Science to Support Development of Nutrient Objectives in San Francisco Bay Estuary

Meeting of SF Bay Technical Advisory Team

December 4, 2010

Background

- State Water Resources Control Board is developing nutrient objectives for California waterbodies
  - Estuaries currently under development
- An objective of first phase of project activities is to review literature and develop a work plan for San Francisco Bay
  - Review will summarize science available to support nutrient objective development and important data gaps
  - “Workplan” will lay out steps to address data gaps and develop nutrient objectives
- San Francisco Bay Technical Advisory Team (TAT) is being formed to assure use of best available science in this effort

Meeting Goals

- Discuss SF Bay TAT member role and time commitment
- Provide feedback on the State of California's conceptual approach to setting nutrient numeric objectives
- Recommend geographic scope of SF Bay literature review and work plan
- Recommend indicators to include in review of SF Bay science to support nutrient objective development

Agenda

- Introductions, meeting goals, review of agenda
- Project background and goals
  - California's conceptual approach to nutrient water quality objectives: Nutrient Numeric Endpoint (NNE) Framework
  - Estuarine NNE Development—Process, approach, and products
- SF Bay literature review and workplan
  - Role of SF Bay Tech Team and time commitment
  - Key review questions
- Discussion
  - Recommendations on geographic scope of effort and candidate indicators
- Wrap up and next steps

Overview of Nutrient Objectives in California

- Defining terms
- California's conceptual approach – Nutrient Numeric Endpoint (NNE) Framework
- Project organization
- Development of Nutrient Objectives in California estuaries
  - Process
  - Phase I activities
  - Context for work in San Francisco Bay

Defining Terms…

Clean Water Act (CWA) mandates water quality criteria (limits) to protect beneficial uses (ecosystem services)

EPA has delegated authority for implementing CWA to California State Water Resources Control Board (SWRCB)

In California, we use "objectives" instead of "criteria"

Objectives are found within a package of water quality standards in Regional Water Quality Control Board (RWQCB) Basin plans and SWRCB Statewide Plans

Objectives can be narrative (descriptive) or numeric

More on Water Quality Objectives….

Objectives are used to assess the condition of the State’s water bodies

If objectives are violated, then the system is placed on a SWRCB’ s 303(d) list for impaired waterbodies

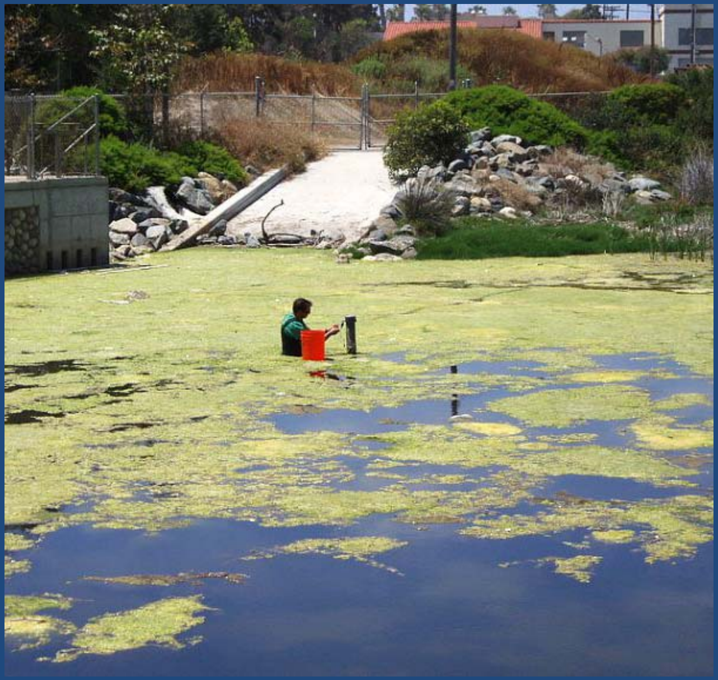
A 303(d) listing can result in the process of setting Total Maximum Daily Loads (TMDL) for that waterbody

Objectives are also used to set effluent limits in point source discharge (NPDES) permits

Objectives are also used in NPS Pollution Control Program

Nutrient Objectives Are Scientifically Challenging

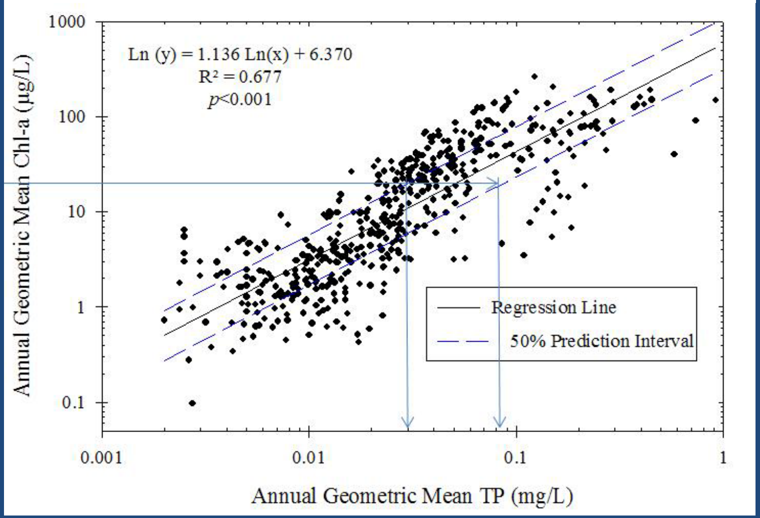
- Nutrients are required to support life
  - How much is too much?
- Toxicity is rarely the endpoint of interest
  - Adverse effects occur at much lower levels
- Using ambient concentrations can give false positives or negatives



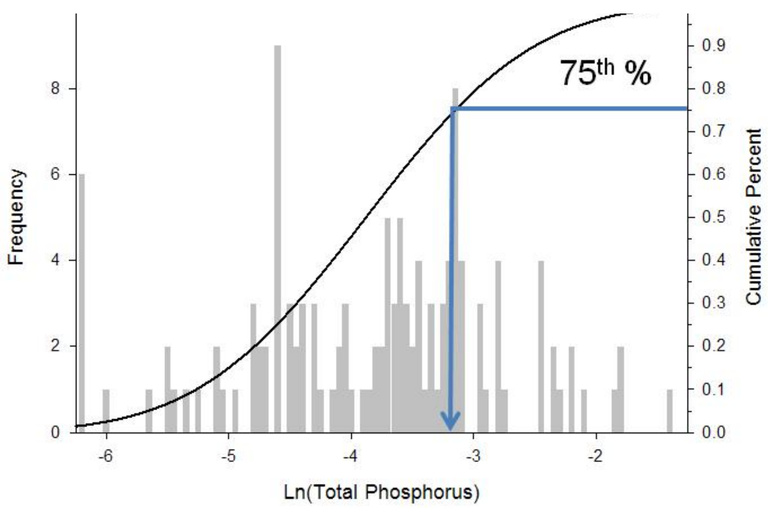
EPA Approach to Setting Nutrient Criteria In Florida Illustrates These Challenges

- Lawsuit settlement requires EPA to develop nutrient criteria for Florida
  - Freshwater criteria in 2010
  - Estuarine in 2011
- Focus on concentrations
- Attempted to correlate concentration with biology
  - Works in lakes, but not in streams
  - Fell back to statistical percentile in streams

Correlation Between Chl a and TP in Lakes



75th %ile of Panhandle Reference Streams

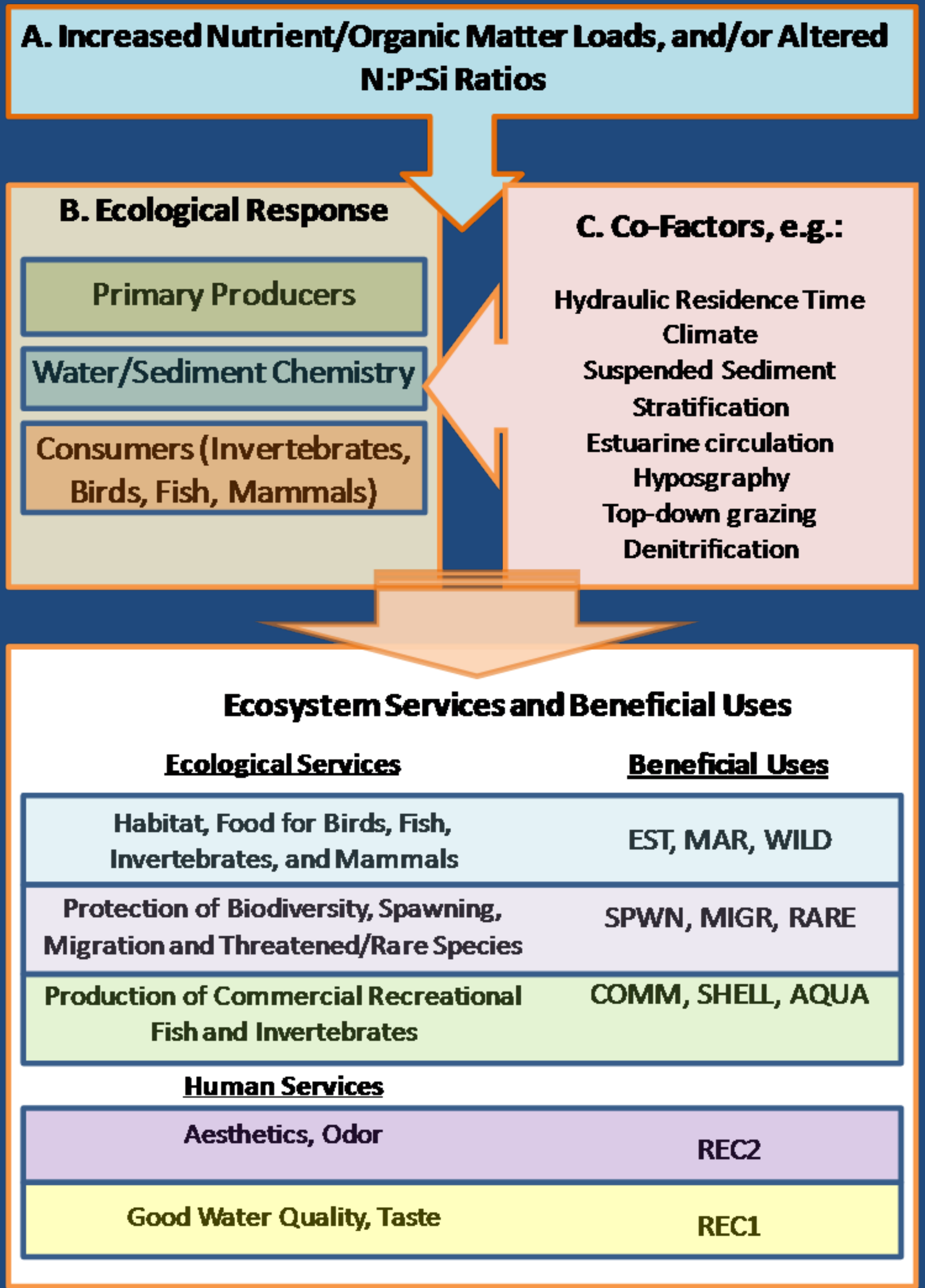


California Has a Different Approach to Establishing Nutrient Objectives

- Diagnosis based on response indicators
  - More direct linkage to beneficial use
  - More integrative measure than nutrient concentrations

Algae and Aquatic Plants

Sediment & Water Chemistry (Dissolved Oxygen, pH)



Conceptual Model: Linking Nutrients, Ecological Response, & Beneficial Uses

Co-factors modulate ecological response

Four Tenets of California's Approach to Nutrient Objectives

- Diagnosis based on response indicators
  - More direct link to beneficial use
  - More integrative measure than nutrient concentrations
- Multiple lines of evidence
  - More robust diagnosis
- Need models to link response indicators to nutrients
  - Nutrient loads rather than ambient concentration
- Use of ranges to accommodate uncertainty in science

Beneficial Use Risk Categories (BURC) Thresholds

BURC I: beneficial uses sustained; not exhibiting nutrient impairment

BURC II: beneficial uses may be impaired; additional information and analysis required to determine the extent of impairment and whether regulatory action is warranted

BURC III: exhibiting nutrient impairment; regulatory action is warranted

California's Approach to Nutrient Objectives: Nutrient Numeric Endpoint Framework

SWRCB Staff Strategy: Narrative objectives with numeric guidance (coined as "NNE")

- Narrative objectives promulgated once
- Numeric guidance can change as science evolves
- Guidance is collectively referred to as the "nutrient numeric endpoint " (NNE) framework

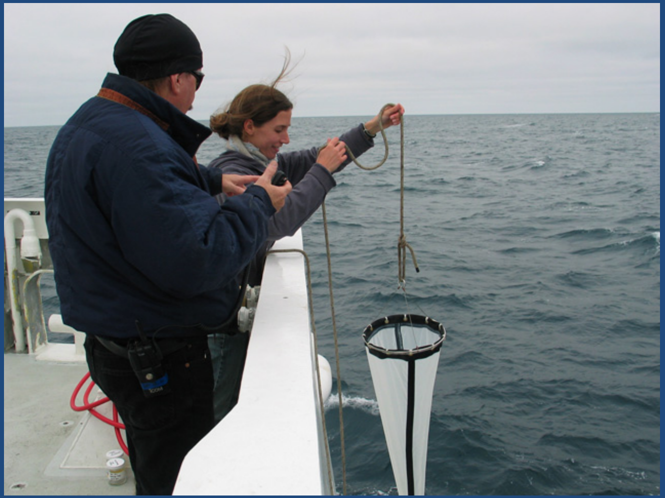
Indicators Will Vary By Aquatic Habitat

Streams and Rivers

Lakes

Estuaries

Ocean



Stream NNE: Example of 303(d) Algal Biomass Thresholds by Beneficial Use

Benthic Algal Biomass

+

pH

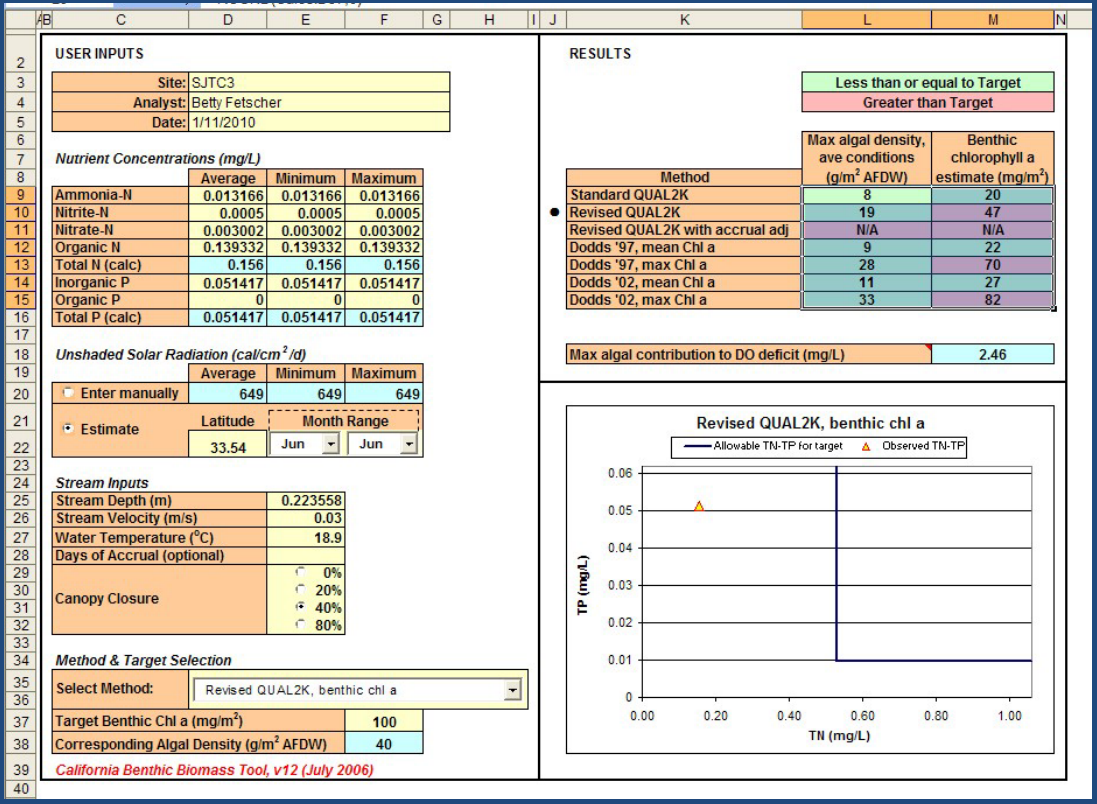
+

Dissolved Oxygen

Response Indicator	Beneficial Use					
	COLD	WARM	REC-1 &-2	MUN	SPWN	MIGR
BURC II Benthic Algal Biomass (mg chl a m^{-2})	150	200	Same as WARM/COLD	100	100	Not Defined

NNE Benthic Biomass Spreadsheet Tool

- Spreadsheet tools to convert response *targets* to site-specific *TN and TP concentration goals*



- Account for co-factors that modify biological response to nutrients

- Used for initial screening – defer to more complete modeling / monitoring studies

Take Home Message

NNE “framework” consists of two components:

- Numeric endpoints – ecological response

- Tools to link ecological response indicators back to nutrients and other co-factors controlling response to eutrophication

NNE numeric endpoints assesses “eutrophication”, not nutrient overenrichment

Status of Nutrient Objective Development by Waterbody Type

Waterbody Type	Status
Streams	Endpoints and tools drafted
Lakes	Endpoints and tools drafted
Enclosed Bays & Estuaries	Endpoints under development
Nearshore Coastal Waters	No work undertaken

Project Organization

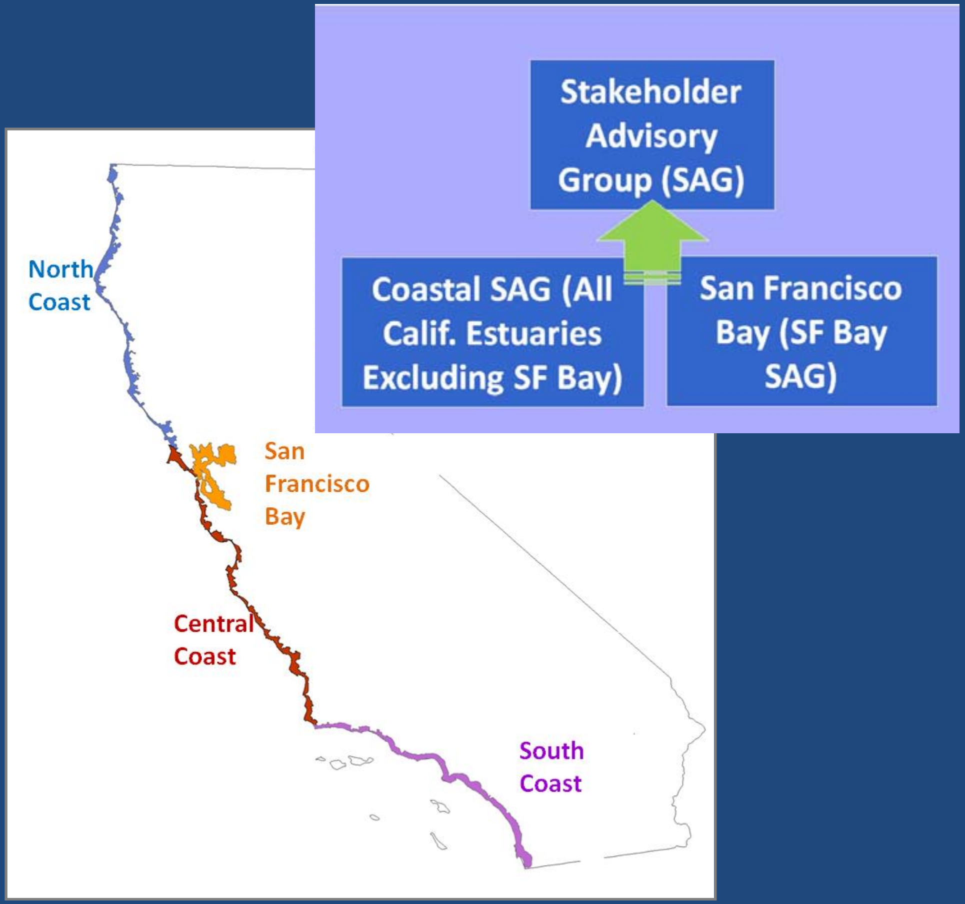
Stakeholder Advisory Group (SAG)

State Water Resources Control Board (SWRCB)

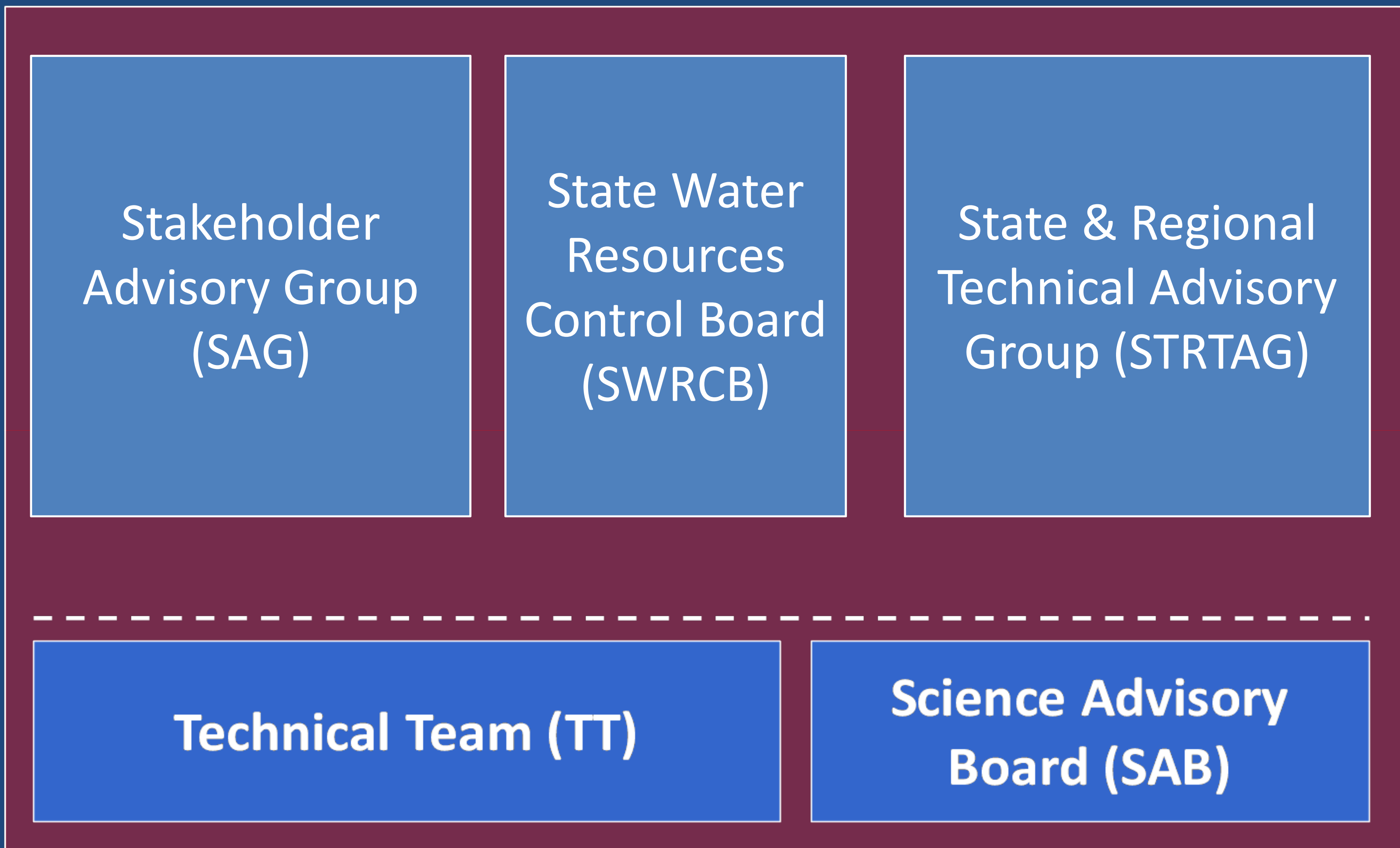
State & Regional Technical Advisory Group (STRTAG)

Stakeholder Advisory Groups (SAGs)

- Role: Provide feedback to SWRCB on NNE science and policy
- Composed of members of regulated community, land owners, environmental NGOs, and interested public



Project Organization



Technical Team

- Role: Synthesize available science relevant for NNE development
- Composed of experts on the ecosystem components impacted by eutrophication

Macroalgae	Submerged aquatic vegetation
Fisheries	Benthic ecology
Hydrodynamics	Phytoplankton/nekton
Biogeochemistry/water quality	

- Team composition can change as a function of focus of the particular product

E-NNE Technical Team

- Martha Sutula (SCCWRP)
- Karen McLaughlin (SCCWRP)
- Peggy Fong (UCLA)
- John Largier (UC Davis)
- Jim Kaldy (EPA ORD
- Naomi Dettenbeck (EPA ORD)
- Nicole Beck (Second Nature, Inc.)
- Camm Swift (Entrix, Inc.)
- Lester McKee (SFEI)
- Jerry Smith (SJSU)
- Mike Saiki (USGS)
- Larry Allen (CSUN)
- Ellen Freund (USD)
- Greg Calliet (MLML)
- Glen Thursby (EPA ORD)

Science Advisory Board

- Role: review products and recommendations of the technical team
- Composed of 3-4 nationally recognized experts in eutrophication (outside of California)
- Operate completely independent of technical team

Project Organization- SF Bay

SF Bay SAG

State Water Resources Control Board (SWRCB)

SF RWQCB

STRTAG

SF Bay Technical Team

Science Advisory Board (SAB)

Project Organization –Key Staff

- SWRCB lead - Rik Rasmussen and Steve Camacho
- SF RWQCB lead- Naomi Feger
- EPA Region 9 – Suesan Saucerman and Terry Fleming
- SF Bay and Coastal SAG Lead – Brock Bernstein
- Statewide Technical Team Lead- Martha Sutula (SCCWRP)
- SF Bay Technical Team –Lester McKee (SFEI)

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Technical Basis to Develop Estuarine NNE Assessment Framework– The Process

Identify target population and propose classification

Develop conceptual models, review indicators, and ID data gaps

Address data gaps with analysis of existing data and new research

Develop assessment framework

State Water Board and Advisory Group Review and Endpoint Selection

E-NNE Development- Two Phases

Phase I:

- Development of NNE for selected indicators based on existing literature
- Majority of effort focused on “other” California estuaries

Phase II:

- Analysis of existing data and research to address data gaps for “other” estuaries
- Nutrient load-response tools
- Elements of work plan focused on San Francisco Bay

Major E-NNE Products- Phase I

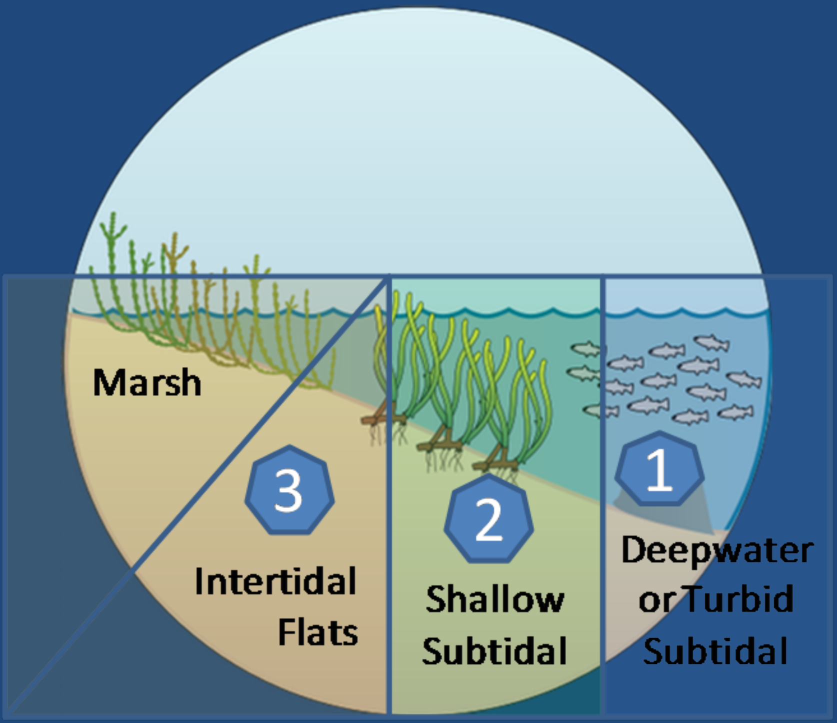
Phase I – Development of NNE for selected indicators based on existing literature

- Target definition and estuarine classification
- Literature review of candidate indicators
- Review of dissolved oxygen objectives
- Studies supporting NNE for macroalgae on intertidal flats
- Literature review and work plan for San Francisco Bay

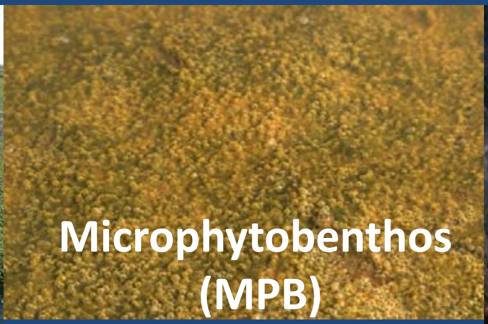
Preliminary Classification

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

Appropriate Indicators Will Vary By Habitat Type



Depth	Dominant Primary Producers
Intertidal Flats	Microphytobenthos (MPB) Macroalgae
Subtidal	MPB Phytoplankton Macroalgae SAV
Deepwater or Turbid Subtidal	MPB Phytoplankton



Inventory and Classification Study Plan

Goal: Compile existing data to develop an inventory and classification of California estuaries

- Enumerate coastal drainages
- Compile existing data (on 190 of 400 drainages)
  - Geomorphology (merged bathymetry topography, wetland habitat distribution, mouth depth and width when open)
  - Tidal forcing (ocean inlet opening timing and duration)
  - Peak freshwater flow
  - Climate (air temperature, no. of cloudy days)
- Preliminary statistical classification

Review of Candidate Indicators for the Estuarine NNE

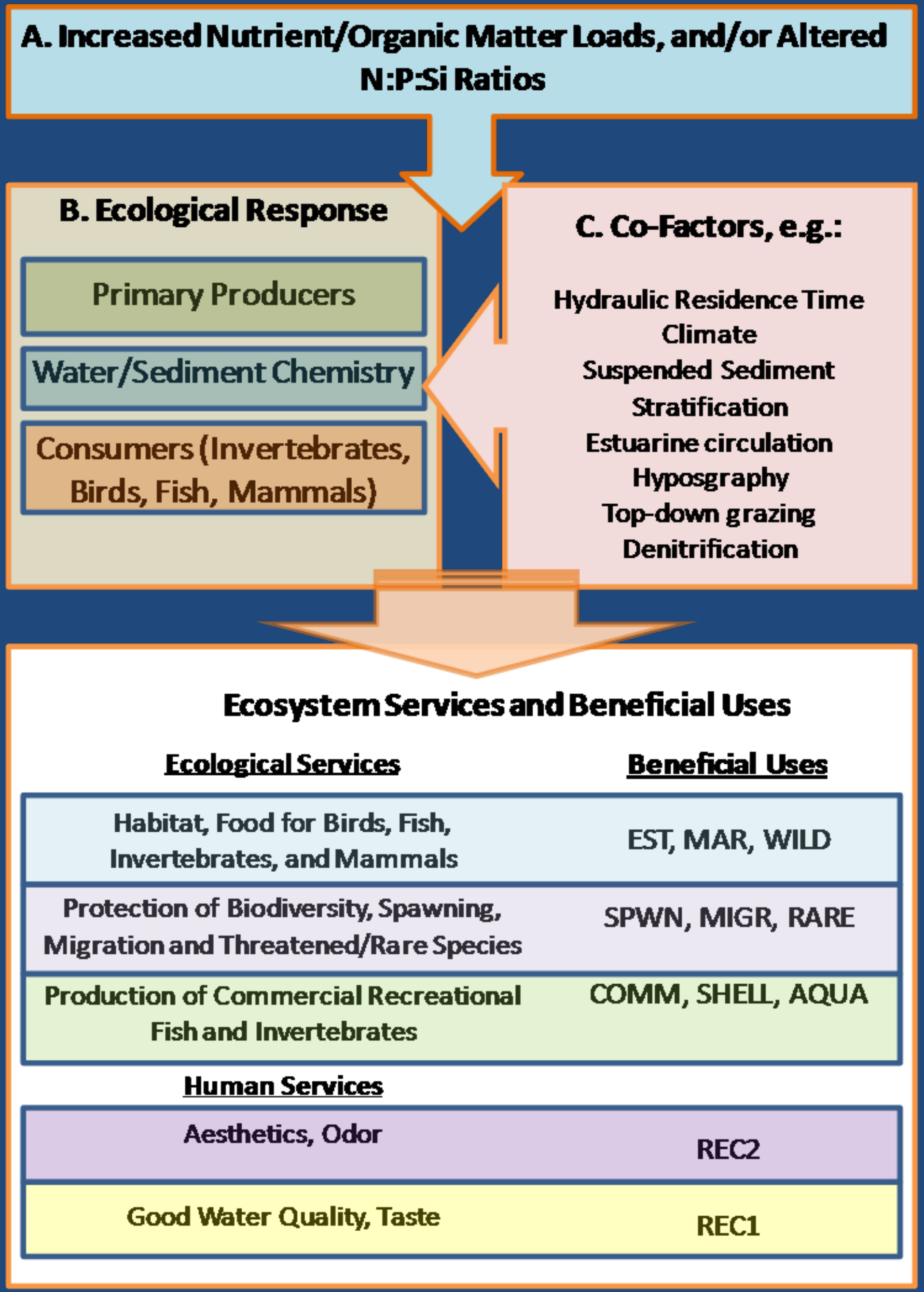
Two Principle Questions:

- Is the candidate an acceptable indicator
  - Need criteria to define “acceptable”
- If so, does science exist to help develop an assessment framework (with thresholds)?
  - If not, what scientific studies are required?

Indicator Review Criteria

- Clear understanding of how indicator changes along disturbance gradient (pristine to most disturbed)
- Dose – response relationship exists between indicator & higher trophic level (link to beneficial use)
- Can develop <u>predictive model</u> between nutrient loads, other co-factors, and ecological response (statistical, spreadsheet, or dynamic simulation models)
- Scientifically sound and practical measurement process
- Show a detectable trend in eutrophication (signal: noise ratio is acceptable)

Conceptual Model: Linking Nutrients, Ecological Response, & Beneficial Uses



Co-factors modulate ecological response

Estuarine NNE Framework: Candidate Indicators

Primary Producers Indicators

- Phytoplankton biomass and/or community composition
- Macroalgal biomass
- Submerged aquatic vegetation
- Microphytobenthos (MPB) biomass and/or comm. composition

Physiochemical Indicators

- Dissolved oxygen
- Ammonia
- Water clarity
- Toxic metabolites (HAB toxins, sulfide)
- Sediment organic matter accumulation
- Benthic/pelagic metabolism

Consumer Indicators

- Benthic macro-invertebrates

Candidate Indicator Review Report

Completed

- Introduction and purpose
- Conceptual models, beneficial uses, list of candidate indicators, & indicator review criteria
- Macroalgae
- Seagrass and Brackish SAV

January 2010

- Phytoplankton
- Microphytobenthos
- Sediment and water chemistry
- Benthic macroinvertebrates
- Synthesis, data gaps and recommendations

Review Identifies Promising Indicators & Is Template for Research Over Next 5 Years

Indicator	Tidal Flats	Subtidal Unveg	Seagrass	Deep/turbid subtidal	Subtidal Unveg.	Subtidal Brackish SAV
	Open Estuaries				Closed Estuaries	
Dissolved Oxygen						
Macroalgal biomass/ cover						
Phytoplankton Biomass						
Phytoplankton Taxonomy						
HAB toxins /sp. abundance						
Macrobenthos taxonomy /biomass						

Not Applicable | Funded | In Planning | Possible | Uncertain

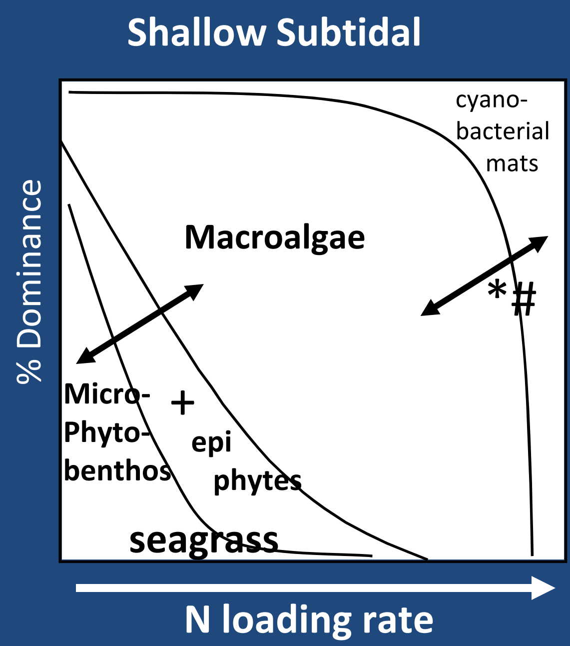
Review of Science for NNE in Estuaries: Example for Mudflat Habitat

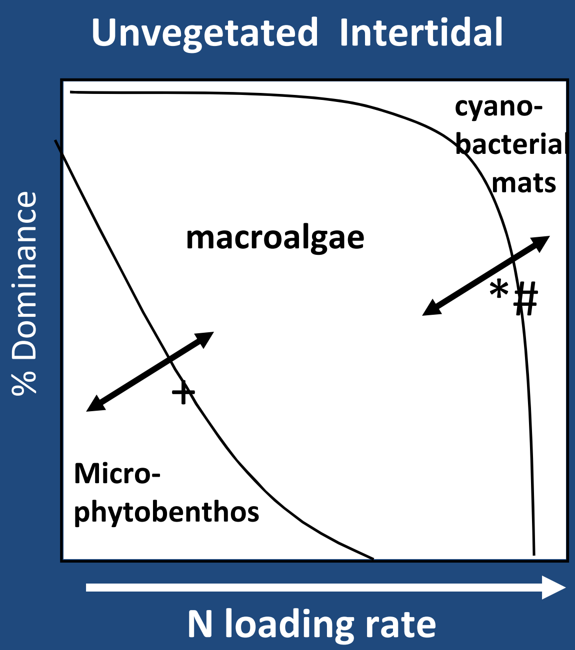
Macroalgal Mats in Mugu Lagoon, Southern California (Photo Credit L. Green)

Indicator Review Criteria

- Clear understanding of how indicator changes along disturbance gradient (pristine to most disturbed)
- Dose – response relationship exists between indicator & higher trophic level (link to beneficial use)
- Scientifically sound and practical measurement process
- Show a detectable trend in eutrophication (signal: noise ratio is acceptable)
- Can develop predictive model between nutrient loads, other co-factors, and ecological response (statistical, spreadsheet, or dynamic simulation models)

Conceptual model of relationships among N-loading rate and the community composition of primary producers in shallow subtidal and intertidal flats of perennially tidal estuaries (Adapted from Valiela et al. 1997)



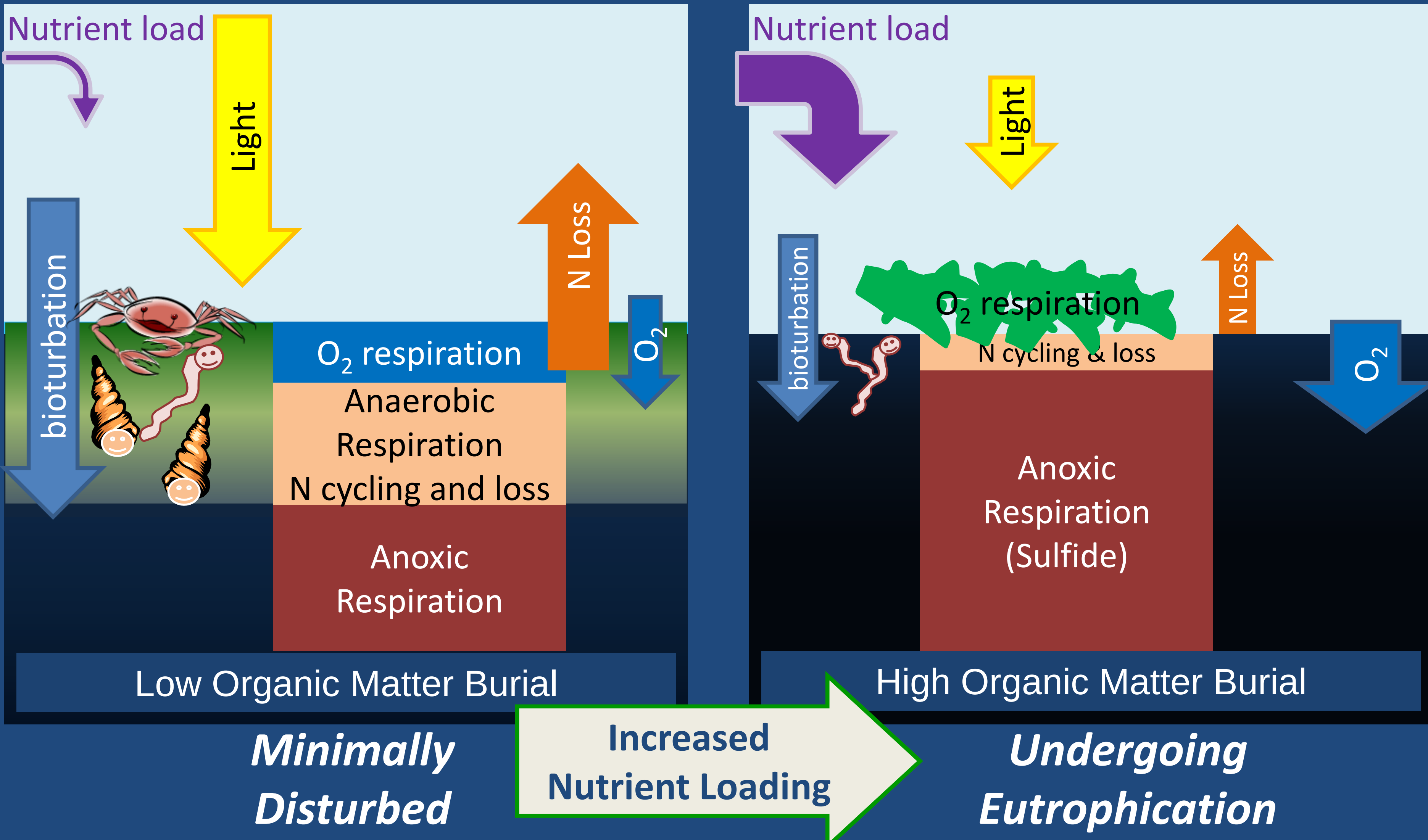


* depends on tidal elevation and water residence time

+ mediated by herbivory

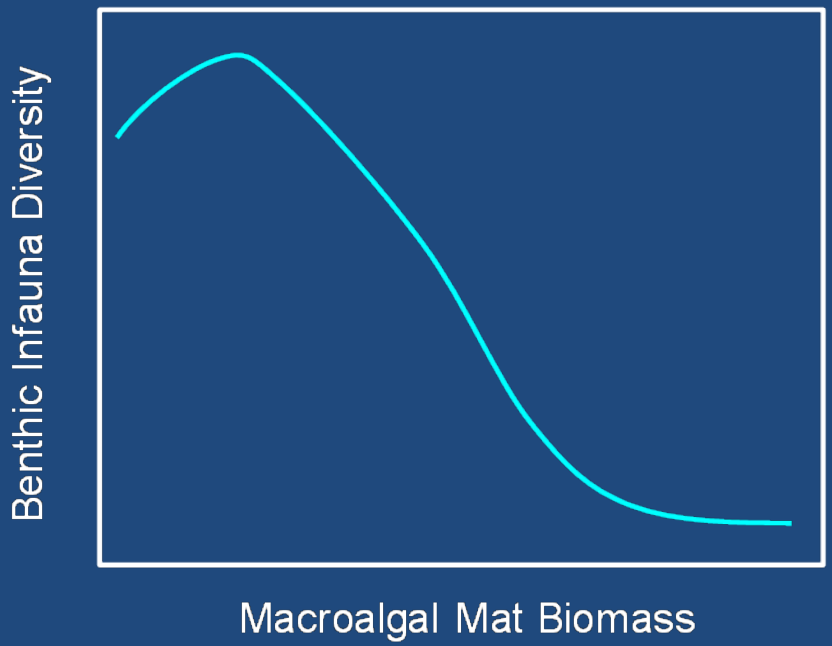
depends on benthic topography

Conceptual Model of Effects of Macroalgae On Infauna in Intertidal Flats



Documented Link with Beneficial Uses: Two Tests

- Weight of scientific evidence demonstrating linkage?
- Dose-response data that support selection of a threshold?



Effects on Management Endpoints of Concern

- Poor surface water quality (strong diel DO fluctuations and hypoxia, increased bacterial growth) and aesthetics: REC1, REC2, EST, MAR, SPWN, RARE, COMM
- Poor benthic habitat quality (Increased sediment organic matter accumulation, increased pore water sulfide, ammonia, etc.): EST, MAR, RARE, COMM, AQUA
- Changes in food web (shifts in food supply for upper trophic levels)
- Loss of critical habitat for fisheries, birds, esp. T&E species

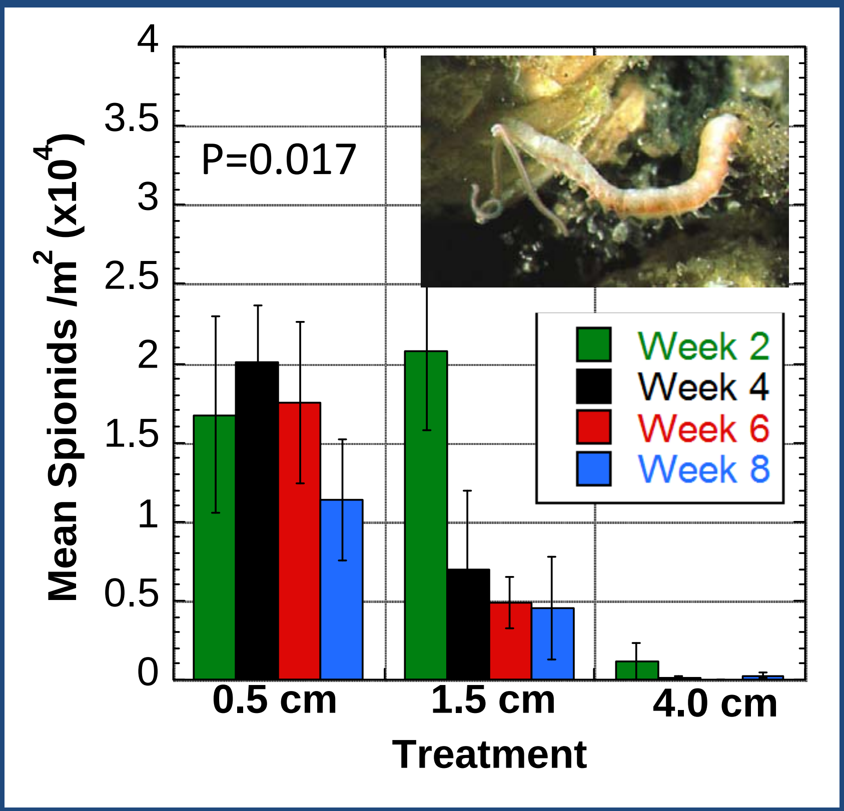
Summary of Studies Documenting Effects of Macroalgae on Infauna on Intertidal Flats

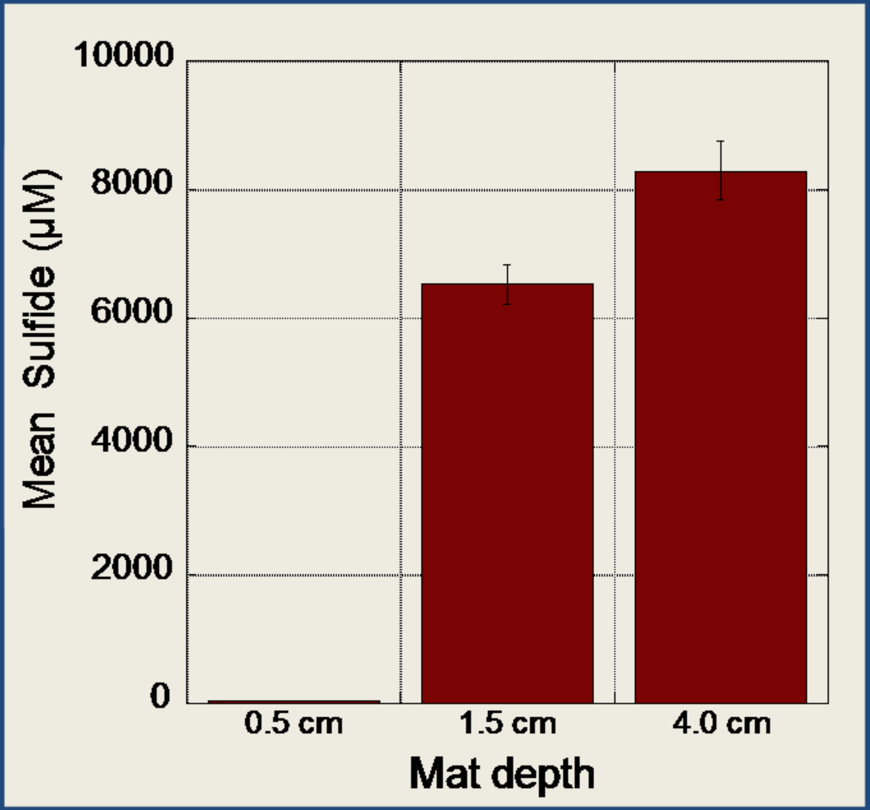
[See Table in Handout]

- Lots of studies demonstrating effects
- Comparison difficult because of disparate methods
- Studies cannot be used to evaluate thresholds, with exception of:
  - Green 2010 (Mugu Lagoon, so. Calif.)
  - Bona et al. 2006 (European Mediterranean)

Macroalgal Blooms on Intertidal Flats Cause Declines in Benthic Infauna Diversity and Abundance

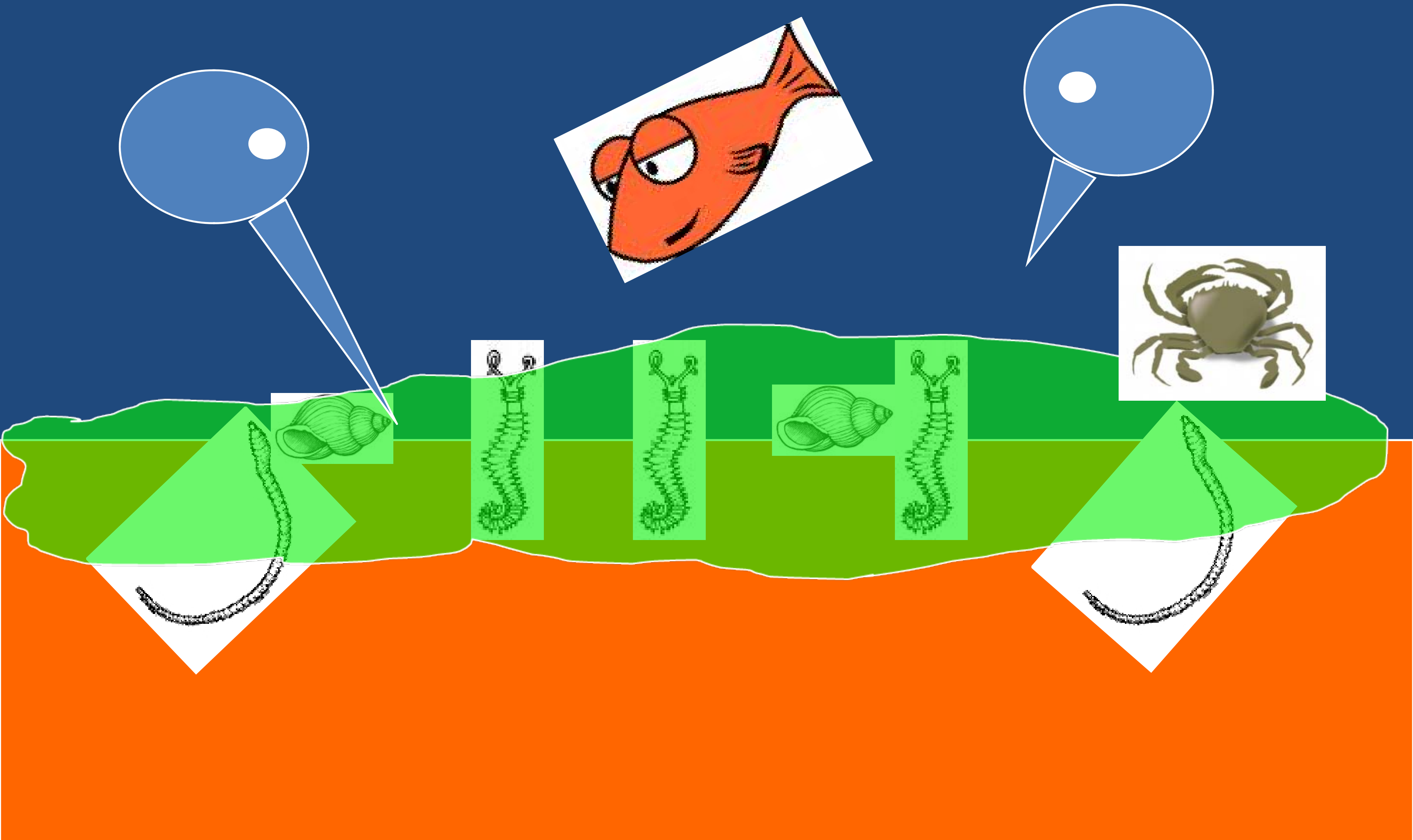
Spionids





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

Macroalgal Blooms Reduce in Availability of Invertebrate Forage Food for Birds and Fish



Indicators of Macroalgal community structure

Abundance–Scientifically well-veted means of measuring

- Biomass (thickness)
- Percent cover

Taxonomic composition

– not relevant for California estuaries

Macroalgae Has A Well-Documented Relationship with Nutrient Loading

- Yes - best example is Waquoit Bay (MA)
  - Total nutrient loads predict algal biomass in 3 sub-basins with differing loads
  - But the relationship is complex (easiest where river sources are dominant)
- Data to establish empirical load-macroalgal response relationships for California estuaries do not exist
- Few examples of use dynamic simulation modeling exist, none local

Information Needs to Be Synthesized into an Assessment Framework

Example of Macroalgal Assessment Framework From EU WDR (from Scalan et al. 2007)

<table>
<tr><td rowspan="5">ALGAL BIOMASS</td><td>>3000 $g\ m^{-2}$</td><td colspan="2">MODERATE</td><td colspan="2">POOR</td><td colspan="4">BAD</td></tr>
<tr><td>>1000 to 3000 $g\ m^{-2}$</td><td colspan="2">GOOD/MODERATE
entrained algae
- monitor</td><td>MODERATE</td><td>MODERATE/POOR
entrained algae
- monitor</td><td colspan="2">POOR</td><td colspan="2">BAD</td></tr>
<tr><td>500 to <1000 $g\ m^{-2}$</td><td colspan="2">GOOD</td><td colspan="2">GOOD/MODERATE
entrained algae
- monitor</td><td colspan="2">MODERATE</td><td>POOR</td><td>POOR</td></tr>
<tr><td>100 to <500 $g\ m^{-2}$</td><td>HIGH</td><td>HIGH/GOOD
entrained
algae -
monitor</td><td colspan="2" rowspan="2">GOOD</td><td rowspan="2">GOOD
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algae
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entrained algae
- monitor</td><td>MODERATE</td><td>MODERATE/POOR
entrained algae
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entrained algae
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Macroalgae on Intertidal Flats: Summary

- Macroalgae meets criteria as “acceptable” indicator
- Additional data on effects of macroalgal mats on infauna in intertidal flats
  - Need various treatment levels and duration
  - Response may vary by sediment type and organic matter content, time of year, estuarine class, climate, etc.
- Lack of information on range of biomass and % cover found over disturbance gradient in California estuaries
- Lack of information on precision and accuracy of nutrient load-response models

Review Identifies Promising Indicators & Is Template for Research Over Next 5 Years

Indicator	Tidal Flats	Subtidal Unveg	Seagrass	Deep/turbid subtidal	Subtidal Unveg.	Subtidal Brackish SAV
	Open Estuaries				Closed Estuaries	
Dissolved Oxygen						
Macroalgal biomass/ cover						
Phytoplankton Biomass						
Phytoplankton Taxonomy						
HAB toxins /sp. abundance						
Macrobenthos taxonomy /biomass						

Not Applicable | Funded | In Planning | Possible | Uncertain

Major E-NNE Products- Phase I

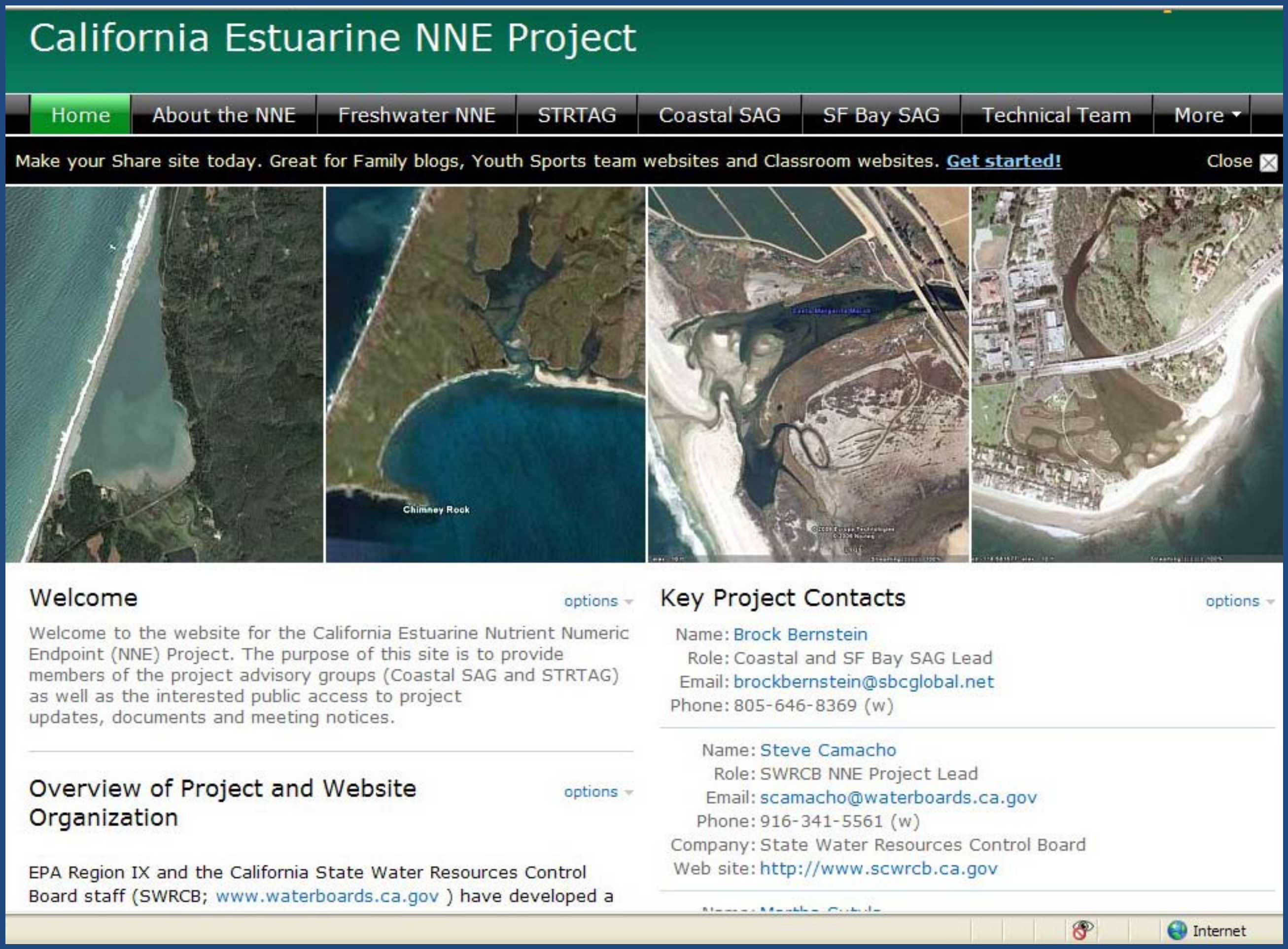
Product	Timeframe
Classification study	Spring 2011
Indicator literature review and broad technical framework	Initial draft late fall 2010 Final draft spring 2011
Bight '08 eutrophication assessment	Oral presentation Fall 2010-Fall 2011 Final report Spring 2012
Literature and work plan for SF Bay	Preliminary work plan Spring 2011 Final work plan Spring 2012
Review of estuarine dissolved oxygen objectives	Preliminary report Spring 2011 Revised report Spring 2012
Studies supporting macroalgal endpoint for intertidal flats	Proposed framework Spring 2012

Results of Phase I will drive work plan for Phase II

Summary

- SWRCB has unified conceptual approach to developing nutrient objectives
  - Central tenets: response indicators, multiple lines of evidence, load-response tools
  - Flexibility in how concept applied given
- Statewide Phase I work provides conceptual framework and broad summary of science to support NNE development in SF Bay
  - Need specific review of SF Bay science, analysis of data gaps, and recommended studies to move forward

For More Information…



Martha Sutula – 714-755-3222 or marthas@sccwrp.org

http://californiaestuarinenneproject.shutterfly.com/

Questions? Comments?

- Feedback on California’s conceptual approach to nutrient objectives?