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Linking Nutrients to Alterations in Aquatic Life in California Wadeable Streams

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EXECUTIVE SUMMARY

In wadeable streams, nutrient enrichment, in concert with other site-specific factors, can result in the overabundance of algal biomass, low dissolved oxygen and altered biotic communities. These changes can have adverse effects on stream ecosystem services. Scientifically-based water quality objectives (WQO) and tools that relate these objectives to nutrient management are needed in California to prevent eutrophication from occurring and to provide targets to restore waterbodies where adverse effects have already occurred.

The California State Water Resources Control Board (SWRCB) is developing nutrient water quality objectives for the State's surface waters. USEPA guidance on nutrient objective development generally recommends three means to set nutrient objectives (USEPA 2000): 1) a reference approach, based on a statistical percentile of nutrient or biotic response indicators in minimally-disturbed waterbodies; 2) an empirical stress-response approach, based on statistical analyses of field data on nutrients, algal abundance and indicators of aquatic life; or 3) a process-based approach, involving identification of ecological responses of concern and mechanistically modeling the linkage back to nutrient loads and other co-factors controlling response.

Among the approaches that the SWRCB staff is considering is the process-based approach, known as the Nutrient Numeric Endpoint (NNE) framework (Tetra Tech 2006). The NNE framework is intended to serve as numeric guidance to translate narrative WQO. It consists of two tenets: 1) assessment and recommended numeric (regulatory) endpoints based on the ecological response of an aquatic waterbody to eutrophication (e.g., algal abundance, dissolved oxygen [DO]) to assess waterbody condition and 2) scoping-level models that link the response indicator endpoints to nutrient inputs and other site-specific factors and management controls. These scoping models were intended to be used to establish default nutrient targets for point source discharge and municipal stormwater permits and total maximum daily loads (Tetra Tech 2006). Tetra Tech (2006) developed the benthic biomass spreadsheet tool (BBST) for use in streams. As the SWRCB prepares to propose nutrient objectives for wadeable streams, scientific analyses of improved data from California statewide stream probabilistic and targeted bioassessment surveys can strengthen the scientific basis for policy decisions. In the context of this study, "endpoints" refer to policy decisions on levels at which point management action should be taken; "thresholds" refer to the output of scientific analyses.

The objectives of this project are three-fold:

• Estimate the natural background and ambient concentrations of nutrients and candidate indicators of primary producer abundance in California wadeable streams;

• Explore relationships and identify thresholds of adverse effects of nutrient concentrations and primary producer abundance on aquatic life indicators in California wadeable streams;

• Evaluate the Benthic Biomass Spreadsheet Tool for California wadeable streams using existing data sets and recommend avenues for refinement.

The intended outcome of this study is research, NOT recommendations for regulatory endpoints for nutrient and response indicators for California wadeable streams. The findings of this research study, as well as other analyses, may be used as lines of evidence considered to support SWRCB policy decisions on nutrient objectives for wadeable streams.

Study Findings

The majority of the State's Wadeable Streams sampled are below the 75th percentile of minimally disturbed "reference sites." California's perennial, wadeable streams, as assessed during the bioassessment index period of late spring through mid-summer, exhibited a skew toward the low end of the primary producer abundance gradient. Nearly 66% of perennial wadeable stream kilometers had estimated benthic chlorophyll a and 59% had estimated TN and TP values below the 75th percentile of each variable at reference sites statewide1. Among the regions, a gradient in algal abundance and nutrient concentrations was observed from high in areas developed by urban and agricultural land uses (South Coast, Central Valley) to low in areas of the state with lower density development (e.g., North Coast and Sierra regions).

Statistically detectable thresholds were found for benthic chlorophyll a, ash-free dry mass (AFDM), and nutrients; benthic chlorophyll a thresholds were below those of TetraTech (2006). This study found statistically significant relationships and thresholds of adverse effects of benthic chlorophyll a, AFDM, and TN and TP concentrations on indicators of benthic macroinvertebrate (BMI) and algal community structure—employed in this study as indicators of aquatic life. Integrative aquatic life indicators (ALIs) such as indices of biotic integrity corresponded to higher thresholds whereas ALI measures specific to constrained groups of "sensitive" taxa generally corresponded to lower thresholds, illustrative of the paradigm of the biological condition gradient. Most of these thresholds of effect exceeded the 75th percentile of these indicators among reference stream reaches statewide, but they were often less than the 95th percentile. The range of benthic chlorophyll a thresholds in this study were generally substantially below the current NNE endpoints protective of beneficial uses recommended by TetraTech (2006; 100 and 150 mg/m2 chlorophyll a for cold [salmonid] and warm water respectively). However, it should be noted that our results are based on instantaneous measurement at low-flow conditions, and as such, do not reflect year-long loads or storm flows. It is not clear to what degree the types of ALI-stressor relationships we observed would hold during rain events.

Validation exercise indicates that there is considerable room for improvement in BBST; inclusion of landscape and site-scale factors provide avenue for model refinement. The BBST models show poor fit, particularly among "stressed" sites (one-third of the data set), when validated against a statewide dataset, which contains benthic chlorophyll a data as currently measured in California ambient monitoring programs. The poor fit is understandable, given that the BBST was optimized for North American temperate streams and that the model predicts maximum algal abundance, a value not verifiably captured during the period in which sampling to generate the project data set occurred. Several landscape- and site-scale explanatory variables were high in their relative influence in the BBST model predicted-observed variance analysis and in preliminary nutrient-algal response models. Nutrient concentrations were important predictors in BBST model predicted-observed variance analysis and boosted regression tree (BRT) models, albeit occupying less prominent roles than other factors, such as temperature and stream substratum type. This finding validates the fundamental NNE approach: site-specific co-factors that vary across the California landscape can influence algal response to nutrients. It also suggests that model

refinements are possible; inclusion of these site- and landscape-scale explanatory variables in preliminary nutrient-algal response models substantially improved model fit over existing BBST models.

Full Text:

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