WORK PLAN

The Development of the Statewide Algal Stream Condition Index (ASCI)
October 2016

Susanna Theroux, Raphael Mazor, Martha Sutula, Eric Stein (SCCWRP)
Pete Ode and Andy Rehn (CADFW)

The California State Water Resources Control Board (State Water Board) is supporting the development of assessment tools that use biological communities to infer ecosystem health. As part of this endeavor, the State has developed a California Stream Condition Index (CSCI; Mazor et al., 2016) that uses benthic macroinvertebrate (BMI) communities to measure the impact of human disturbance of biological communities. As a compliment to the CSCI, the State is now developing an Algal Stream Condition Index (ASCI) to infer biologic condition and give partners an additional tool for determining impacts of human development, specifically those related to nutrient over-enrichment, eutrophication, and water chemistry. One immediate application of ASCI development is to support the implementation of biostimulatory substances and biointegrity policy for wadeable streams (SWRCB 2014).

The goals of ASCI Development Project are to:

- Develop a predictive index of biologic integrity base on algal species composition and ecological traits in California streams;
- Evaluate the performance of the algal index in California streams across diverse geochemical and geographic landscapes and under the influence of various stressors;
- Provide guidance on the implementation of algal index scores in conjunction with other biological indices for the assessment of California streams; and
- Communicate the findings of these analyses to the State Water Board and stakeholder groups.

This project consists of 5 major tasks:
1. Assemble the ASCI development dataset
2. Evaluate levels of anthropogenic stress and select reference sites
3. Develop a predictive index of taxonomic completeness and ecological structure
4. Evaluate ASCI performance
5. Outreach to regulatory and stakeholder workgroups and final technical report

<u>Task 1. Assemble ASCI development dataset</u>
SCCWRP will generate a composite dataset representing algal taxonomy data from 2008-present collected as part of the following 5 monitoring campaigns:

- The Southern California Stormwater Monitoring Coalition's (SMC) stream monitoring program

- California's statewide Perennial Stream Assessment (PSA)
- SCCWRP's southern California Stream Algae Index of Biotic Integrity (IBI) development project
- The Bay Area Regional Monitoring Coalition (RMC)
- California's Reference Condition Management Program (RCMP)

The sampling sites for the first four datasets (SMC, PSA, Algal IBI, RMC) were chosen using a probability-based design, making these data useful for deriving statistical estimates of the extent and magnitude of stream condition. All samples were collected using the approved, standardized methods of California's Surface Water Ambient Monitoring Program (SWAMP; Fetscher et al. (2009) and Ode (2007)), enabling the comparison of algae data across sampling programs and across geographies.

These datasets contain variables on algal taxonomic composition (diatoms, soft bodied algae and cyanobacteria) and, where available, water chemistry and physical habitat characteristics. GIS data for individual sampling sites will be derived from the National Hydrology Database (NHD; http://nhd.usgs.gov/) database, including catchment scale data from the StreamCAT database (https://www.epa.gov/national-aquatic-resource-surveys/streamcat). Algae taxonomic names will be harmonized using the SWAMP lookup tables (http://swamp.waterboards.ca.gov/SWAMP_Checker/DisplayLookUp.php?List=OrganismLookUp_Algae) and forthcoming Algal Standard Taxonomic Effort (STE) as a guide. Sampling sites currently covered in developmental dataset are show in Figure 1. This resulting dataset will be split 80:20 into calibration and validation datasets for ASCI development.

Task 1 Deliverable: A final, harmonized dataset used for index development composed of algae taxonomy, station GIS, physical habitat, and water chemistry data where available.

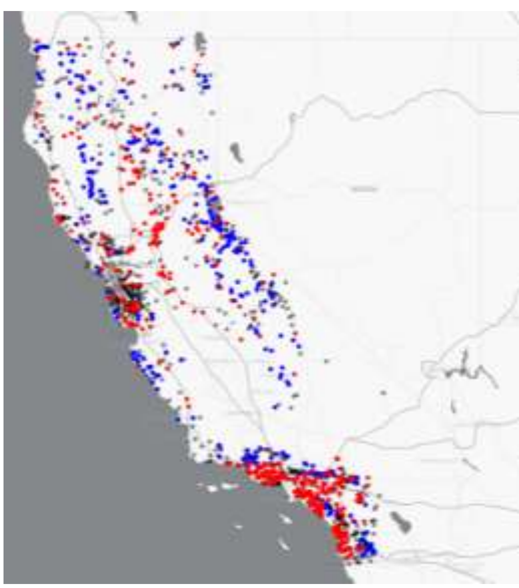

Figure 1. Map of California sampling sites with algal taxonomy data included in developmental dataset. Grey circles are all sampling sites, reference sites in blue and stressed sites in red.

Task 2. Designate reference sites

The premise of a predictive index relies on the precise selection of reference condition that will serve to calibrate inferences of stream community composition and condition. Reference screening parameters are intended to exclude sites that have undergone anthropogenic modification including mining, paved roads, and agricultural development (Table 1). Both the CSCI (Mazor et al., 2016) and the Algal Index of Biotic Integrity (Algal IBI; Fetscher et al., 2014) used a combination of the following screening criteria for approximating human impact and identifying reference sites as described in Ode et al. (2016). All screening metrics can be derived from GIS data, in combination with field measurements (e.g., human activity in the riparian zone) where available. Sites are rejected if they fail to meet a single reference screening threshold.

Task 2 Deliverable: Custom scripts for screening reference sites and resulting reference sites designations.

Table 1. Reference screening criteria, modified from Ode et al., 2016. Code 21 is a measure of heavily managed vegetation (parks, golf courses). W1_Hall is a composite measure of riparian disturbance. WS = watershed.

Metric	Scale	Threshold	Unit
% agriculture	1k, 5k, WS	3	%
% urban	1k, 5k, WS	3	%
% agriculture + % urban	1k, 5k, WS	5	%
% Code 21	1k, 5k	7	%
	WS	10	%
Road density	1k, 5k, WS	2	km/km2
Road crossings	1k	5	crossings
	5k	10	crossings
	WS	50	crossings
Dam distance	WS	10	km
% canals and pipelines	WS	10	%
Producer mines	5k	0	mines
W1_HALL (Riparian activity)	site	1.5	-

Task 3. Develop a predictive index of taxonomic completeness and ecological structure

3.1 Algal Index component 1: Taxonomic completeness

Modeled after the California Stream Condition Index (Mazor et al., 2016), the ASCI will be composed to two key components. The first component provides a measure of taxonomic completeness, in which taxa observed at a site are compared to taxa found at similar reference sites in similar environmental settings (e.g., similar climate, watershed area, or geology).

Deviation from expectation will provide of measure of observed versus expected (O/E) taxa distributions.

To generate expected taxa distributions, we will use a modeling approach based on classification and regression tree (CART) analysis (e.g., RandomForest, boosted regression trees), implemented in the software program R, to predict the probability of observing taxa based on environmental parameters across California's diverse geographic landscape. The suite of candidate environmental predictors to be explored (compiled as part of Task 1) include environmental gradients derived from in-field measurements as well as natural and/or anthropogenic gradients derived from GIS variables (Table 2). At a minimum, we will explore the same set of predictors that were evaluated for development of the CSCI. The result of this analysis will be a list of environmental variables that can be used to predict taxonomic composition at sites across the State.

Table 2. An abbreviated list of candidate environmental predictor variables.

Category	Number of variables	Variable topics
Location	5	Area of watershed, elevation, latitude, longitude
Climate	12	Temperature, precipitation, atmospheric cations
Geology	12	Bedrock mineral concentrations, conductivity, catchment soil composition

3.2 Algal Index component 2: Ecological structure

The second component of the ASCI will implement a predictive multi-metric indicator (pMMI) approach. In the development of the pMMI, we will first calculate metrics that characterize a wide suite of important ecological functions and aspects of biodiversity. This step requires the determination of trait attributes (such as response to nutrient stress, dissolved oxygen levels, salinity tolerance) for all algae taxa. These algal attributes will be derived from previously reported trait assignments found in the literature as well as trait attributes that were determined empirically from species distributions across California (Fetscher et al., 2014). Metrics will be derived from these trait attributes by calculating number of taxa, percentage of taxa and percentage of individuals for each attribute. Additional metrics will be derived from taxonomic information e.g. percent cyanobacteria and total species richness. Assemblages of between five and ten metrics will be evaluated for performance with regards to responsiveness to environmental condition and stressor gradients, as well as temporal stability and independence from other metrics (Stoddard et al., 2008). Reference sites will be scored using the final metrics and pMMI scores will again be derived based on algal community composition deviation from reference expectations. A selection of candidate algal metrics are presented in Table 3.

For both components of the ASCI, metric performance will be screened using both relative abundance and presence/absence species data as well as both soft-bodied algae and diatoms, together and separately. For final ASCI calculation, the values from the O/E and pMMI components of the index will be averaged to yield a composite ASCI score.

Table 3. Candidate metrics for the multi-metric index development. Modified from Fetscher et al., 2014.

Category	Metrics
Tolerance/sensitivity	Association with specific water-quality constituents (nutrients, organic carbon, metals)
	Tolerant to low dissolved oxygen
	Tolerant to high-ionic-strength/saline waters
Autecological guild	Nitrogen-fixers
	Saprobic/heterotrophic taxa
	Toxin-producing algae
Phenotypic guild	Motile species
Relationship to reference	Taxa associated with reference vs. non-reference sites (Wang and Stevenson 2005)
Taxonomic groups	Chlorophyta, Rhodophyta, Zygnemataceae, heterocystous cyanobacteria
Community composition	Alpha diversity (total richness), endemic/invasive species

3.3 ASCI implementation

In order to use the ASCI to its fullest potential, end-users need a standardized way to calculate scores from taxonomic and environmental data. We will make the ASCI code and development datasets publically available via github.com or similar platform. The online tools will also be accompanied by adequate directions for data preparation and interpretation.

Task 3 Deliverables:

3.1) O/E component: Table summarizing output from the various forms of CART analyses employed and graphs showing relationships between top predictors of model performance and the magnitude/direction of deviations between observed and predicted benthic algal communities

3.2) MMI component: The final list of trait attributes and their reference site distributions will be provided. Also included will be statistical relationships between trait attribute distributions at reference versus highly-impacted sites.

3.3) ASCI implementation: ASCI reproducible code, training datasets, and guidance document will be made publicly available online via github.com or similar.

<u>Task 4. Evaluate Algal Stream Condition Index performance</u>

A number of aspects of performance, such as spatial and temporal variability, and performance across nutrient and other stressor gradients, need to be understood in order to use the index in management decisions. Evaluating performance in different settings, both natural (e.g., oligohaline) and artificial (e.g., engineered channels) is a priority research area. Additionally, we will compare the performance of the ASCI index against both the existing California Stream Condition Index (CSCI) and the Algal Index of Biotic Integrity (Algal IBI).

Task 4 Deliverable: Graphs and tables summarizing ASCI performance in comparison to biological indicators and geographic, temporal, and stressor gradients, to be included in Final Report.

Task 5: Outreach to Regulatory and Stakeholder Workgroups and Final Technical Report
SCCWRP will communicate the project approach and results of the project to the SWRCB and its wadeable stream regulatory (RG) and stakeholder advisory groups (SAG) via regularly scheduled meetings. Outreach will be provided upon request for other groups such as the SWAMP Roundtable, Stormwater Monitoring Coalition (SMC), and CASQA (California Stormwater Quality Association). Outreach will be performed via 1-hour webinars or presentations at SMC meetings or CASQA conferences.

SCCWRP will produce a final technical report that includes a description of data sources, analytical methods used, and results of data analyses for Tasks 1-4 above. The report will: 1) summarize the calibration and validation of the ASCI 2) compare ASCI performance across diverse geographic and temporal ranges 3) compare ASCI performance to preexisting indices, the CSCI and IBI 4) Summarize any caveats on the ASCI performance and suggestions for future improvements to the index 5) Provide guidelines on interpreting ASCI scores for biological assessment.

Task 5 Deliverable: Final report, prepared for submission to a journal for publication. PowerPoint presentations from a minimum of 3 oral presentations to regulatory and stakeholder groups (e.g. SMC, CASQA, SCCWRP symposium).

References

Fetscher AE, Busse LB, Ode PR (2009) Standard operating procedures for collecting stream algae samples and associated physical habitat and chemical data for ambient bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 002.

Fetscher AE, Stancheva R, Kociolek JP, Sheath RG, Stein ED, Mazor RD, Ode PR, Busse LB (2014) Development and comparison of stream indices of biotic integrity using diatoms vs non-diatom algae vs a combination. Journal of Applied Phycology 26: 433– 450.

Mazor RD, Rehn AC, Ode PR, Engeln M, Schiff K, Stein ED, Gillett DJ, Herbst DB, Hawkins CP (2016) Bioassessment in complex environments: designing an index for consistent meaning in different settings. Freshwater Science 35:249–271.

Ode PR (2007) Standard operating procedures for collecting macroinvertebrate samples and associated physical and chemical data for ambient bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 001.

Ode PR, Rehn AC, Mazor RD, Schiff KC, Stein ED, May J, Brown LR, Herbst DB, Gillette DD, Lunde K, Hawkins CP (2016) Evaluating the adequacy of a reference site pool for ecological assessments in environmentally complex regions. Freshwater Science 35:1, 237-248.

State Water Resources Control Board (2014) Proposed Workplan for Development of a Nutrient Control Program. www.waterboards.ca.gov/plans_policies/nutrients.shtml

Stoddard JL, Herlihy AT, Peck DV, Hughes RM, Whittier TR, Tarquinio E (2008) A process for creating multimetric indices for large-scale aquatic surveys. Journal of the North American Benthological Society 27:4, 878-891.

Appendix A. Deliverables and Timeline

Task	Description	Estimated Date
1	Developmental dataset	3/2017
2	Reference site designation	3/2017
3	Index development- Graphs and tables summarizing O/E model, MMI model and ASCI model and validation	6/2017
4	Graphs and tables summarizing ASCI use in context of other bioindicators	9/2017
5.1	Oral presentation on workplan and reference definition	12/2016
5.2	Oral presentation on preliminary results of index construction and performance	4/2017
5.3	Oral presentation on comparison of ASCI performance to other indices	6/2017
5.4	Draft final report	9/2017
5.5	Final report	12/2017