METHODS TO MEASURE PHOSPHORUS AND MAKE FUTURE PROJECTIONS
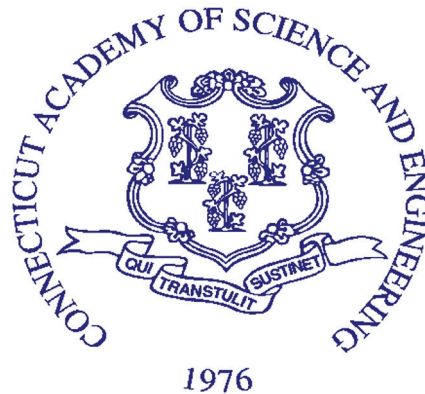
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A REPORT BY

THE CONNECTICUT ACADEMY OF SCIENCE AND ENGINEERING

FOR

THE CONNECTICUT DEPARTMENT OF ENERGY AND ENVIRONMENTAL PROTECTION

Methods to Measure Phosphorus and Make Future Projections

A Report By

The Connecticut Academy of Science and Engineering

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LIST OF ACRONYMS

AFDM	Ash-Free Dry Mass
ATP	Adenosine Triphosphate
BCG	Biological Condition Gradient
BMP	Best Management Practice
CALM	Consolidated Assessment and Listing Methodology
CGS	Connecticut General Statutes
Chl-a	Chlorophyll-a
CO_2	Carbon Dioxide
CT WQS	Connecticut Water Quality Standards
DEEP	Connecticut Department of Energy and Environmental Protection
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
EF	Enrichment Factor
EPA	US Environmental Protection Agency
CT IWQR	Connecticut Integrated Water Quality Report
MMI	Multi-Metric Index
N	Nitrogen
NPDES	National Pollutant Discharge Elimination System
O_2	Oxygen
pH	A measure of acidity or alkalinity of a substance
QAPP	Quality Assurance Project Plan
TDI	Trophic Diatom Index
TITAN	Threshold Indicator Taxa Analysis
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
WQS	Water Quality Standards
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

BACKGROUND

Public Act No. 12-155, An Act Concerning Phosphorous Reduction in State Waters, sets forth a process for making recommendations regarding a statewide strategy to reduce phosphorus loading in inland, non-tidal waters to comply with US Environmental Protection Agency (EPA) standards.

The Connecticut Department of Energy and Environmental Protection (DEEP) established working groups and a coordinating committee to address the issues mandated by this legislation. Three working groups were charged with formulating recommendations for the purpose of policy development: Working Group #1: Statewide Response to Phosphorus Non-point Pollution; Working Group #2: Methods to Measure Phosphorus and Make Future Projections; and Working Group #3: Municipal Options for Coming into Compliance with Water Quality Standards. The overarching Coordinating Committee comprises the co-chairs of the three working groups with oversight by a DEEP deputy commissioner and a representative from a Connecticut town. The Coordinating Committee was tasked with guiding the project, with responsibility for overall direction and timing, and addressing cross-cutting issues.

At the request of DEEP, the Connecticut Academy of Science and Engineering (CASE) was engaged to conduct a study of specified tasks regarding the science involved and to make recommendations for the development of methods to measure phosphorus and make future projections for the consideration of Working Group #2.

OBJECTIVE

The overall objective of this study was to meet the legislative intent of Public Act 12-155, which was to conduct an evaluation and develop recommendations to determine the scientific methods with which to measure the impacts of phosphorus pollution in inland, non-tidal waters. At the start of the study process, the CASE Research Team and Study Committee, in consultation with DEEP and Working Group #2, considered which inland waters should be included in the study. Most states, including Connecticut, already have numeric standards for nutrients for lakes and reservoirs, and therefore it was decided that these standards are sufficient and do not need to be revisited.

TASKS

This study focused on conducting research on the following tasks for the purpose of developing recommendations, for consideration of Working Group #2, and the overall project, for setting phosphorus goals:

- Task 1: How does phosphorus impact water quality in general and what factors are important in Connecticut?

- Task 2: What is Connecticut's current approach to addressing phosphorus to comply with water quality standards?

- Task 3: How can phosphorus impacts be measured in non-tidal waters such that relevant contributing stressors are considered to comply with water quality standards?

- Task 4: What methodologies are appropriate for use in Connecticut to measure phosphorus impacts on water quality and aquatic life and other designated uses?

Study research included a comprehensive literature review and interviews, as well as guest speaker presentations to the CASE Study Committee. Additionally, members of Working Group #2 were invited to attend and participate in CASE Study Committee meetings and were provided with an opportunity to comment on the draft study report. This report was provided to Working Group #2 for the state's consideration in establishing site-specific phosphorus goals for Connecticut's streams and rivers.

BRIEF STATEMENT OF PRIMARY CONCLUSION

Setting appropriate standards for limiting the amount of phosphorus discharged into a stream or river is complicated because numerous other factors (including, but not limited to, riparian areas, temperature, water flow, topography, vegetation, sediments, and soils) will likely affect the degree of impact/impairment of the phosphorus on the stream or river. The variation between the amount of phosphorus entering the watercourse and the degree of impairment, coupled with the large amount of variation in stream phosphorus concentration, makes setting a single numerical phosphorus standard inappropriate. Utilization of the "stressor-response model" that links a stressor such as phosphorus pollution to the ecological state of a stream reach (segment) can address this complexity. The ecological state or health of the watercourse/body can be linked to the specific "designated uses" incorporated by and upon which the Connecticut Water Quality Standards are based.

The stressor-response model involves using response parameters (i.e., dissolved oxygen, benthic algae, water clarity, pH, diatoms, invertebrates, toxic species, fish) to establish phosphorus impairment. This approach entails measuring a single or multiple response parameters and uses statistical approaches to link the parameter to a desired stream state in order to set a standard. According to the EPA, this method consists of building a conceptual model, collecting data through synthesis and monitoring, and creating the stressor-response relationship. The statistical approach used to set response parameters varies; the EPA has recently documented an approach that allows for the direct utilization of response parameters as criteria.

Diatoms and dissolved oxygen are very good measures of biotic integrity. Because of their strong correlation to phosphorus impairment, ability to integrate changes over time and space, and cost effectiveness, it is recommended that these two parameters be used by Connecticut as the "response parameters" in developing numeric criteria (or future response parameter standards) for phosphorus. Connecticut has performed an initial analysis of the use of diatoms for determining a concentration-based nutrient criteria in streams, including

statistical approaches to evaluate the relationship between diatom species and phosphorus concentrations. DEEP should continue to utilize this approach and their Interim Phosphorus Reduction Strategy for Connecticut Freshwater Non-Tidal Waste-Receiving Rivers and Streams (Interim Strategy) (see Appendix B) derived therefrom while continuing to collect data to implement this report's recommendations.

The strength of this approach requires a significant amount of data. The state should continue sampling the diatom community and add diurnal dissolved oxygen measurements. These measurements are deemed complementary. The goal of the state should be to move from the Interim Strategy to a decision framework that includes phosphorus concentrations and these response parameters. As this is a rapidly evolving area of scientific inquiry, with statistical methods used to derive numeric criteria improving over time and with new data as well as scientific and methodological improvements, DEEP should re-evaluate its approach every 3–5 years in a manner that is transparent to all stakeholders.

RECOMMENDATIONS

The following are recommendations for the state's consideration:

1. Continue sampling diatom community assemblage, but add diurnal dissolved oxygen. As presented above, these response parameters are complementary and new dissolved oxygen sensors are highly accurate and relatively cost effective. The state should consider partnering with other states for diatom data from other larger streams and rivers and concentrating initial dissolved oxygen data collection on larger streams and rivers.

2. Add sites to the state's sampling regime, allowing for further refining criteria via stratification/classification. A large number of sites are needed for stratification and classification of landscape variables such as ecological health (e.g., Biological Condition Gradient (BCG) tiers), geology, stream size or residence time that might allow for better protection of streams and rivers in the future.

3. Consider using diatom data and newly collected dissolved oxygen data to develop response parameter standards in addition to numeric criteria standards to allow for a decision framework approach (See Table 5-3).

4. Develop a stratification/classification system. In particular, the DEEP Interim Strategy (Appendix B) was created for freshwater, non-tidal, waste-receiving rivers and streams, but the diatom analysis was done mostly using data from small streams (Smucker et al., 2013b). Future efforts need to focus on collecting enough data to determine if stratification based on river size (i.e., wadeable/nonwadeable) is needed, as there are initial indications that river size influences the diatom community (Charles et al., 2010). One potential method is to stratify based on stream order or systems that are seston (suspended matter) or benthic dominated. The state also needs to stratify and set standards that will protect the degradation of healthy streams. This should be done by further stratification under the already established BCG tier system. That is, standards should be considered for each BCG tier. Possible ways to do this may be stratifying by land use, ecological health (e.g, macroinvertebrate indices – Multi-Metric Index [MMI]), or the already established enrichment factor.

5. Pursue and collect a set of secondary measurements that will further help isolate phosphorus as the cause of impact and potentially help with the stratification process. These measurements are discussed in greater detail in the Recommendation Details section (Section 5.3.2) of the report.

6. Statistical analysis of data to relate response parameters to phosphorus concentrations should be conducted on a rolling basis and reported to the general public. As additional data are collected, the type of statistical analysis applicable and the power of the statistical test chosen may change. The scientific literature is also constantly critiquing and improving statistical methods used for community analysis (e.g., Cuffney and Qian, 2013; Juggins et al., 2013; Baker and King, 2013), and this will allow for the adoption of the most appropriate methods.

7. Consider collaborating with neighboring states that use diatoms and dissolved oxygen. Currently each state pursues its own analysis, but multi-state analysis (e.g., EPA Ecoregions) would increase the power of statistical analysis and might provide further insights about the linkage between the diatom community composition and dissolved oxygen or nutrients. States might find it necessary to standardize methods to enable data sharing in the future.

8. For impaired watersheds, continue and accelerate the process of creating stream management plans similar to those in the CT IWQR, incorporating these plans into a GIS, and perform response parameter measurements more frequently. Stream management plans provide a comprehensive overview of stream characteristics and recommended management strategies. Given the findings in Connecticut and New Jersey that phosphorus impairment is most strongly linked to urban and agricultural land cover and that riparian buffers can modify phosphorus impairment (Charles et al., 2010;Smucker et al., 2013b), management plans would need to focus heavily on the potential impairment from urban and agricultural practices and detail the status of riparian buffers. Having a more detailed understanding of stream reaches will increase the portfolio of options for remediation. The detailed mapping of stream characteristics (e.g., physical characteristics, riparian vegetation) for stream management plans will also benefit efforts to stratify streams when creating criteria, although this will require documenting the plans in GIS and creating variables from the plans for use in statistical analysis.

9. Begin to collect data on phosphorus import into watersheds and consider collecting additional economic/recreational use data. These are described in more detail in the "Recommendation Details" section (Section 5.3.2) of the report.

Additional details regarding these recommendations are provided in Section 5.3.2, including Secondary Measurements (Section 5.3.2.1), Economic Approaches (Section 5.3.2.2), and The Import of Phosphorus to Watersheds (Section 5.3.2.3).

Implementation Strategy

As mentioned, the CASE Study Committee deems that the DEEP Interim Strategy (Appendix B) was justified. Although there were some questions with the TITAN model (Cuffney and Qian, 2013), these questions have been addressed in the scientific literature (Baker and King, 2013). Furthermore, when performing the statistical analysis for Connecticut, Smucker et al. (2013) used approaches other than TITAN to evaluate changes in phosphorus concentration

and diatom communities. The approach taken by the state aligns with the guidance provided by the EPA. Thus the Interim Strategy was a reasonable and justified approach for setting numeric criteria. That said, this is still a rapidly evolving area of scientific inquiry. The statistical methods used to derive numeric criteria will continue to improve with time and new data. Furthermore, the response parameters used to set criteria will also change with scientific and methodological advancements. Finally, response variables can also now be used directly in decision making which overcomes some of the problems associated with the standard set using statistical methods.

The proposed set of recommendations should be pursued by the state over the next 3-5 years with the following considerations:

- Utilize new oxygen optodes, which have made the accurate measurement of dissolved oxygen during multi-day deployments possible at a relatively low cost. The diurnal (24-hour period) change in dissolved oxygen offers enough complementary information for it to be incorporated into the current DEEP sampling scheme. A potential strategy would be to place the probes at each site a few days prior to visiting for the involved sampling of variables already measured by the state.

- In addition to including dissolved oxygen in the current rotation of sites, DEEP should consider more frequent measurements of response indicators at phosphorus-impacted sites to ascertain when an acceptable level of phosphorus abatement has been achieved. This will be particularly pertinent if the response variables are incorporated into a decision framework.

- DEEP should strive to increase the number of sites within their database by increasing the number of sites visited, or partnering with neighboring states that already have an active program with similar measurements.

- Similar to current practices, a greater percentage of the measurements should be performed in the summer when impacts are greatest. Shoulder season measurements, however, still provide data needed to ascertain range of conditions.

- During the next five years, progress on recommendations #5 and #8 can be pursued.

- In 3-5 years, DEEP should re-evaluate the Interim Strategy depending on the status of the data sets. A new statistical analysis of the data should be pursued with the new, larger data set. This new analysis would be able to determine if sites need to be classified based on landscape variables such as land use, geology or stream size. At this point, dissolved oxygen data could be incorporated and the larger data set could be used to create a decision framework (Table 5-3). It is reasonable to expect this re-evaluation to occur every 3 to 5 years.

- Finally, during this period, the state should consider mechanisms to facilitate the data collection necessary for recommendation #9.