DRAFT WORK PLAN
"EXPERT INTERPRETATION OF THE BIOLOGICAL CONDITION GRADIENT IN CALIFORNIA WADEABLE STREAMS"
NOVEMBER 2016 UPDATE

Martha Sutula, Eric Stein, Raphael Mazor, Susanna Theroux (SCCWRP)
Michael Paul, Benjamin Jessop, Jeroen Gerritsen (Tetra Tech Inc.)

INTRODUCTION AND GOAL OF DOCUMENT

The California State Water Resources Control Board (State Water Board) is developing a combined biostimulatory substances and biointegrity policy and a program of implementation for the state's surface waters (SWRCB 2014). For wadeable streams, the State Water Board staff proposes to establish a narrative biostiumulatory objective applicable to all water body types and numeric guidance specifically for wadeable streams. A science plan has been developed to support the Water Board staff to create numeric guidance for wadeable streams (Sutula et al. 2015). Element 1.2 of that plan describes work to "Determine the numeric range of stream nutrient and response indicators that correspond to varying levels of beneficial use support."

One of the three approaches to accomplish Element 1.2, identified in the Sutula et al. (2015) Science Plan, is the development of a "Biological Condition Gradient" (BCG) model, with the intent to map that interpretation specifically onto wadeable stream bioassessment indices. The BCG, developed by biologists from across the United States, is a narrative conceptual model that describes changes to the ecological attributes of biological communities and ecosystems along a gradient of increasing anthropogenic stress (Figure 1, Appendix A and related information). Even in different geographic and climatological areas, a similar sequence of biological alterations occurs in aquatic ecosystems in response to increasing stress. In practice, this conceptual model can be made quantitative by first identifying the critical attributes of an aquatic community and then describing how the attributes change in response increasing anthropogenic stress. Experts score sites in ~ six bins of condition, from minimally disturbed "reference" condition to very low condition, using information on taxonomic composition of fauna (e.g. benthic macroinvertebrate) or flora (algae) and other information on natural environmental gradients. After scoring the sites, experts will be asked to reconcile their classification of sites to BCG bins and come to consensus on the ecological rationale used for this classification. The range of macroinvertebrate California Stream Condition Index (CSCI), the algal stream condition index (ASCI) scores, and other indicators of eutrophication (benthic chl-a, ash-free dry mass, algal percent cover) represented by each BCG bin will be summarized. These response indicator "BCG" bins will be mapped back to nutrient concentrations.

This document describes the objectives, proposed approach, key products and timeline for the development and application of the BCG model, based on benthic macroinvertebrates and algae for California wadeable streams.

Appendix (A) provides the list of BCG expert panelists with their biographies.

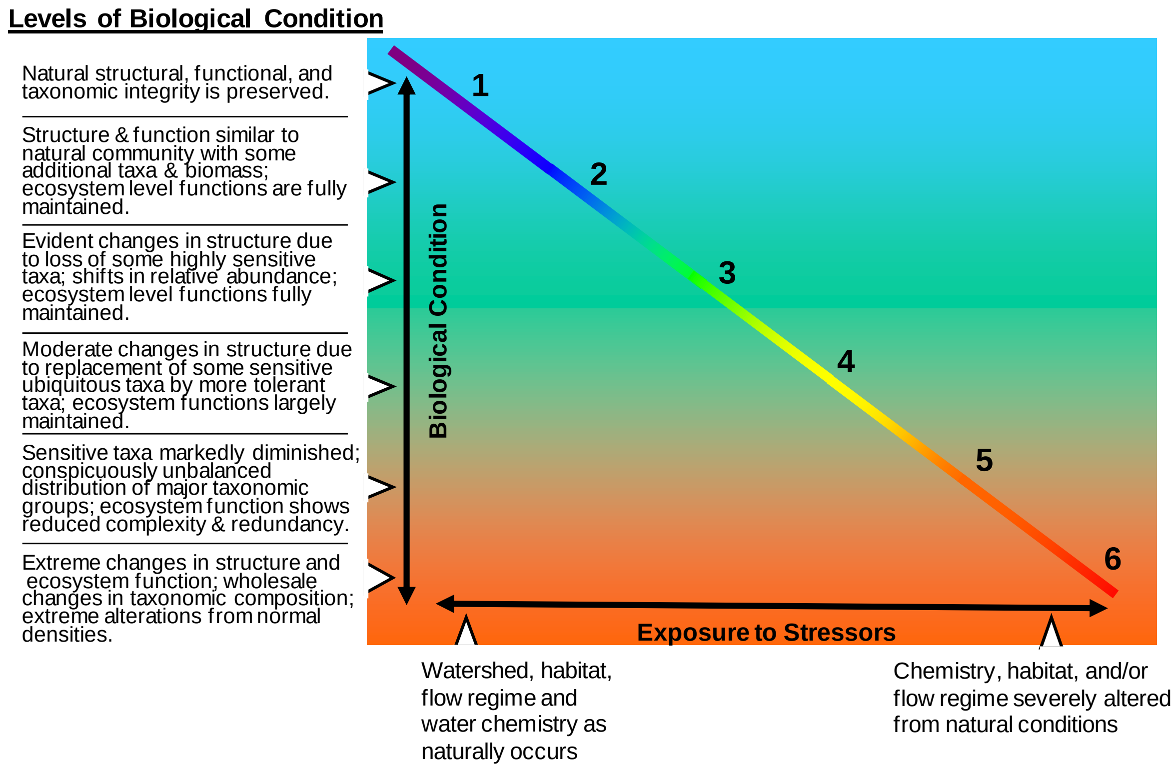


Figure 1. The Biological Condition gradient (BCG), modified from Davies and Jackson 2006. The BCG was developed to serve as a scientific framework to synthesize expert knowledge with empirical observations and develop testable hypotheses on the response of aquatic biota to increasing levels of stress. It is intended to help support more consistent interpretations of the response of aquatic biota to stressors and to clearly communicate this information to the public, and it is being evaluated and piloted in several regions and states.

Project Goal and Approach

The goal of the project to produce a BCG model for California wadeable stream fauna and flora that can be used to place sample sites in bins of ecological condition and can be used to relate algal and invertebrate assemblage metrics, organic matter accumulation, and nutrient gradients along these same bins.

Approach:

1. Conduct expert workshops to elicit from stream benthic macroinvertebrate and algal experts the categorization of a suite of selected sites along the biological condition gradient;
2. Get consensus from experts on the final BCG bin assignments for selected sites in California by stream class;
3. Describe BCG binned distributions in CSCI and ASCI scores;

4. Produce a report describing BCG expert interpretation, the range of BCG binned response indicators and how those BCG bins compare to ranges found by Fetscher et al. 2014 and reference distributions.

Approach and Detailed Task Description

The approach to develop and apply a BCG model consists of 6 tasks:

Task 1. Identify Experts
Task 2. Manage Data and Develop Supporting Information for Expert Scoring
Task 3. Develop the BCG Categorization Protocol and Supporting Information for Expert Scoring
Task 4: Develop BCG Model, Based on Expert Scoring and Reconciliation
Task 5: Crosswalk BCG Condition Categories to Ranges of CSCI and ASCI scores
Task 6: Produce a Report Summarizing BCG Model and Application

Task 1. Identify Experts

The purpose of this task is to identify 15 stream ecologists that represent expertise in using benthic macroinvertebrate (BMI) and algal community data to describe stream condition. For BMI, 10 experts will recruited represent a range of expertise needed to apply required to represent 9 California wadeable stream ecoregions. For algae, 5 experts will be recruited, as current taxonomic expertise representing California ecoregions is not available. Experts will be drawn from academic institutions, consultants, or agency staff. Experts can reside inside or outside of California, but should have expertise in California ecoregions.

Task 1 Deliverables: 1) *Draft list of experts (Appendix B), and 2) Final list of experts*

Task 2: Manage Data and Update Tolerance Values for Macroinvertebrate and Algal Functional Traits

The purpose of this task is to: 1) aggregate and manage stream bioassessment data for use throughout the project, 2) conduct exploratory analyses and update the database of tolerance values for BMI and algal functional traits.

2a. Update existing stream bioassessment databases.

Existing bioassessment databases will be updated to append data, already compiled, that have complete stressor and response information and that are readily available.

2b. Conduct stress-response exploratory analyses and define attributes and update trait tolerance values based on California taxa

The conceptual BCG model relies on a set of attributes, and some sort of expected values for the attributes. Attributes are in the broad categories of taxonomic attributes, organism condition, functional attributes, and spatial attributes. Stream biological monitoring generally obtains information on the taxonomic attributes (species richness, identity of taxa, abundance, and relative abundance) and less frequently on the other attribute groups. The primary attributes available are on sensitivity and tolerance of taxa, and these have been widely reported in the bioassessment literature. In spite of widely published tolerance values (e.g., Merritt et al. 2008 [4th edition], many published tolerance values tend to be earlier work from different areas of the country, that are propagated through successive compilations. They may or may not apply to California and the species and varieties that occur in California. Data analyses will be conducted to support the following objectives and to update the database of tolerance values for functional traits, as needed.

- Confirm data density for taxa in each ecoregion,
- Map taxon distributions,
- Compile existing associations between stressors and established bioassessment metrics and compile information on available traits and/or functional taxon relationships.

2c: Prepare Data for Expert Scoring

The purpose of this task is to select sites that represent designated classes of interest and that represent the full range of stressors (nutrients, response indicators) values to which the BCG will be applied. The type and quantity of data will be determined by Task 2a and b and the final numbers of experts, but will include data on sites representing a gradient of conditions across multiple ecoregions. At a minimum, it will include taxonomic data, sample metadata, ecoregional and classification information, and general information on environmental gradients. This analysis is essentially a synthesis of analyses from Task 2a and b, updated based on Task 3 feedback from the experts. The sites should span the range of disturbance identified in Task 2a, from least disturbed that can be found (sensu Stoddard et al. 2006), to the most disturbed and altered, again within each recognized stream class. Sites can be assigned to 5 or 6 bins of disturbance. Extent of disturbance is used to help select sites given to the panel, but is not communicated to the panelists.

Experts will be given a set of ~100 sites from each identified class of streams, relevant to the assemblage (algae or benthic macroinvertebrates), to score independently, without data on stressors. The timing of this subtask is such that at the initial workshop (Task 3), the data will be ready except for the final classification. As soon as the classification is agreed to and finalized by the experts, selection of sites can be made and the data will be distributed to the experts at the end of the workshop.

Task 2 Deliverables:

Updated database for use throughout project,
Geographic distributions, stress-response associations, traits/functional associations
Selected sites and associated data for use by experts

Task 3 Develop the BCG Categorization Protocol and Supporting Information for Expert Scoring

The purpose of this task is to assemble experts, introduce the protocol for categorizing sites, agree on how to account for natural gradients, and develop supporting databases of taxonomic attributes, tolerance values and/or functional traits.

Task 3a. Introduce Protocol for Classifying Sites

A general protocol exists for the development and calibration of quantitative BCG model. Two webinars and a short (2-day) workshop to introduce new experts to the concept and process lays a foundation in advance of the actual classification and scoring workshop. This can be conducted as combination of webinars and/or face-to-face workshop, depending on the final mix of novice vs experienced panelists; an in-person workshop may be more effective if the experts include a fair number of novices to the BCG. The webinars and introductory workshop will have the following objectives:

- Introduction to BCG in context of WQ management,
- Conduct a trial run of classifying a handful of sites to familiarize participants,
- Get consensus on what site information will be given to experts (e.g. raw taxonomic data, calculated metrics and reference expectation for those metrics, environmental gradients).
- Detailed work with taxonomic lists: experts begin to rate/rank taxa as indicators of stress, based on stress-response associations, and as indicators of BCG attributes. This step can continue as homework for finalization at 2nd workshop

The first part of the meeting will be a relatively thorough explanation of the BCG with emphasis on the conceptual model as described in Davies and Jackson (2006). Two key handouts that will be useful to participants throughout the process are brief descriptions of each level of the BCG, and brief descriptions of attributes of structure, function, and other components, and how they respond to anthropogenic stress (Table 1, Table 2).

3b. Conduct a Trial run and Agree on Scoring Protocol

The expert panel will be given data from 3 – 5 sites, generally spanning the range of stresses found in California. Participants will be given no information on land use, physical, or chemical stress in the sites, and they will be asked to assign each site to one of the 6 levels of the BCG and rank sites, on their own. After they have assigned the sites, the group will reconvene to tally and discuss the results. This exercise is a preview for the homework that will be assigned to the panel. The panelists will then discuss how they rated sites and agree upon a protocol for all to follow when they are rating the sites.

Task 3 Deliverables:

Introductory Webinars and/or Expert Workshop on BCG
Agreement from experts on BCG attributes

Task 4: Develop a BCG of California Wadeable Streams from Expert Scoring and Reconciliation

The purpose of this task is to have experts develop consensus on scoring or ranking sites, and to elicit rules from the experts that they use in their scoring. Experts will score the sites provided in Task 3, independently. A second workshop of two- to three-days will bring the experts back together to reconcile their scores and ranks and to identify the rules that they can agree on. The goal of this workshop is to reconcile the scoring to develop consensus on a set of rules that are transparent, and levels of condition that are ecologically interpretable and meaningful, in order to translate these BCG bins to ranges of scores for the CSCI, algal SCI, and organic matter indicators (benthic chl-a, AFDM, and percent cover).

Deliverables:

Expert Scoring Workshop on BCG and Follow up Webinars

Presentation summarizing consensus on scoring of sites to yield condition classification, and elicitation of rules

Task 5: Crosswalk BCG Condition Categories to Ranges of CSCI and ASCI scores

The utility of the BCG model for to support policy decisions lies in relating each of the BCG categories to ranges in CSCI and ASCI (when available). Furthermore, thresholds using other approaches than the BCG already exist. Fetscher et al. (2014) identified breakpoints in relationships between CSCI index scores and stressor gradients (algal abundance and nutrients). These breakpoints correspond to thresholds in stressor gradients where adverse effects on biological response metrics occur. It is useful to understand the how Fetscher et al. (2014) and reference derived ranges relate to those derived from BCG categories.

The purpose of this task is to derive BCG referenced ranges in the CSCI, algal SCI and 2) compare those ranges to Fetscher et al. (2014) thresholds and reference levels.

Deliverables:

Presentation summarizing the relationship of BCG tiers to intermediate indicators and stressor gradients of interest

Task 6: Produce a Report Summarizing BCG Model and Application

The purpose of this task is to produce a draft and final report summarizing BCG model development and applications for identifying ranges of concentrations of intermediate response and stressors indicators of interest, relative to Fetscher et al. (2014).

Deliverables:

Draft Report

Final Report

Schedule of Deliverables

Task No.	Description of Deliverable	Estimated Schedule for Completion
Task 1	**Identify Experts**	
1.1	List of algal and benthic macroinvertebrate experts (Appendix B)	July 31, 2016
Task 2	**Manage Data and Prepare for Use By Experts**	
2.1	Updated database for use throughout project	September 30, 2016
2.2	Presentation geographic distributions, stress-response associations, traits/functional associations	September 30, 2016
2.3	Prepare selected sites and associated data for use by experts	October 31, 2016
Task 3	**Develop the BCG categorization protocol and supporting information for expert scoring**	
3.1	Presentations used in introductory webinars and/or expert workshop on BCG with preliminary assignment of species and other BCG attributes	December 31, 2016
Task 4	**Develop a BCG of California Wadeable Streams from Expert Scoring and Reconciliation**	
4.1	Presentations from Expert Scoring Workshop on BCG and follow up webinars (as needed)	July 31, 2017
Task 5	**Crosswalk BCG Condition Categories to Ranges of CSCI and ASCI scores**	
5.1	Presentation summarizing the relationship of BCG tiers to CSCI and ASCI	July 31, 2017
Task 6	**Report Summarizing BCG Model Development and Application**	
6.1	Draft report	September 30, 2017
6.2	Final report	November 30, 2017

References

Davies, S.P. and S.K. Jackson. 2006. The biological condition gradient: a descriptive model for interpreting change in aquatic ecosystems. Ecological Applications 16:121-1266.

Fetscher, A.E., M.A. Sutula, A. Sengupta and N. Detenbeck. 2014a. Improving Tools to Link Nutrients to Adverse Effects on Stream Ecosystem Services in California. U.S. EPA Office of Research and Development Regional Ecosystem Services Research Program (REServe).

Merritt, R.W., Cummins, K.W. & Berg, M.B. 2008. An introduction to the aquatic insects of North America. Dubuque, Kendall/Hunt Publishing Company, 1214 p. [4th edition]

Paul M., Lincoln A., Butcher J. 2015. A reference-based approach to deriving nutrient numeric endpoints for California wadeable streams. Draft report available upon request.

Stoddard, J. L., and coauthors. 2006. Mid-Atlantic Integrated Assessment (MAIA)–State of the Flowing Waters Report. U.S. Environmental Protection Agency, Office of Research and Development, EPA/620/R-06/001, Washington, DC.

Sutula M., Fetscher, E., Stein E., Paul M., Butcher J. and Detenbeck N. 2015. Science plan to support development of a nutrient control program for California Wadeable Streams. www.waterboards.ca.gov/water_issues/programs/nutrient_objectives/development/docs/science_plan.pdf

Appendix A.

Table A1. BCG Attributes and Description

BCG Attributes	Description
I. Historically documented, sensitive, long-lived or regionally endemic taxa:	Refers to taxa known to have been supported in a waterbody or region prior to enactment of the Clean Water Act, according to historical records compiled by state or federal agencies or published scientific literature. Sensitive or regionally endemic taxa have restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often due to unique life history requirements. They may be long-lived, late maturing, low fecundity, limited mobility, or require a mutualist relation with other species. May be among listed endangered/threatened or special concern species. Predictability of occurrence is often low, therefore, requiring documented observation. Recorded occurrence may be highly dependent on sample methods, site selection and level of effort.
II. Highly Sensitive Taxa:	Refers to taxa that naturally occur in low numbers relative to total population density but may make up large relative proportion of richness. They may be ubiquitous in occurrence or may be restricted to certain micro-habitats, but because of low density, recorded occurrence is dependent on sample effort. Often stenothermic (having a narrow range of thermal tolerance) or cold-water obligates; they are commonly k-strategists (populations maintained at a fairly constant level; slower development; longer life-span). They may have specialized food resource needs or feeding strategies and are generally intolerant to significant alteration of the physical or chemical environment; is often the first taxa observed to be lost from a community.
III. Inter-mediate Sensitive Taxa, (or Sensitive and Common Taxa):	Refers to taxa that are ordinarily common and abundant in natural communities when conventional sample methods are used. They often have a broader range of thermal tolerance than Sensitive- Rare taxa. These are taxa that comprise a substantial portion of natural communities, and that often exhibit negative response (loss of population, richness) at mild pollution loads or habitat alteration.
IV. Taxa of Intermediate Tolerance:	Refers to taxa that make up a substantial portion of natural communities; may be r-strategists (early colonizers with rapid turn-over times; "boom/bust" population characteristics). They may be eurythermal (having a broad thermal tolerance range). May have generalist or facultative feeding strategies enabling utilization of relatively more diversified food types. Readily collected with conventional sample methods. May increase in number in waters with moderately increased organic resources and reduced competition but are intolerant of excessive pollution loads or habitat alteration.
V. Tolerant Taxa:	Taxa that make up a low proportion of natural communities. These taxa often are tolerant of a broader range of environmental conditions and are thus resistant to a variety of pollution or habitat induced stress. They may increase in number (sometimes greatly) in the absence of competition. Commonly r-strategists (early colonizers with rapid turn-over times; "boom/bust" population characteristics), able to capitalize when stress conditions occur. These are the last survivors in severely disturbed systems.
VI. Non-native or Intentionally Introduced Species	With respect to a particular ecosystem, any species that is not found in that ecosystem. Species introduced or spread from one region of the U.S. to another outside their normal range are non-native or non-indigenous, as are species introduced from other continents.
VII. Organism Condition (especially of	General indicators of organism health, such as deformities, anomalies, lesions, tumors, or excess parasitism are all external indicators of condition.

long-lived organisms)	
VIII. Ecosystem Function	Function includes trophic levels, production, respiration, total biomass and biomass in functional levels, P/R ratios, etc.
IX. Spatial and Temporal Extent of Detrimental Effects	The spatial extent of damage or degradation from a particular source.
X. Ecosystem Connectance	Natural connections and relation among ecosystem units, such as extent fragmentation, connections of riparian areas with the stream and floodplain, etc.

Description of the Biological Condition Gradient Levels

Although the BCG is continuous in concept, it has been divided into six levels to provide as much discrimination of different levels of condition as workgroup members deemed discernable, given current assessment methods and robust monitoring programs. It has been divided into six levels (as opposed to single pass-fail criteria) to foster both identification of consistent condition classes and management of the gradient of condition. Defining the levels between 3 and 5 was a challenge to the workgroup and entailed considerable discussion. The workgroup ultimately agreed some states and tribes may only be capable of discriminating 3-4, levels while others might be capable of discerning 6 levels based on characteristics of their database and monitoring program. However the workgroup agreed that the important role of the BCG model is to be a starting point for a state or tribe to think about how to use biological assessments and criteria to refine their designated aquatic life uses and to communicate more clearly about biological condition. There is no expectation that states and tribes must establish six levels of use classes. The ultimate number of the levels is a state or tribal determination.

Level 1: Natural or native condition.

Native structural, functional, and taxonomic integrity is preserved; ecosystem function is preserved within the range of natural variability.

Level 1 represents biological conditions as they existed (or still exist) in the absence of measurable effects of human disturbance. The Level 1 biological assemblages that occur in a given biogeophysical setting are the result of adaptive evolutionary processes and biogeography that selects in favor of survival of the observed species. For this reason, the expected Level 1 assemblage of a stream from the arid southwest will be very different from that of a stream in the northern temperate forest. The maintenance of native species populations and natural diversity of sensitive, long-lived species is essential for Levels 1 and 2. Non-native taxa are permissible in Level 1 only if they cause no displacement of native taxa, although the practical uncertainties of this provision are acknowledged. Attributes I and II (e.g., historically documented and sensitive taxa) assess the status of native taxa and thus should also identify threatened or endangered species when classifying a site or assessing its condition.

Level 2: Minimal changes in structure of the biotic community and minimal changes in ecosystem function.

Virtually all native taxa are maintained with some changes in biomass and/or abundance; ecosystem functions are fully maintained within the range of natural variability.

Level 2 represents the earliest changes in densities, species composition, and biomass that occur as a result of slight physical disturbances (such as increased temperature regime) or enrichment. There may be some reduction of a small fraction of highly sensitive or specialized taxa (Attribute II) or loss of some endemic or rare taxa. Level 2 can be characterized as the first change in condition from natural and it is most often manifested as slightly *increased* richness and density of taxa from Attributes III and IV, relative to Level 1 conditions.

Level 3: Evident changes in structure of the biotic community and minimal changes in ecosystem function.

Evident changes in structure due to loss of some rare native taxa; shifts in relative abundance of taxa but sensitive-ubiquitous taxa are common and abundant; ecosystem functions are fully maintained through redundant attributes of the system.

Level 3 represents readily observable changes that often occur in response to organic enrichment or increased temperature. The "evident" change in structure for Level 3 is interpreted to be perceptible and detectable decreases in sensitive-rare or highly sensitive taxa (Attribute II) and increases in sensitive-ubiquitous taxa or opportunist organisms (Attributes III and IV). Attribute IV taxa (intermediate tolerants) may increase in abundance as an opportunistic response to nutrient inputs.

Level 4: Moderate changes in structure of the biotic community with minimal changes in ecosystem function.

Moderate changes in structure due to replacement of some sensitive-ubiquitous taxa by more tolerant taxa, but reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups; ecosystem functions largely maintained through redundant attributes.

Level 5: Major changes in structure of the biotic community and moderate changes in ecosystem function.

Sensitive taxa are markedly diminished; conspicuously unbalanced distribution of major groups from those expected; organism condition shows signs of physiological stress; ecosystem function shows reduced complexity and redundancy; increased build-up or export of unused materials.

Changes in ecosystem function (as indicated by marked changes in food-web structure and guilds) are critical in distinguishing between Levels 4 and 5. This could include the loss of functionally important sensitive taxa and keystone taxa (Attribute I, II and III taxa) such that they are no longer important players in the system, though a few individuals may be present. Keystone taxa control species composition and trophic interactions, and are often, but not always, top predators. Tolerant non-native taxa (Attribute VI) dominate some assemblages and organism condition (Attribute VII) deteriorates. As an example, removal of keystone taxa by overfishing has greatly altered the structure and function of many coastal ocean ecosystems (Jackson et al. 2001).

Level 6: Severe changes in structure of the biotic community and major loss of ecosystem function.

Extreme changes in structure; wholesale changes in taxonomic composition; extreme alterations from normal densities and distributions; organism condition is often poor; ecosystem functions are severely altered.

Level 6 systems are taxonomically depauperate (low diversity and/or number of organisms) compared to the other levels. Extremely high or low densities of organisms caused by excessive organic enrichment or severe toxicity may characterize Level 6 systems.

IMPORTANT DEFINITIONS

Definitions of Terms used in the Biological Condition Gradient (Modified from Davies and Jackson 2006).

Historically Documented Taxa: refers to taxa known to have been supported in a waterbody or region prior to enactment of the Clean Water Act, according to historical records compiled by state or federal agencies or published scientific literature.

Invasive species – a species whose presence in the environment causes economic or environmental harm or harm to human health. Native species or non-native species may show invasive traits, although this is rare for native species and relatively common for non-native species. (Please note – this term is not currently included in the Biological Condition Gradient).[1]

Non-native or intentionally introduced species – with respect to a particular ecosystem, any species that is not found in that ecosystem. Species introduced or spread from one region of the U.S. to another outside their normal range are non-native or non-indigenous, as are species introduced from other continents.

Sensitive taxa: intolerant to a given anthropogenic stress; first species affected by the specific stressor to which they are "sensitive" and the last to recover following restoration.

Sensitive or regionally endemic taxa: taxa with restricted, geographically isolated distribution patterns (occurring only in a locale as opposed to a region), often due to unique life history requirements. May be long-lived, late maturing, low fecundity, limited mobility, or require mutualist relation with other species. May be among listed Endangered/Threatened or special concern species. Predictability of occurrence often low, therefore, requiring documented observation. Recorded occurrence may be highly dependent on sample methods, site selection and level of effort.

Highly Sensitive Taxa: taxa that naturally occur in low numbers relative to total population density but may make up large relative proportion of richness. May be ubiquitous in occurrence or may be restricted to certain micro-habitats, but because of low density, recorded occurrence is dependent on sample effort. Often stenothermic (having a narrow range of thermal tolerance) or cold-water obligates; commonly K-strategists (populations maintained at a fairly constant level; slower development; longer life-span). May have specialized food resource needs or feeding strategies. Generally intolerant to significant alteration of the physical or chemical environment; are often the first taxa observed to be lost from a community.

Intermediate Sensitive Taxa: ordinarily common and abundant in natural communities when conventional sample methods are used. Often having a broader range of thermal tolerance than Sensititve- Rare taxa. These are taxa that comprise a substantial portion of natural communities, and that often exhibit negative response (loss of population, richness) at mild pollution loads or habitat alteration.

Taxa of Intermediate Tolerance: taxa that comprise a substantial portion of natural communities; may be r-strategists (early colonizers with rapid turn-over times; "boom/bust population characteristics). May be eurythermal (having a broad thermal tolerance range). May have generalist or facultative feeding strategies enabling utilization of relatively more diversified food types. Readily collected with conventional sample methods. May increase in number in waters with moderately increased organic resources and reduced competition but are intolerant of excessive pollution loads or habitat alteration.

Tolerant Taxa: taxa that comprise a low proportion of natural communities. Taxa often are tolerant of a broader range of environmental conditions and are thus resistant to a variety of pollution or habitat induced stress. They may increase in number (sometimes greatly) in the absence of competition. Commonly r-strategists (early colonizers with rapid turn-over times; "boom/bust" population characteristics), able to capitalize when stress conditions occur. Last survivors.

attribute: measurable part or process of a biological system

ecosystem-level functions: processes performed by ecosystems, including, among other things, primary and secondary production; respiration; nutrient cycling; decomposition.

function: processes required for normal performance of a biological system (may be applied to any level of biological organization)

life-history requirements: environmental conditions necessary for completing life cycles (including, among other things, reproduction, growth, maturation, migration, dispersal)

maintenance of populations: sustained population persistence; associated with locally successful reproduction and growth

native: an original or indigenous inhabitant of a region; naturally present

non-detrimental effect : do not displace native taxa

refugia: accessible microhabitats or regions within a stream reach or watershed where adequate conditions for organism survival are maintained during circumstances that threaten survival, eg drought, flood, temperature extremes, increased chemical stressors, habitat disturbance, etc

spatial and temporal ecosystem connectance: access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life; the opposite of fragmentation; necessary for metapopulation maintenance and natural flows of energy and nutrients across ecosystem boundaries

structure: taxonomic and quantitative attributes of an assemblage or community, including species richness and relative abundance

Appendix B.

List of BCG Panel Experts and Biographies, By Expertise

Algal Taxonomy and Ecology

Donald Charles, Ph.D., Leader, Phycology Section, The Academy of Natural Sciences' Patrick Center for Environmental Research (http://diatom.ansp.org/).

Dr. Charles is leader (since 1992) of the Phycology Section in the Patrick Center for Environmental Research (PCER) and a professor in Drexel's Department of Biodiversity, Earth and Environmental Science. He was Ruth Patrick Chair in Environmental Science, ANSP (2005 – 2010) and served a year each as Director and Acting Director of the PCER. He obtained a B.Sc. from The SUNY College of Environmental Science and Forestry (1971) and from Syracuse University (1971), his M.Sc. from Cornell University (1974), and his Ph.D. from Indiana University (1982). He worked as Aquatic Ecologist for New York State's Adirondack Park Agency (1973-1977), held research positions at Indiana University (1982-1986), and was a university-cooperator Limnologist at the U.S EPA's Environmental Research Laboratory in Corvallis, OR (1987-1991). He has authored / co-authored more than 60 scientific articles and over 65 reports. Research interests include ecology of diatoms and their use as environmental indicators in assessment of river water quality and in paleolimnolgical studies; basic and applied aspects of nutrient enrichment, acidification, and climate change; and ecoinformatics. He helped lead efforts to develop a diatom BCG approach for the state of New Jersey.

Rex L. Lowe, Ph.D. Professor Emeritus of Biological Sciences, Bowling Green State University

Rex Lowe received his Bachelor of Science and Doctor of Philosophy degrees in botany at Iowa State University. He is currently Professor Emeritus at Bowling Green State University (BGSU) where he has won awards for outstanding teaching and research. Dr. Lowe teaches courses on Freshwater Algal Ecology, Limnology and Great Lakes Ecosystems. In addition to BGSU, Dr. Lowe also teaches in the summers at The University of Michigan Biological Station, Michigan State University's Kellogg Biological Station and Ohio State University's Stone Laboratory and has recently moved to the Center for Limnology at the University of Wisconsin. In 2008 Lowe was awarded the Wilder Chair for a distinguished botanist at the University of Hawaii where he studied freshwater algal endemics. In 2014 he was awarded the prestigeous Award of Excellence from the Phycological Society of America for sustained research excellence. Professor Lowe has trained and graduated over 70 graduate students including 16 PhDs. Lowe's scholarly books and manuscripts (> 150) cover topics concerning algal ecology and diatom systematics.

Robert Sheath, Ph.D., Department of Biological Sciences, California State University San Marcos

Dr. Robert Sheath is a professor of the Department of Biological Sciences at California State University San Marcos. His research interests focus on the evolution, ecology, biogeography and systematics of freshwater algae and their use as water quality indicators. This research involves a combination of field and laboratory work, including advanced microscopy and molecular analyses. Dr. Sheath is the past Editor of the *Journal of Phycology* and a co-editor of *Freshwater Algae of North America: Ecology and Classification*. 2nd ed. An algal genus was named in his honor, *Sheathia*, and is distributed in North America, Europe and New Zealand. The lab was named California Primary Algae Lab by the California Water Board because it has the expertise, including adding considerably to the state flora, naming 4 new species to science and creating a widely accessible web site.

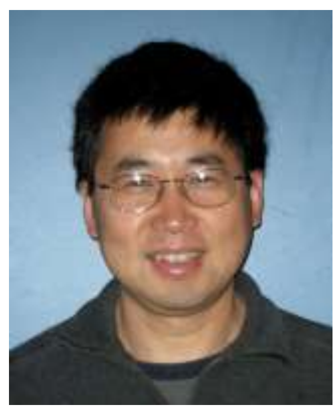
Sarah Spaulding, Ph.D., USGS, INSTAAR, University of Colorado, (http://instaar.colorado.edu/~spauldis/)

Sarah is an Ecologist for the US Geological Survey, working on the National Water Quality Assessment program. She works with an excellent group of taxonomists at INSTAAR, University of Colorado, focusing on improving the process of assessment in streams and rivers. Sarah is the Chair of the Editorial Review Board for a national diatom flora in the form of an online database, Diatoms of the United States. Sarah would like everyone to know about diatoms, particularly analysts and managers, and for all of us to work towards improving biotic condition in freshwaters.

Rosalina Stancheva Hristova, Ph.D., Department of Biological Sciences, California State San Marcos.

Dr. Rosalina Stancheva is a chief scientist at the California Primary Algae Laboratory of the Surface Water Ambient Monitoring Program (SWAMP) of the State Water Board at California State University San Marcos. She received a PhD in Phycology from the Sofia University, Bulgaria in 2004 where she was teaching courses in systematics of algae and fungi, ecology of algae, and diatom analysis. In 2005 she began doing research on diatoms from streams in the western USA for the US Environmental Protection Agency's Environmental Monitoring and Assessment Program. In the past 9 years she has been developing soft-bodied algae and diatoms as bioindicators for stream in California as part SWAMP, including standard laboratory and quality control operating procedures, online taxonomic identification tool and algal index of biotic integrity. Her research centers on freshwater algae taxonomy, ecology, and biogeography, diversity of nitrogen-fixing and toxin-producing cyanobacteria in streams in California. She discovered four new to science freshwater species of green algae from SWAMP data set. Recently her studies are focused on the stream diatom flora in California.

Yangdong Pan, Ph.D. Department of Environmental Science and Management at Portland State University (PSU).



Dr. Yangdong Pan is professor of the Department of Environmental Science and Management at Portland State University (PSU). His research centers on freshwater ecology and conservation. Specifically, he uses algal assemblages to monitor and assess ecological risk in freshwater ecosystems including lakes, wetlands and rivers. He has participated several national surface water quality programs such as the US Environmental Protection Agency's Environmental Monitoring and Assessment Programs (EMAP) in the Mid-Atlantic Region and in the western USA with a focus on periphyton indicators development. Recently, he has been collaborating with Chinese environmental professionals on several water-quality projects including ecology and management of algal blooms in shallow lakes, drinking water source protection, and ecological risk assessment of lakes and streams in the Jiuzhaigou National Park, a UNESCO world natural heritage site. He teaches limnology, freshwater algae, ecology of streams/river, and two graduate-level courses on environmental and biological data analysis.

Benthic Macroinvertebrate Taxonomy and Ecologists

Larry Brown, Ph.D., Research Biologist, USGS, California Water Science Center. https://profile.usgs.gov/lrbrown.

Larry R. Brown is a Research Biologist with the U.S. Geological Survey, California Water Science Center. Dr. Brown has over 35 years of experience working in California aquatic systems. He is a recognized expert on the ecology of California fishes and has published on California fishes, benthic macroinvertebrates and benthic algae. Dr. Brown is currently involved in studies of the effects of climate change on selected fish species in the Central Valley watershed and San Francisco Estuary, factors associated with declines in pelagic fish populations of the San Francisco Estuary, and effects of hydrologic alteration on California stream systems. In the course of his work, Dr. Brown has authored or coauthored over 80 scientific articles and reports.

Jim Carter, Research Scientist, USGS Menlo Park, CA.

Jim Carter is a researcher for the National Research Program (Water Mission Area) of the U.S. Geological Survey. He has held this position at the western region center in Menlo Park, CA since 1981. He has a Ph.D. from the Department of Entomology, University of California, Berkeley. His research has focused on numerous aspects of aquatic ecology. Lotic studies have emphasized: 1) determining the influence of fluvial geomorphology and landscape characteristics on the distribution of stream benthic invertebrates at a variety of spatial and temporal scales and 2) identifying the effects of sample collecting, processing and analyzing on the interpretation of lotic bioassessments. Lentic studies include comprehensive research on the benthic fauna of a western hypereutrophic lake (Upper Klamath Lake, OR). These studies have emphasized: 1) identifying factors that influence the large and small scale spatial and temporal distribution of invertebrates, 2) determining the effects benthic invertebrates have on nutrient cycling, and 3) developing a lake food web model using stable isotopes of carbon, nitrogen, and sulfur.

David Herbst, Ph.D., Research Scientist, UC Santa Barbara, Sierra Nevada Aquatic Research Laboratory.

Dave Herbst received a PhD in zoology and entomology from Oregon State University in 1986 and has been a research scientist with UC Santa Barbara since that time, stationed at the Sierra Nevada Aquatic Research Laboratory. My early research was mainly on the physiology and ecology of invertebrates from saline lakes (Mono and Owens Lakes in California, Abert in Oregon, Walker and Big Soda in Nevada), using comparative ecology and field and lab experiments to study effects of salinity. In the 1990s I began doing research on BMIs in streams of the Sierra Nevada and worked for 15 years to develop a bioassessment program and indicators for the eastern Sierra and central coast regions of California. My stream research spans long-term studies of the effects of sediment deposition, acid mine drainage, livestock grazing, habitat restoration, forest management, introduced species (trout, New Zealand mud snail), and monitoring of climate change and drought in Sierra Nevada headwaters.

Jeanette Howard, Ph.D., Associate Director of Science, Water Program, the Nature Conservancy.

Jeanette Howard, PhD, Associate Director of Science, Water Program, The Nature Conservancy, California. Dr. Howard leads TNC's freshwater science engagements which focus on developing and fostering a science enterprise to sustain healthy aquatic ecosystems in California. This work includes conservation planning for freshwater biodiversity statewide, defining environmental flows for water policy and management, and on-the-ground research projects to evaluate conservation actions.

Bill Isham, Senior Ecologist, AMEC Foster Wheeler, San Diego CA

Mr. Isham received a bachelors degree in Biological Sciences from Florida Institute of Technology. He has worked for private environmental consultants since 1991, including MEC Analytical (1991-2005), Weston Solutions (2005-2014), and Amec Foster Wheeler (2014-present). Mr. Isham has 25 years of experience in freshwater stream, marine, and wetland ecology. He has extensive project management experience with active participation in every phase of environmental monitoring including survey design, field collections, laboratory sample analyses and taxonomy, data management/interpretation, and reporting. As a taxonomist, he specializes in freshwater aquatic insects as well as marine and freshwater fish (adult and larval stages). Since 2001, he has been, at various times, the director for regional NPDES permit compliance stream bioassessment programs in San Diego, Orange, Los Angeles and Riverside counties and is familiar with every major watershed in southern California. He has managed numerous monitoring projects related to stream and wetland restoration, mitigation, spill impacts, construction and BMP effectiveness, overseeing multidisciplinary efforts for baseline, performance and impact monitoring. He has also contributed to NEPA/CEQA documents, EIR/EIS's, Biological Opinions, and habitat management and restoration plans.

Jason May, Aquatic Ecologist, USGS California Water Science Center.
https://profile.usgs.gov/jasonmay

Jason T. May is an aquatic ecologist with the U.S. Geological Survey, California Water Science Center. Mr. May has over 14 years of experience working in California aquatic systems. He has published on California fishes, benthic macroinvertebrates and benthic algae. Mr. May is currently involved in studies of the effects of urbanization on stream systems across the United States, modeling of responses of stream macroinvertebrate communities to land use changes, and investigations of mercury and other trace metals contamination associated with abandon mine lands. In the course of his work, Mr. May has authored or coauthored over 30 scientific articles and reports.

Patina Mendez, Ph.D., UC Berkeley's Environmental Sciences Program.

Dr. Patina Mendez is freshwater ecologist and a Continuing Lecturer for UC Berkeley's Environmental Sciences Program. She is a specialist in the life history characteristics (e.g., life cycle timing, feeding, reproductive strategies, etc.) of freshwater invertebrates and how they are linked with habitat. She also investigates models of benthic macroinvertebrate community structure using life history traits in spatially large datasets. Her taxonomic area is caddisflies (Trichoptera), a group of insects that spend most of their life cycle in an aquatic larval stage that builds a case or retreat. Her projects include using distribution records of caddisflies in California streams to help broaden understanding of species diversity and changes in distributions over the past 100 years. She is also a curator of the Trichoptera Literature Database, a bibliography of 14,000 references on Trichoptera.

Allison O'Dowd, Ph.D., Associate Professor, Environmental Science and Management, Humboldt State University.

Dr. Alison O'Dowd is an Associate Professor in the Department of Environmental Science and Management at Humboldt State University and Co-Director of the HSU River Institute. Dr. O'Dowd has conducted research in the fields of stream ecology and restoration for over 15 years. Dr. O'Dowd's specific research areas include: the development of biological condition gradients in urban watersheds, stream and wetland restoration, the ecology and eradication of invasive species, the impacts of wildfire on stream communities, the biological significance of step-pool sequences in mountain streams, and the management of dam releases to assist migrating salmonids. Dr. O'Dowd's research methods use benthic macroinvertebrates as indicators of water quality in urban and natural freshwater ecosystems. Dr. O'Dowd's research is primarily located within California, with a focus on California's North Coast. Study areas include: the Eel River, Smith River, Klamath River, Lake Tahoe Basin, and Humboldt Bay and San Francisco Bay watersheds.

John Olson, Ph.D. Assistant Professor, California State Monterey Bay.

John Olson completed his PhD in Watershed Science at Utah State University and postdoctoral studies at the Desert Research Institute. He is currently an assistant research professor at the Desert Resarch Instiute, and is joining the faculty at Cal State Monterey Bay in January 2017. His research focuses on understanding how landscape patterns in geology, climate, vegetation and other environmental factors affect surface water chemistry; how differences in water chemistry in turn affect stream biota; and how these relationships can be applied to managing freshwater resources. He has worked with US EPA, USGS, and natural resource agencies in Georgia, Utah, Wyoming, Wisconsin, and Oregon to improve bioassessments of streams and rivers. Some of his recent projects include empirically modeling natural water chemistry to establish water chemistry baselines and nutrient criteria nationwide, determining how invertebrate distributions are affected by geology, and developing predictive models of fish and algae distributions based on environmental DNA samples and remote sensing data.

Andy Rehn, Ph.D., Research Biologist, California Department of Fish & Wildlife Aquatic Bioassessment Lab (ABL)

Andrew Rehn earned a PhD in Entomology from UC Davis in 2000 and has been a biologist with the California Department of Fish & Wildlife Aquatic Bioassessment Lab (ABL) for the last 16 years. At ABL he helped develop several of the state's first biological indices and led studies on spatial variability in bioassessment samples and comparability of samples collected by different methods. Special research interests have included the effects of hydropower dams and wildfires on aquatic macroinvertebrates. More recently he co-authored the California Stream Condition Index by creating models to relate natural environmental variability to species distributions. He is the lead coordinator of the statewide Perennial Stream Assessment and the statewide Reference Condition Monitoring Plan. As a founding member of the Southwest Association of Freshwater Invertebrate Taxonomists and the California Freshwater Algae Working Group, he has played a leading role in establishing the state's taxonomic data quality standards for bioassessments, which have become a model for national programs.