Division of Surface Water
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Trophic Index Criterion – Rationale and Scoring

Introduction

Pollution associated with municipal and industrial point sources has largely been controlled, often with dramatic results, under the Federal Water Pollution Control Amendments of 1972, commonly known as the Clean Water Act (CWA). For example, prior to 1985, nearly 70 percent of the state's waters were too polluted to support fishing and recreation, and 20 percent were so polluted as to be functionally dead. Here, organic enrichment - essentially raw sewage - and pollutants like metals from industrial sources were the most proximate causes of impairment. By 2006, fewer than 35 percent of the state's waters were considered impaired; however, of those, sediment, habitat destruction, flow alteration and nutrients were the four leading causes of impairment (Ohio EPA 2006). The common thread running through those remaining causes of impairment is that they are all principally derived from diffuse sources related to land use practices; few of which are regulated in an environmentally meaningful way under the CWA.

That is not to say that efforts to address pollution from diffuse sources have been wanting or unfruitful. Sediment pollution from agricultural sources has been greatly reduced through broadly prescriptive, incentives-based programs (Richards et al. 2009). More recently, pollutants associated with urban storm water have been addressed under the umbrella of the NPDES system (*i.e.*, MS4 permits). And to address the issue of nutrient pollution, U.S. EPA (2001a) published suggested nutrient criteria using a reference range approach, and authorized states to develop regionally specific, scientifically defensible criteria (U.S. EPA 2001b).

Most of the existing numeric water quality criteria are built on a sound technical basis owing to well-defined, dose-response relationships between individual pollutants and aquatic organisms. These relationships are so well-defined as to allow confident predictions of environmental outcomes; hence, our administrative and regulatory infrastructure is largely predicated on tabular or algorithmic numeric criteria. However, unlike toxicants and putrescible materials, the effects of nutrient pollution on fish or macroinvertebrates are indirect, and therefore not predictable through simple dose-response curves, or highly deterministic models.

That said, relationships between nutrients and stream eutrophication have been well documented (Dodds and others 1997, Smith and others 1999, Biggs 2000), and a sufficient number of field studies exist tracing the links between nutrients and algae, macroinvertebrates or fish, that a reasonably complete picture exists of how biological condition changes over a nutrient gradient. The upshot of all this is that there is a dose-response relationship of sorts, though that response cannot be interpreted in the traditional sense because of the indirect pathways over which it is expressed, and because of the confounding factors that tend to mute, obscure, or exacerbate the responses. The dose-response relationship, such as it is, can be exploited, however, because there is a reasonably predictable and consistent response between increasing nutrient concentrations and periphyton (reviewed by Hillebrand 2002), and between periphyton and dissolved oxygen concentrations (Morgan et al. 2006, Huggins and Anderson 2005, Heiskary et al. 2010, Miltner 2010). The Ohio EPA nutrient criteria study (Miltner 2010) was predicated on tracing the steps from nutrients to periphyton (as given by chlorophyll-a), from periphyton to dissolved oxygen, and from dissolved oxygen to macroinvertebrates and fish, with the goal of identifying benchmarks or thresholds at each step that would help define where a given water body is positioned along a continuum of enrichment.

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The Trophic Index Criterion

The Trophic Index Criterion (TIC) is a composite index that brings together the measures of nutrients, periphyton, dissolved oxygen, and biological assemblages by awarding points to successive ranges of each indicator, where the ranges are defined by benchmarks identified in the nutrient study. Hence, the TIC provides a structured method of aggregating data collected on Ohio's streams and rivers into a nominal scale that is essentially a translator for the condition of a water body relative to nutrient enrichment. As such, it can be applied independently to dictate the imposition of appropriate nutrient management programs including NPDES permit limits, waste-load allocations, and abatement strategies for landscape pollution.

Table 1. The Trophic Index Criterion (as currently proposed in draft form).

Biological Assemblages	**Dissolved Oxygen**	**Benthic Algae**	**Nutrients**[†]	**Trophic Index Criterion**
Meet applicable biocriteria (12)	Normal variation‡ <6 mg/l (12)	<107 mg/m^2 (8)	Concentrations typical of low disturbance systems (6)	**Acceptable** **(38-22)**
	Modest swings >6 mg/ (6)	107-183 mg/m^2 (4)	Concentrations typical of healthy streams in working landscapes (3)	
Within the range of non-significant departure (6)	Wide swings >7 mg/l (1)	Enriched 183-320 mg/m^2 (1)	Concentrations observed with high-intensity land use and WWTP loadings (1)	**Threatened** **21-14**
Fail biological criteria (0)	Extreme swings >9 mg/l or swings >7 mg/l and minimum D.O. <WQS (0)	Thick to nuisance levels >320 mg/m^2 (0)	Concentrations typical of highly disturbed systems; effluent domination; >50% chance of biological impairment (0)	**Impaired** **13-0**

[†]See Table 2 for nutrient concentration ranges

‡Measured as the difference between the daytime maximum concentration and the morning minimum

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Table 2. Trophic Index Criterion scoring for the nutrient component.

Total Phosphorus (mg/l)	Dissolved Inorganic Nitrogen (mg/l)				
	≤0.44	0.44-1.10	1.10-3.60	3.60-6.70	≥6.70
≤0.04	6	3	3	1	0
0.04-0.08	3	3	3	1	0
0.08-0.13	3	3	1	1	0
0.13-0.40	1	1	1	0	0
≥0.40	0	0	0	0	0

A Note on TIC Categorical Levels

Boundaries set for the TIC (i.e., Acceptable, Threatened and Impaired) are assigned using the rationale that the biological indicators can be used to set the ceiling and floor of the threatened range. For example, if full biological attainment (i.e., a score of 12) occurs where two or more of the enrichment indicators suggest over-enrichment (i.e., a component score of 1), then the site will usually be classed as threatened. Also note that marginal biological performance with one of the enrichment measures indicating over-enrichment would class the site as impaired. This approach recognizes that the biological indicators can be stressed by nutrient enrichment before showing statutory impairment as defined by the biocriteria. Conversely, it is worth noting that full biological attainment accompanied by normal variation in daily dissolved oxygen concentrations yields an acceptable TIC rating regardless of what the other enrichment indicators show. This construct recognizes and dampens the reality of environmental variability inherent in chemical measures. It also allows for the determination of reasonable potential, given that dissolved oxygen concentrations can be reliably modeled (Cox 2003).

Implementation in NPDES Permits

Demonstration of impairment or reasonable potential to a receiving water body will invoke permit limits for nutrients, typically phosphorus. The default limits are 1.0 mg/l TP and 10 mg/l DIN. These limits are anticipated to be iterative through two successive 5 year permit cycles to allow for pursuing other options including habitat restoration and water quality trading. If, after two cycles, the water body remains impaired due to nutrient over-enrichment, nutrient target values based on ranges defined by empirical relationships will form the basis of discharge limits. The agency is evaluating if any current rules would need to be revised to implement this approach. Values to be used in the derivation of water quality based effluent limits are as follows:

Aquatic Life Use and QHEI	**TP (mg/l)**	**DIN (mg/l)**
Exceptional warmwater habitat and all QHEI scores	0.060	3.0
Warmwater habitat and QHEI score = 12 to 64	0.13	3.0
All other aquatic life uses and QHEI scores	0.30	3.0

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