4. Scientific Foundation for Assessment of Biostimulatory Impacts to California Estuaries, Enclosed Bays, and Inland Waterbodies, Sutula SCCWRP Technical Report [TR] 871.

Charge Questions:

- Comment on the adequacy of conceptual models and indicators/measures reviewed in **Sutula TR 871** to provide a conceptual, scientific foundation for understanding pathways of impact of eutrophication and linkage to biostimulatory substances and conditions, across all waterbody types in California.
- Are there technical ways to address stakeholder concerns?

Technical Report #871 presents a comprehensive review of the science concerning biostimulatory factors that affect eutrophication is surface waters. Given the ultimate need for numeric guidance and models linking indicators with designated uses, this review would be strengthened if it concluded with initial suggestions/recommendations for these quantitative analyses.

Conceptual Model

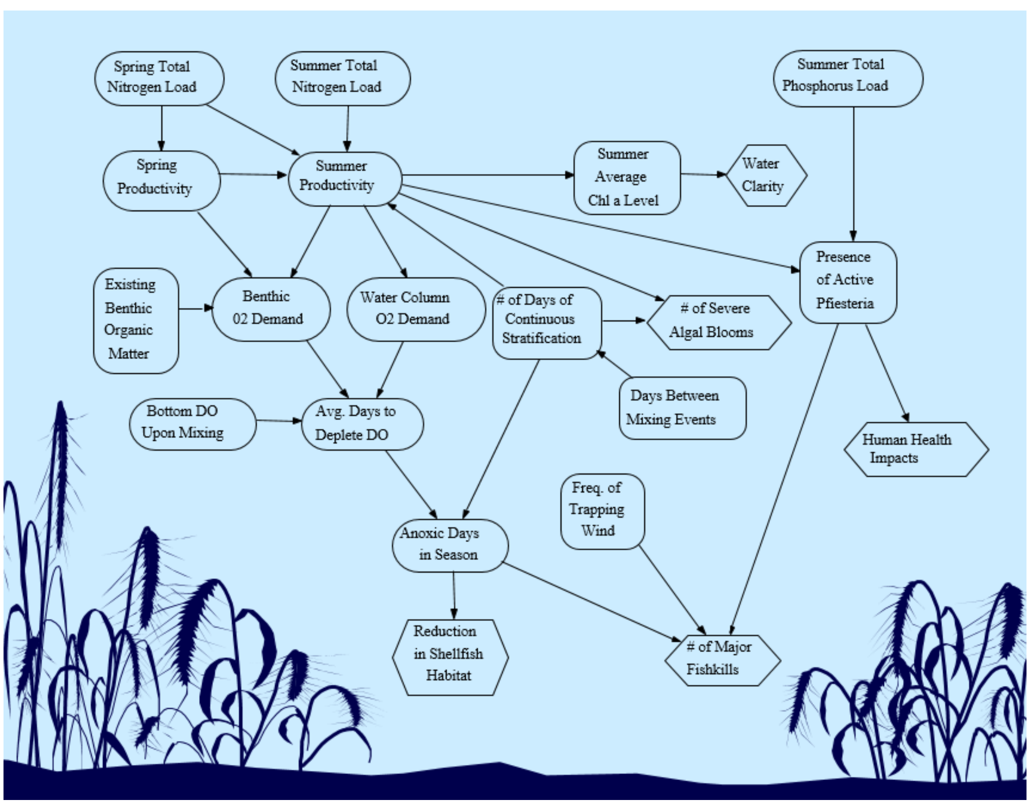
As noted in the report, a conceptual model consists of (1) a description of components and relationships, and (2) a diagram characterizing these relationships. The conceptual model diagram in Figure 2.3 provides an initial foundation for this Technical Report. The comprehensiveness of Figure 2.3 allows the reader to assess whether anything relevant has been left out. Figure 2.15 provides another example of a comprehensive model. Either of these diagrams may serve as a starting point for a more informative sequence of conceptual model diagrams leading to a numeric model, as described in the Causal Analysis section below.

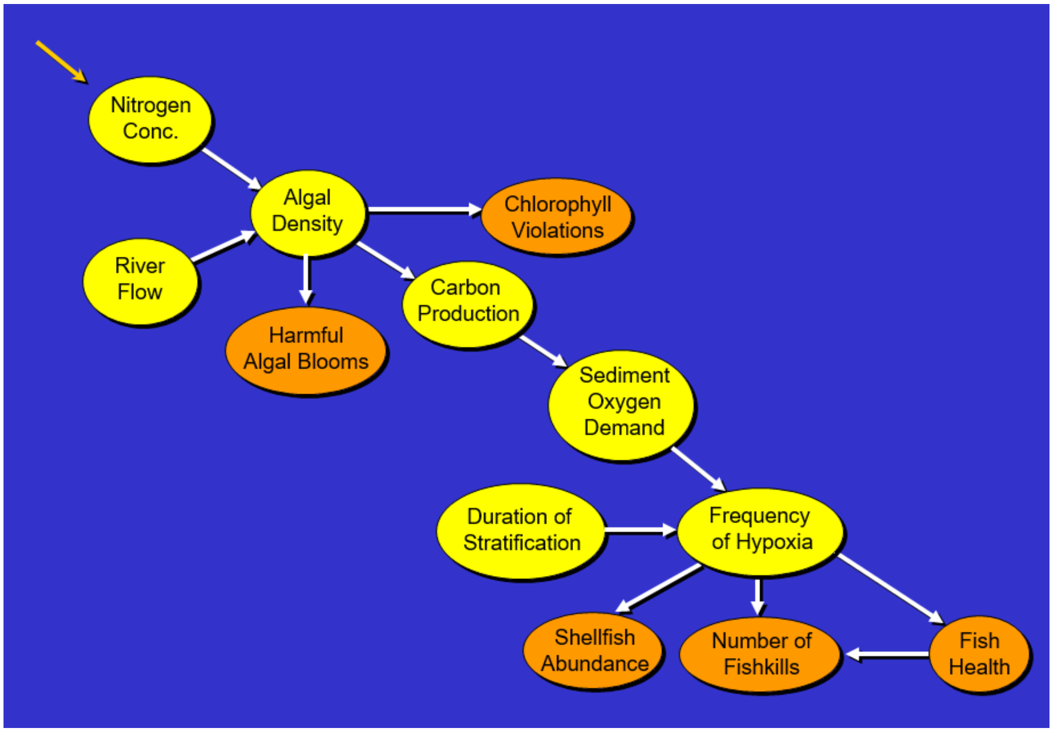
The conceptual model should illustrate linkages among biostimulatory elements, and it should add bacteria/disease and shifts in competitive hierarchies as mechanisms for change in biological condition along nutrient gradients. Adding expectations for science to link human activities to biostimulatory drivers will be needed to solve biostimulatory problems. Adding linkages between impacts on ecosystems services and designated uses and indicators of human well-being, would correspond with new emphases by the USEPA, new data being generated by social-natural science partnerships, and ultimately critical for justifying sustainable management strategies – versus sole justification on legislated objectives derived from rules and regulations in the Clean Water Act.

Differentiating between benthic algal biomass and sestonic (water column) biomass is an important and needed distinction. Dissolved organic carbon (DOC) plays an important role in light variability in many streams. DOC concentration in streams and rivers is commonly well-linked to the extent of wetlands in a catchment. Continuous dissolved oxygen (DO) monitoring is a useful tool in streams to estimate primary production and ecosystem respiration. To get the most out of these measurements, reaeration coefficients should be used to determine gas flux between the water column and the atmosphere. There are both modeling and geomorphic tools to help estimate reaeration coefficients at a site.

Causal Analysis

Drawing from the literature review in this Report, a sequence of causal models for specific beneficial uses would be useful as graphical indicators of key linkages. These causal models, accompanied by explanatory text, would be intended to describe to stakeholders how scientists moved from an original complex conceptual model to a simple diagram that corresponds to a numeric criterion protective of a designated use. This process would assist in an explanation concerning why certain causal relationships in the big model were excluded in the final simple numeric model. The two figures below illustrate moving from a comprehensive graphical conceptual model to a simpler model that was used for assessing a nitrogen TMDL for the Neuse River Estuary (North Carolina).





At various points in the Report, causal assessment is discussed. In addition, stakeholder concerns include a request for causal analysis. The report provides an excellent discussion of the causal variables and relationships involved in eutrophication. This includes comprehensive background for the development of casual graphical models, which can then be evaluated with available data. In the past 25 years, early work in path analysis (Wright 1921) has been substantially improved to provide a causal interpretation for probabilistic modeling approaches (Pearl and Mackenzie 2018). Structural equation modeling (Kline 2015), Bayesian networks (Cowell et al. 1999), and counterfactuals (Morgan and Winship 2015) are among the methods (and references). The USEPA (2017) has developed an excellent program, CADDIS (Causal Analysis/Diagnosis Decision Information System) to guide causal modeling. This report would be strengthened with a quantitative causal analysis.

Indicators

In the US, eutrophication-related water quality standards and criteria/indicators widely exist. For example, most states have dissolved oxygen criteria intended to be protective of designated uses that are impacted by oxygen depletion, resulting from nutrient-enhanced algal production. In addition, many states have adopted nutrient or chlorophyll criteria. State water quality standards are established in accordance with Section 303(c) of the Clean Water Act and must include a designated-use statement and one or more water quality criteria (indicators, as used in TR 871). Indicators should serve as measurable surrogates for the narrative designated use; in other words, measurement of the indicators provides an indication of attainment of the designated use. Additionally, violation of the indicator level is a basis for regulatory enforcement, which typically requires establishment of a TMDL. Thus, good indicators should be easily measurable and good predictors of the attainment of designated use.

Designated uses evolved from the goals of the Clean Water Act. As part of the water quality standard for a regulated water body, they are typically expressed as brief narrative statements listing the uses that the waterbody is intended to support, such as drinking water, contact recreation, and aquatic life. Water quality criteria/indicators should then be chosen as measurable quantities that essentially serve as predictors of attainment of the designated use.

This basis for indicator selection – that they must be good predictors of the attainment of designated uses, is the motivation for the analysis described in Reckhow (2005), where the process of numeric water quality criteria/indicator selection is based on the effectiveness of an indicator as a predictor of designated use. From a prescriptive standpoint, a good indicator should be an easily measurable surrogate for the narrative designated use and should serve as an accurate predictor of attainment. To illustrate how this could be accomplished, Reckhow et al. (2005) used structural equation modeling to quantify the relationship between designated use and possible water quality indicators. This identified the best predictor of designated use, which would become a water quality indicator.

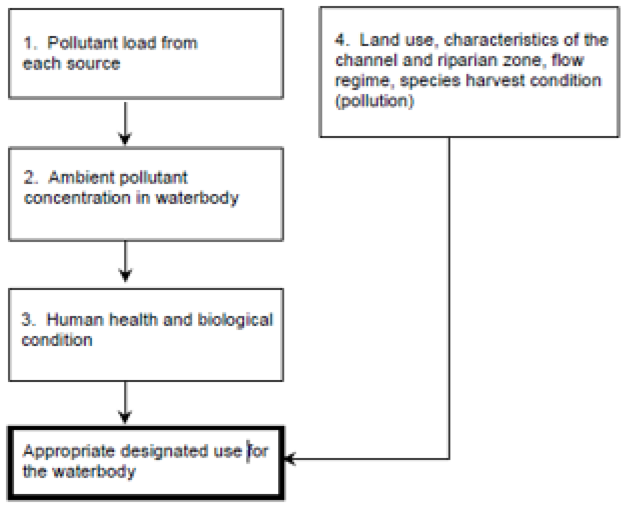
The current U.S. EPA approach for nutrient criteria development is a mix of science and expert judgment. In 1998, the President’s Clean Water Action Plan directed the EPA to develop a national strategy for establishing nutrient criteria. The resultant multiyear study produced a set of documents and recommended criteria based on ecoregions and waterbody type. Specific modeling methodologies were proposed to aid in the extrapolation of reference conditions and to assist managers in setting loading allowances once nutrient criteria have been established. In addition, enforcement levels for the proposed criteria were based on “reference waterbodies” perceived to reflect essentially unimpacted or minimally-impacted conditions. One key problem with a reference condition approach as advocated by EPA is that it does not need stakeholder judgment concerning desirable (beneficial) water quality uses as required in a water quality standard.

In principle, standard setting should be viewed from the perspective of decision making under uncertainty, involving interplay between science and public opinion. The determination of designated uses reflects public values, both in the statements in the Clean Water Act and in the waterbody-specific statement of designated use. The selection of the criterion is a choice based largely on science. Selection of a good criterion, one that is easily and reliably measured and is a good indicator of designated use, is largely a scientific determination.

However, determination of the *level* of the criterion associated with the attainment-nonattainment transition ideally requires the integration of science and values. Natural variability and scientific uncertainty in the relationship between the criterion and the designated use imply that selection of a criterion level with 100% assurance of use attainment is generally unrealistic. Accordingly, scientific uncertainty and attitude toward risk of nonattainment should be part of the criterion level decision. Therefore, the decision on a criterion level might be addressed by answering the following question - acknowledging that 100% attainment is impractical for most criteria, what probability (or, perhaps, what percentage of space-time) of nonattainment is acceptable? EPA guidance addresses this question by suggesting that (an arbitrarily-chosen) 10% of samples may violate a criterion before a waterbody is listed as not fully supporting the designated use. Reckhow et al. (2005) proposed using risk analysis of indicator level nonattainment to answer this question.

In summary, regardless of the methods used to select indicators and indicator attainment levels, there are distinct roles for science and for policy analysis. TR 871 should be clear about this distinction.

An additional consideration that was discussed in NRC (2001) is where in the causal chain from pollutant source to designated use should a water quality criterion be placed? Referring to the figure below (taken from NRC 2001), the NRC panel recommended that the preferred criterion “location” should be as close as possible to the designated use, which is the “human health and biological condition” box. If instead, the pollutant loading or waterbody pollutant concentration box was selected, there would be additional hidden uncertainty in the causal chain (in the figure) to designated use. This hidden uncertainty can be reduced by selection of a criterion as close as possible to designated use.



If nutrients become the indicators of eutrophication, TP and TN should be the preferred nutrient forms. DIN and biological available P are good indicators of short-term changes in eutrophication. However, over the longer term, total N and total P are the best nutrient forms for practical use in predictive models.

References

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