Goal for Today's PM Session Is to Get your Feedback on:

Part I

Biostimulatory operating assumptions

Wadeable Stream Eutrophication Synthesis

- Conceptual model and review of indicators
- Scientific bases for numeric targets
  - Aquatic life related uses
  - Human related uses

Martha Sutula
marthas@sccwrp.org

Raphael Mazor
raphaelm@sccwrp.org

Water Board Basin Plans have An Narrative Biostimulatory Objective

WB Staff Plans for Phase 1: Guidance for consistent interpretation of narrative objective across all waterbody types, and numeric guidance for wadeable streams

Toxic cyanobacterial bloom in Clear Lake

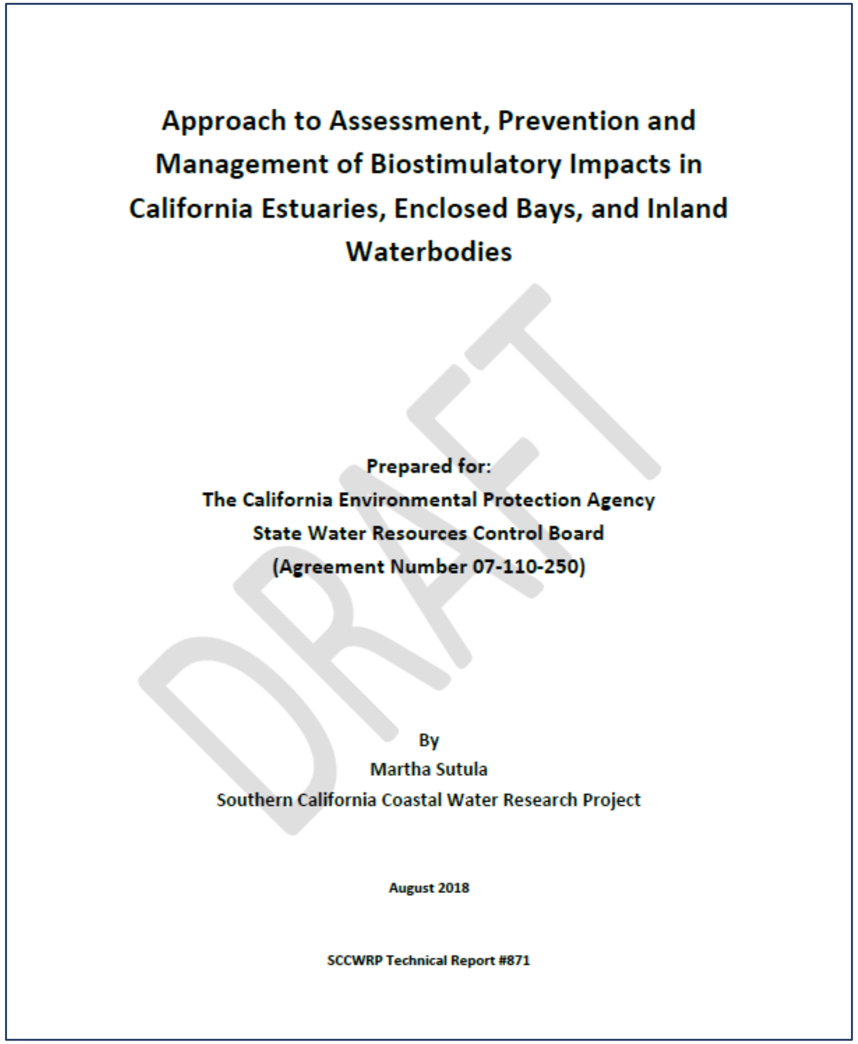
Hypoxia-induced fish kill

Impact to fish habitat and aesthetics of trout stream

"waters shall not contain biostimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses"
 - Central Coast Water Board Basin Plan 1990

"Biostimulatory Principles" Document Represents Tech Team's Operating Assumptions Supporting Approach to Biostimulatory

- General resource for generating conceptual models and indicators where no numeric guidance exist
- 40 + years of global eutrophication science
  - Completed California eutrophication science on estuaries and (now) wadeable streams
- Operating assumptions



Approach to Assessment, Prevention and Management of Biostimulatory Impacts in California Estuaries, Enclosed Bays, and Inland Waterbodies

DRAFT

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

By
Martha Sutula
Southern California Coastal Water Research Project

August 2018

SCCWRP Technical Report #871

Support Consistent Interpretation of Narrative Objective (In Advance of Numeric Guidance)

- ★ Definitions of eutrophication (the problem) and biostimulatory
- Typology of waterbodies (framework for numeric guidance)
- Generic conceptual models of risk pathways, indicators and linkage to beneficial uses
- Evidence of eutrophication impacts to California Waterbodies (problem statement)
- ★ Key assumptions and principles (foundation for science we've conducted on wadeable streams, estuaries done thus far)

Builds off of Nutrient Numeric Endpoints Framework (Tetra Tech 2006)

★ *Assume that you may want to discuss this today, so presentation will focus on this, but can respond to anything*

Key Definitions That Frame Biostimulatory Science

Eutrophication (the Problem): the accelerated delivery, *in situ* production, and/or accumulation of organic matter within an aquatic ecosystem (Nixon 1995, Cloern 2001)

Nutrient Management

Low Impact Development

Watershed Restoration

Environmental Flows

Biostimulatory Substances and Conditions: substances such as nutrients (i.e. nitrogen, phosphorus, organic matter) or conditions, such as altered temperature, hydrology, etc. that can cause eutrophication (Cloern 2001, Paerl et al. 2011)

“Biostimulatory” Science

10 Key Assumptions and Principles

1. “Biostimulatory drivers” are defined as substances such as nutrients (i.e. nitrogen (N) and phosphorus (P) and associated organic matter) or conditions, such as altered physical habitat, temperature, hydrology, etc. that can cause eutrophication.
2. Assessment of biostimulatory impacts is based on the diagnosis of eutrophication and its consequences; inclusion of causal nutrients or other biostimulatory drivers are part of a comprehensive causal assessment and risk prevention approach.
3. Biostimulatory impacts to beneficial uses can be assessed through a framework developed for each waterbody type, with indicators that represent lines of evidence.
4. Assessment of biostimulatory impacts can consider evidence for impacts to both human and wildlife (aquatic and terrestrial) related beneficial uses.
5. Statewide bioassessment indices can be used as assessment endpoints from which to derive biostimulatory targets protective of aquatic life and related beneficial uses.

“Biostimulatory” Science

10 Key Assumptions and Principles

6. To account for total “biostimulatory” potential, thresholds should be based on total nutrients (as opposed to dissolved inorganic form) and for both N and Ps, as opposed to just controlling what is considered limiting on-site (either N or P).
7. Eutrophication symptoms may be caused by biostimulatory drivers far-field from the waterbody; thus assessment of biostimulatory impacts should take a watershed-wide approach.
8. Biostimulatory conditions can be a focal point of development of watershed-specific numeric targets and adaptive management strategies.
9. Implementation options to address biostimulatory conditions and substances should recognize the complexity of these drivers and how they can vary spatially and temporally from watershed to watershed and among certain waterbodies.
10. Generic conceptual models provided are a starting point for more specific model development at a watershed- or waterbody-specific scale.

Outline of Eutrophication Synthesis Report

Report is ~90% complete; We expect advisory group questions and comments to inform additional work

- Definitions, with citation of "Approaches…" report
  - Eutrophication
  - Biostimulatory substances and conditions
  - Wadeable streams
- Wadeable Streams conceptual models and literature review of pathways of adverse impacts on beneficial uses
- ★ Evaluation of candidate eutrophication indicators
  - Eutrophication Response
  - (Causal) Biostimulatory Drivers
- ★ Synthesis of Threshold Science, As Basis for Policy Decisions on Numeric Targets
  - Aquatic Life
  - Human

Assume that you may want to discuss this today, so presentation will focus on this, but can respond to anything

Key Findings, Part I: Conceptual Models and Indicators

- 40 year of eutrophication science of wadeable streams provides a robust basis for conceptual model and candidate indicators

- We've identified response or causal indicators that can serve as either primary and/or supporting lines of evidence in biostimulatory assessment (ultimately a Water Board staff judgment call)
  - Organic matter accumulation
  - Water column or benthic chemistry
  - HAB cell density and toxins
  - Biostimulatory drivers (nutrients)

Many of these measures have strong basis for thresholds.

Summarized in Part II of this presentation

Response Indicator Review Criteria

Indicators Should:

- Have a clear link to beneficial uses
- Show a trend either towards increasing or/and decreasing eutrophication with an acceptable signal: noise ratio
- Have a predictive relationship with biostimulatory drivers that can be modeled (empirical or mechanistic modeling)
- Have a scientifically sound and practical measurement process, with available SOP
- Have a scientific basis for a numeric target

It would be beneficial if indicators also:

- Were easy to understand to a non-technical audience (unambiguous)
- Is currently in routine use in statewide ambient monitoring programs
- Were adaptable for use at a range of spatial scales

Candidate Response Indicators Were Reviewed Using these Criteria

Table 2.3. Evauation of wadeable stream eutrophication response measures vis-à-vis evaluation criteria. Asterick (*) denotes applicability to eutrophication diagnosis at the metric level. Number represents strength of measure for each evaluation criterion, from 3 = best to 1= worst, while no number indicates no basis. Y= used in SWAMP or PSA assessments. H= human uses (REC1, MUN); AL = Aquatic life uses (WARM, COLD, WILD, RARE, SPAWN, MIGR)

Biostimulatory Indicator	Linkage to BU	BU Type	Robust Signal: Noise	Cost Effective	In Routine Use	SWAMP or PSA?	Model to Biostimulatory Drivers?	Basis for Numeric Target?
Organic Matter Accumulation								
Benthic and/or planktonic algal biomass (benthic chl-a, water column chl-a)	3	AL	3	3	3	Y	3	3
Benthic or floating macroalgal percent cover	3	AL, H	1	3	3	Y	1	AL= 1, H = 3
Benthic or planktonic AFDM, or organic C, N, P	3	AL	3	3	3	Y	3	3
Aquatic macrophytes: biomass, shoot height, density	2	AL		1	1		1	
Aquatic macrophyte percent cover	1	AL		3	3	Y	1	
Water and Benthic Chemistry								
Continuous DO and pH; Diel range	3	AL	3	2	3		3	3
Water column or sediment oxygen demand	1	AL	1	1	1		3	
Ecosystem metablism and trophic state	2	AL	2	1	1		3	
Dissolved organic carbon, trihalomethane	3	H	3	3	3		3	1
Aquatic Community Measures								
Planktonic or benthic algal community composition	3	AL	3 *	3	3	Y	2	3
Benthic macroinvertebrate community composition	3	AL	3*	3	3	Y	2	3
Harmful Algal Blooms								
Benthic cyanoHAB cell density and toxin	3	H, AL	2	3	3	Y	2	1
Particulate cyanoHAB cell density and toxin	3	H, AL	3	3	3	Y	2	3
CyanoHAB toxin concentration in tissue	3	H, AL	3	3	3		2	3
SPATT toxin concentration	2	H, AL	3	3	2		1	1

Applicability of Key Indicators and Bases for Threshold Science

Wadeable Streams

Good Light Penetration

Poor Light Penetration (Turbidity, Flow)

Best evidence from CA biointegrity stress-response

Benthic Chla

AFDM

% Cover

TN and TP

TN and TP

Sestonic Chla

Other State Literature

Benthic Cyanobacteria Cell Density & Toxins

Diel DO

Diel DO

DO, pH, Sestonic Cyanobacteria Cell Density, Particulate Toxins, tissue toxins

Basin Plan WQO, Statewide Guidance, Other State Literature

Non wadeable Streams

Goal for Today's PM Session Is to Get your Feedback on:

Biostimulatory operating assumptions

Wadeable Stream Eutrophication Synthesis

Conceptual model and review of indicators

Scientific bases for numeric targets

Aquatic life related uses

Human related uses

Part II

Martha Sutula
marthas@sccwrp.org

Raphael Mazor
raphaelm@sccwrp.org

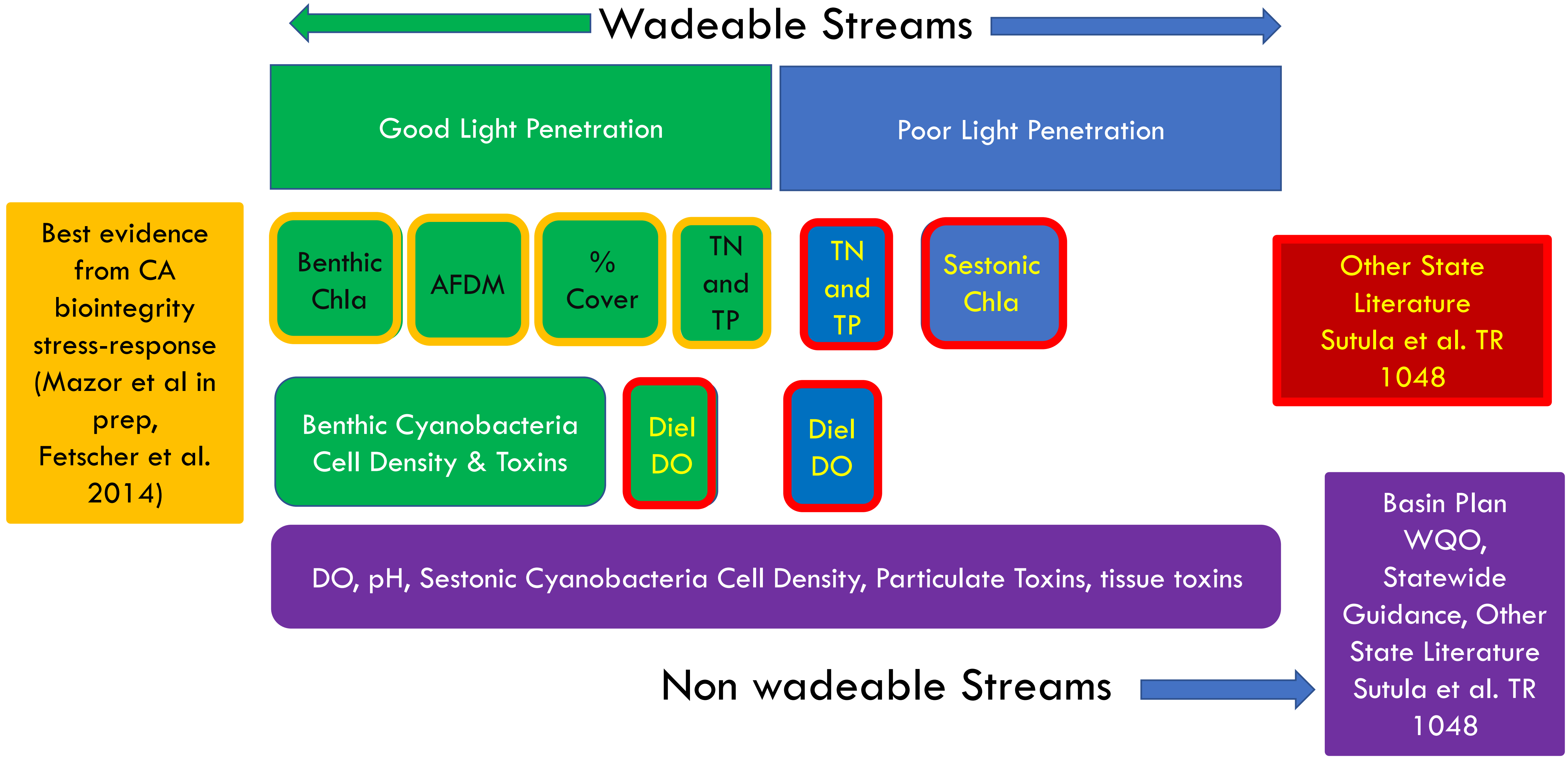
Key Findings, Part II: Thresholds for Aquatic Life and Human Uses

- Strong empirical evidence for aquatic life-related thresholds for nutrients and organic matter indicators
  - Thresholds are validated with significant increased risk to AL indicators
  - Empirical evidence supported by literature that describes mechanistic basis for relationships
  - Thresholds vary based on confidence level and stringency of approach (e.g. aquatic protection endpoints REF30, REF10, REF1), but all within a fairly narrow range

- Thresholds to protect human uses rely to a greater degree on literature, existing basin plans and guidance

- Most tend to focus the numbers, but the devil is in the details (how is indicator and comparison to threshold assessed), so you will want to pay attention to that to
  - In eutrophication synthesis, we are mostly silent on this, pending more detail on policy options

WHAT ARE YOU MOST INTERESTED IN DISCUSSING?



What Science Products Can Be Used to Answer Biostimulatory Policy Questions?

Q7. What are the biostimulatory thresholds that are protective of aquatic life and human uses?

Wadeable streams, dominated by benthic primary producers (most streams in state): TN, TP, Benthic Chla, AFDM, macroalgal % cover, DO diel variability

- %ILE OF REFERENCE: Fetscher et al. (2014)- 75th and 95th, ecoregion and statewide
- %ILE OF REFERENCE: Mazor et al. in prep – 90th, ecoregion and statewide

- CHANGEPOINT: Fetscher et al. (2014) – Comparative for CSCI and So Cal algal IBI, statewide)
- CHANGEPOINT: Mazor et al. in prep – Raw taxonomy for bugs and algae, statewide

- PROTECTION ENDPOINT: Mazor et al. in prep – 30th, 10th and 1st percentile of reference, BCG bins 3 and 4 for bugs (CSCI) and algae (ASCI)
- **Literature from other states, using comparable approaches, state criteria: Sutula et al. TR 1048, notably Jessup et al. (2015) for New Mexico streams**

Wadeable streams, dominated by sestonic primary producers (most streams in state): TN, TP, water column chl-a, DO diel variability

- **Literature from other states, using comparable approaches, state criteria: Sutula et al. TR 1048**

Comparisons of CA Wadeable Stream Thresholds By Approach

- Protection endpoints for CSCI and ASCI
- Percentile of range of biostimulatory values at reference sites (90th shown here)
- Change point analyses

Table 4.1 Range of TN, TP thresholds, Benthic Chl-a, AFDM associated with protection of CSCI and ASCI_H at a relative probability of 90% confidence, at varying levels of percentile of reference, from 30th to 1st. compared to reference distribution and taxon-specific changepoints for eutrophication factors. Red text highlights reference distributions that are higher than the derived Ref10 threshold, or taxon-specific change-points that are below the derived Ref10 threshold. SBA: soft-bodied algae. BMI: Benthic macroinvertebrates. n: number of reference sites.

Benchmark	Total N	Total P	Chl-a	AFDM	% cover
Derived thresholds- CSCI					
Eutrophication threshold for Ref30	0.34	0.024	14	12	10
Ref10	0.59	0.104	28	20	13
Ref01	1.95	0.401	65	37	26
Derived thresholds- ASCI					
Eutrophication threshold for Ref30	0.13	0.026	24	17	18
Ref10	0.32	0.080	43	30	20
Ref01	1.67	0.394	122	80	33
Reference distributions					
90th percentile - Statewide (n=524)	0.25	0.058	31	27	39
- Chaparral (n=76)	0.24	0.075	34	20	42
- Central Valley (n=1)	0.16	0.027	23	13	41
- Deserts and Modoc (n=38)	0.51	0.104	46	35	50
- North Coast (n=106)	0.14	0.030	22	15	29
- South Coast (n=115)	0.31	0.039	34	62	43
- Sierra Nevada (n=164)	0.15	0.058	24	17	35
Taxon-specific changepoints					
Diatom Increasers	0.44	0.082	47	18	17
Diatom Decreasers	0.38	0.048	11	11	18
SBA Increasers	0.58	0.075	26	19	16
SBA Decreasers	0.17	0.034	36	15	23
BMI Increasers	0.65	0.091	71	31	68
BMI Decreasers	0.65	0.080	31	20	28

Comparisons of CA Wadeable Stream Thresholds to

Changepoint Literature Values (other states)

Nutrient Criteria (other states)

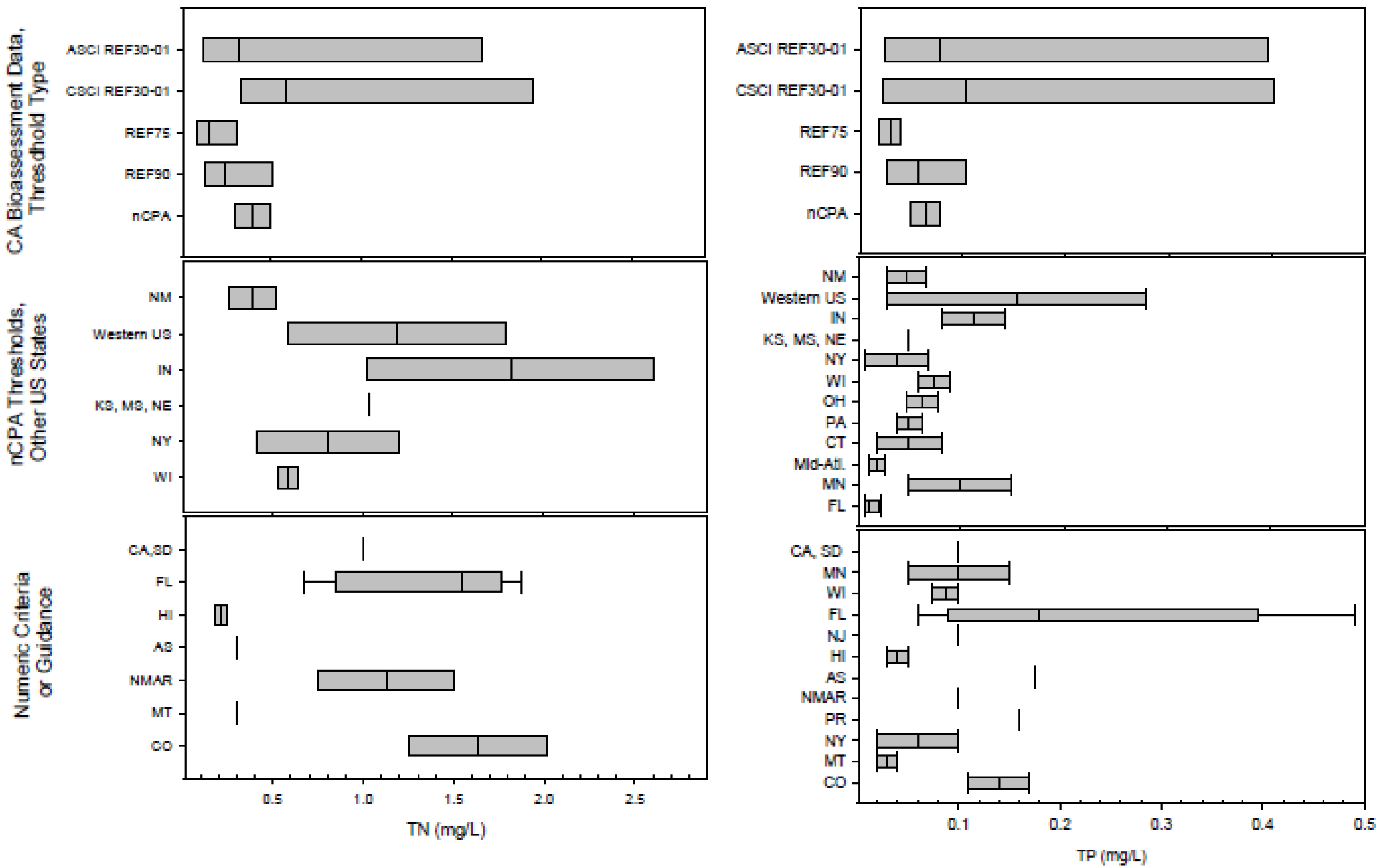
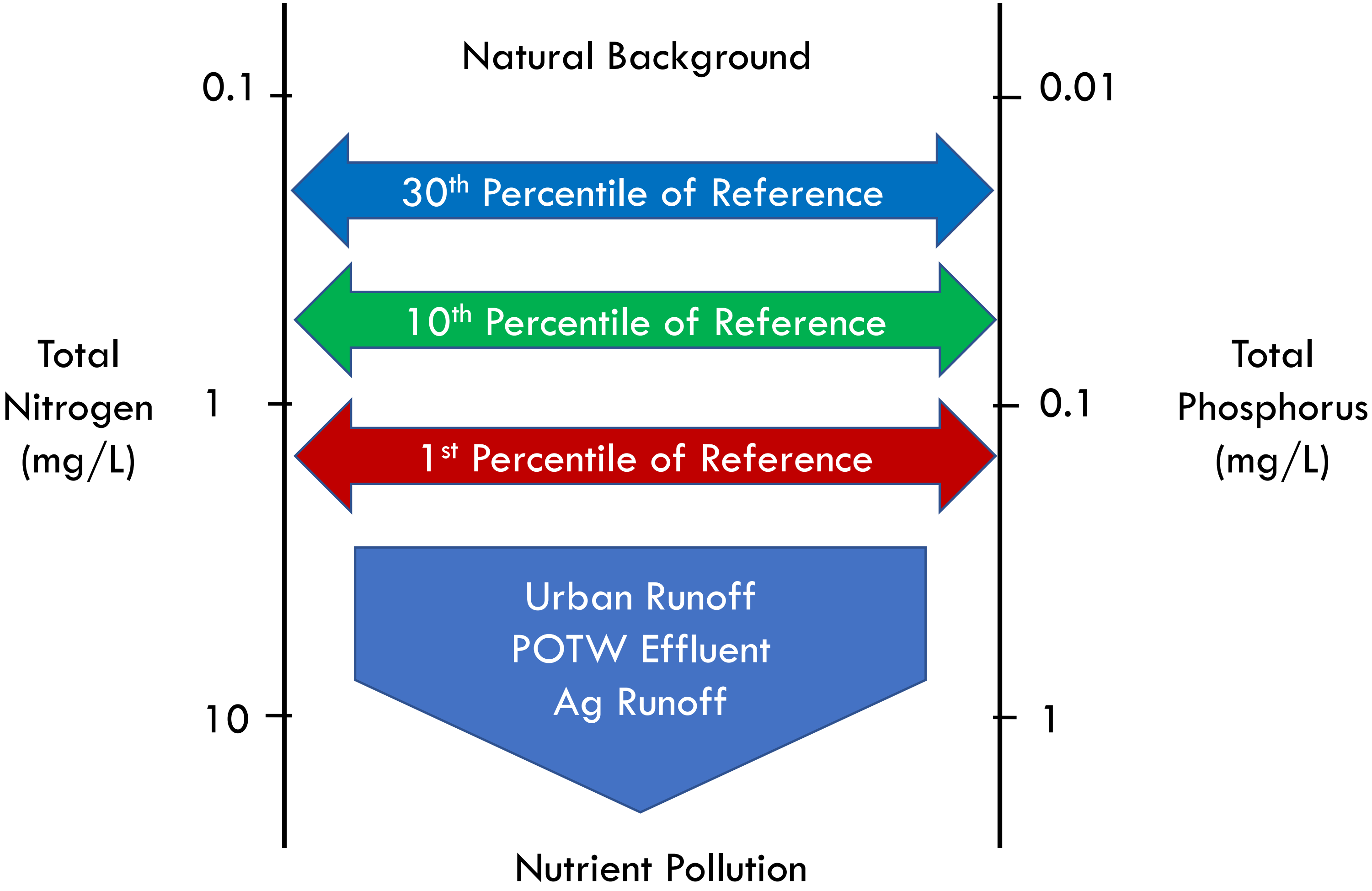


Figure 4.1 Ranges of literature derived TN (left panel) and TP (right panel) thresholds relative to adopted state criteria. Top panel represents threshold derived from CA wadeable stream bioassessment data (Mazor et al. in prep, Fetscher et al. 2014). In ASCI and CSCI REF30-01 bars, mean represents REF10. REF75th and 90th are the ecoregional ranges, while the mean line represents the statewide mean. Middle panel represents published studies of change point analyses (nCPA) for other states/territories and includes a variety of stream types including wadeable and nonwadeable streams. Bottom panel summarizes adopted criteria. Ranges in bar represents adopted criteria for different stream types or classes. NMAR = Northern Mariana, AS =American Samoa, PR= Puerto Rico

Thresholds that Associated with Levels of Protection of Aquatic Life Are Extremely Low Relative to Urban/Ag Runoff and POTW Wastewater



Aquatic Life Derived Benthic Chl-a Also Within Range of Other State Literature

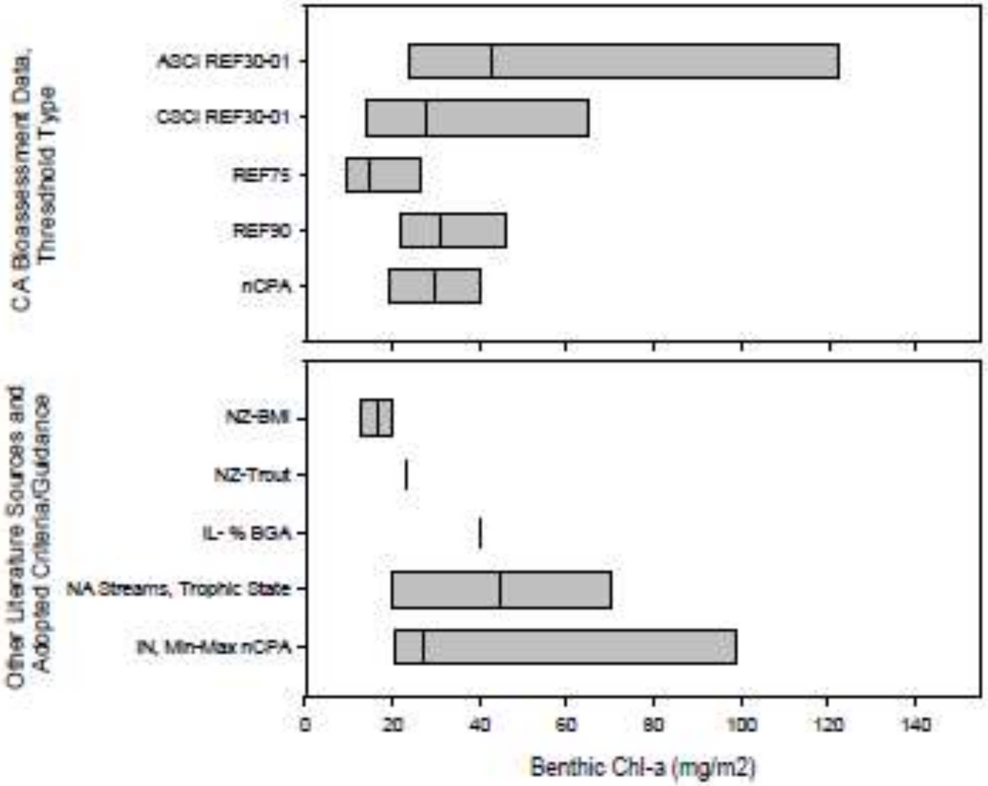


Figure 4.2 Threshold benthic chl-a ranges for CA wadeable stream bioassessment data (top panel; Mazor et al. in prep and Fetscher et al. 2014), compared to other literature values protective of aquatic life (bottom panel). Mean of ASCI and CSCI REC30-01 bars represents REF10. REF75th and 90th show the ecoregional range and the statewide mean line. Change point analyses =nCPA. Thresholds protective of BMI and trout in New Zealand (NZ) are mean values; IL thresholds are protective against > 10% BGA. North American (N.A.) trophic state range represent boundaries of oligotrophic and eutrophic streams, while IN values represent min, mean and max change points for BMI, algae and fish.

AFDM May Have Issues with False Positive at Low End of Disturbance Gradient

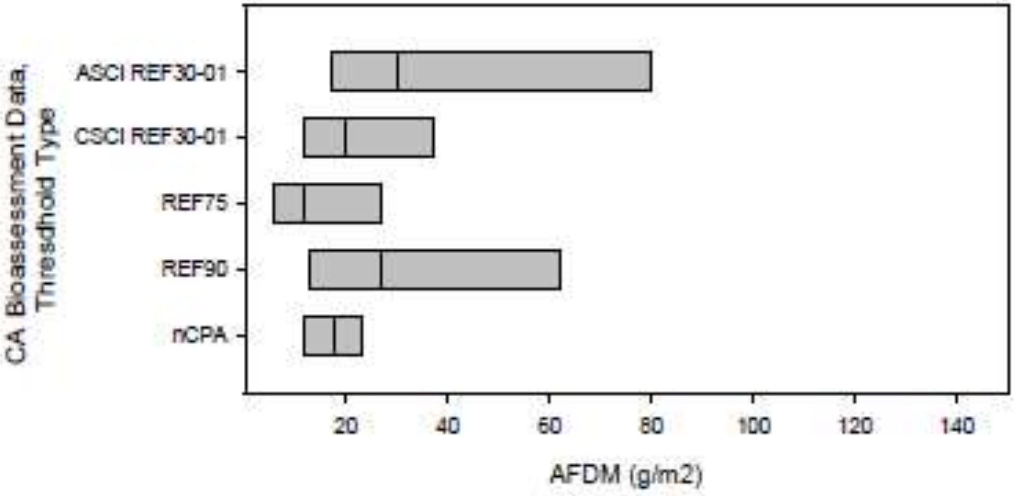


Figure 4.4 Ranges of AFDM of aquatic life thresholds derived from California wadeable stream bioassessment data (Mazor et al. in prep, Fetscher et al. 2014). In ASCI and CSCI REC30-01 bars, mean represents REF10. REF75th and 90th is the ecoregional range, while the mean line represents the statewide mean. Change point analyses are designated as nCPA.

Wadeable Streams Aquatic Life Response and Biostimulatory Thresholds

Response

- Benthic Chl-a
- Ash-free Dry Mass
- Macroalgal Cover
- Sestonic Chl-a
- Dissolved oxygen and pH
- Diel DO Variability
- Particulate cyanoHAB cell count and toxins
- CyanoHAB tissue toxin concentrations
- SPATT
- CSCI and ASCI or component metrics

Other response indicators are derived from existing basin plans, state guidance, or are "placeholders" for emerging science

Causal

- TN, TP

Basis for Stream Water column Chl-a Thresholds: Quick Snapshot

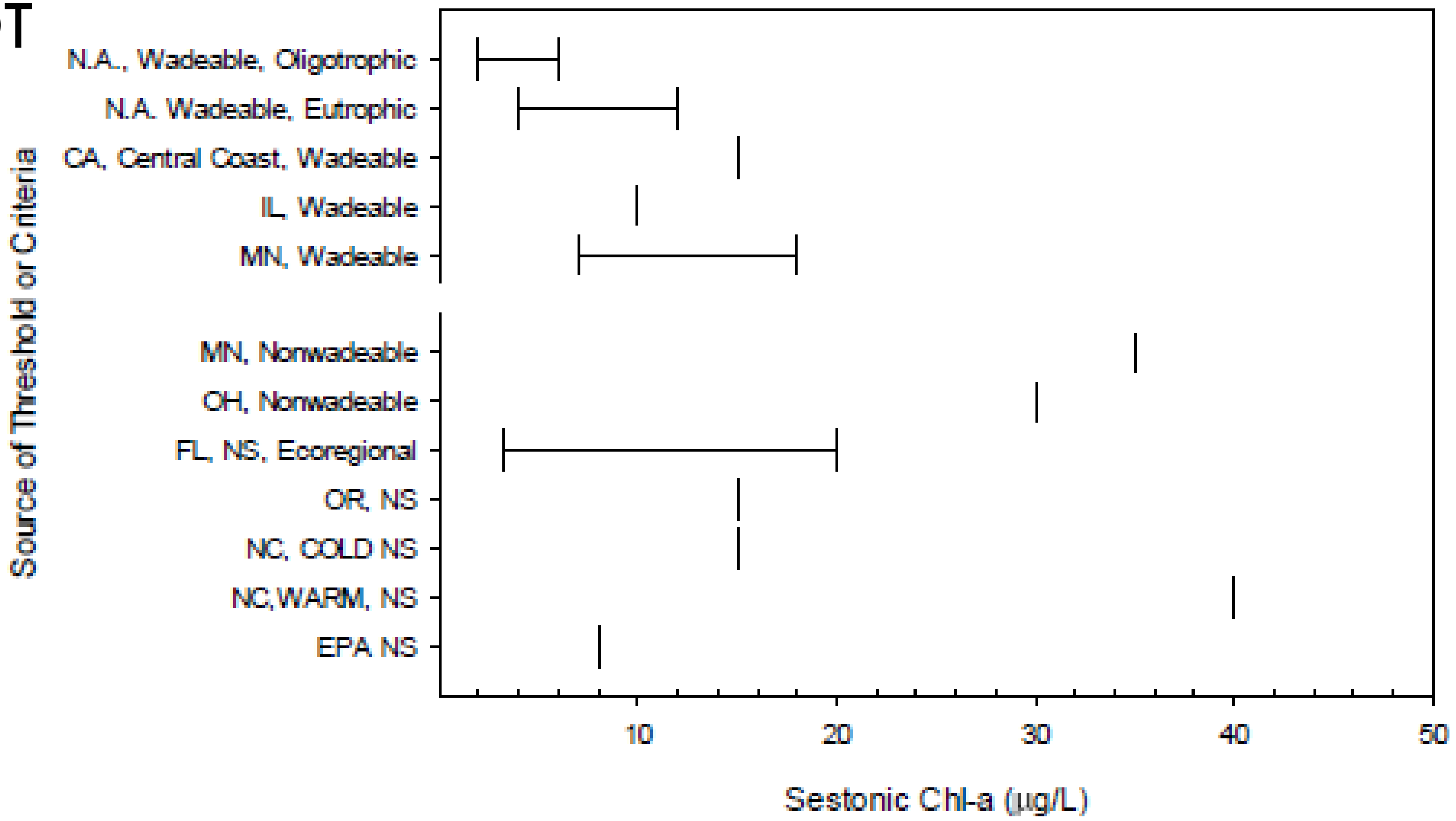
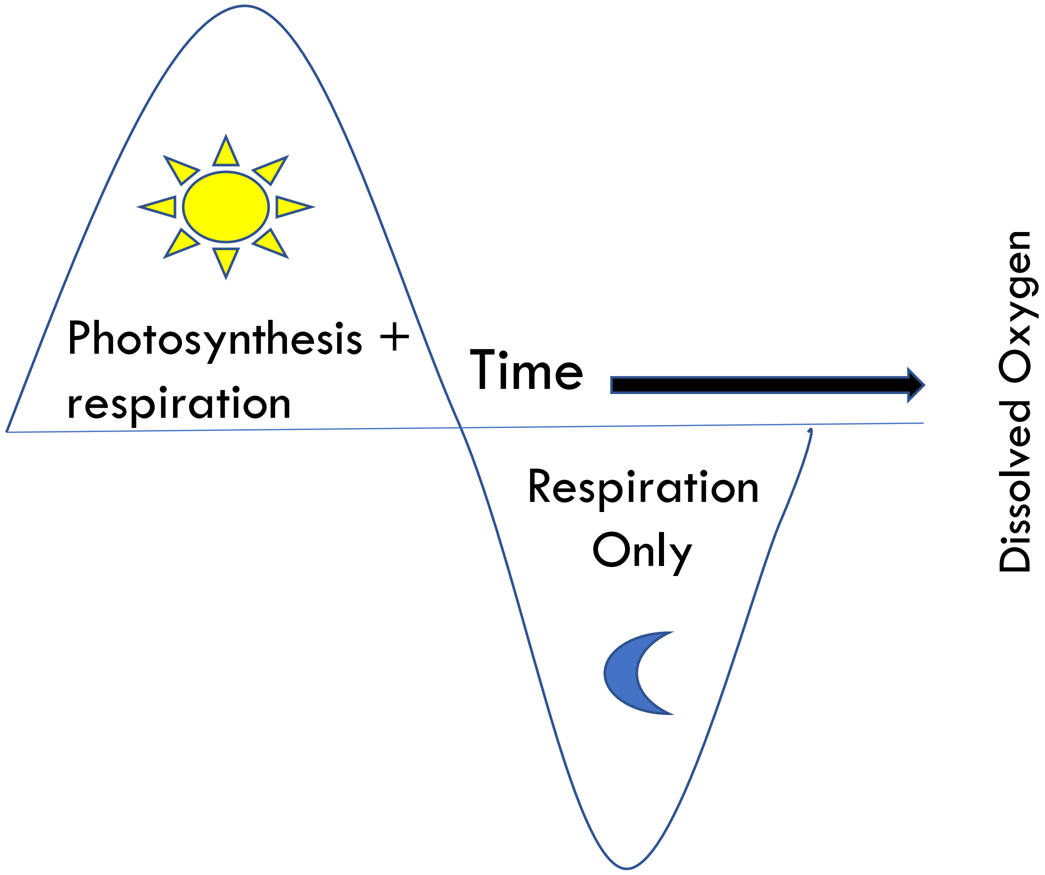


Figure 4.5. Ranges of literature derived Sestonic Chl-a thresholds and adopted state criteria for wadeable versus nonwadeable streams. All threshold criteria sources above orange line are for wadeable streams and nearly all from peer-reviewed literature sources. The exception is the CA Central Coast Regional Water Board, which adopted 15 µg/L to interpret their biostimulatory objective, based on peer-reviewed literature sources. Below the line includes literature sources or adopted criteria for either non-wadeable streams or streams and rivers where the type is not specified (NS).

DO and pH Diel Variability

- For DO and pH, the diel variability is linked to fish and invertebrate impacts, is an easier endpoint to model mechanistically, and requires a shorter timeframe to monitor to assess



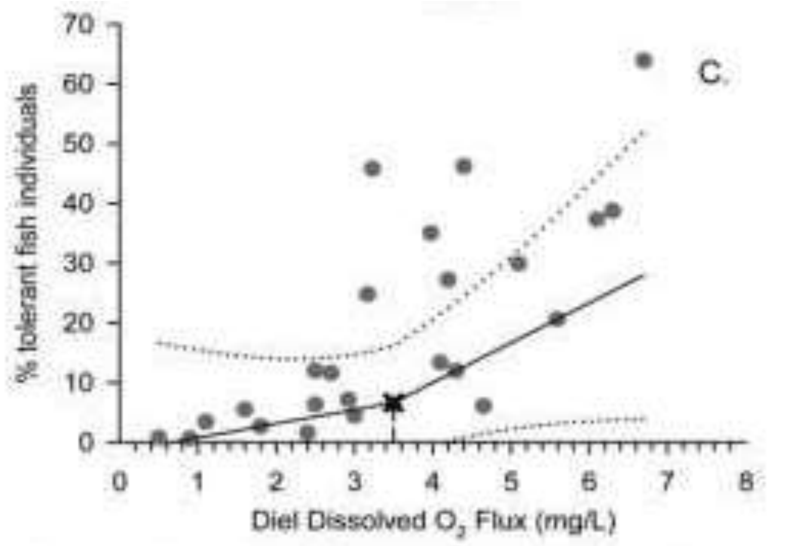


Figure 3. Examples of 75th-percentile additive quantile regression smoothing (AQRS) showing data sets with upper and midpoint lower thresholds (% sensitive fish individuals, Central region, biomonitoring data) (A) and midpoint threshold only (% intolerant fish individuals, Central region, biomonitoring data) (B), and upper breakpoint only (% tolerant fish individuals, River Nutrient Study) (C).

Summary of Thresholds Values for DO Diel Variability

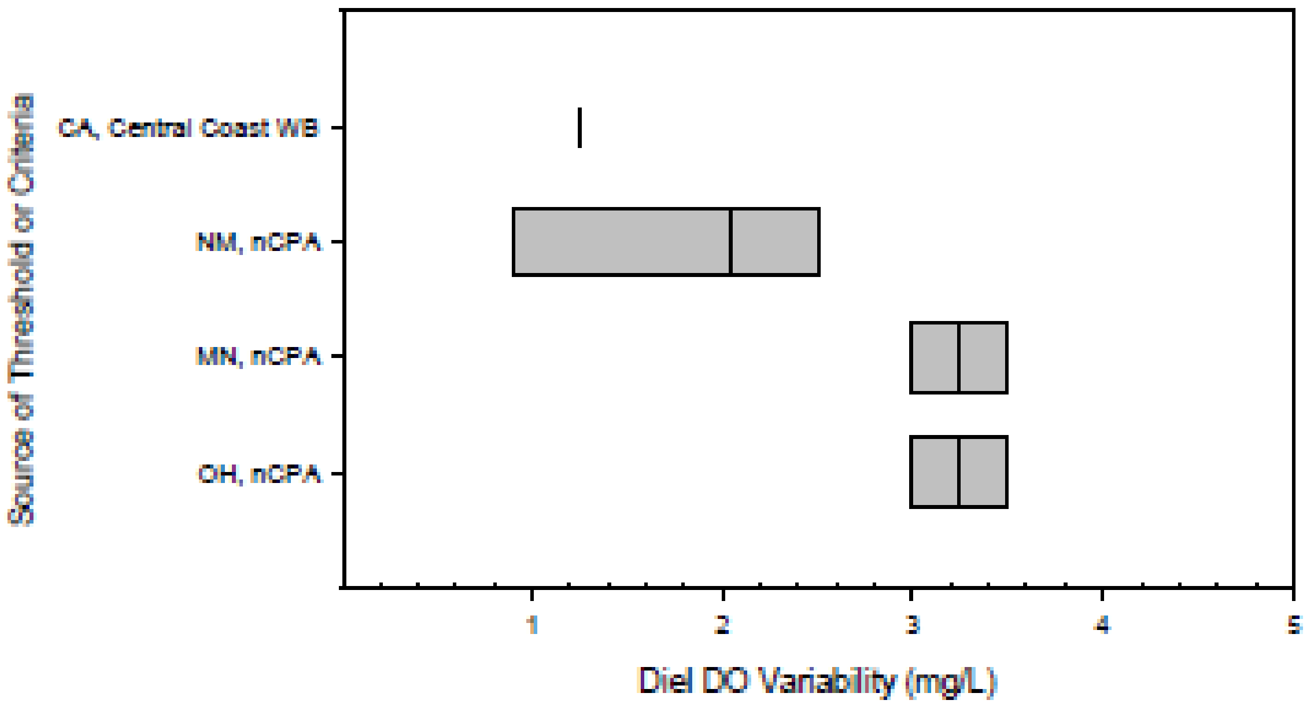


Figure 4.6 Ranges of literature derived diel variability thresholds (California versus other states) relative to adopted state criteria. Ranges of NM, MN, and OH are from change point (nCPA) analyses.

Table 3.12 Summary of diel DO thresholds and associated TN and TP protection thresholds from peer-reviewed and grey literature-based sources.

Region	Type	Protection Endpoint	DO Diel Variability Threshold (± mg/L)	Nutrient Thresholds (mg/L)		
				TN	TP	Source
Central Coast, California	Screening Value	O2 deficit associated with NO3 biostimulation	1.25	1 mg/l NO3[6]	--	Worcester et al. (2010)
	COLD	Reference or near reference that always met either COLD or WARM DO objectives	2.0			
	WARM		3.0			
New Mexico	Volcanic	BMI Changepoint median 90th percentile of reference	-- 2.51	 0.36	 0.059	Jessup et al. (2015)
	Flat	BMI Changepoint median 90th percentile of reference	1.21 2.04	 NS	 0.099	
	Steep	BMI Changepoint 90th percentile of reference	-- 0.085	 0.30	 0.035	
Minnesota	Wadeable COLD	Fish community, BMI taxa richness.	3.0	--	0.050	Heiskary and Bouchard (2016)
	Wadeable WARM		3.5	--	0.100	
	Large Rivers		4.5	--	0.150	
Ohio	Wadeable Streams	High quality Management	3.0 3.5	0.44 DIN 1.1 DIN	0.04 0.1	Miltner (2010)
	Large rivers	Fish IBI change point	3.5		0.130	Miltner et al. (2010)

Wadeable Streams Human Uses (Water Resources, Consumption, & Recreation) Thresholds

Primary Lines of Evidence

- Macroalgal Percent Cover: REC2
- CyanoHAB particulate toxins: MUN, REC1
- CyanoHAB tissue concentrations: COMM, AQUA, SHELL
- DOC and trihalomethane: MUN

Supporting Lines

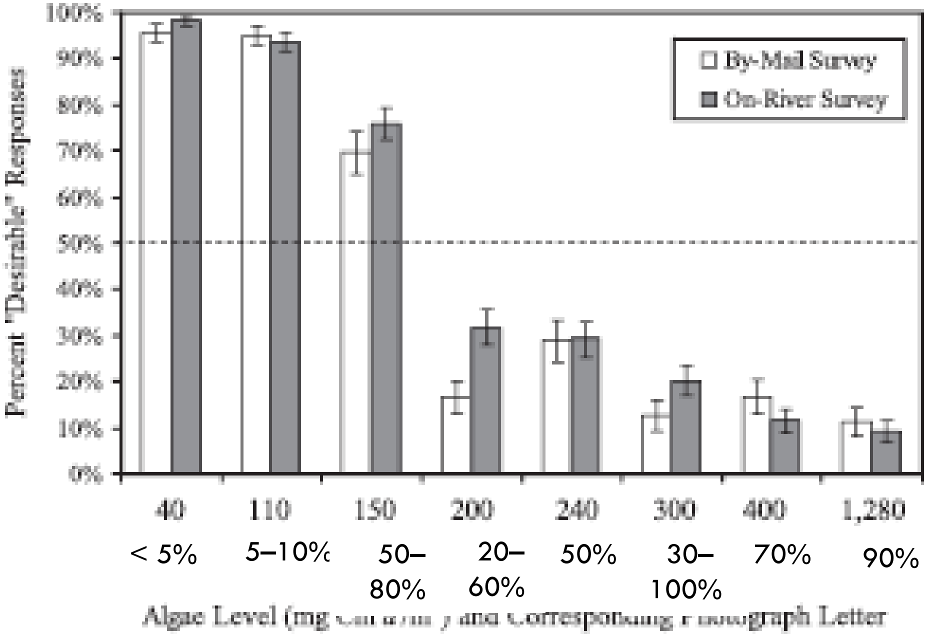
- Cyanotoxin SPATT: MUN, REC1

Causal Lines

TN and TP

Macroalgal Percent Cover Impacts to Recreational Use

- Aesthetic nuisance conditions are caused by the fraction of stream surface covered by visible periphyton mats, especially filamentous green algae and in particular Cladophora.
- Basis for thresholds:
  - Welch (1988) > 20 % is nuisance to aesthetics; 100 to 150 mg m2 benthic chla
  - Suplee et al. (2009) and Jakus et al (2017) recreational user survey; strongly tied to Cladophora mat cover (also drives up biomass), less “generic cover”, > 20%, > 150 mg m2
  - West Virginia: > 25% cover undesirable for > 50% of respondents (Responsive Management 2012)



We strongly suspect that CA biomass estimates are NOT comparable with that of other states

Would be worthwhile doing a comparison of methods AND refinement of Fetscher et al. (2009) to improve quantitative estimate of organic matter accumulation

REC-2 Thresholds Are Roughly Comparable to Aquatic Thresholds for % Cover and Benthic Chl-a

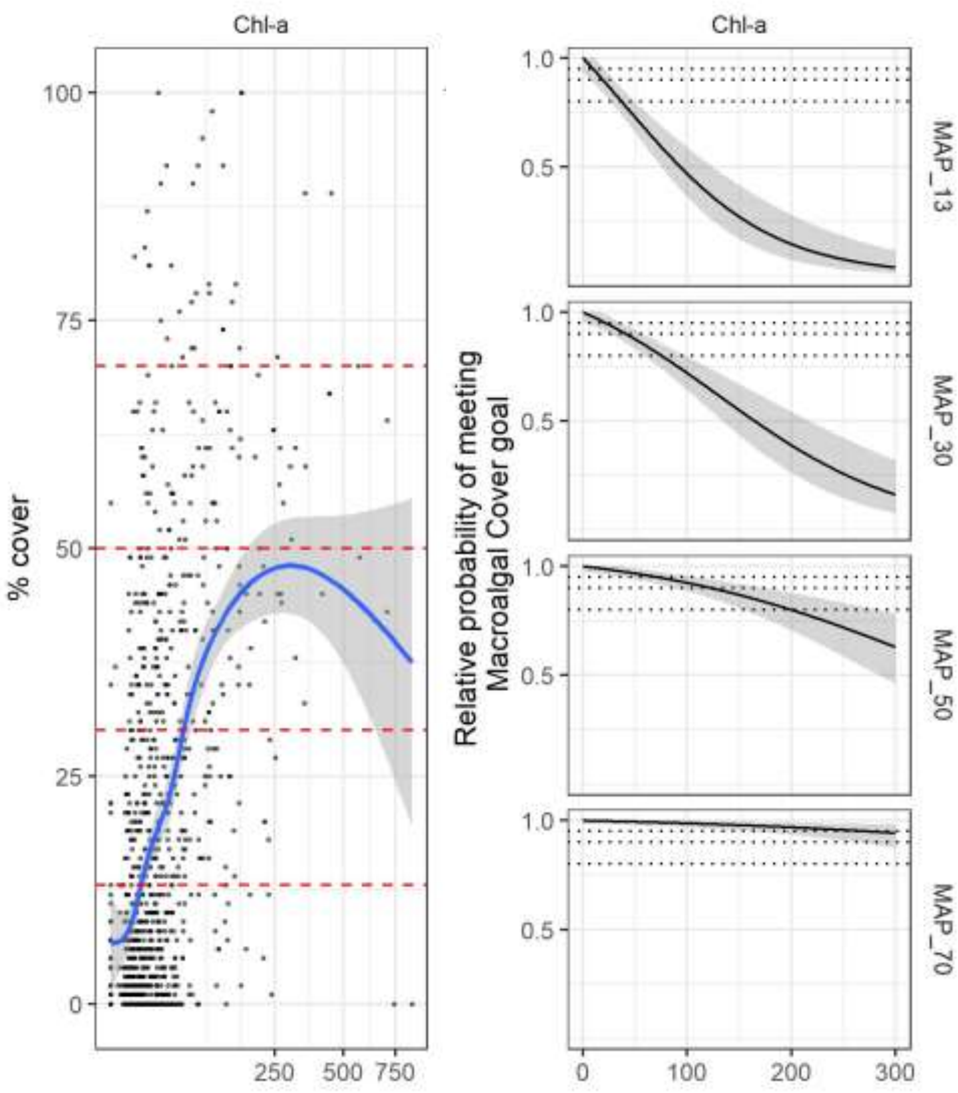
Comparison of Cover Targets: Aquatic Life Versus Recreational Use (Literature-Based)

CSCI- 90% Prob REf10	ASCI- 90% Prob REf10	Literature Recreational Use
13%	21 %	> 20 to 25% Cover

Comparison of Biomass Thresholds (mg/m-2) with 90% Prob. Of Meeting Aquatic Life Versus Range of % Cover Goals*

CSCI-REf10	ASCI-REf10	13% Cover	30% Cover	50% Cover
28	58	19	41	123

* Numbers are provisional, pending model validation



Human Uses: Basis for Cyanotoxin Thresholds….

- Primary Line
  - Particulate cyanoHAB cell densities and toxins (CCHAB triggers, Table 3.16)
  - CyanoHAB toxin concentrations in tissues (OEHHA 2012)

- Supporting Line
  - SPATT Toxin (Kudela et al. references)

Table 3.16. CCHAB trigger levels for cyanotoxin impacts to human health (from MyWaterQualityPortal.ca.gov).

	Caution Action Trigger	Warning TIER I	Danger TIER II
Primary Triggers [a]			
Total Microcystins [b]	0.8 µg/L	6 µg/L	20 µg/L
Anatoxin-a	Detection [c]	20 µg/L	90 µg/L
Cylindrospermopsin	1 µg/L	4 µg/L	17 µg/L
Secondary Triggers			
Cell Density *(Toxin Producers)*	4,000 cells/mL	--	--
Site Specific Indicators of Cyanobacteria	Blooms, scums, mats, ect.	--	--

[a] The primary triggers are met when ANY toxin exceeds criteria.
[b] Microcystins refers to the sum of all measured microcystin variants. (See Box 3)
[c] Must use an analytical method that detects ≤ 1µg/L Anatoxin-a.

Table 3.15 California Office of Environmental Health Hazard Assessment (OEHHA) recommended cyanotoxin action levels under selected scenarios (from OEHHA 2012).

	Microcystins[1]	Anatoxin-a	Cylindro-spermopsin	Media (units)
Human recreational uses[2]	0.8	90	4	Water (µg/L)
Human fish consumption	10	5000	70	Fish (ng/g) ww[3]
Subchronic water intake, dog[4]	2	100	10	Water (µg/L)
Subchronic crust and mat intake, dog	0.01	0.3	0.04	Crusts and Mats (mg/kg) dw[5]
Acute water intake, dog[6]	100	100	200	Water (µg/L)
Acute crust and mat intake, dog	0.5	0.3	0.5	Crusts and Mats (mg/kg) dw[5]
Subchronic water intake, cattle[7]	0.9	40	5	Water (µg/L)
Subchronic crust and mat intake, cattle[7]	0.1	3	0.4	Crusts and Mats (mg/kg) dw[5]
Acute water intake, cattle[7]	50	40	60	Water (µg/L)
Acute crust and mat intake, cattle[7]	5	3	5	Crusts and Mats (mg/kg) dw[5]

[1] Microcystins LA, LR, RR, and YR all had the same RfD so the action levels are the same.
[2] The most highly exposed of all the recreational users were 7- to-10-year-old swimmers. Boaters and water-skiers are less exposed and therefore protected by these action levels. This level should not be used to judge the acceptability of drinking water concentrations.
[3] Wet weight or fresh weight.
[4] Subchronic refers to exposures over multiple days.
[5] Based on sample dry weight (dw).
[6] Acute refers to exposures in a single day.
[7] Based on small breed dairy cows because their potential exposure to cyanotoxins is greatest. See Section VI for action levels in beef cattle.

DOC and Trihalomethane (THM): MUN

- Trihalomethanes (THMs) are byproducts of drinking water treatment that result from the chlorination or bromination of certain dissolved organic carbon (DOC) compounds.
  - Known and suspected carcinogens
  - EPA (2003) suggested 0.080 mg/L total THM in potable water distribution system
- Algal blooms in wadeable streams leak DOC. The Stage I Disinfection Byproducts Rule requires removal of DOC by water treatment plants when the source water concentration exceeds 2 mg/L DOC, a limit easily exceeded during benthic algal blooms
- CALFED (2004) has an objective of 3 mg/L organic carbon in source water

Other Issues Not Currently Addressed In Synthesis, But Would Like to, With More Policy Context

- How should thresholds be applied? Statistics matter!
  - Mean vs maximum vs minimum?
  - Duration of effects?
  - Minimum number of samples to estimate effect?
- Whether or how to use multiple lines of evidence
- Seasonality
  - wet versus dry weather
  - Winter dry versus summer dry
- Analytical variability versus threshold significant digits
- Temporal variability of nutrients in reference streams
- Relevance of indicators and thresholds for protection of downstream uses
- Biostimulatory thresholds were biointegrity constrained by landscape development

What Else?

Take Home Message: Conceptual View of Review and Timeline of Completion of Technical Products

Finalize Spring 2019 | **Finalize as Policy Options Become Clarified** | **Finalize Before Staff Report**

Biointegrity Tools, CSCI (Mazor et al. 2016) ASCI (Theroux et al. in prep), Channels in Developed Landscapes, Beck et al in review)

Reference Distribution, Biointegrity Interpretation Support (Ode et al. 2016, BCG Paul et al in prep)

Biostimulatory CA-specific analyses protective of Biointegrity (Fetscher et al. 2014, Mazor et al. in prep)

Iterations on stress-response analyses

Wadeable Stream Eutrophication Synthesis (Sutula et al. TR 1048)
Approaches to Assessment, Prevention and Management (Sutula TR 871)