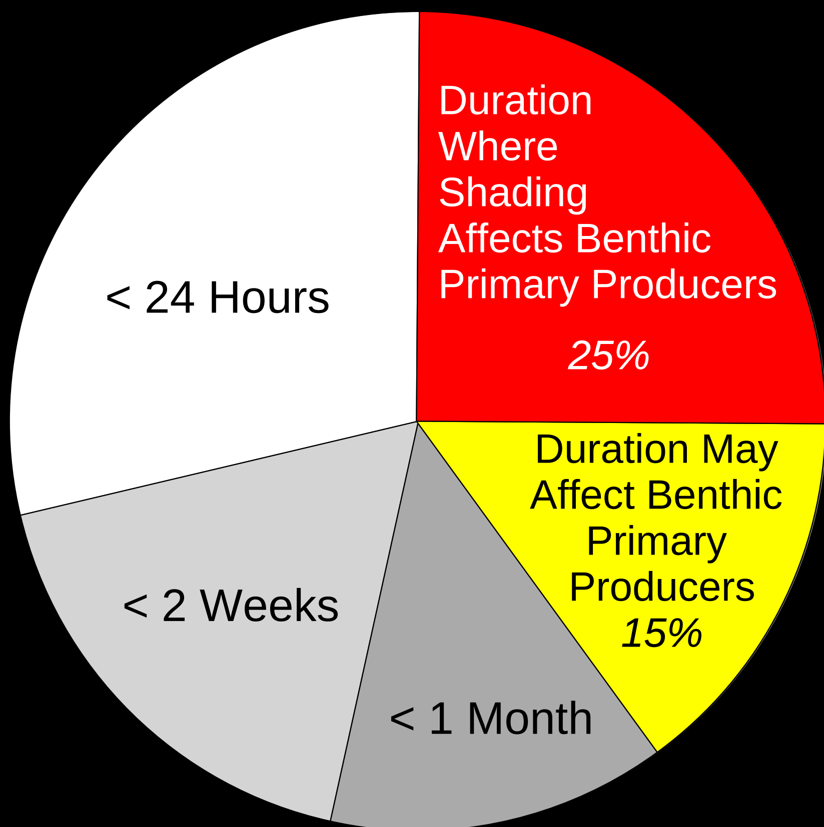


# Magnitude and Duration of Phytoplankton Blooms Adversely Affect Benthic Primary Producers




Ruiz and Romero, *Marine Ecology Progress Series*, 2001

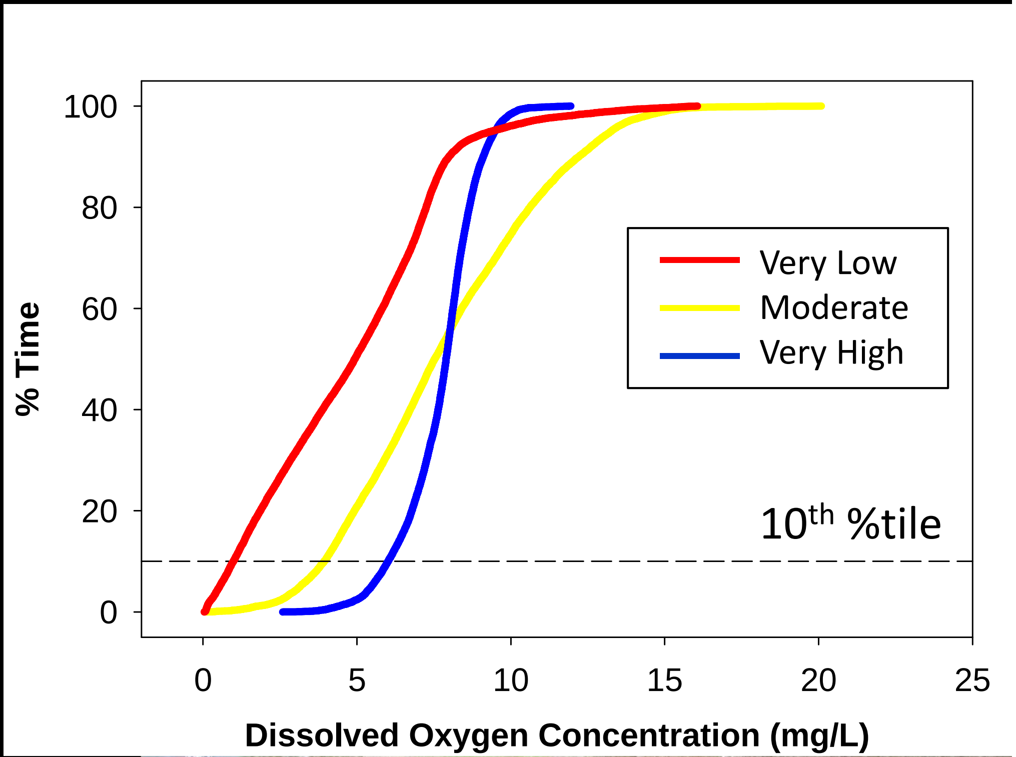
# Bloom Duration is a Concern for the SCB Estuaries




Bloom Duration Interpreted from Daily Averages of Instantaneous 15 Minute Interval Chlorophyll Data

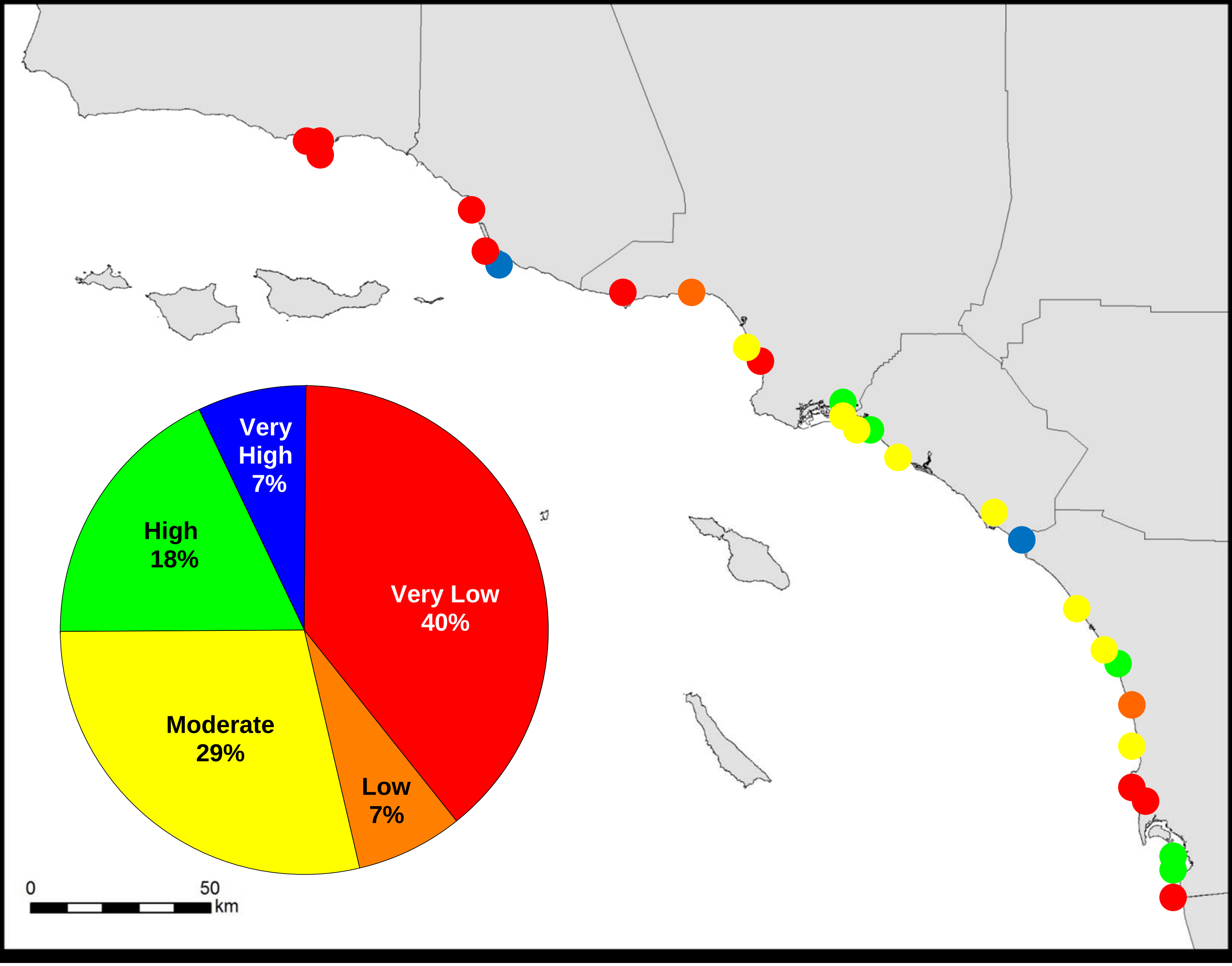
# Dissolved Oxygen Assessment

| Ecological Condition Interpreted from WFD Framework | 10th percentile of hourly running average DO data (mg/L) |
|---|---|
| Very High | ≥ 5.7 |
| High | 4.0 - 5.7 |
| Moderate | 2.4 - 4.0 |
| Low | 1.6 - 2.4 |
| Very Low | < 1.6 |

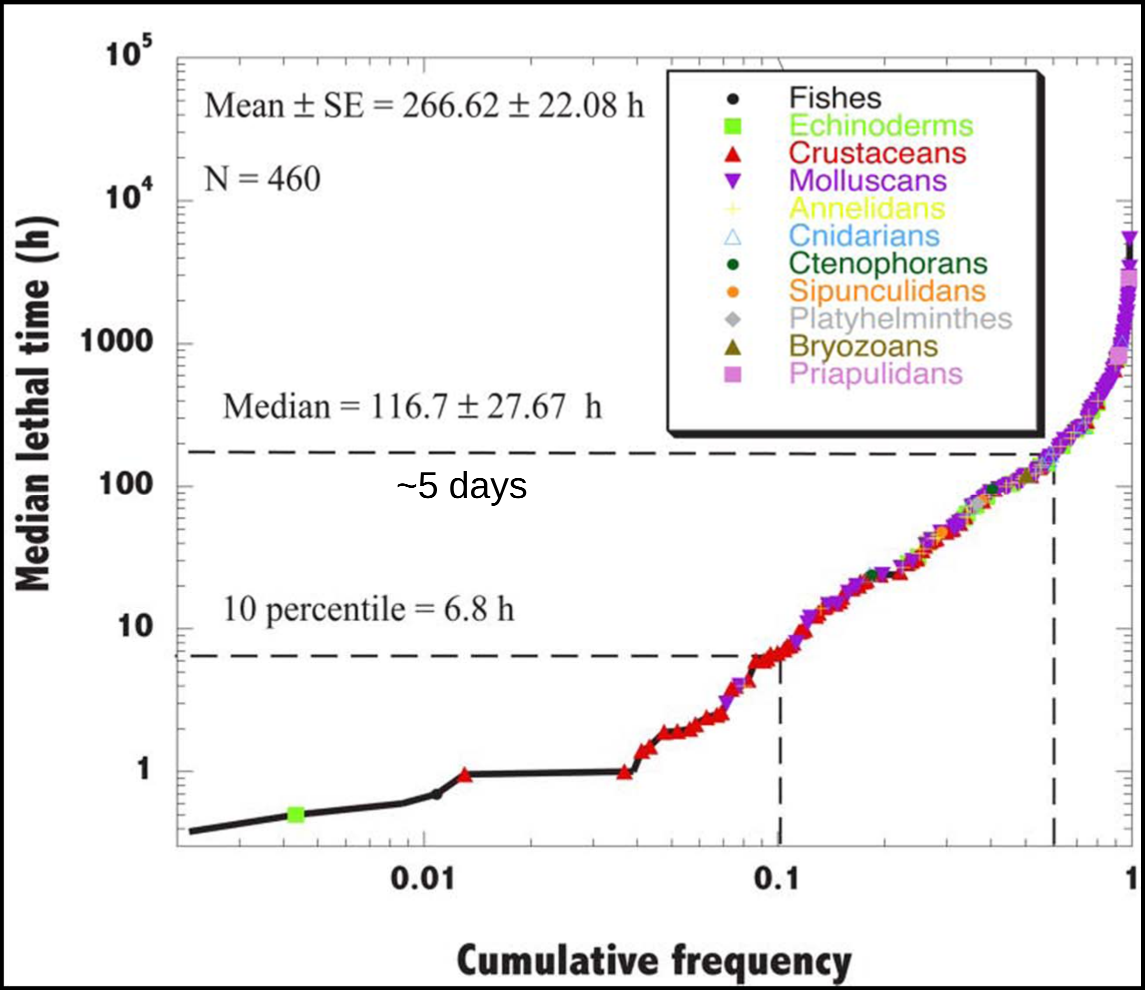



# 75% of Segments had DO Indicative of Degraded Condition

| 5th percentile of hourly DO data (mg/L) | |
|---|---|
| Very High | ≥ 5.7 |
| High | 4.0 – 5.7 |
| Moderate | 2.4 – 4.0 |
| Low | 1.6 – 2.4 |
| Very Low | < 1.6 |



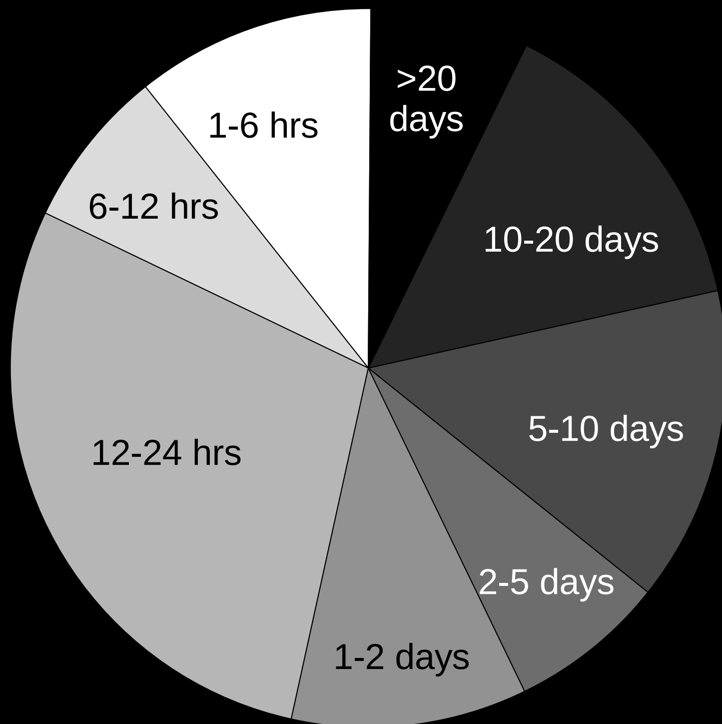
# Magnitude and Duration of Hypoxia Adversely Affect Ecosystem Quality




Vaquer-Sunyer, Duarte *PNAS* 2008

# Duration of Hypoxic Events (DO < 4 mg/L) is a Concern for SCB Estuaries

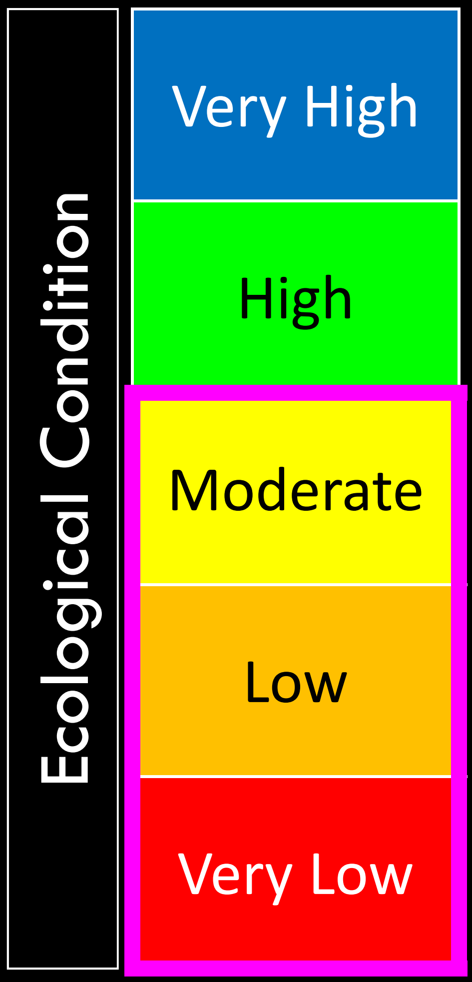
Hourly Averaged Data




Longest Single Event in
All Estuaries

# Eutrophication is Pervasive in Southern California Estuaries

| Indicator | % With Ecological Condition Less than High |
|---|---|
| Any One | 96% |
| Macroalgae | 78% |
| Phytoplankton | 39% |
| Dissolved Oxygen | 63% |
| Either Primary Producer & DO | 52% |



# Uncertainties

- Did we adequately capture variability?
  - Temporal variability
  - Spatial variability
- What is the appropriate assessment framework for SCB estuaries?
  - What are the right indicators?
  - Relevance of European thresholds?
  - Little guidance on data management
  - Little guidance on frequency of sampling or how to incorporate event duration

# How Do SCB Estuaries Compare?

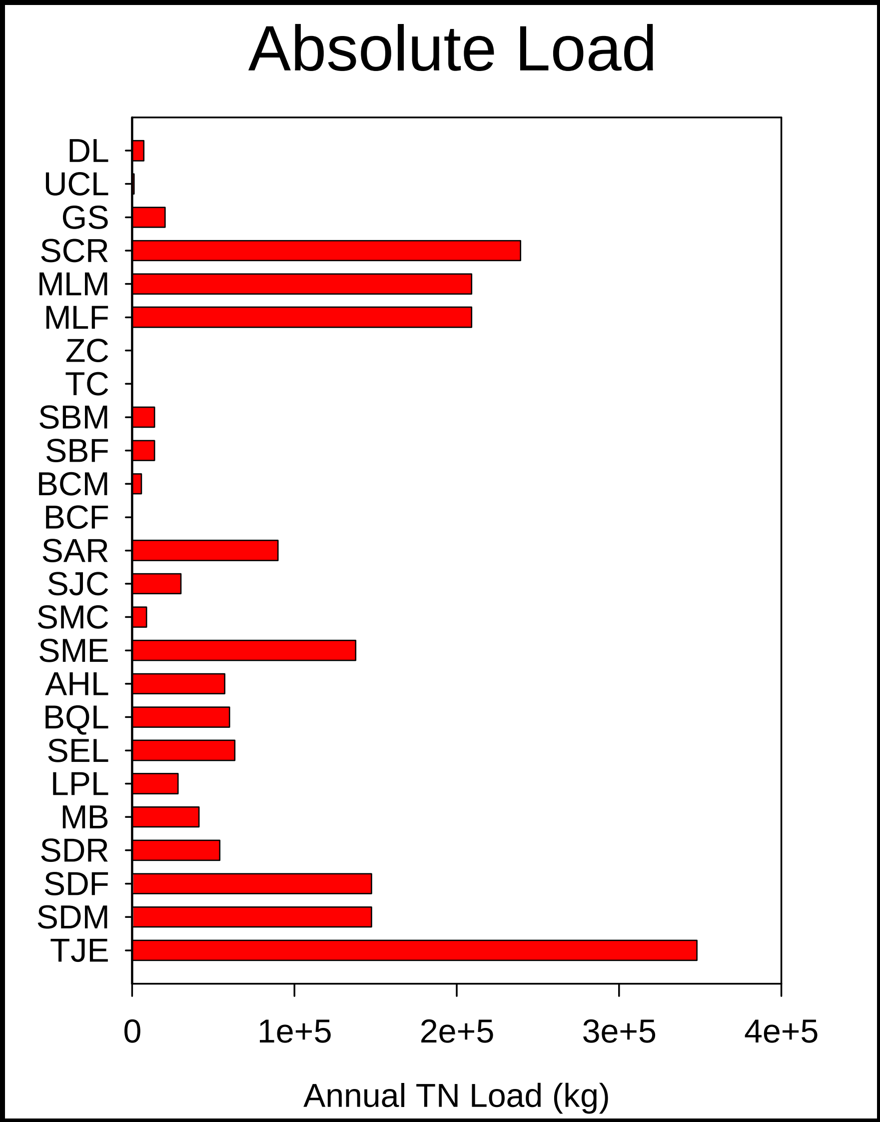
| overall rank | | Segment | Segment Rank by Indicator* | | |
|---|---|---|---|---|---|
| | | | Macroalgal | Phytoplankton | Dissolved Oxygen |
| Highest Condition | 1 | Batiquitos Lagoon | 7 | 10 | 3 |
| | 2 | Seal Beach | 5 | 12 | 4 |
| | 3 | Los Penasquitos Lagoon | 6 | 7 | 10 |
| | 4 | Bolsa Chica | 15 | 11 | 5 |
| | 5 | Mugu Lagoon | 18 | 19 | 1 |
| | 6 | San Diego Bay | 10 | 15 | 7 |
| | 7 | Santa Ana R. Wetlands-Diked | 14 | 2 | 9 |
| | 8 | Seal Beach- Diked | 9 | 8 | 14 |
| | 9 | San Elijo Lagoon | 8 | 5 | 17 |
| | 10 | San Mateo Lagoon | 24 | 18 | 2 |
| | 11 | Topanga Lagoon | 2 | 13 | 16 |
| | 12 | Tijuana River Estuary | 11 | 1 | 19 |
| | 13 | San Diego Bay- Diked | 22 | 24 | 6 |
| | 14 | Agua Hedionda Lagoon | 3 | 20 | 11 |
| | 15 | Ballona Lagoon- Diked | 19 | 3 | 13 |
| | 16 | Santa Margarita Estuary | 20 | 21 | 12 |
| | 17 | San Juan Creek | 4 | 25 | 8 |
| | 18 | Zuma Lagoon | 17 | 14 | 18 |
| | 19 | Bolsa Chica- Diked | 21 | 4 | 15 |
| | 20 | Ballona Wetlands | 13 | 6 | 26 |
| Lowest Condition | 21 | Mission Bay | 12 | 9 | 27 |
| | 22 | Goleta Slough | 23 | 17 | 23 |
| | 23 | Mugu Lagoon - Diked | 26 | 26 | 20 |
| | 24 | San Diego River | 16 | 23 | 24 |
| | 25 | UCSB Campus Lagoon | 25 | 22 | 22 |
| | 26 | Santa Clara River | 1 | 27 | 21 |
| | 27 | Devereux Lagoon | 27 | 16 | 25 |

# Bight '08 Eutrophication Assessment: Filling in the Data Gap

**Key Questions:**

- What is the extent and magnitude of eutrophication in southern California estuaries?
- What is the relationship between expression of eutrophication and nutrient inputs?
- What are the implications for nutrient management?

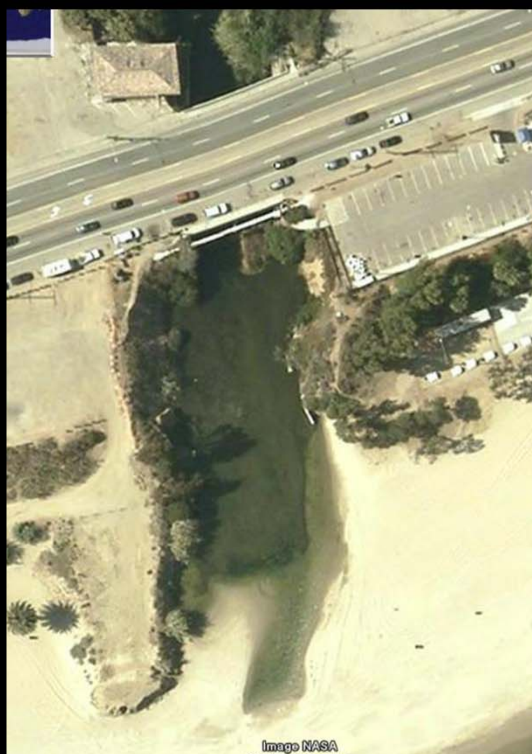
# Nutrient Loads to SCB Estuaries are Variable



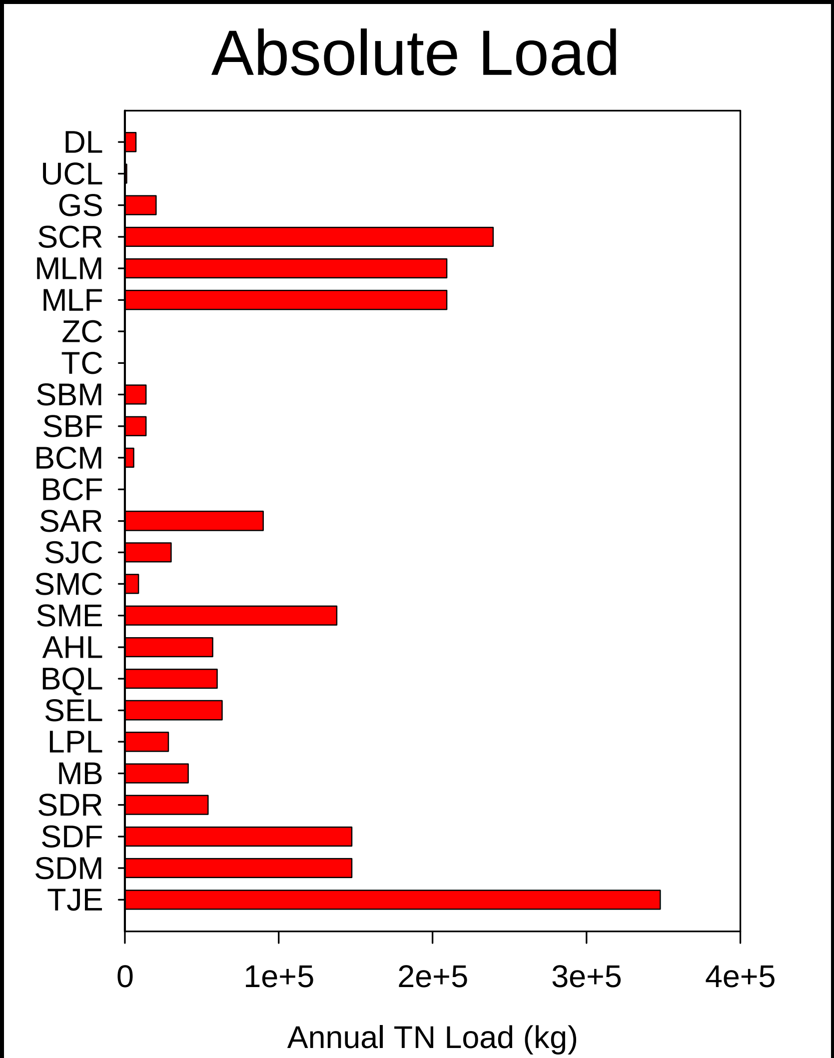
# Estuary Size Affects Its Ability to Assimilate Nutrient Loads

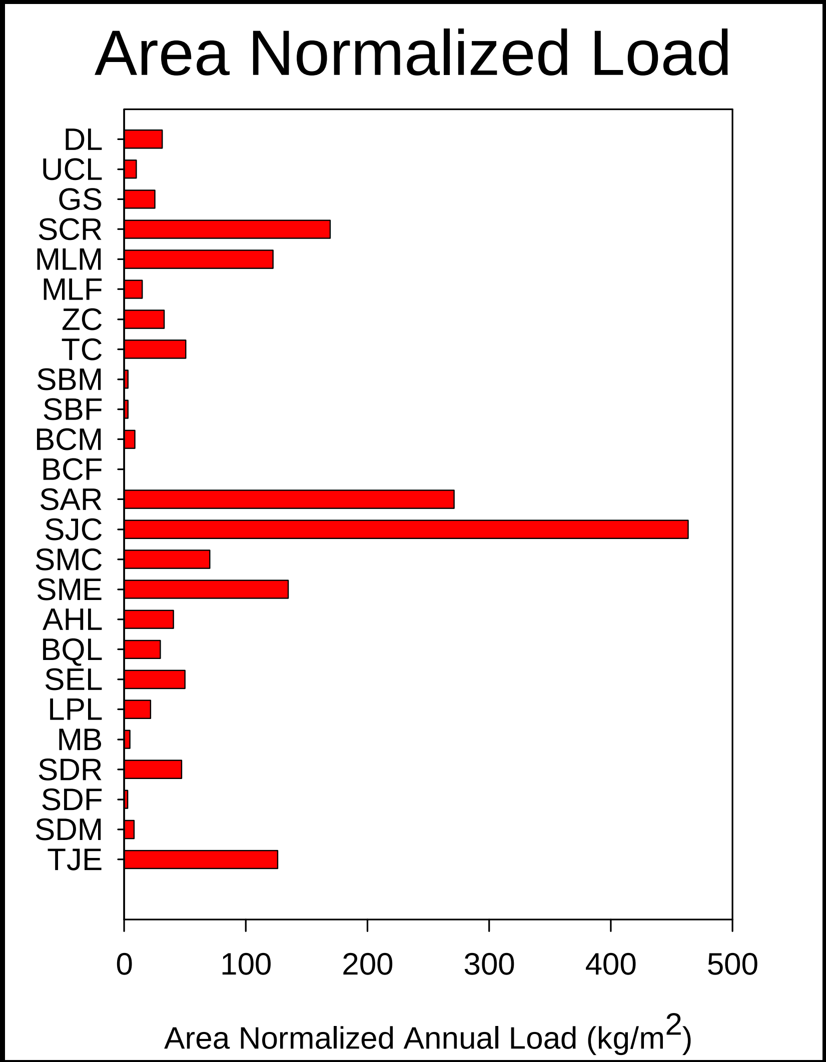
Topanga Canyon Lagoon
3.68 $km^2$

Mission Bay
8,795 $km^2$

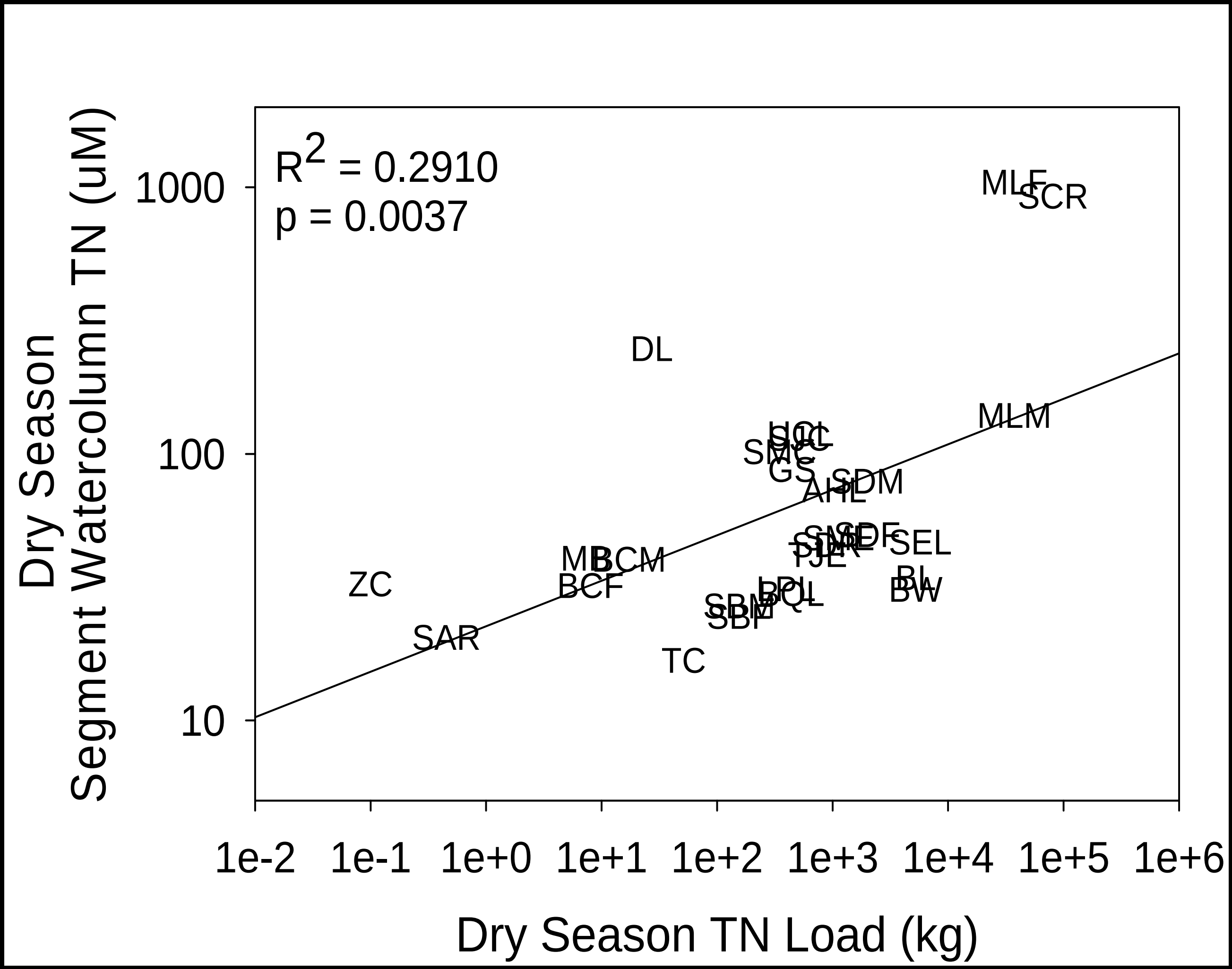



# If Loads Are Area-Normalized, Loading "Hot Spots" Change

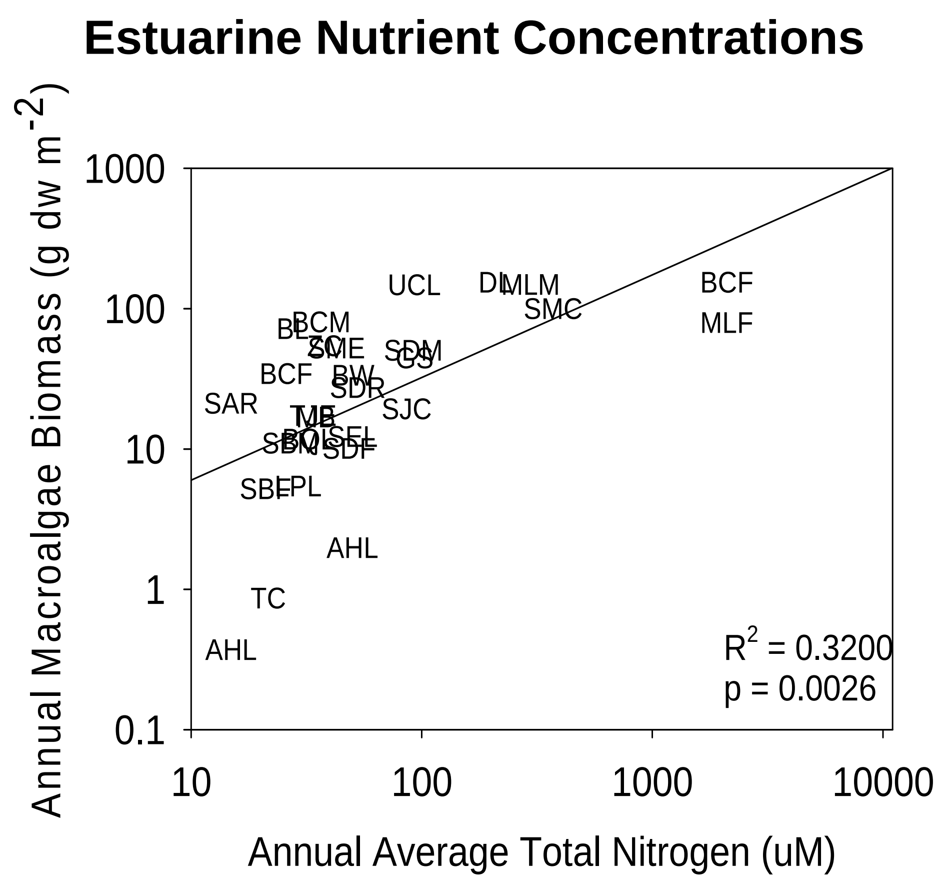


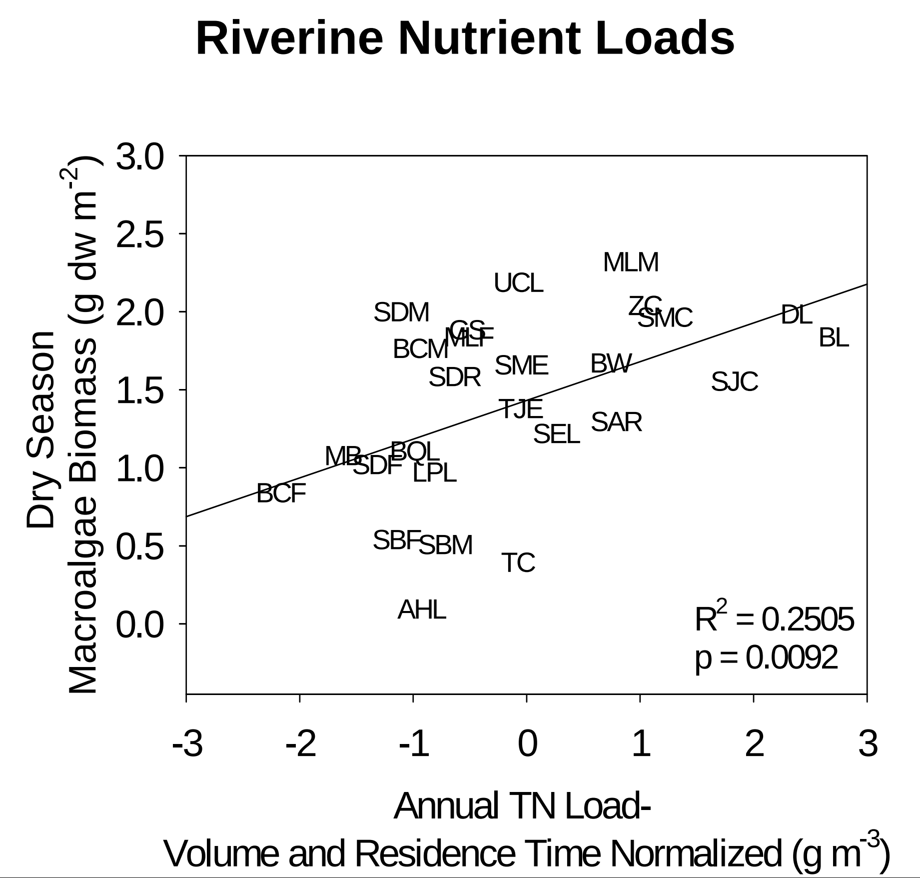



# Riverine Nutrient Loads are Correlated with Estuarine Concentrations

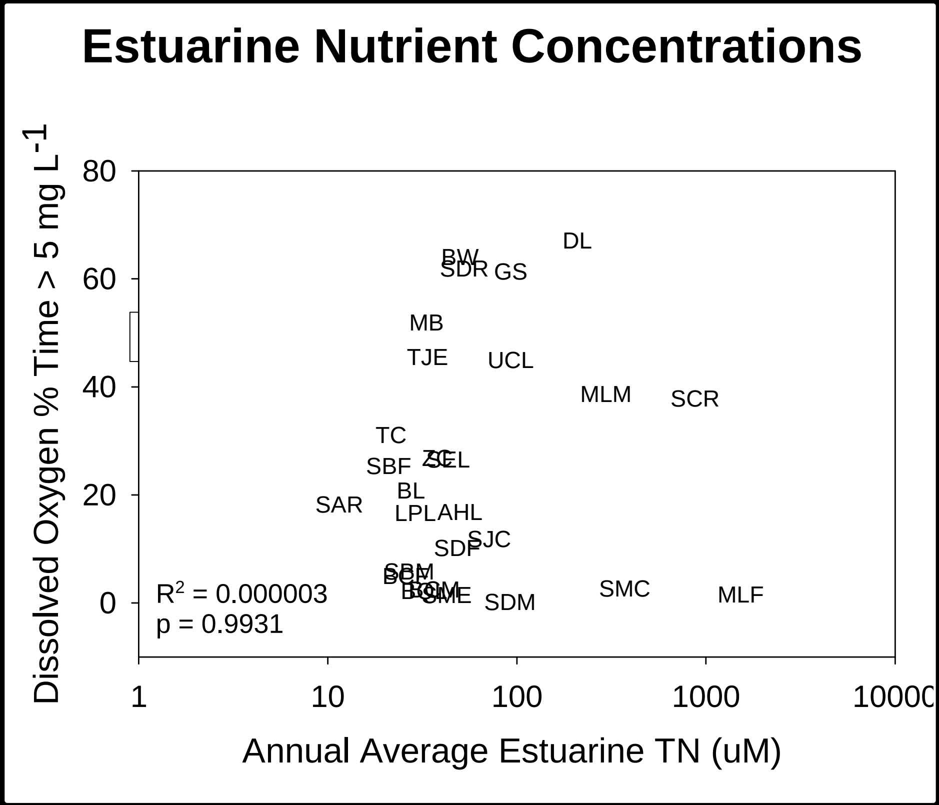


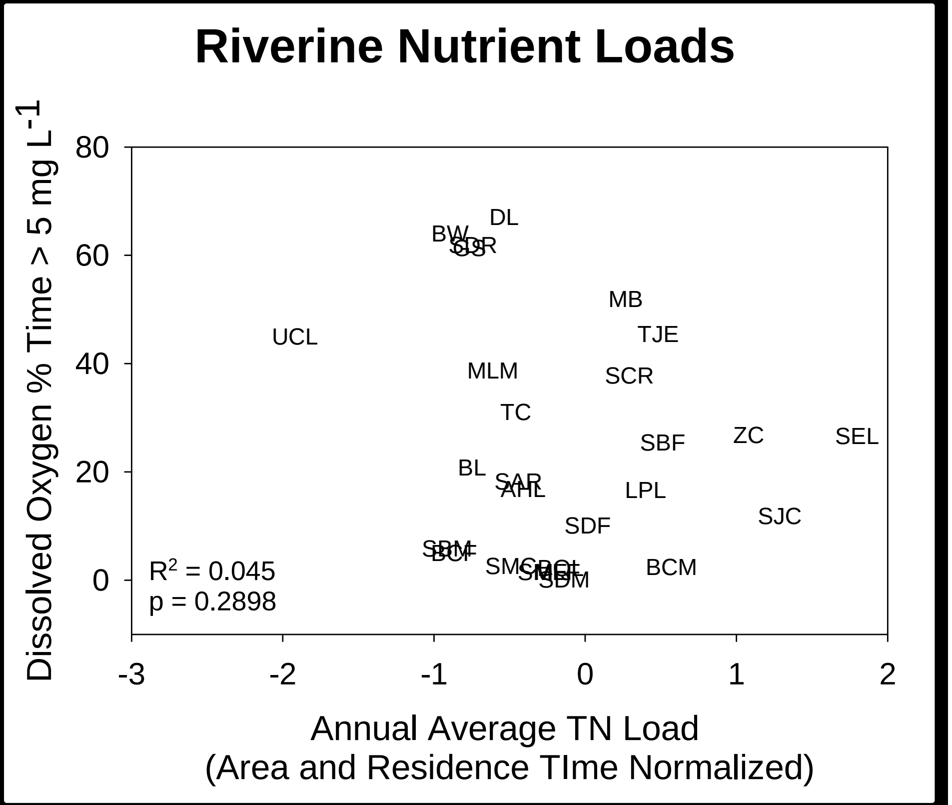
# For Algae, Response Related to Nutrient Inputs; Reflecting Disturbance Gradient



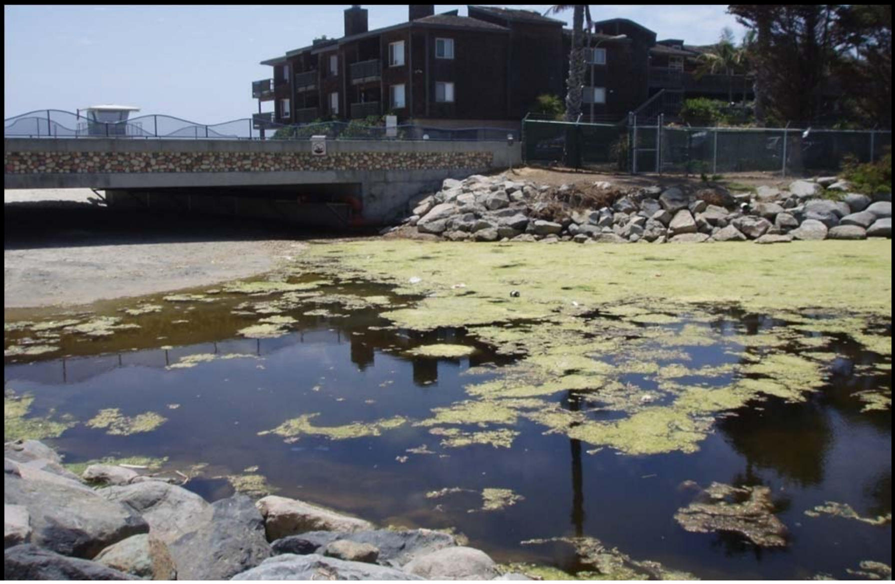
# For Dissolved Oxygen, No Relationship with Nutrient Inputs

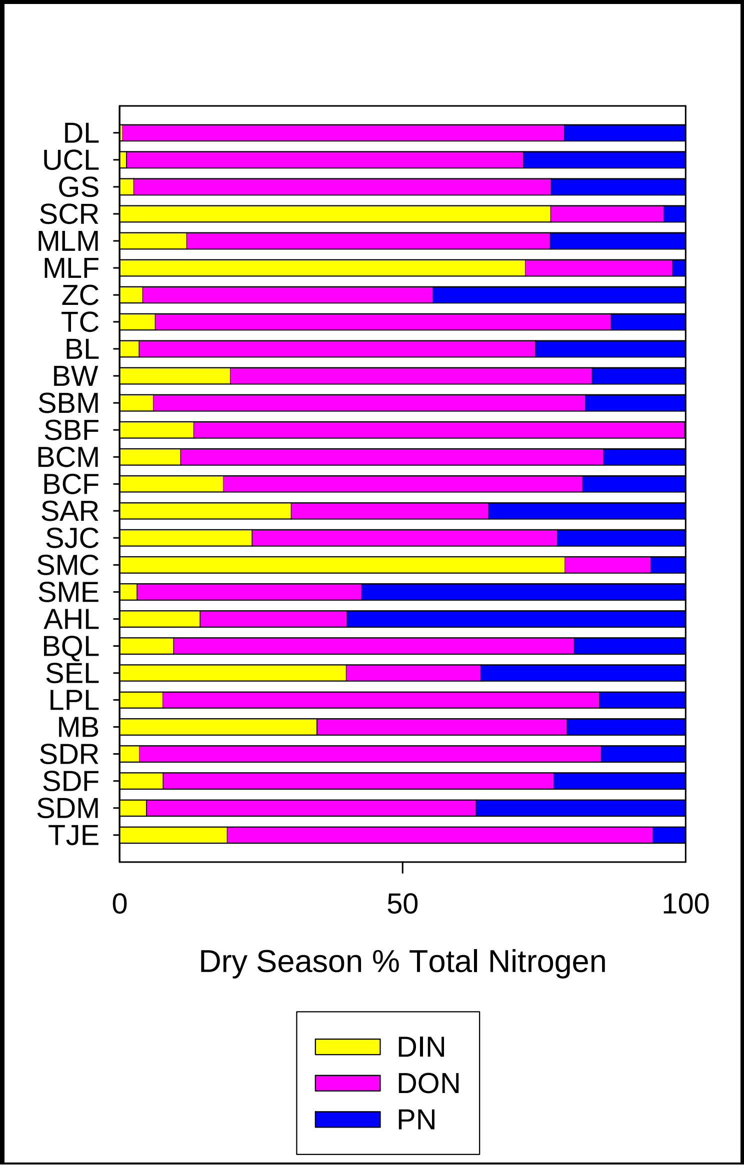


# Why the Poor Correlation?

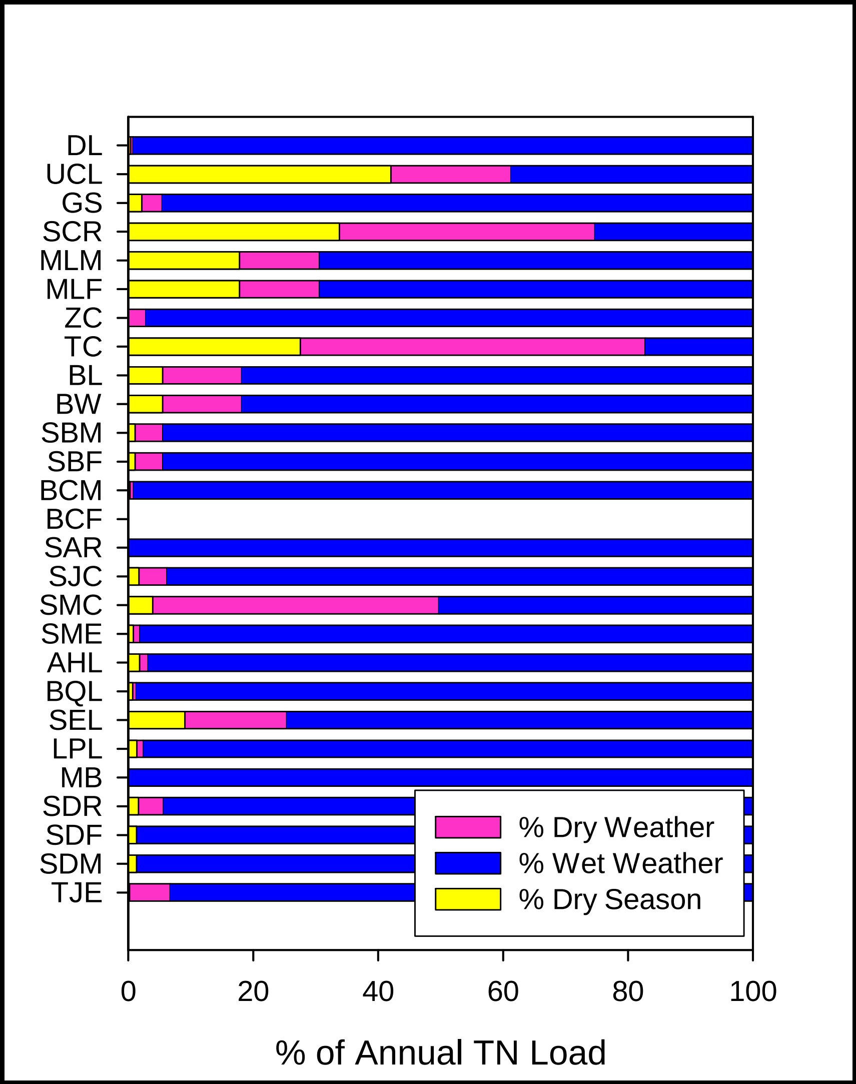
- Ambient Concentrations Are "Left-Overs"
  - Not a true representation of exposure
- Most of TN is DON and PN
  - Macroalgae are leaky



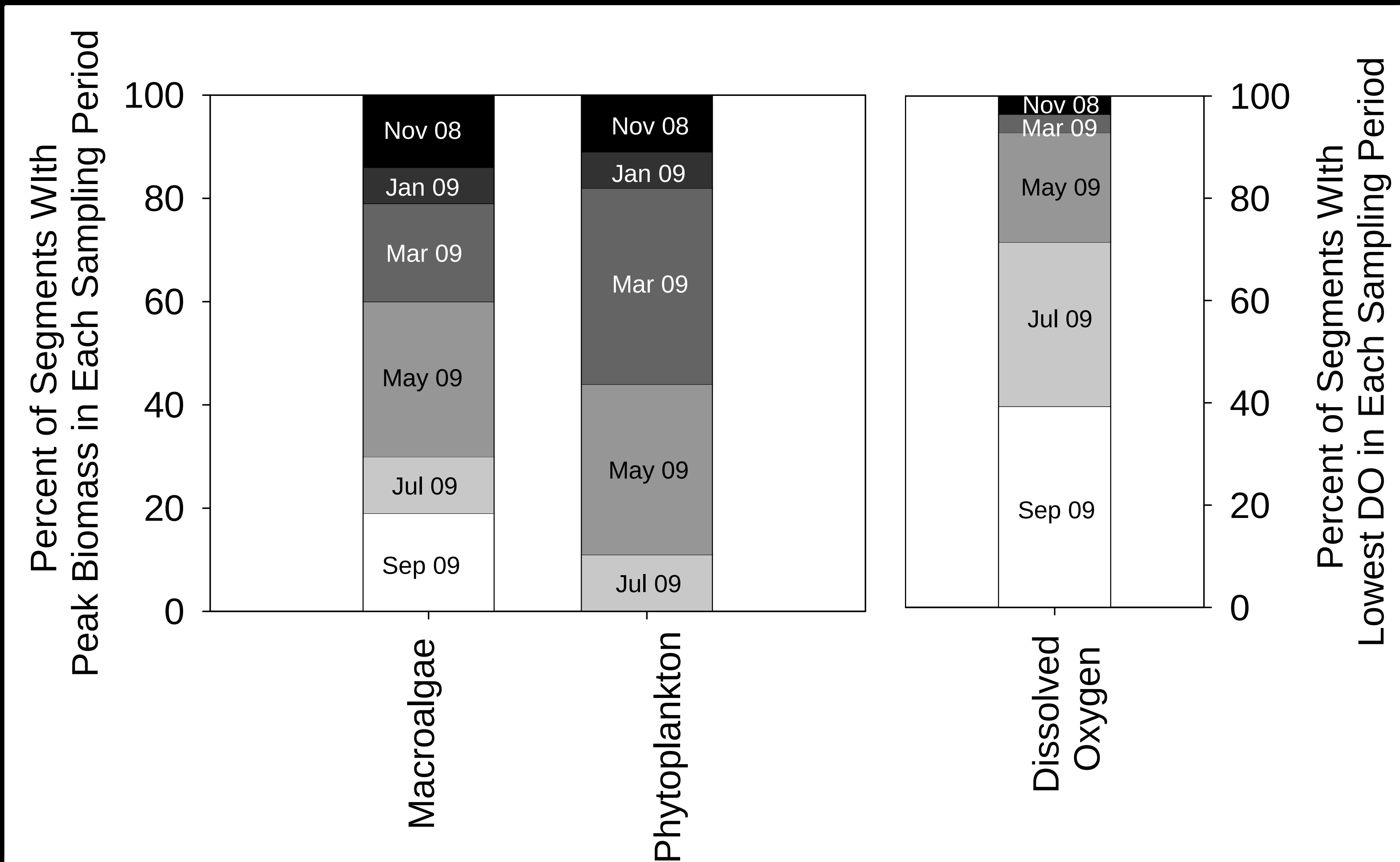


# Critical Periods are Decoupled:

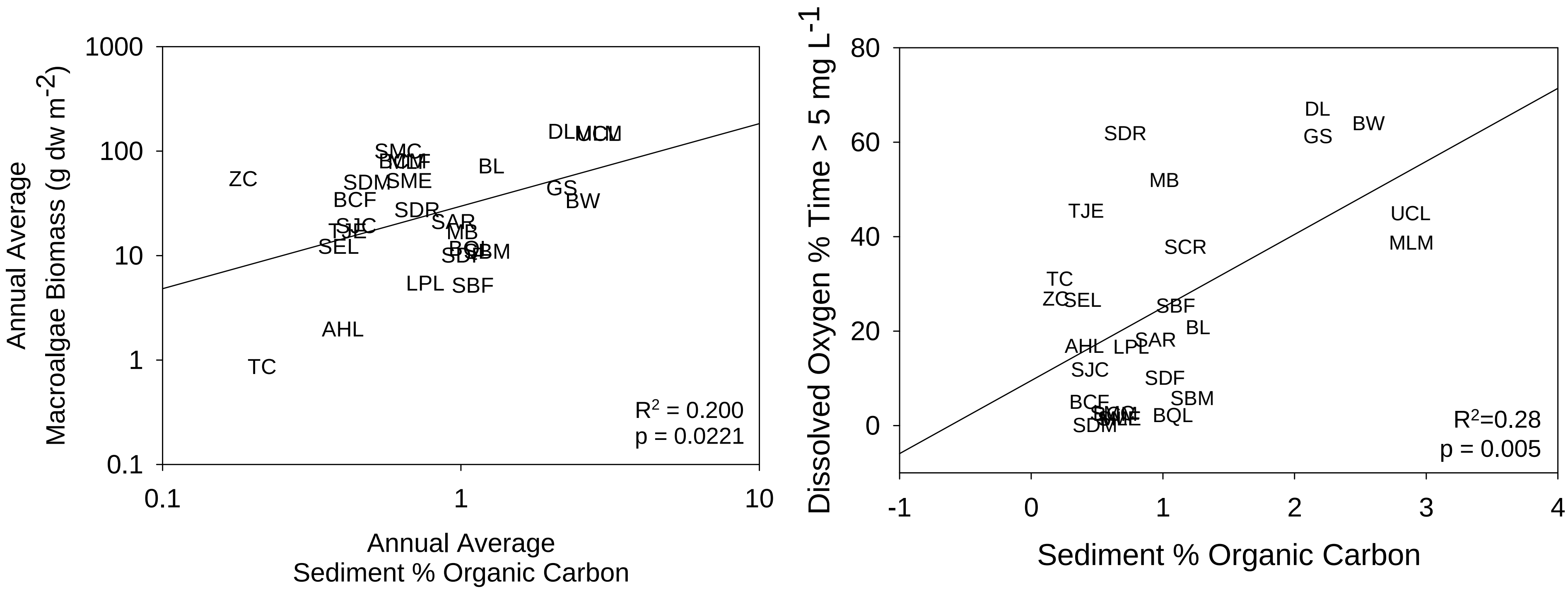
## Wet Weather Dominates Nutrient Loads...



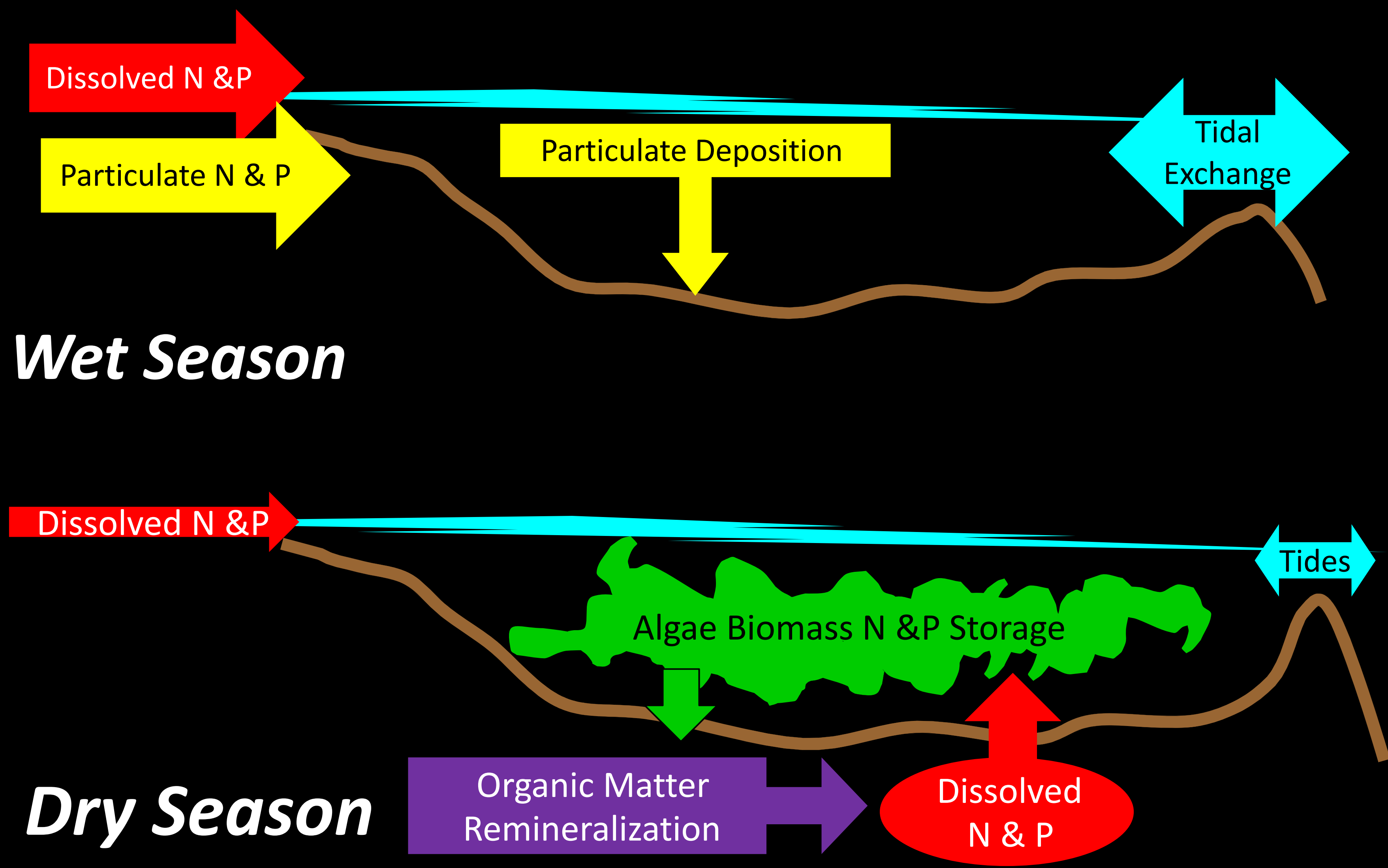
# ...But Critical Period For Indicators is Typically Dry Season



# Macroalgal Biomass and Dissolved Oxygen are Significantly Correlated to Sediment Nutrients

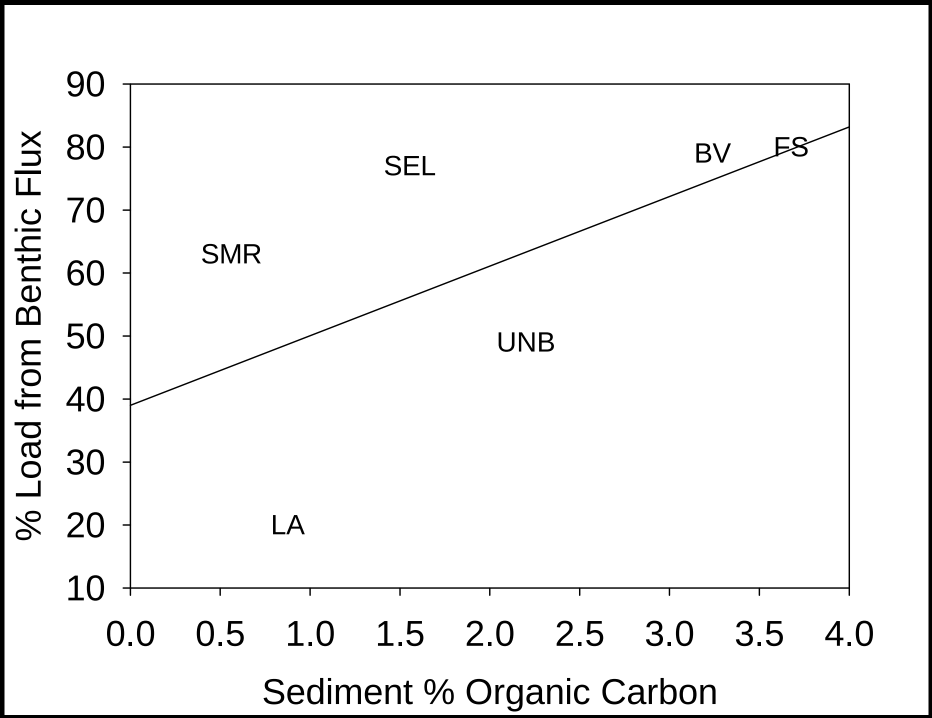


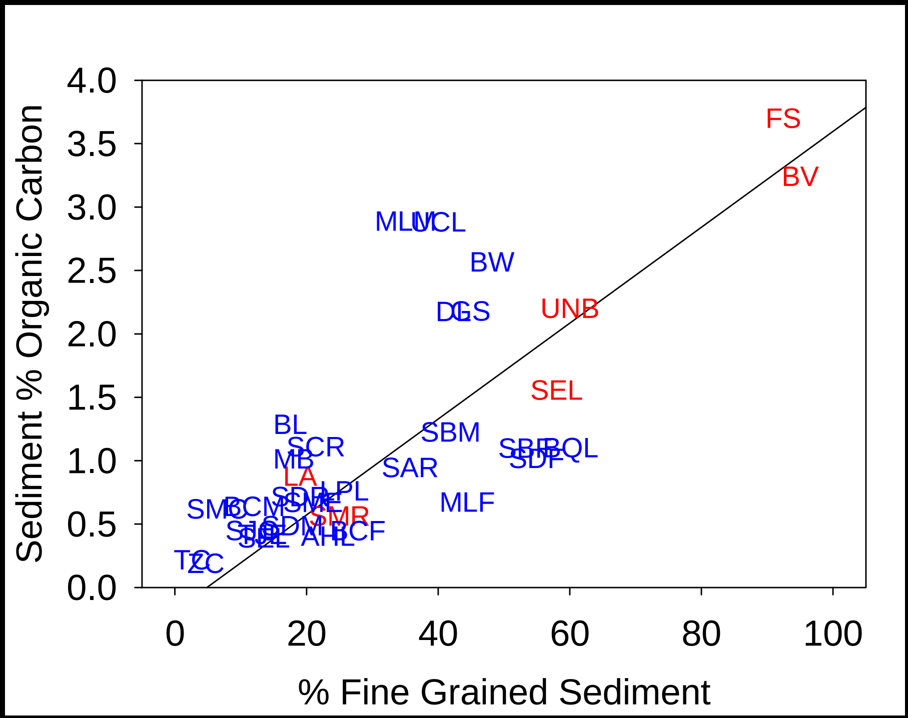
# Wet Season Particulate Deposition is a Source of Dry Season Nutrient Loads



# Relative Contribution of Sediment Nutrients Varies By Estuary

Contribution of Sediment Nutrients Increases as Sediment % Fines and Organic Matter Increase




[1] McLaughlin et al. 2008

[2] Berelson et al., unpublished data

RED McLaughlin et al. 2008

BLUE Bight 08 Eutrophication Assessment

# Estuarine Class is Important:

## Some Estuaries are More Susceptible to Eutrophication

Fluvial ⟷ Lagoonal

**Hydrology**

Higher water velocity | Lower water velocities

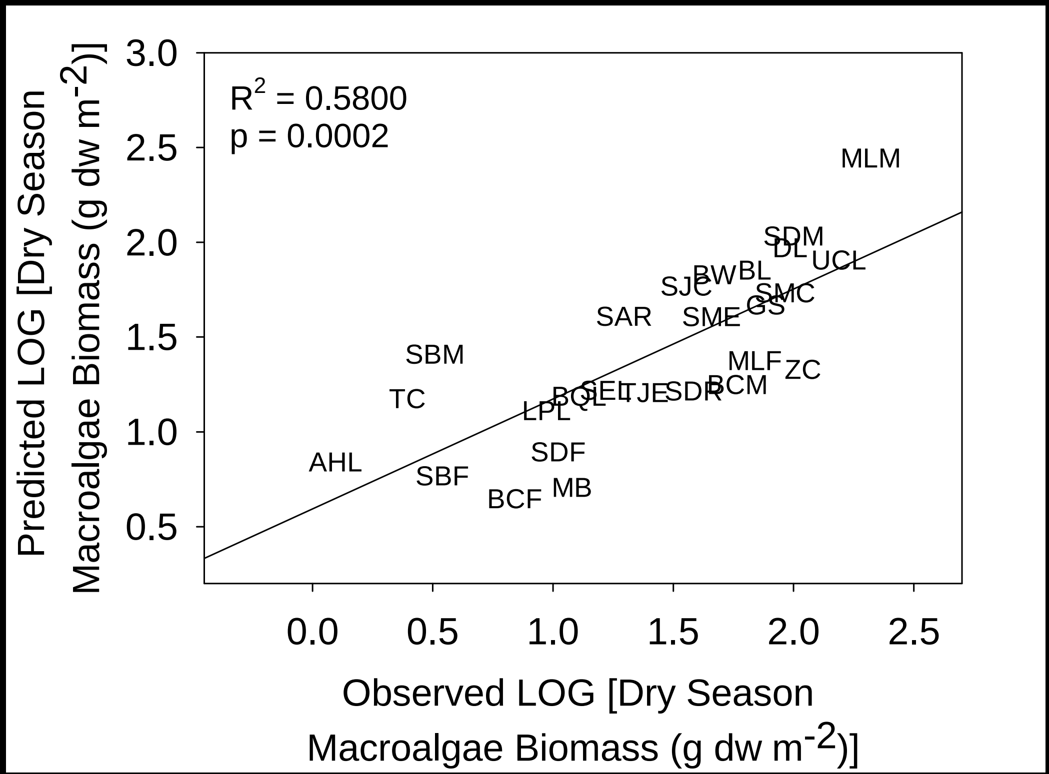
**Physical Habitat**

Sandy sediments | Fine grained sediments

**Biogeochemistry**

Low sediment OC & benthic flux, low algal biomass | High sediment OC & benthic flux, high algal biomass

# Best Model Fit Accounts for Nutrient Loads, Sediment %OC, and Residence Time




| Y | X | $R^2$ | P Value |
|---|---|---|---|
| Macroalgae Biomass | Diurnal Z | 0.3820 | 0.0008 |
| | Annual % OC | 0.1893 | 0.0263 |
| | Annual TN Load | 0.0536 | 0.1197 |
| | **Whole Model** | **0.5800** | **0.0002** |

# Example: Closed Inlet During Critical Period For Macroalgae

# Nutrient-Response Relationship is Governed by Site-Specific Factors

- Across estuaries, nutrient loads and ambient nutrient concentrations are equally correlated with response
  - More reflective of disturbance gradient than true measure of exposure

- Across estuaries, estuary class drives large component of variability in nutrient-response relationships

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**Key Questions:**

- What is the extent and magnitude of eutrophication in southern California estuaries?
- What is the relationship between expression of eutrophication and nutrient inputs?
- What are the implications for nutrient management?

# Managing Eutrophication:
## Need Site-Specific Nutrient Targets

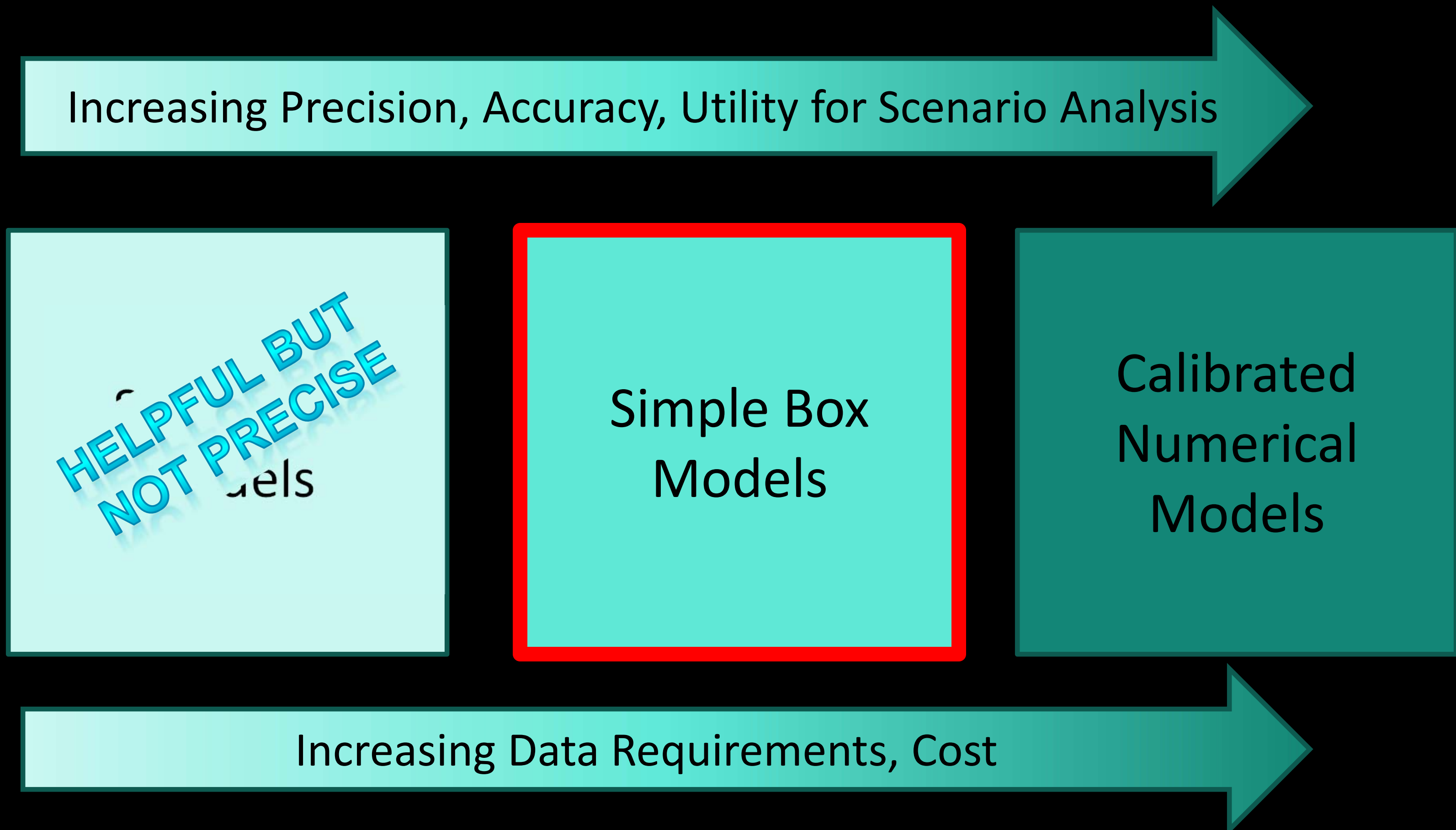
- We assess indicators of eutrophication, but we manage nutrients

- We need models to make the connection between nutrient input and biological response

# Challenges

- How do you make the assessment?
  - What indicators do you use?
  - How do you integrate the data?
- What should the target look like?
  - Ambient concentrations (e.g., Basin Plan Objectives)
  - Nutrient loads (e.g., TMDL)
  - Sediment nutrients
- How should site specific factors be incorporated?
  - Geomorphology: depth, volume
  - Hydrology: residence time

# Next Step… Simple 1-D Box Models




- Account for residence time
- Build in simple empirical relationships between sediment %OC and benthic flux

# Conclusions from Bight ‘08 Study

- Eutrophication is pervasive in SCB estuaries
- Across estuaries, nutrient loads and ambient nutrient concentrations are equally correlated with response
  - More reflective of disturbance gradient than true measure of exposure
- Across estuaries, estuary class drives large component of variability in nutrient-response relationships
- Nutrient-response models must account for site-specific factors, e.g.
  - Residence time
  - Benthic nutrient fluxes

# Questions?

Bight 08 Estuaries Eutrophication Assessment report is available:

ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/711_B08EE.pdf

For more information:

Karen McLaughlin
karenm@sccwrp.org