Response to Charge Question

Nutrient Issues

Summary Report
of the NJDEP Science Advisory Board

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Report
of the
Nutrient Work Group
of the
New Jersey Department of Environmental Protection
Science Advisory Board

SAB Approval

September 19, 2013

Executive Summary

Nutrients are essential for all life. However, when present in excessive amounts in aquatic ecosystems, nutrients can lead to a condition known as accelerated eutrophication, i.e., the rapid deterioration of water quality due to abundant plant growth and decay with subsequent impairment of uses. The classic fish kill due to depletion of oxygen in a lake is a common manifestation of nutrient impairment.

The United States Environmental Protection Agency (USEPA) has identified nutrients as one of the leading causes of water quality impairment in the nation's waters and is encouraging states to develop specific criteria based on regional and site differences. The New Jersey Department of Environmental Protection (the Department) has had, for many years, numeric and narrative water quality criteria for nutrients. During approximately the last ten years, the Department has been conducting original research to identify improved numeric nutrient criteria. The focus of the research has been on nontidal streams where impacts from the nutrients phosphorus and nitrogen are most apparent.

With the assistance of the Patrick Center for Environmental Research at the Philadelphia Academy of Natural Sciences, the Department has considered alternative approaches to its traditional nutrient criteria. That research and the potential for application of it to the development of new nutrient criteria have been presented to the Science Advisory Board (SAB) for comment. A Nutrient Work Group consisting of members from the SAB and two of its Standing Committees was formed to consider the matter along with members of the Department. This report presents the Work Group's recommendations and findings in regard to the Charge questions posed by the Department.

The matter is indeed complex and is not without a diversity of opinions. The Nutrient Work Group congratulates the Department for its initiative and dedicated effort. That effort has considered the application of a Trophic Diatom Index (TDI) and a diatom based Biological Condition Gradient (BCG) approach to identify nutrient impairment in nontidal, fresh water, wadeable streams. The Department divided the state of New Jersey into four separate ecoregions for consideration of these concepts.

A simple executive summary can not do justice to the complexity of the matter or the Department's efforts, and it is highly recommended that the reader review this report in its entirety which of itself is still only a summary of the compendium that could be written on this matter. The principal findings of the Nutrient Work Group are as follows:

1. While it is possible to define relationships between a diatom index and nutrient level, as an independent method, the TDI approach is unable to define levels of nutrient impairment, and therefore has limited utility for defining numeric nutrient criteria.

2. The BCG is a conceptual model that provides a reasonable method to describe changes in biological communities along a disturbance gradient. However, the extension of the BCG concept to the definition of numeric nutrient criteria also has limitations. An unintended consequence of such an approach is that unimpaired waters with high nutrient levels may obtain a poor BCG score.

3. The Department's work shows that there may be an empirical relationship between BCG score and total phosphorus concentration in the Ridge and Valley / Northern Highlands and the Northern Piedmont ecoregions. No such relationship is observed in the Inner or Outer Coastal ecoregions. Low aquatic system pH exhibits a dominating effect on diatom community structure and the availability of phosphorus for plant growth.

4. For total nitrogen, no relationship with BCG is observed in any of the four ecoregions.

5. The relationship between a diatom-based BCG score and phosphorus in some ecoregions may be useful in determining a threshold that triggers disturbance or change. However, a higher (i.e., poorer) diatom-based BCG score does not always mean a higher degree of nutrient impairment. Use of BCG scores for assessment of impacts from total nitrogen in any ecoregion is not supported.

In an additional Charge question, the Department has asked the SAB to comment on the current program for monitoring of diurnally varying dissolved oxygen (a matter of consequence to nutrient impairment). The principal findings of the Nutrient Work Group on this question are as follows:

1. Diurnal monitoring three days after a "non-scouring event" can be used to indicate possible nutrient impairment, but such monitoring should be postponed until 14 days after a "scouring event". It is recommended that a "non-scouring event" be defined as no more than ½ inch of rain in any 24 hour period. It is further recommended that the Department conduct additional research to develop a definition of a "scouring event".

2. There is no diurnal dissolved oxygen swing that would represent, in and of itself, water quality impairment for New Jersey streams. The Department may wish to explore whether there is a basis for defining a numeric diurnal swing in dissolved oxygen that indicates impairment in New Jersey streams.

These findings support a weight of the evidence approach in assessing nutrient impairment for aquatic systems. No single metric can conclusively define whether a waterbody is nutrient impaired, nor can any single metric be used to define the level of nutrient reduction necessary to eliminate impairment.

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Nomenclature

BCG = Biological Condition Gradient
Department = New Jersey Department of Environmental Protection
DO = Dissolved Oxygen
N = Nitrogen
N.J.A.C. = New Jersey Administrative Code
NJDEP = New Jersey Department of Environmental Protection
NJPDES = New Jersey Pollutant Discharge Elimination System
P = Phosphorus
SAB = Science Advisory Board
SWQS = Surface Water Quality Standards
TDI = Trophic Diatom Index
TMDL = Total Maximum Daily Load
TN = Total Nitrogen
TP = Total Phosphorus
USEPA = United States Environmental Protection Agency
WLA = Wasteload Allocation

I. Background

Nutrients are essential for all life. Starting at the base of the food web, nutrients such as phosphorus (P) and nitrogen (N) are essential for primary production. Nutrients are cycled in ecosystems. They are present in the abiotic environment (dissolved inorganic N or P in water), become incorporated into plants during photosynthesis and are converted to organic forms such as nucleic acids and proteins. They are later transferred to the animals that consume the plants. Algae are important primary producers in a stream ecosystem, turning nutrients into food for aquatic invertebrates and fish. When animals excrete wastes, and plants and animals die, the nutrients are returned back to the environment during the process of decay, as bacteria and fungi convert the organic forms of the nutrients back into inorganic forms.

Nutrient levels affect the amount of animal and plant biomass that can be supported by an aquatic ecosystem; as nutrients increase, more and more plant and animal biomass can be supported. While this appears to be a good thing, there is a point at which nutrients become excessive, leading to eutrophication. Eutrophication is characterized by excessive algal and plant growth and decay, negatively impacting water quality and eventually impairing aquatic life and human recreational uses such as swimming and fishing. Phosphorus, an essential nutrient, is usually present in freshwaters in lower concentrations than nitrogen, relative to algal kinetic demands; as a result, phosphorus is often assumed to be the limiting nutrient for plant growth in freshwater systems. In reality, both phosphorus and nitrogen are often present in concentrations that exceed algal kinetic demands. The algae nutrient - growth rate relationship is described by a saturation based function, i.e., growth rates increase with increasing nutrient concentration up to a threshold concentration above which increasing nutrient concentration has virtually no impact on growth rate.

Under the right conditions, the addition of phosphorus to a freshwater ecosystem will increase plant growth. When the plants die, they are decomposed by bacteria. The decomposition process consumes oxygen, and may reduce dissolved oxygen in deeper waters to levels so low that there is not sufficient oxygen to support fish and other organisms. While mobile forms of aquatic life may be able to leave areas with depressed oxygen levels, other species such as sedentary shellfish cannot and may die (and decay, thus exacerbating the low oxygen problems). Eutrophication restricts water use for fisheries, recreation, industry, and drinking, due to the growth of undesirable algae and aquatic weeds and depletion of oxygen. Eutrophic drinking water supplies may experience periodic blooms of harmful cyanobacteria, which can produce taste and odor problems. Furthermore, algal blooms can cause swings in pH due to net consumption of CO_2 by photosynthesis during the day and production by respiration at night.

The United States Environmental Protection Agency (USEPA) has identified nutrients as one of the leading causes of water quality impairment in the nation's waters and is encouraging states to develop specific criteria based on regional and site differences. In NJ, considerable research over the last 10 years has demonstrated that some sites with total phosphorus greater than 0.1 mg/l (NJDEP's regulatory threshold for nontidal streams where phosphorus has rendered the waterway unsuitable for its existing or designated uses) seem quite healthy and unimpaired, while other sites with phosphorus levels below 0.1 mg/l appear impaired. Thus, a single numeric criterion applied broadly and independently is not appropriate for all locations, i.e., one size does not fit all. For this reason, NJDEP considers a number of indicators other than phosphorus concentration when assessing nutrient impacts. Examining biota for signs of stress may serve as one indicator of nutrient impact. One of the USEPA recommended approaches for developing nutrient criteria is based on stressor-response relationships using biological indicators. Nutrient concentrations, especially phosphorus, can fluctuate in developed watersheds because of increased non-point source pollution and stream bank erosion following storms. Several water samples may not effectively represent the cumulative supply of nutrients over time because of the variation in concentrations. In contrast, biological communities develop and are exposed to nutrients over a period of weeks or months. The cumulative supply of nutrients influences which species survive and may determine the overall community structure. Diatom communities have been studied and used in many places as indicators of nutrient levels.

A. New Jersey's Nutrient Criteria

The New Jersey Department of Environmental Protection (Department) has been considering whether to make changes to its nutrient criteria in the New Jersey Surface Water Quality Standards (SWQS) at N.J.A.C. 7:9B. The term "Nutrient" is defined in the SWQS at N.J.A.C. 7:9B-1.4 as follows:

> *"Nutrient" means a chemical element or compound, such as nitrogen or phosphorus, which is essential to and promotes the growth and development of organisms.*

For all practical purposes, the Department's deliberations regarding nutrient criteria are focused on controlling the levels of nitrogen and phosphorus in surface waters so as to avoid the growth of plants, in variety or amount, that interfere with the existing or designated uses of those surface waters.

The present nutrient criteria in the SWQS are both narrative and numeric as follows:

7:9B-1.5(g) Nutrient policies are as follows:

1. *These policies apply to all waters of the State.*

2. *The Department may develop watershed-specific translators or site-specific criteria through a Total Maximum Daily Load (TMDL). Site specific criteria shall be incorporated at N.J.A.C. 7:9B-1.14(g).*

3. *The Department shall establish water quality-based effluent limits for nutrients, in addition to or more stringent than the effluent standard in N.J.A.C. 7:14A-12.7, as*

necessary to meet a wasteload allocation established through a TMDL, or to meet the criteria at N.J.A.C. 7:9B-1.14(d)4.

4. *Activities resulting in the nonpoint discharge of nutrients shall implement the best management practices determined by the Department to be necessary to protect the existing or designated uses.*

7:9B-1.14(d)4. Nutrients

i. *All Classifications: Except as due to natural conditions, nutrients shall not be allowed in concentrations that render the waters unsuitable for the existing or designated uses due to objectionable algal densities, nuisance aquatic vegetation, diurnal fluctuations in dissolved oxygen or pH indicative of excessive photosynthetic activity, detrimental changes to the composition of aquatic ecosystems, or other indicators of use impairment caused by nutrients.*

ii. *Phosphorus (mg/L)*

(1) *FW2 Non Tidal Streams: Concentrations of total P shall not exceed 0.1 in any stream, unless watershed-specific translators are established pursuant to N.J.A.C. 7:9B-1.5(g)2 or if the Department determines that concentrations do not render the waters unsuitable in accordance with (d)4i. above.*

(2) *FW2 Lakes: Concentrations of total P shall not exceed 0.05 in any lake, pond or reservoir, or in a tributary at the point where it enters such bodies of water, unless watershed-specific translators are developed pursuant to N.J.A.C. 7:9B-1.5(g)2 or if the Department determines that concentrations do not render the waters unsuitable in accordance with (d)4i. above.*

The above passage from the SWQS references an effluent standard in the NJPDES Regulations at N.J.A.C. 7:14A-12.7 which states the following:

Phosphorus effluent standard
The effluent standard for phosphorus discharged to a freshwater lake, pond or reservoir, or tributaries to these waterbodies is that, at a minimum, no effluent shall contain more than 1.0 mg/l total phosphorus (as P), as a monthly average, unless the discharger(s) to such a waterbody can demonstrate that a less stringent requirement will not result in a violation of the Surface Water Quality Standards (N.J.A.C. 7:9B) or that the control of point sources alone, in the absence of effective nonpoint source controls, will not result in a significant reduction of phosphorus loadings to the waterbody.

B. <u>Charge to the Science Advisory Board</u>

The matter of nutrient criteria has been a priority issue for the Department for many years. The USEPA has also promoted the incorporation of numeric nutrient criteria in water quality standards adopted by States. Consistent with the emphasis that the USEPA and the Department have placed on the development of nutrient criteria, the Department has included nutrient criteria as a priority issue for the Science Advisory Board (SAB). The *Draft Issues for the Science Advisory Board* of September 8, 2010 includes the following issue:

> *"Site-specific factors may mitigate or exacerbate biological responses to excessive nutrients. What are the best state-of-the-art approaches for technically sound and implementable nutrient thresholds/criteria in fresh and coastal waters?"*

After numerous deliberations between the SAB Nutrient Work Group and Department staff (see Appendix 1 for a summary of those proceedings), the following Revised Amended Charge Question 1 has been posed to the SAB.

A. Based on the science, does the SAB support the TDI methodology to assess diatom community structure and develop inference models?

B. Does the SAB agree that the BCG framework is a reasonable method to describe changes in biological communities along a disturbance gradient?

C. Does the SAB agree with the following statements regarding relationships between instream total phosphorus and total nitrogen concentrations and diatom community BCG tiers?

(i) Results supported combining the Piedmont with the Ridge & Valley ecoregions.

(ii) Because of the dominating effect of low pH on diatom community structure, geographic applicability of the BCG approach was limited to sites with pH above 5.5. This removed significant portions of the outer coastal plain (specifically the Pinelands region) from the analysis.

(iii) Below the fall line in the Inner and Outer Coastal Plain, relationships between TP and BCG tiers are not clear. The Academy's report discusses the confounding influence of clays in the rivers which bind with reactive phosphorus nullifying its biological availability. Additionally, natural phosphorus-bearing minerals contained in the geologic material underlying portions of these watersheds may also confuse these relationships.

(iv) Relationships between nitrogen concentrations and BCGs in all ecoregions were unclear.

D. Recognizing that the Department wants to use multiple lines of evidence to determine numeric nutrient criteria, does the science and methods support use of BCG above the fall line as one of these lines of evidence for total phosphorus? For total nitrogen?

II. Recommendation Regarding Revised Amended Charge Question 1

Diatoms, microscopic algae found in almost all aquatic habitats, are increasingly the subject of research relating to the assessment of the ecological health of water resources. Diatoms are primary producers at the base of the food chain, and their responses reflect conditions in a waterway. A change in water quality or other environmental factors will allow some species of diatoms to reproduce more quickly, while others become less able to compete, resulting in a change in community composition. While many diatoms are planktonic, many others are periphytic, attached to rocks and other substrates. It is the periphytic diatom community that is most often sampled for environmental assessments. Periphytic diatom sampling protocols are well developed (http://diatom.acnatsci.org/nawqa/Protocols.aspx). Within the last two decades, diatom indices have been developed and have gained popularity as a tool to provide an integrated reflection of water quality. For instance, diatom assessment is one component of the European Union's Water Framework Directive (http://ec.europa.eu/environment/water/water-framework/index_en.html).

Benthic diatom species composition responds directly to nutrients (Pan and Lowe, 1994, Pan et al., 1996), and can be a more stable indicator of trophic status than nutrient concentrations or algal biomass, since these can vary considerably over a short time. Studies in New Jersey showed that variation in diatom species composition at 97 study sites is closely related to nutrient concentrations, and that nutrients could explain differences among samples better than other water chemistry and physical habitat characteristics. The Department also investigated the utility of using macroinvertebrates as an index of nutrient status in New Jersey streams, but found that diatoms appeared to be more robust and predictive (NJDEP 2011). Benthic macroinvertebrates and fish, while useful in evaluating aquatic life conditions, also reflect effects of other stressors (e.g., pH, erosion/siltation, toxics, etc) to a greater degree. Johnson and Hering (2008) found that in lowland streams, the composition of benthic diatom assemblages showed the strongest response to elevated nutrient concentrations (R^2 = 0.830), followed by macrophytes (0.711), fish (0.443) and invertebrates (0.391). Macrophyte richness was slightly better correlated with the habitat gradient than diatom richness and both were better predictors than either fish or invertebrate assemblage composition. In contrast, for mountain streams, invertebrate assemblage composition was the best predictor of changes in nutrient concentrations, followed by macrophyte and benthic diatom assemblages and fish diversity. While the above research suggests correlation between benthic diatom composition and nutrients, correlation to nutrient derived impacts was not established.

Nutrient inference models estimate nutrient concentrations in a stream by using diatom abundances and their nutrient preferences, based on overall patterns in species composition. A diatom sample consisting of mostly low-nutrient diatoms will have a low estimated nutrient concentration. In contrast, a diatom sample consisting of mostly high-nutrient diatoms will have a high estimated nutrient concentration (Danielson, 2009).

With the assistance of the Academy of Natural Sciences of Philadelphia, Department staff has been engaged in an extensive research effort regarding the subject in question. The findings of that effort have been provided in the following documents which have been considered by the SAB's Nutrient Work Group in formulating this recommendation:

- Ponader et al., 2007
- Ponader et al., 2008
- Charles et al., 2010
- Charles et al., 2011

Question 1A: ***Based on the science, does the SAB support the TDI methodology to assess diatom community structure and develop inference models?***

Finding:

The Nutrient Work Group agrees that it is possible to define relationships between a diatom index and nutrient level, i.e., one can develop a model that has diatoms or a diatom index as an input and expected nutrient level as an output. However, it is incumbent upon the Nutrient Work Group to assert that a diatom – nutrient relationship should not be used for anything more than that (e.g., a diatom – nutrient relationship is not a diatom – nutrient impairment relationship and cannot, without scientifically defensible evidence, be extended to a definition of nutrient criteria for protection against nutrient impairment).

Discussion:

The Department found that diatoms appear to be robust and predictive (NJDEP 2011); therefore, they plan to use the TDI to augment the state's routine water quality monitoring network. The TDI methodology is based on the premise that diatom community structure changes with nutrient concentration, and the Nutrient Work Group agrees that diatom community composition can change along a nutrient concentration gradient in New Jersey wadeable streams. This is supported by other scientific literature (e.g., see Van Dam et al., 1994, and Lange et al., 2011) that clearly demonstrates that diatoms exhibit nutrient preferences. Passy (2008) clearly states: "diatoms exhibit well documented nutrient preferences and many species require high nutrient concentrations for growth and reproduction." The Department's TDI papers themselves provide useful science in support of this relationship. Ponader et al., 2007 and Ponader et al., 2008 list diatom species optima and tolerances for both TP and TN (Table 2). "Optima" indicate the nutrient concentration each species prefers, while "tolerances" indicate the range of nutrient concentration preferred by each species. Consequently, the Nutrient Work Group agrees that it is possible to define relationships between a diatom index and nutrient level, i.e., one can develop a model that has diatoms or a diatom index as an input and expected nutrient level as an output.

Much can be learned by assessing diatom community structure in this manner. The research cited above demonstrates that diatom community structure can vary along a nutrient concentration gradient since diatom species vary in their preference for nutrient concentration. However, in any given location a number of other factors will also influence diatom community structure, such as land use, stream flow, vegetation, shading, and presence of other contaminants. Potapova and Charles (2002) found that the presence of environmental factors correlated with nutrient concentrations and should be taken into account when species–nutrient relationships are studied because these internal correlations of environmental factors in a data set can lead to incorrect conclusions about species nutrient requirements.

The Nutrient Work Group differentiates disturbance from impairment in the following way – 'disturbance' indicates a change from a baseline or initial condition as is commonly represented by a 'disturbance' gradient; 'impairment' indicates a level of disturbance which has been found to impede, prevent or impact an intended use. The above approach is unable to define levels of nutrient impairment (i.e., change in diatom composition in itself is not an indicator of nutrient impairment), and therefore has limited utility for defining numeric nutrient criteria. The Department indicates in Appendix 2, and the Work Group agrees, that its research did not conclude that "impaired" conditions are delineated along a diatom or nutrient gradient, i.e., diatom communities associated with high nutrient concentrations are not indicative of "impaired" conditions. Nonetheless, the monitoring and observance of diatom community structure can be helpful as contributing information in assessing the health of a wadeable stream.

A stream might be considered "impaired" if its diatom community did not support viable communities in other trophic levels (e.g., grazers, invertebrates, or fish). The Nutrient Work Group is not aware of data demonstrating differential trophic community quality associated with different diatom assemblages. However, some other studies may be relevant to this issue. Although not focused on nutrients but on light, Huggins et al. (2004) found that different periphyton communities do provide differential nutritional benefits to grazers. They studied biofilms under varying light regimes in two sites (north and south) in Lake St. Pierre (Quebec, Canada). Biofilms growing under greater light exposures found in the south were characterized by a greater biomass and nutrient content, but their total fatty acid (FA) contents and ratios of elemental nutrients were not significantly different from the north. There was a relatively greater abundance of chlorophytes and cyanobacteria in the south, along with a greater proportion of low nutritional quality saturated fatty acids (SAFA). Conversely, biofilms growing in the north had a greater relative abundance of diatoms, as well as greater eicosapentaneoic acid (20:5x3) and docosahexaneoic acid (22:6x3) concentrations (two FAs implicated in the physiological competency of grazers). The prevailing community structures created differences in the nutritional status of the biofilms for benthic grazers at the two sites. The biofilms from the southern site had greater food quantity at the expense of quality, while biofilms from the northern site had less food, but of a better quality. Despite this, the nutritional regime in the south supported a greater productivity at higher trophic levels. This study, while not directly bearing on the nutrient/diatom issue at hand, may indicate that different diatom assemblages may be of differential nutritional value.

***Question 1B:* Does the SAB agree that the BCG framework is a reasonable method to describe changes in biological communities along a disturbance gradient?**

Finding:

The BCG is a conceptual model that provides a reasonable method to describe changes in biological communities along a disturbance gradient. However, the extension of the BCG concept to the definition of numeric nutrient criteria has limitations. The use of BCG as an indicator of nutrient impairment assumes that areas with high disturbance are always impaired by nutrients, and that reducing nutrients would restore the impairment. The Nutrient Work Group does not think that this has been clearly demonstrated. In addition, high BCG scores may simply be the result of high nutrient levels, and do not always indicate an impaired condition. The reason is that many of the species associated with impaired conditions also prefer high nutrient conditions. As a result, unimpaired waters with high nutrient levels may obtain a high BCG score. Similarly, reducing nutrient levels may lower a BCG score without affecting other measures of impairment.

Discussion:

During discussions, the SAB's Nutrient Work Group, including members of the Department, agreed that the term "framework" in the above question should be changed to "conceptual model".

The BCG – Biological Condition Gradient - reflects the fact that as environmental quality deteriorates, the biotic community changes, with increasing changes in structure and function. Davies and Jackson (2006) initially proposed the BCG as a descriptive model that describes how ten ecological attributes changed in response to increasing levels of stressors. They divided this gradient of biological condition (focusing on macroinvertebrates and fishes) into six tiers ranging from very high quality to highly impaired, useful to scientists and managers. The model was tested by determining how consistently a group of expert biologists assigned samples of macroinvertebrates or fish to the six tiers. Thirty-three macroinvertebrate biologists concurred in 81% of their 54 assignments, and eleven fish biologists concurred in 74% of their 58 assignments. These results supported the contention that the BCG represents aspects of biological condition common to existing assessment methods using macroinvertebrates and fish.

Figures 1 through 3 portray the concepts behind the BCG conceptual model. This approach is widely used and accepted by the scientific community (Davies and Jackson, 2006; Danielson et al. 2012) and is a reasonable method to describe changes in biological communities along a disturbance gradient.

The BCG approach has been extended to algal metrics by other states including Maine, where they developed a stream algal model based on the BCG that is explicitly tied to tiered aquatic life uses in Maine's water quality standards. Using a modified Delphi method, five aquatic biologists independently evaluated algal community metrics for 230 samples from streams and rivers across the state and assigned a BCG tier (1-6) and Maine water quality class (AA/A, B, C, non-attainment of any class) to each sample. Assignments were unanimous for 53% of samples, and 42% of samples differed by only 1 class. The biologists debated and developed consensus class assignments. A linear discriminant model built to replicate a priori class assignments correctly classified 95% of 150 samples in the model training set and 91% of 80 samples in the model validation set (Danielson et al. 2012).

The diatom BCG for New Jersey was produced similarly during a workshop in which experts examined diatom communities from 95 study sites in New Jersey (Ponader et al. 2007, 2008). These scientists had general agreement on assigning each community to a location along a gradient of stress and deteriorating biological condition, so that each site could be assigned to a numerical "grade" reflecting its condition. The grades ranged from 1 (historically documented, sensitive, long-lived or regionally endemic taxa) to 6 (primarily non-indigenous taxa), based on the diatom metrics such as the percent tolerant. (2 = highly sensitive taxa, 3 = intermediate sensitive taxa, 4 = taxa of intermediate tolerance, 5 = tolerant taxa). No streams fitting into class 1, 2, or 6 were found in New Jersey. Environmental data were obtained (chemistry, habitat data, invertebrate data), and total phosphorus (TP) concentration ranged from 15 to >700 ug/l. Data were analyzed by multiple statistical methods, including ordinations of community data. The experts assigned taxa to BCG attributes based on their distribution along stressor gradients. Overall there was considerable agreement among the experts, with the averages of BCG scores assigned by each participant being within 0.3 units of each other (Charles et al. 2010).

However, the extension of the BCG concept to the definition of numeric nutrient criteria may have some limitations. For example, the use of BCG as an indicator of nutrient impairment assumes that areas with high disturbance are always impaired by nutrients, and that reducing nutrients would reduce the impairment. The Nutrient Work Group does not think that this has been clearly demonstrated. As noted above, diatom communities associated with high nutrient concentrations are not necessarily "unhealthy" or indicative of "impaired" conditions. The Department's research found no correlation between BCG scores and traditional ecological health indicators such as taxa richness, diversity, or percent dominant taxa. The Department feels that the BCG approach is superior to these traditional methods. Perhaps, but it is equally possible that high BCG scores may simply be the result of high nutrient levels, and do not always indicate an impaired condition. The reason is that many of the species associated with impaired conditions also prefer high nutrient conditions. Charles et al. 2010 (page 23) states, "The Diatom TP and TN Indices tend to vary linearly with Average Diatom Workshop BCG Score…" As a result, unimpaired waters with high nutrient levels may obtain a high BCG score. Similarly, reducing nutrient levels may lower a BCG score without affecting other measures of impairment.

It is generally true that nutrient concentration increases with disturbance. (Bourgeois-Calvin 2008; Brett et al. 2005; Busse et al. 2006; Watson et al. 1981) Since diatom communities will vary along a nutrient concentration gradient, it is not surprising that BCG scores may also vary along a nutrient concentration gradient. With regard to a relationship between BCG and nutrient concentration, high BCG scores may not necessarily indicate nutrient impairment but impairment from any cause. For example, areas of the Inner Coastal Plain that are not nutrient impaired, but are naturally high in phosphorus, received elevated BCG scores in this effort.

***Question 1C(i):* Does the SAB agree that the Department's research results support combining the Piedmont with the Ridge & Valley ecoregions.**

Finding:

The Nutrient Work Group concurs that combining the data for these two regions is supported.

Discussion:

This in fact was a recommendation that came out of the Nutrient Work Group deliberations. Figure 4 shows the Department's study sites overlaid on physiographic regions. Figure 5 shows the Department's findings for BCG score versus total phosphorus (TP) concentration for Ridge and Valley study sites combined with Northern Highlands study sites. These data alone do not support a definitive relationship between BCG score and TP concentration in this region. Figure 5 also shows the Department's findings for BCG score versus total phosphorus (TP) concentration for Northern Piedmont study sites. Again, these data alone do not support a definitive relationship between BCG score and TP concentration in this region. However given that (a) the range of TP concentrations studied for these two figures overlap, and (b) the data in these two figures are consistent where they do, it is reasonable to combine the two. Essentially, this would combine the results from all three of the physiographic regions north of the fall line in New Jersey, providing a more robust BCG model and a greater range of phosphorus conditions to analyze. (The "fall line" is illustrated in Figure 4 by the dotted line separating the Northern Piedmont region from the Inner Coastal Plain. A fall line is a geomorphologic change between an upland region of relatively hard crystalline rock and a coastal plain of softer sedimentary rock.)

The combined data set is depicted in Figure 6 and exhibits a relationship of the form:

$$BCG_s = BCG_{smax} * [1 - \exp(- k * TP)]$$

where:

BCG_s = BCG score as a function of TP concentration
BCG_{smax} = maximum BCG score possible
k = a constant determining the rate of increase in BCG score with TP concentration

or

$$BCG_s = BCG_{smax} * [TP / (K_s + TP)]$$

where:

K_s = a half saturation constant that determines the rate of increase in BCG score with TP concentration

BCG_{smax} appears to have a value of about 5 for the range of TP concentrations studied.

In conclusion, the Nutrient Work Group concurs that combining the data for these two regions is supported.

***Question 1C(ii):* Does the SAB agree that because of the dominating effect of low pH on diatom community structure, geographic applicability of the BCG approach was limited to sites with pH above 5.5. This removed significant portions of the outer coastal plain (specifically the Pinelands region) from the analysis.**

Finding:

The Nutrient Work Group agrees that the low pH sites should be analyzed separately.

Discussion:

The Pinelands region of New Jersey is characterized by surface waters with noticeably reduced pH levels (i.e., pH values are typically below 5.5.). The pH has a determining effect on diatom community structure (Dixit et al. 1992; Dixit et al., 1999). Furthermore, pH affects phosphorus speciation and availability through iron chemistry dynamics and other chemical mechanisms. Therefore, the Nutrient Work Group agrees that the low pH sites should be analyzed separately.

***Question 1C(iii):* Does the SAB agree that below the fall line in the Inner and Outer Coastal Plain, relationships between TP and BCG tiers are not clear. The Academy's report discusses the confounding influence of clays in the rivers which bind with reactive phosphorus nullifying its biological availability. Additionally, natural phosphorus-bearing minerals contained in the geologic material underlying portions of these watersheds may also confuse these relationships.**

Finding:

The Nutrient Work Group concurs that BCG-nutrient relationships are not clear for the Inner or Outer Coastal Plain.

Discussion:

Phosphorus tends to bind to soil and sediment particles and when it does it is not available to be taken up by plants. A close relationship has been reported between sediment organic carbon content and its phosphorus sorption capacity (Novak and Watts, 2006). Below the fall line, New Jersey streams generally exhibit increased sedimentation, increased iron, and increased occurrence of glauconitic formations (i.e. greensands, which are granular like sands but behave chemically like clays). As a result, a smaller fraction of the total phosphorus tends to be available in streams below the fall line, confounding the relationship between phosphorus and BCG scores.

Figure 5 illustrates data for the Outer Coastal Plain comparable to that discussed above for the Piedmont and the Ridge & Valley ecoregions. Note that no discernible relationship is observed. It is possible that more data particularly, for sites with higher TP concentrations, may enable discernment of a relationship, but no such data are presently available.

Figure 5 also illustrates comparable information for the Inner Coastal Plain study sites, with similar results. The presence of iron-rich clays which bind with reactive phosphorus, nullifying its biological availability, is widely acknowledged. (Pettersson 1998 and Surridge et al., 2007)

The above results from below the fall line are clear in one respect, i.e., BCG score does not correlate to nutrient concentration. Therefore, the Nutrient Work Group concurs that BCG-nutrient relationships do not exist for the Inner or Outer Coastal Plain. However, we encourage the Department to continue its research on this topic.

***Question 1C(iv):* Does the SAB agree that relationships between Nitrogen concentrations and BCGs in all ecoregions were unclear.**

Finding:

The Nutrient Work Group agrees that nitrogen does not correlate well with BCG scores.

Discussion:

Figure 7 illustrates the Department's findings with regard to nitrogen and BCG score. Relationships for the Inner and Outer Coastal Plain are not supported. Similarly, the results do not support relationships for Ridge and Valley / Northern Highlands data or Northern Piedmont data individually. Combining the two also would not appear to result in a defensible relationship. Therefore, the Nutrient Work Group agrees that relationships between nitrogen concentrations and BCGs in all ecoregions are unclear.

In general, phosphorus is the more limiting nutrient in freshwater systems, while nitrogen is more limiting in estuarine and coastal waters. In other words, freshwater streams tend to contain more nitrogen than phosphorus relative to algal kinetic demands. As a result, it is not surprising that nitrogen does not correlate well with BCG scores in freshwater streams.

Question 1D: ***Recognizing that the Department wants to use multiple lines of evidence to determine numeric nutrient criteria, does the science and methods support use of BCG above the fall line as one of these lines of evidence for total phosphorus? For total nitrogen?***

Finding:

The relationship between a diatom-based BCG score and phosphorus in regions above the fall line may be useful in determining a threshold that triggers disturbance or change. However, the Nutrient Work Group, based on current scientific evidence, is not convinced that a higher diatom-based BCG score always means a higher degree of nutrient impairment. Use of BCG scores for assessment of impacts from total nitrogen is also not supported.

Discussion:

The Department has been engaged in an extensive effort focused on the development of biologically based numeric nutrient criteria. This research has produced valuable information that can be used, along with other metrics, in assessing the association between elevated nutrient concentrations and biological changes.

As noted prior, the Department's data show a correlation between a diatom based BCG score and TP concentration above the Fall Line. (Below the Fall Line, no relationship has been established.) The Nutrient Work Group does express a concern that this relationship is purely empirical and is not accompanied by a clear cause and effect description, which may limit its utility. The BCG score provides a useful indication of biological changes, but whether those changes are deleterious must be determined through further studies using other empirical means. At least based on the information provided, the Nutrient Work Group is not convinced that a higher diatom-based BCG score always means a higher degree of nutrient impairment. The relationship between a diatom based BCG score and phosphorus in regions above the fall line may be useful in identifying a threshold that triggers disturbance or change. Excessive growth and accumulation of algae or other plants, and the dominance by a small number of taxa may be considered indicative of nutrient impairment. However, at any specific location, a high diatom based BCG score alone is not necessarily indicative of nutrient impairment. Therefore, use of a diatom based BCG score alone to establish numeric nutrient criteria is not supported.

The Nutrient Work Group asserts that a diatom based BCG score can be used in concert with other metrics to assess nutrient impacts and perhaps restoration thresholds. If the Department determines through direct empirical means (e.g., low dissolved oxygen or excessive algal density) that a location is nutrient impaired, the BCG-TP relationship might be helpful in identifying the cause of that impairment as excessive nutrients. The Department may be able to make use of the BCG-TP findings above the fall line where nutrient impairment is confirmed by other empirical means. The Nutrient Work Group supports the use of the Department's BCG model for understanding how diatom communities change with increasing TP concentration, but did not conclude that the Department should use the method for numeric nutrient criteria development.

The above findings are applicable to total phosphorus. As discussed above, use of BCG scores for assessment of impacts from total nitrogen is not supported.

III. Recommendation Regarding Initial Charge Question 2

The following is the Nutrient Work Group's recommendation to the SAB with regard to Initial Charge Question 2. (See Appendix 1 for the complete list of Charge Questions.) For simplicity the question has been divided into two sub questions, i.e., 2A and 2B as per below.

***Question 2A*: Evaluate the USGS method currently used by NJDEP to perform diurnal DO sampling and recommend any changes to simplify field utility without losing scientific validity.**

Finding:

The Nutrient Work Group recommends that diurnal monitoring three days after a "non-scouring event" can be used to indicate possible nutrient impairment, but should wait until 14 days after a "scouring event". The "non-scouring event" is not relevant for periphyton sampling, only diurnal monitoring. The Nutrient Work Group recommends that a "non-scouring event" be defined as no more than ½ inch of rain in any 24 hour period.

Discussion:

The dissolved oxygen (DO) in waterbodies undergoes diurnal fluctuations because photosynthesis by plants, which releases oxygen into the water, occurs only during the daytime. During the nighttime hours, plants, microbes, and animals all respire, removing oxygen from the water. Thus, DO tends to be lowest just before dawn and rises during the course of the day. After dusk, it decreases. However, how low it goes is affected by temperature, turbulence, water flow, and other environmental conditions. Daytime water monitoring, therefore, may not provide a complete picture of the stresses that aquatic organisms face. Low DO is exacerbated by high summer temperatures and low flow conditions. NJDEP does not currently collect grab samples at night, but does get information from some automated continuous monitors.

Obtaining diurnal DO data to indicate nutrient impairment should be done during periods of stable flow, and should be avoided soon after large rainfall events. Severe rainfall and rapid waterflow may scour benthic diatoms from the rocks. Macroinvertebrate species richness and relative population abundance were drastically reduced after scouring events, which altered substrate morphology and disturbed microhabitats. Most populations are either eliminated or greatly reduced in abundance after heavy rainfall. (Calder et al. 2012).

The method referenced in this question is actually a Department method, not a USGS method. Currently, the Department performs short-term diurnal DO monitoring during the growing season (May through October) not less than 72 hours after a rainfall event of ½ inch or more per day, and when stream flow is not more than the 70^{th} percentile flow (i.e., that stream flow which is exceeded 70% of the time which is often referred to as the D70 flow). The Department performs monitoring not just for diurnally varying DO but for other diurnally varying parameters such as pH and temperature that are affected by or related to photosynthesis. The following discussion applies to diurnal monitoring for all such parameters.

While the Department did not specifically ask for guidance regarding its periphyton sampling requirements, the Nutrient Work Group recognizes that in lotic environments (i.e. most streams), it is periphyton and/or aquatic plants that are driving the diurnally varying dissolved oxygen conditions. For periphyton sampling, the Department adds an even more stringent precipitation requirement that sampling be performed not less than 14 days after a rainfall event of ½ inch or more per day.

The SAB's Nutrient Work Group noted that the SAB's Water Quality and Quantity Committee has also made recommendations regarding diurnal DO sampling. Those recommendations focus on how to interpret the results of diurnal DO sampling, whereas this report is focused on when short-term diurnal sampling would be best performed.

The SAB's Nutrient Work Group recommended that the Department continue with its current specification that short-term diurnal DO monitoring occur when stream flow is at or below the D70 flow for that stream. Our collective experience indicates that the 70th percentile flow provides a reasonable threshold for identifying critical conditions for diurnal monitoring. A less restrictive flow condition would result in some diurnal measurements being made during less than critical periods, thereby underestimating the diurnal swing for parameters like DO and pH. On the other hand, a more restrictive flow condition would make it much more difficult to perform diurnal monitoring, and would not affect the diurnal monitoring results significantly.

Furthermore, the SAB's Nutrient Work Group supported the seasonal requirement for short-term diurnal monitoring, to the extent that the purpose of it is to assess impairment. While streams may exhibit substantial productivity during the traditional "non-growing" season of November through April, lower stream temperatures will make it much less likely that significant diurnal swings will result in violations of minimum dissolved oxygen criteria.

It is recommended that the Department modify its sampling protocol to recognize that there are two different antecedent precipitation conditions relevant to diurnal monitoring and associated periphyton sampling:

1. Rainfall events that cause (a) short term dilution of waterway constituents, and (b) increase in water depth of receiving waters (i.e., a "non-scouring event"). These are events from which a waterway will typically return to its pre-rainfall condition within three days.

2. Rainfall events which are of such a magnitude and/or duration that they cause significant scouring of attached biota residing within the waterway (i.e., a

"scouring event"). These are events from which a waterway will typically return to its pre-rainfall condition within approximately fourteen days.

It is recommended that diurnal monitoring can be conducted three days after a "non-scouring event", but should be postponed until 14 days after a "scouring event". The "non-scouring event" is not relevant for periphyton sampling, only diurnal monitoring. The Nutrient Work Group recommends that a "non-scouring event" be defined as no more than ½ inch of rain in any 24 hour period. This definition is consistent with the Department's current monitoring protocol.

Finally, it is recommended that the Department conduct additional research to develop a definition of a "scouring event". The Department currently requires that there not be a rainfall event of ½ inch or more in any 24 hour period for the 14 days prior to periphyton sampling to ensure that scouring will not have had an effect on the periphyton sampling results. This is an overly restrictive definition of a "scouring event" which is an event that occurs rarely and is of greater magnitude (and less frequency) than ½ inch of rain in 24 hours. Since scouring is a function of stream velocity and substrate, the SAB's Nutrient Work Group recommended that the Department consider defining a scouring event by metrics such as velocity and substrate. A metric such as stream flow could be considered since stream flow can be related directly to velocity.

***Question 2B*: A corollary is to investigate what DO swings would indicate impairment due to primary productivity.**

Finding:

The SAB's Nutrient Work Group is not aware of any dissolved oxygen swing that would represent, in and of itself, a water quality impairment for New Jersey streams. The Department may wish to explore whether there is a basis for defining a numeric diurnal swing in DO that indicates impairment in New Jersey streams.

Discussion:

Aquatic organisms respire both day and night. During the day, however, there is typically more oxygen created by photosynthesis than is used up by respiration, so DO concentrations typically go up during the day and down at night when photosynthesis stops. Healthy streams have smaller amplitude daily changes or flux of dissolved oxygen and sufficient oxygen at night to prevent stressful conditions for aquatic organisms. Nutrient enriched streams with excess algal growth can have substantial amounts of photosynthesis during the day but a great amount of respiration at night from all of the organisms and decaying organic matter. Dissolved oxygen levels can plummet at night and cause stress and suffocation of aquatic life (Danielson, 2009b).

Some studies have found that large, daily swings in dissolved oxygen can harm aquatic life. In a study of a large number of streams in Tennessee, DO levels were affected by the amount of periphyton in the streams. Although DO levels generally stayed above regional criteria, diurnal fluctuations were more pronounced when algal densities were above reference stream conditions. Extreme changes in DO levels were considered to have detrimental effects on aquatic life, even when criteria for minimum concentrations are met (Arnwine and Sparks 2003). Studies in Minnesota found a significant relationship between DO flux and benthic invertebrates in a study of large rivers (Heiskary and Markus 2003). As DO flux increased from 4 mg/l to around 7 mg/l, the number of different types of mayflies, stoneflies, and caddisflies decreased from 20 to 10. In a follow up study of large rivers, they found very strong inverse relationships between DO flux and the number of different kinds of fish and macroinvertebrates that are sensitive to pollution (Heiskary 2008). In addition, they found strong positive relationships between DO flux and the number of pollution-tolerant macroinvertebrate taxa. High DO flux tended to occur with high temperature, high nutrient concentrations, low DO, and high chlorophyll *a* concentrations (Heiskary and Markus 2003, Heiskary 2008), all of which are detrimental to water quality.

The SAB's Nutrient Work Group is not aware of any dissolved oxygen swing that would represent, in and of itself, a water quality impairment for New Jersey streams. In phytoplankton-dominated systems (typically lentic systems) such as the Passaic River at Dundee Dam, it has been demonstrated that diurnal dissolved oxygen swings are related to algal concentration. (Uchrin 1988) In view of the findings discussed above, the Department may wish to explore whether there is a basis for defining a numeric diurnal swing in DO that indicates impairment in New Jersey streams.

APPENDIX 1

Meetings, Work Group Composition and Changes in Questions

The *Draft Issues for the Science Advisory Board* of September 8, 2010 includes the following issue:

> *"Site-specific factors may mitigate or exacerbate biological responses to excessive nutrients. What are the best state-of-the-art approaches for technically sound and implementable nutrient thresholds/criteria in fresh and coastal waters?"*

Tom Belton (the Department's liaison to the SAB on the nutrient criteria issue) provided the SAB with a presentation about the issue at the SAB meeting of October 18, 2010. A Nutrient Work Group consisting of members of the SAB and its Standing Committees was formed, and an initial meeting of the Work Group was held with several members of the Department on November 23, 2010. The initial members of the Work Group were Judith Weis, David Vaccari, and Raymond Ferrara of the SAB and Thomas Amidon of the Water Quality and Quantity Standing Committee. Dr. Vaccari is also the Chairperson of the Water Quality and Quantity Standing Committee. Dr. Ferrara agreed to serve as the Chairperson for the Nutrient Work Group.

An outcome of the November 23rd meeting was the identification of five specific questions to be considered by the Work Group in lieu of the more general issue and question of September 8th mentioned above. The five initial charge questions posed to the Nutrient Work Group were as follows:

1. Evaluate the utility for using the NJ diatom-based TDI [Trophic Diatom Index] and TALU [Tiered Aquatic Life Use] studies for developing bio-criteria and related protective nutrient concentrations for wadeable streams (i.e., for both phosphorus and nitrogen).

2. Evaluate the USGS method currently used by NJDEP to perform diurnal DO sampling and recommend any changes to simplify field utility without losing scientific validity. A corollary is to investigate what DO swings would indicate impairment due to primary productivity.

3. Evaluate whether NJDEP should expand their current sampling regime from the growing season to include annual or seasonal data and are there consequences for assessing impairment to designated uses (e.g., do winter algal blooms cause DO sags in summer).

4. Evaluate what the appropriate averaging period should be for nutrient criteria, which then determines the averaging period for assessing monitoring data. For example, should the

phosphorus criterion of 0.1 mg/l in streams be assessed as a monthly average criterion, annual average criterion, or a seasonal peak criterion?

5. Evaluate what indicator to use for nitrogen aquatic life use impairment in coastal bays, focusing on Barnegat Bay and the research going on there now. Are there ways to develop downstream protective numbers based on upstream concentrations or loads?

The Department requested that the 5 questions be addressed in the above order.

Conference calls were arranged to discuss Question 1 (February 7, 2011) and Question 2 (January 20, 2011). Members of the Department and the USGS participated in these calls to offer their expertise and advice. Don Charles of the Academy of Natural Sciences of Philadelphia also participated in the Question 1 conference call, as the Academy has assisted the Department in conducting research on the issue.

Subsequent to the two above-mentioned conference calls, it was decided that the Work Group should be further expanded beyond the initial four members. Additional volunteers were sought from the SAB and its Standing Committees. We were fortunate to add four additional members to the Work Group – Kirk Barrett, Keith Cooper and Christopher Uchrin of the Water Quality and Quantity Standing Committee, and Jonathan Kennen of the Ecological Processes Standing Committee. (Kirk Barrett has subsequently resigned from the Water Quality and Quantity Standing Committee and hence the Work Group due to his acceptance of a faculty position at Manhattan College in New York.)

A meeting of the expanded Work Group was held on May 5, 2011 to discuss Question 1. In addition to the Work Group members, several members of the Department were present and Don Charles made a presentation about the research that the Academy had conducted for the Department. As a result of this meeting, the Department decided that it would like to amend Question 1. On May 24, 2011 the Department forwarded an amended Question 1 to the Work Group as follows:

SAB Nutrient Work Group
Amended Charge Question 1.

Are the scientific approaches used in the Trophic Diatom Indices (TDI) studies and the Diatom Biological Condition Gradient (BCG) paper* sound? Are the conclusions drawn from them sound? Could the approaches be improved upon or the conclusions firmed by additional studies? If so, how?*

Specifically:
Conclusions drawn from the TDI: Diatom community structures strongly correlate with phosphorus and nitrogen levels. If TP and TN levels are reduced (or increased), we will see a corresponding change in the diatom communities.

Conclusion from the BCG study: a BCG, as described by USEPA, can be developed for diatom communities in NJ.

**Papers for Review*

1. Ponader, K.C. Charles, D.F. and T.J. Belton. 2007. Diatom-Based TP and TN Inference Models and Indices for Monitoring Nutrient Enrichment of New Jersey Streams, Ecological Indicators, Vol. 7, pp 79-93.

http://www.sciencedirect.com/science/article/pii/S1470160X05001123

2. Ponader, K.C., Charles, D.F., Belton, T.J. and Winter, D.M. 2008. Total phosphorus inference models and indices for coastal plain streams based on benthic diatom assemblages from artificial substrates. Hydrobiologia, Volume 610, Number 1: 139-152.

http://www.springerlink.com/content/1gn1531g28552086/

3. D.F. Charles, A.P. Tuccillo and T.J. Belton. 2010. Diatoms and the Biological Condition Gradient in New Jersey Rivers and Streams: A basis for developing nutrient guidance levels, Final Report submitted to the New Jersey Department of Environmental Protection by the Patrick Center for Environmental Research, Philadelphia Academy of Natural Sciences, September 21, 2010 (PCER Report No. 10-03)

http://www.state.nj.us/dep/dsr/nutrient/bcg-talu-final-report.pdf

The Work Group met again on May 12, 2011 to deliberate, and on June 9, 2011 to prepare a draft response to the Amended Question 1.

On August 1, 2011 Chairperson Ferrara asked Tom Belton whether the Department had any amendments to Questions 2 through 5. On August 11, 2011 Mr. Belton responded that there were no changes to Questions 2 through 4, but the Department would like the Work Group to defer Question 5 indefinitely. On August 3, 2011 Mr. Belton also offered an additional PowerPoint presentation of recent work that the Department and the Academy had conducted relevant to Amended Question 1. On August 31, 2011 the Work Group met to (a) draft a response to Amended Charge Question 1, (b) draft a response to Charge Question 2, and (c) chart a course of action to address Charge Questions 3 and 4.

A draft interim report regarding the above Questions 1 and 2 was discussed at the SAB meeting of October 20, 2011. In a memo dated November 23, 2011 the NJDEP Nutrient Criteria Work Group (a separate work group consisting of only NJDEP staff from various related bureaus/divisions within the Department) offered its comments on the SAB Work Group's presentation of October 20. As a result of various subsequent discussions, the Department decided again to refine and revise its set of questions for the SAB, and on February 6, 2012 the Department presented a revised set of questions including a Rationale and Background Information to replace the previously presented Amended Charge Question 1. This Revised Amended Charge Question 1 is as follows (the complete document including Rationale and Background Information is provided as Appendix 2 to this report):

A. Based on the science, does the SAB support the TDI methodology to assess diatom community structure and develop inference models?

B. Does the SAB agree that the BCG framework is a reasonable method to describe changes in biological communities along a disturbance gradient?

C. Does the SAB agree with the following statements regarding relationships between instream total phosphorus and total nitrogen concentrations and diatom community BCG tiers?

   i. Results supported combining the Piedmont with the Ridge & Valley ecoregions.

   ii. Because of the dominating effect of low pH on diatom community structure, geographic applicability of the BCG approach was limited to sites with pH above 5.5. This removed significant portions of the outer coastal plain (specifically the Pinelands region) from the analysis.

   iii. Below the fall line in the Inner and Outer Coastal Plain, relationships between TP and BCG tiers are not clear. The Academy's report discusses the confounding influence of clays in the rivers which bind with reactive phosphorus nullifying its biological availability. Additionally, natural phosphorus-bearing minerals contained in the geologic material underlying portions of these watersheds may also confuse these relationships.

iv. Relationships between Nitrogen concentrations and BCGs in all ecoregions were unclear.

D. Recognizing that the Department wants to use multiple lines of evidence to determine numeric nutrient criteria, does the science and methods support use of BCG <u>above</u> the fall line as one of these lines of evidence for total phosphorus? For total nitrogen?

The Work Group subsequently met on multiple occasions to discuss this revised Amended Charge Question 1.

APPENDIX 2

NJDEP Rationale and Background Information - Nutrient Issue Questions for the Science Advisory Board

NJ's evaluation of diatom community data to assess nutrient impacts to wadeable streams

States and tribes have been tasked by USEPA with developing numeric nutrient criteria for their waters that are 1) protective of designated uses, 2) ecoregionally based, and 3) supported by multiple lines of evidence. The scientific literature suggests that diatoms are effective indicators of overall nutrient levels in waterbodies so DEP explored that option to see if they could play a role in helping develop nutrient criteria.

Initial Perspective: NJ seeks assessments of nutrient impacts directly on biological communities. Other than the consequences of low DO, fish and benthic macroinvertebrates are a few trophic levels removed from the direct effects of excess nutrient enrichment. Algae, in contrast, being direct consumers of nutrients will often directly reflect the impacts of nutrient enrichment. Of all the algal forms, diatoms are the most effective tool for community assessment. Forming silica shells arranged like a petri-dish, diatoms can be easily sampled, permanently preserved, identified to species, are ubiquitous in aquatic environments, and have been extensively studied on a world-wide basis. Changes in diatom communities under increasing nutrient concentrations reflect similar changes seen at higher trophic levels; simplification of community structure, loss of ecosystem function and redundancy, loss of sensitive (sometimes rare) species and their replacement with ubiquitous tolerant species, increases in overall biomass and changes in taxonomic diversity.

I. Establish Diatom-based nutrient inference models (see Ponader et al, 2007).

1. Based upon diatom nutrient preferences.
2. Demonstrated that diatom community makeup can significantly change along a nutrient concentration gradient in NJ wadeable streams.
3. Limitation: Unable to discern impairment thresholds. "Healthy" or "impaired" biological (i.e. diatom) conditions are not clearly delineated along the nutrient/diatom gradient.

II. Address the limitations identified with the diatom-based nutrient inference model (Charles et al. 2011). Establish a relationship between in-stream nutrient concentration with diatom community "impairment". Utilized a nationally recognized descriptive framework for biological condition in waterways covering pristine to severely impaired conditions developed as a cooperative effort between EPA and states with contractor support provided by Tetra Tech.

1. BCG gradients divide biological communities into 6 tiers. Tier 1 reflects natural or pristine conditions while tier 6 represents severe degradation. NJ used a BCG to calibrate

its benthic macroinvertebrate data to indicate support/nonsupport of aquatic life use as have other states.

2. The Academy of Natural Sciences of Philadelphia conducted a workshop to develop a BCG for diatoms in NJ wadeable streams with participants from a team of phycologists, DEP staff, and Tetra Tech.
3. The BCG provided DEP with a means to distinguish biologically impaired sites from healthy sites using wadeable stream diatom communities.

III. Examine Diatom community condition (BCG tiers) vs. Nutrient Level (Charles et al. 2011). Are there relationships between instream total phosphorus and total nitrogen concentrations and diatom community BCG tiers?

1. Results supported combining the Piedmont with the Ridge & Valley ecoregions.
2. Because of the dominating effect of low pH on diatom community structure, geographic applicability of approach was limited to sites with pH above 5.5. This removed significant portions of the outer coastal plain (specifically the Pinelands region) from the analysis.
3. Below the fall line in the Inner and Outer Coastal Plain, relationships between TP and BCG tiers are not clear. The Academy's report discusses the confounding influence of clays in the rivers which bind with reactive phosphorus nullifying its biological availability. Additionally, natural phosphorus-bearing minerals contained in the geologic material underlying portions of these watersheds may also confuse these relationships.
4. Relationships between Nitrogen concentrations and BCGs in all ecoregions were unclear.

Note: Additional data for the northern portion of the state have been collected to clarify both TP and N relationships to the BCG tiers in that portion of the state as well as to enhance the diatom/nutrient inference model regressions.

<u>Questions for the Science Advisory Board</u>:

In relation to the above information and references listed and previously provided:

1a) Based on the science, does the SAB support the TDI methodology to assess diatom community structure and develop inference models?

1b) Does the SAB agree that the BCG framework is a reasonable method to describe changes in biological communities along a disturbance gradient?

1c) Based upon a review of the statements under heading III above: Does the SAB agree with these limitations and conclusions?

1d) Recognizing that the Department wants to use multiple lines of evidence to determine numeric nutrient criteria, does the science and methods support use of BCG above the fall line as one of these lines of evidence for total phosphorus? For total nitrogen?

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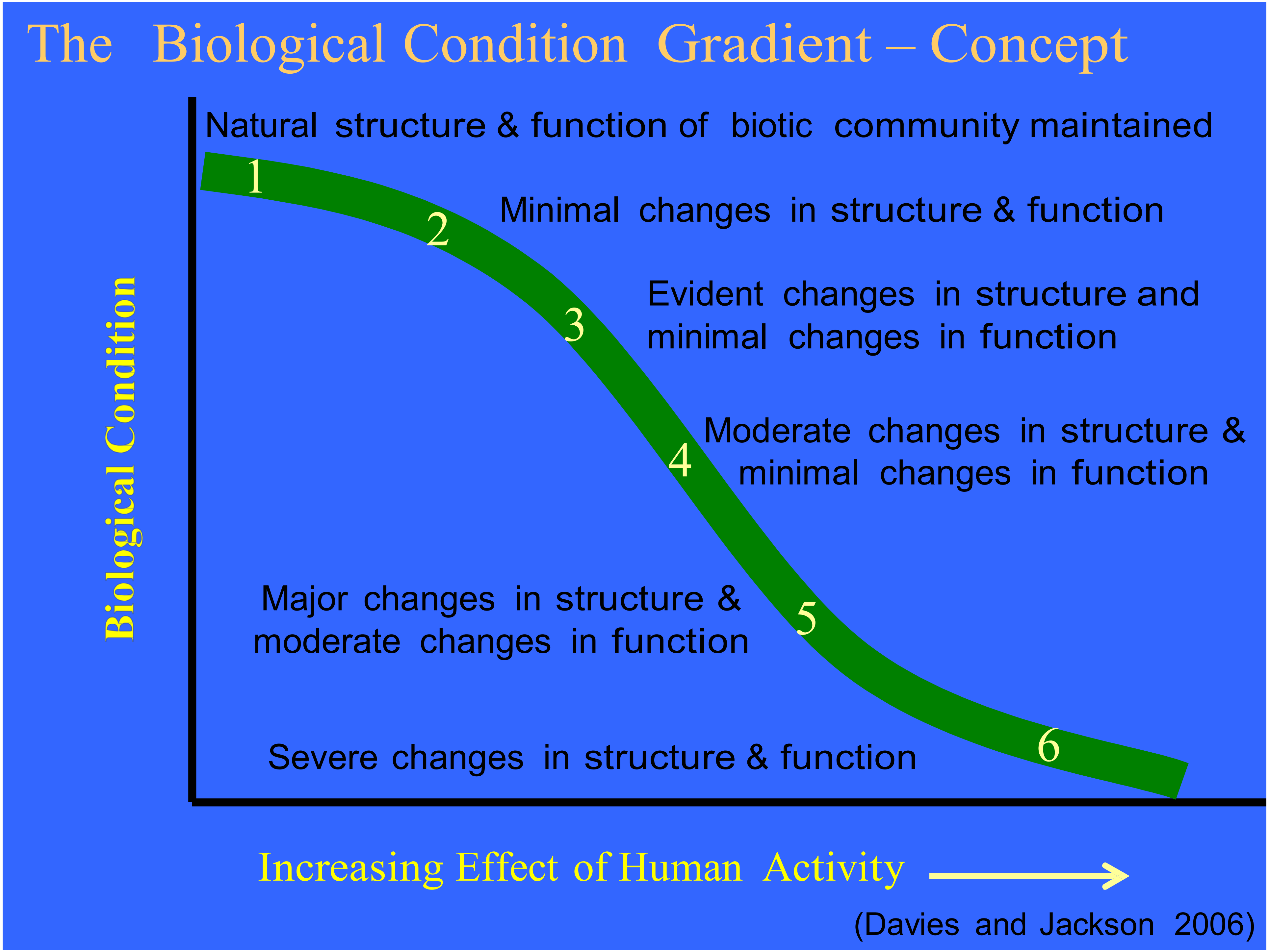

The Biological Condition Gradient – Concept
Natural structure & function of biotic community maintained
1
2
Minimal changes in structure & function
3
Evident changes in structure and minimal changes in function
4
Moderate changes in structure & minimal changes in function
5
Major changes in structure & moderate changes in function
6
Severe changes in structure & function
Biological Condition
Increasing Effect of Human Activity
(Davies and Jackson 2006)

Figure 1

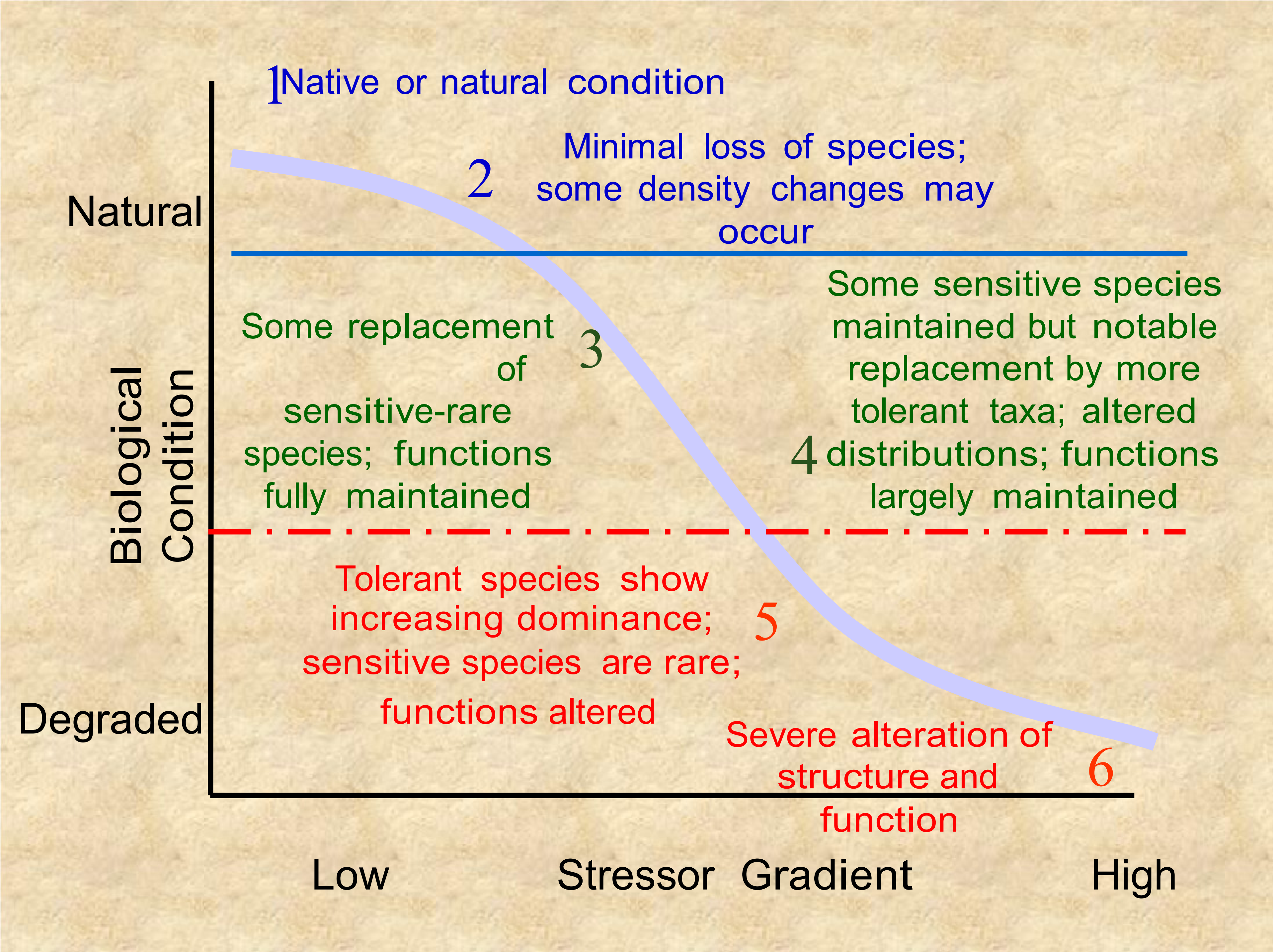
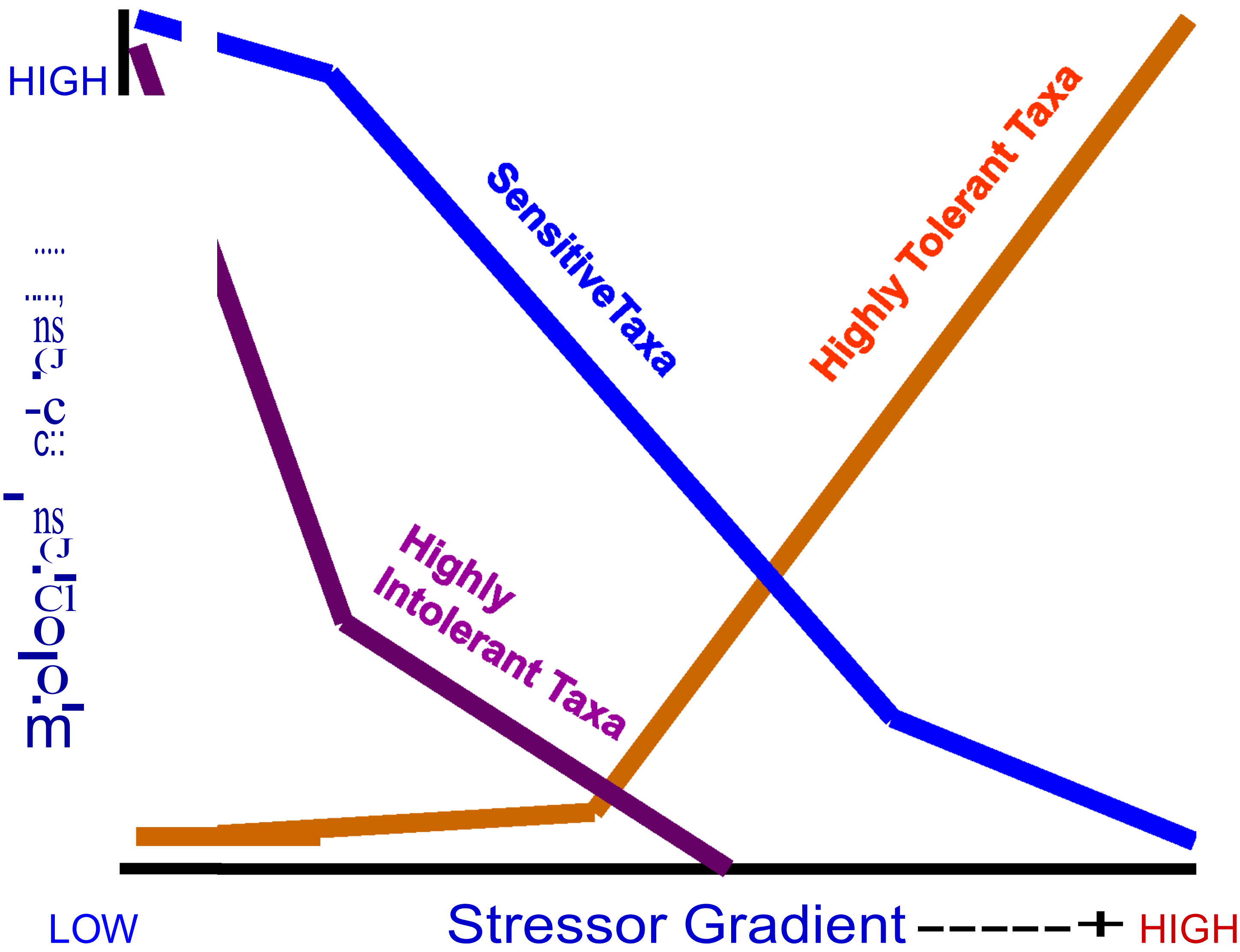

1 Native or natural condition
2 Minimal loss of species; some density changes may occur
Natural
3 Some replacement of sensitive-rare species; functions fully maintained
4 Some sensitive species maintained but notable replacement by more tolerant taxa; altered distributions; functions largely maintained
Biological Condition
5 Tolerant species show increasing dominance; sensitive species are rare; functions altered
Degraded
6 Severe alteration of structure and function
Low
Stressor Gradient
High

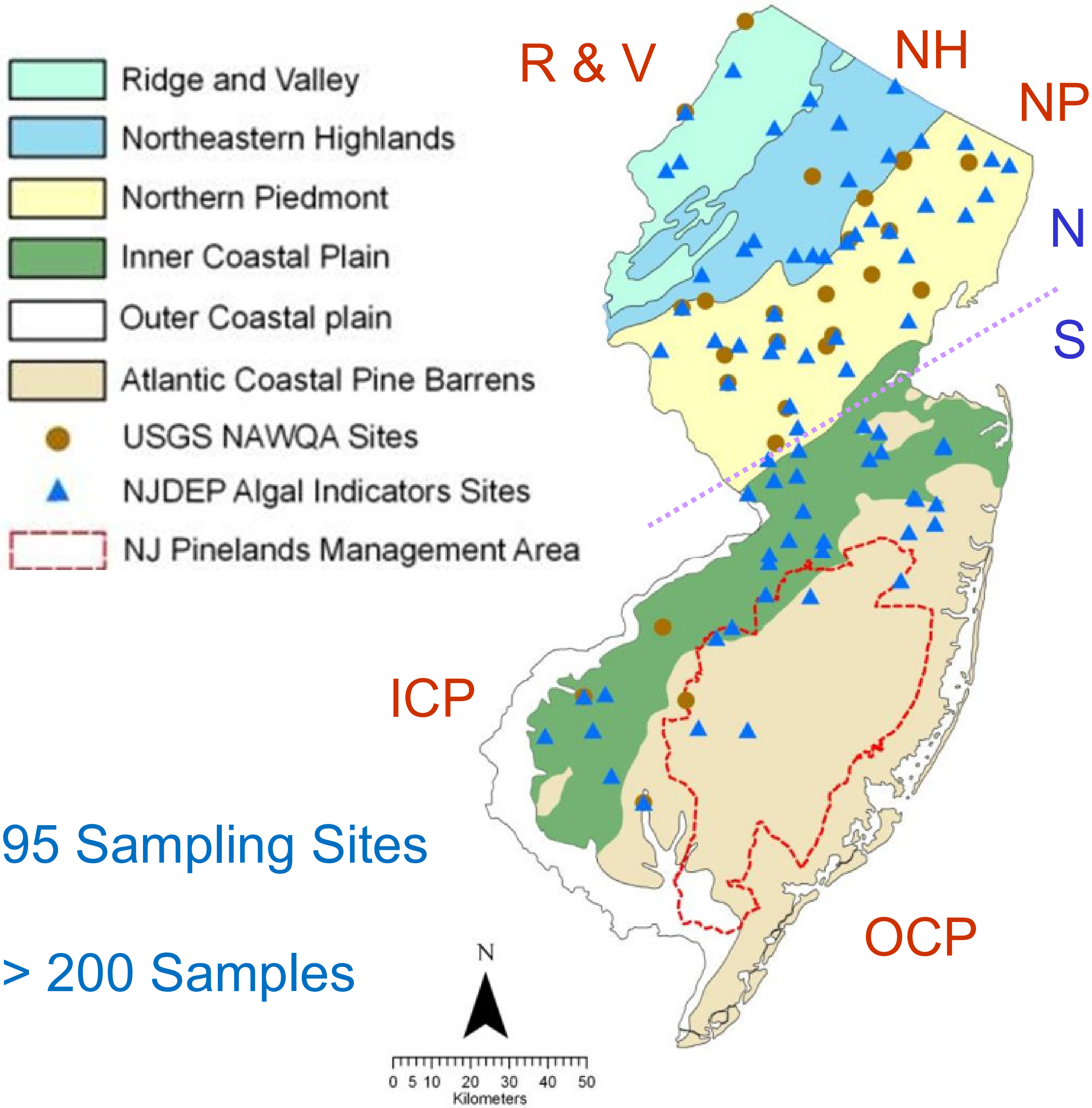
Figure 2

Biological Indicators: Behavior Along the Stressor Gradient



Modified from Original Courtesy of Chris Yoder, CABB

Figure 3



New Jersey Study Sites and Ecoregions

North
High-gradient
Rock substrate
pH > 7

South
Low-gradient
Sand / silt substrate
pH < 7 and > 5.5

95 Sampling Sites

> 200 Samples

Figure 4

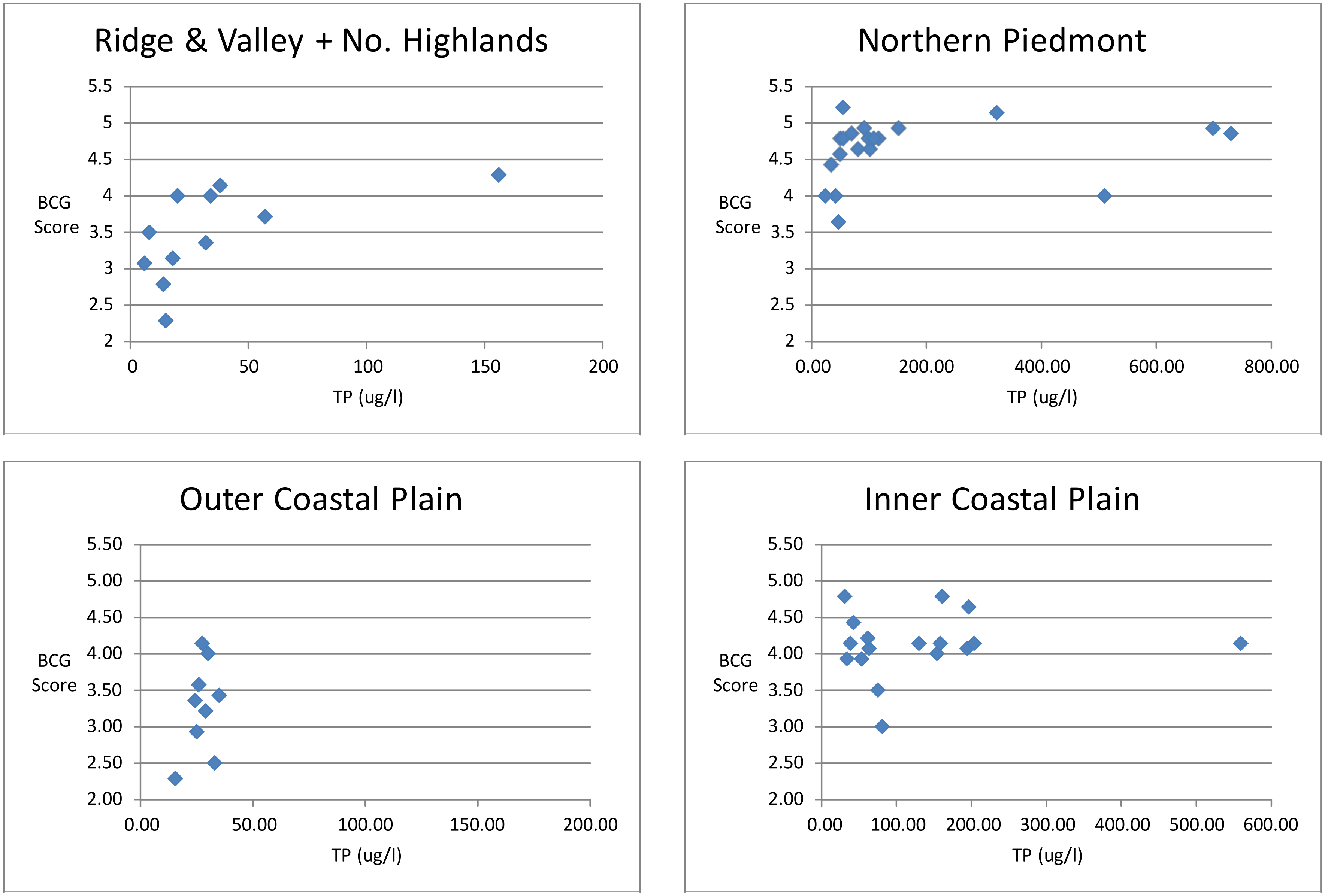


Figure 5 BCG Workshop Score versus Total Phosphorus Concentration for All Ecoregions

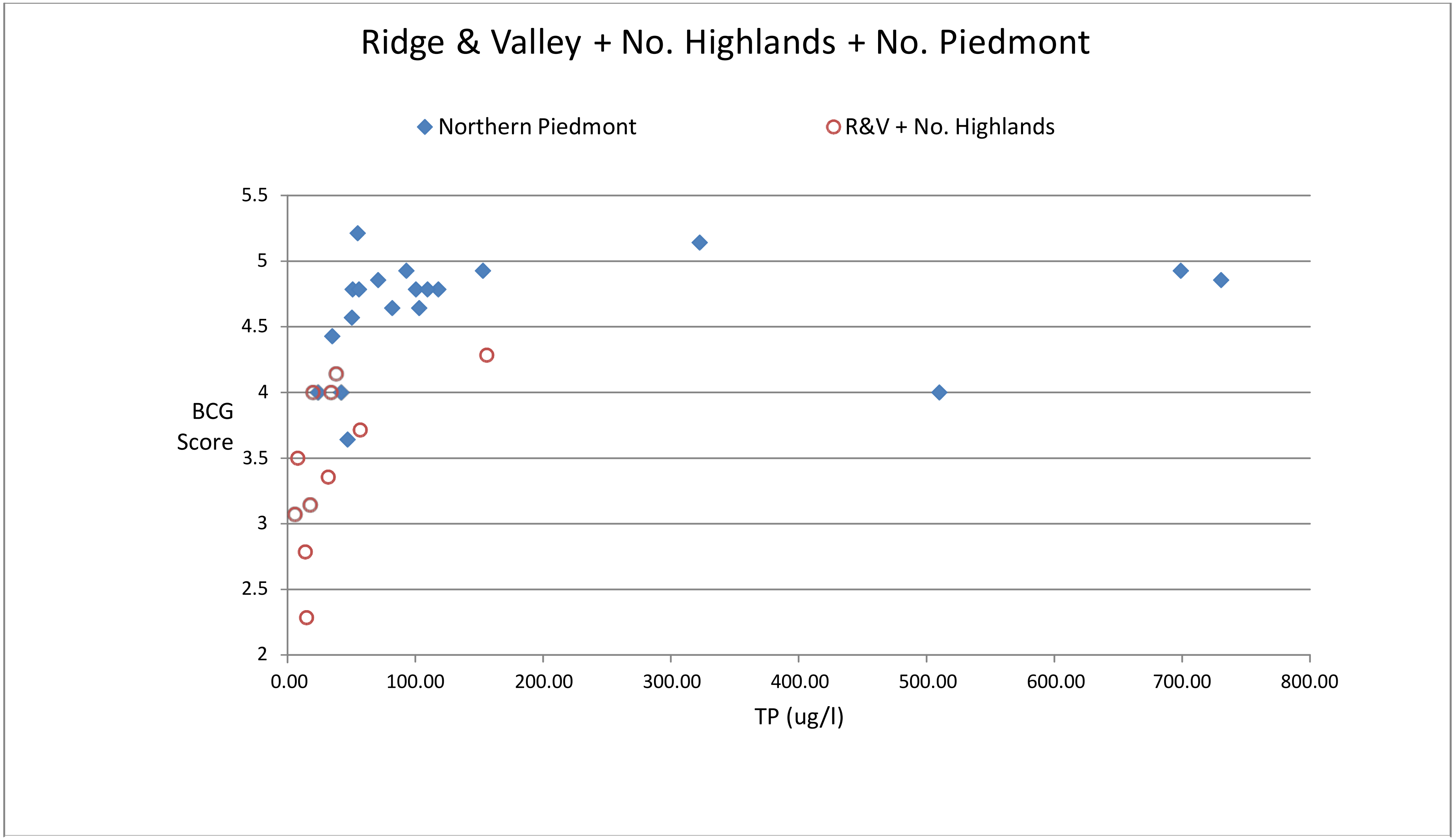


Figure 6 BCG Workshop Score versus Total Phosphorus Concentration for Combined Ecoregions

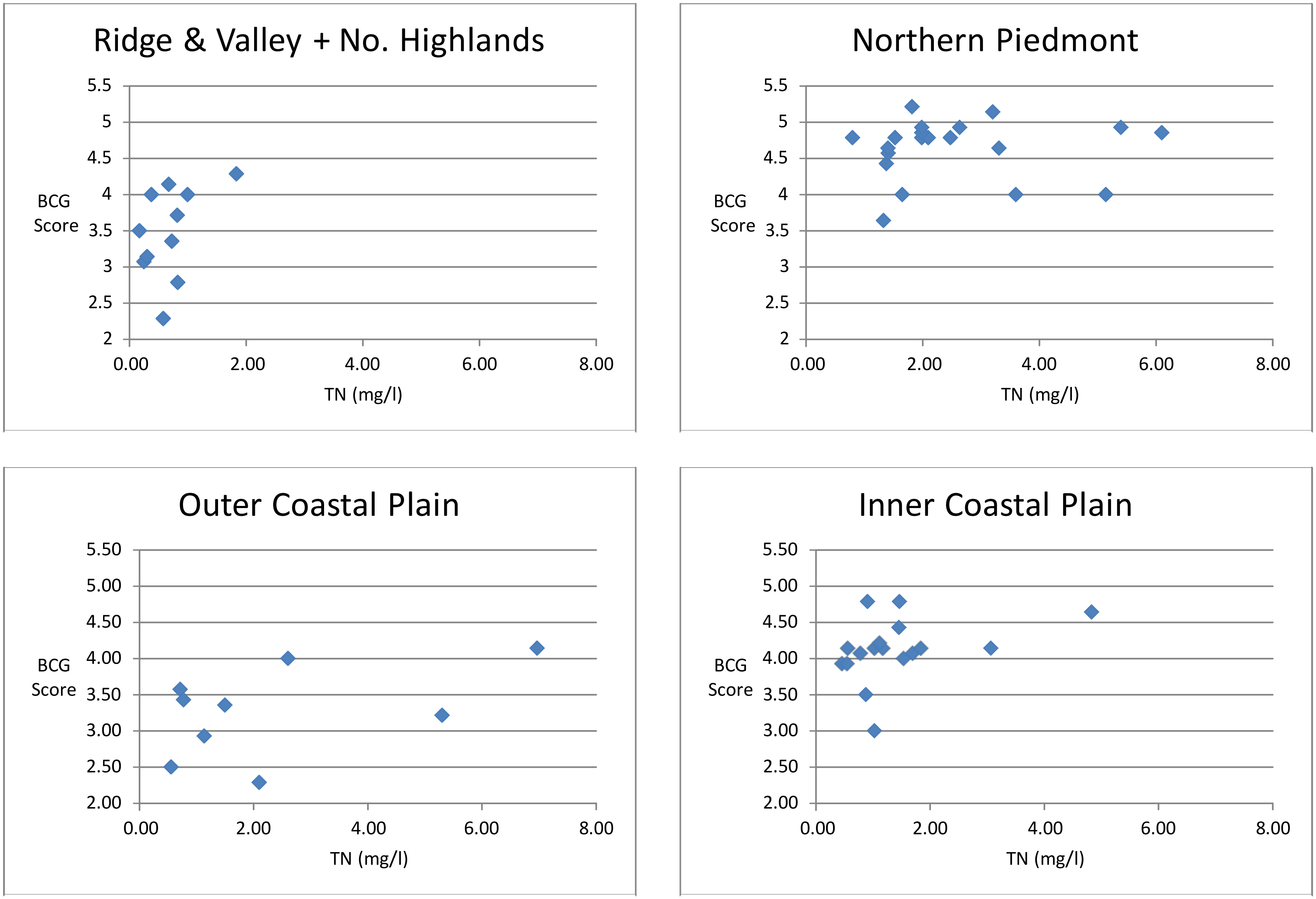


Figure 7 BCG Workshop Score versus Total Nitrogen Concentration for All Ecoregions