Diatoms and the Biological Condition Gradient in New Jersey Rivers and Streams:

A basis for developing nutrient guidance levels

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Executive Summary

The purpose of this study was to develop the basis for scientifically defensible regulatory guidelines for aquatic life designated uses and biotic integrity using algal diatoms. It incorporated a consensus-building process based on USEPA's biological condition gradient. Primary data for this study were collected by the Academy of Natural Sciences' Patrick Center between 2000-2005 as part of a state-wide monitoring study to develop protocols and an assessment methodology for using algal diatoms to assess freshwater quality, specifically as it applies to nutrients and cultural eutrophication. The primary goal for this previous five year assessment was to bolster NJ's extant quantitative nutrient criteria (and narrative policies) through establishment of scientifically defensible response indicators (trophic diatom index or TDI); and to augment the state's routine water quality monitoring network. This project assessed the relationship between benthic diatom and water chemistry samples collected from over a hundred sites in five New Jersey ecoregions: Northern Piedmont, Northeastern Highlands, Ridge and Valley, and Inner and Outer Coastal Plains. Multivariate analysis showed that nutrient concentrations explain significant proportions of the variation in diatom species composition. Nutrient inference models and the two TDIs developed (northern and southern New Jersey) provided good measures of biological response to nutrient conditions.

In the subsequent study, described here, the Patrick Center determined ranges of diatom phosphorus and nitrogen TDIs that reflect protection of specific designated uses under the Clean Water Act; primarily aquatic life and biotic integrity. To do this, the Patrick Center used a conceptual model that describes ecological changes, from pristine to completely degraded, that take place in flowing waters with increased anthropogenic degradation. This model, called the Biological Condition Gradient (BCG), promotes more consistent application of the Clean Water Act by identifying tiers or condition classes that can be operationally defined in a consistent manner. The BCG is broken up into tiers or categories, each described by narrative statements on presence, absence, abundance, and relative abundance of several groups of diatom taxa. These statements are consensus best-professional judgments based on years of experience of many biologists in a region, and reflect accumulated biological knowledge. The goal of the diatom BCG study was to define ecological attributes for diatom taxa and assemblages that can be used with a set of rules to assign sites to tiers on the BCG. This process assigned 57 sample sites selected from the TDI database to four categories of ecosystem impairment (representing minor to major change from natural condition). Assignments of sites to BCG Categories were based on diatom assemblage composition only (no environmental data provided) and were made by seven diatomists at an expert-panel workshop. Boundaries between the BCG Categories were used to divide sites into excellent, good, fair, or poor ecological condition. The last step was to relate the phosphorus and nitrogen TDIs to BCG Category boundaries to specify ranges of TDI index values that distinguish sites with acceptable and unacceptable nutrient conditions.

The first step in this study was to develop a stressor gradient based on water chemistry, physical habitat and land-use data collected for the sites. Statistical analyses showed that several stressor variables were more important than others, that they can correlate with each other, and that they vary in importance among ecoregions. Defining a stressor gradient along which study sites could be arranged was necessary for both preliminary assignments of taxa to BCG Categories and to compare with assignments of sites to BCG Categories by diatom experts and NJDEP

biologists. Stressors were defined as water chemistry and physical habitat variables strongly influenced by human activities that potentially influence aquatic communities. They can result from point and non-point sources, habitat alteration, hydrologic modification, and other factors. They did not include biological factors. Nor did they include nutrient measures because results of the BCG calibration were to be used to help define nutrient-criteria categories. Physical habitat variables included land-use characteristics of the entire watershed above the sampling point (% forest plus wetland, % urban, and % agriculture) and physical habitat features of the immediate sampling locations (channel alteration, bank vegetative protection, riparian vegetative zone width, and % open). The water chemistry variables included chloride, conductivity, dissolved oxygen (DO; mg/L, average % saturation, and minimum % saturation), temperature (average and maximum), biochemical oxygen demand (BOD), turbidity, and bacteria counts (fecal coliform).

Study sites and samples could be classified clearly into southern and northern New Jersey zones based on both diatom assemblages and environmental characteristics. All northern sites were high-gradient streams with rock substrates; all southern sites were low-gradient with no rock substrate, only sand, silt and clay. Within the northern zone, there were sufficient differences in diatom assemblages and environmental characteristics to distinguish the Northern Piedmont from the combined Ridge and Valley and Northern Highland ecoregions. Though there were some differences between the latter two, they were not sufficient to keep them separate for data analysis. In the southern zone, there were significant differences between the Inner Coastal Plain and Outer Coastal Plain ecoregions. The Inner Coastal Plain sites generally had higher nutrient concentrations, and somewhat higher pH and conductivity, and many were turbid due to silt and clay (based on visual assessment).

Comparisons of the stressor gradient with biological data showed that diatom assemblage composition was responsive to the stressor variables and was therefore potentially a good indicator of stress. Statistical analysis showed that the eight environmental variables used to derive the stressor-gradient could each explain significant amounts of variability in assemblage composition, alone and in combination. Land-use percents, chloride, and riparian vegetation explained the greatest amounts of variation. An implication of these results is that if human activities were managed to reduce the stress from these variables, ecological conditions represented by diatom assemblages could be improved.

Taxa were then assigned to BCG Attributes based on their distribution along stressor gradients represented by percent land-use categories, chloride, conductivity, DO, temperature, and stressor-scores. Taxa were assigned only to Attributes II-V; there was insufficient information to determine that a taxon was in Attribute I (historically documented) or VI (non-native or intentionally introduced). Taxa were assigned to Attribute II (sensitive-rare) if they were most abundant in the low-stress sites and occurred there almost exclusively; usually they were less abundant taxa. Taxa were assigned to Attribute III (sensitive / ubiquitous) if they were primarily in low-stress sites, and their relative abundance declined with increasing stress; they were typically taxa often found elsewhere in undisturbed sites. Taxa were assigned to Attribute IV (intermediate tolerance) if they were distributed throughout the length of the stress gradients; most species were assigned this Attribute. Taxa were included in Attribute V (tolerant taxa) if they were most abundant in the higher-stress sites and were in less abundance in the lower-stress sites.

The assignments of sites to BCG Categories provided by diatom experts at the workshop then served as the basis for calibrating BCG decision models. In making their decisions, diatomists relied primarily on abundance of the more common taxa and their knowledge and experience about ecological conditions of sites where those were most often found. Of the 57 sites evaluated by the expert panel, 2 were in BCG Category 2 (assemblages like natural communities but with additional species) 10 in Category 3 (mostly sensitive-ubiquitous taxa), 27 in Category 4 (increased abundance of intermediate tolerant and tolerant taxa), and 18 in Category 5. No sites were assigned BCG Categories 1 or 6 as most experts envisioned a BCG Category 6 diatom assemblage as being heavily dominated by one or a few Very Tolerant taxa, typical of what is reported in the literature for sites below sewage treatment plant or industrial outfalls. Due to site selection restrictions in the TDI development, no such assemblages were among those evaluated. Among northern zone ecoregions, the Ridge and Valley and Northern Highlands had the lowest average BCG Category (least impaired BCG Category) and the Northern Piedmont the highest (most impaired). In the southern zone, the Inner Coastal Plain on average had higher BCG Categories (e.g., 4s and 5s) whereas the Outer Coastal Plain was mostly lower (e.g., less impaired sites, 2s and 3s). BCG scores were generally greater for sites with higher percents of non-forest land-use. For example, all sites with BGC scores greater than 4.0 had < 50% forest + wetland land-use. The importance of land-use stressors varied among ecoregions.

A key step in the BCG calibration process is to develop decision rules to assign sites to BCG Categories based on diatom count data. Participants at the diatom expert-panel workshop recommended basing decision-rules primarily on the percents of diatoms in the BCG Attributes (e.g., % Tolerant). Rules must be based on a thorough examination and understanding of how percents in Attributes (sensitive to tolerant species) vary with site BCG Categories (2 to 5). Though these relationships are strong and expected, they are not, on their own, sufficient to unequivocally assign new samples to BCG Categories. Additional criteria would need to be used, possibly diatom metrics, indicator taxa, water chemistry characteristics, or land-use.

Relationships of nutrients to other stressors and diatom data were analyzed as part of the process of developing nutrient guidance options. Total phosphorus concentrations collected in the TDI studies ranged from 15 to over 700 µg/L, though most values were less than 200 µg/L; TN ranged from about 0.5 to over 8 mg/L, though most values were less than 4 mg/L. The proportions of taxa in BCG Attributes vary consistently with TP and TN, and can be used as a basis for assigning samples to nutrient categories. Sensitive taxa (BCG Attributes II and III) are associated with low nutrient concentrations, Intermediate Tolerant taxa with moderate to low concentrations, and Tolerant taxa with higher nutrient concentrations. Inner Coastal Plain sites have a somewhat different pattern than the other three ecoregions in that high TP concentrations are associated with higher proportions of sensitive taxa and lower proportions of tolerant taxa. Proportions of sites in BCG Categories also vary consistently with TP and TN concentration. Sites with lower average BCG scores are associated with lower nutrient concentrations and vice versa. Inner Coastal Plain sites have higher phosphorus concentrations for BCG scores greater than 4.0 compared with other ecoregions, but nitrogen relationships are comparable.

Options for nutrient criteria were developed by examining phosphorus and nitrogen concentrations associated with boundaries between BCG Categories. NJDEP has used the boundary between BCG Category 4 and 5 in another study using macroinvertebrates to distinguish sites supporting (unimpaired) or not supporting (impaired) the interim goals of the Clean Water Act, based on Jackson and Davies (2006). This boundary was used in this study to identify nutrient concentrations associated with unimpaired sites (BCG Categories 2-4). Because each ecoregion had different ranges of phosphorus and nitrogen, it was most appropriate to examine each separately. These BCG boundaries were then compared with the New Jersey TDIs because they are based on a direct relationship between the index values and measured phosphorus and nitrogen concentrations. The TDIs varied linearly with the average workshop BCG scores and distinguished reasonably well between workshop BCG Categories.

In general, results show that diatom assemblages are responsive to a variety of stressors affecting NJ streams and that they contain sufficient ecological information to assign sites to BCG Categories. These relationships correspond with nutrient concentrations and can be used to help develop regulatory guidelines for nutrients. There are several issues related to limitations and uncertainties in these relationships. Yet the scientific basis, applicability, and procedures for using diatoms as the basis of numeric nutrient criteria can be improved by further study. Additional sampling should be done to represent a wider range of nutrient concentrations, especially to provide more even distributions within individual ecoregions. More sites should be sampled that are in as close to natural conditions and severely impaired conditions (e.g., below STP and industrial outfalls) as possible to help better identify taxa in Attributes II and VI, which will in turn help better assign sites to BCG Categories. Water chemistry, including nutrients, and diatoms should be sampled more frequently to provide better quantification of site nutrient conditions and temporal variability.

Introduction

Excess nutrients are one of most important water quality problems in New Jersey and many other areas of the US. Agencies have a significant need for science-based nutrient criteria to serve as a basis to better protect rivers and streams. One of the most relevant and effective approaches for developing regulatory guidelines for nutrients is to base them on relationships between nutrient concentrations and biological indicators of ecological condition and designated uses. Diatom algae have one of the strongest relationships with nutrient concentrations of all aquatic biota and have been used widely as trophic and impairment indicators. But most of the relationships developed to date are continuous, and it is difficult to identify response thresholds that could be used to set nutrient regulatory boundaries. The Biological Condition Gradient approach provides a process for creating categories defined in terms of levels of impairment that can then be used to develop regulatory guidelines for nutrients. We applied the BCG approach to diatom assemblages in New Jersey rivers and streams and associated the resulting category boundaries with N and P concentrations and corresponding diatom nutrient indices. Guidelines for regulating nutrients are presented that could be employed to help protect streams from impairment due to increased nutrient concentrations.

Background

The NJDEP funded a five year study by the Patrick Center for Environmental Research at the Academy of Natural Sciences of Philadelphia, to develop state-wide monitoring protocols and an assessment methodology for use with algal diatoms to assess freshwater quality, specifically as it applies to nutrients and cultural eutrophication (Ponader et al. 2007, 2008). The primary goal was to bolster NJ's extant quantitative nutrient criteria (and narrative policies) through establishment of scientifically defensible response indicators (diatom total phosphorus (TP) and total nitrogen (TN) indices); and to possibly augment the state's routine water quality monitoring network. We assessed the relationship between benthic diatom and water chemistry samples collected from 77 river and stream sites in 5 NJ ecoregions: Northern Piedmont, Northeastern Highlands, Ridge and Valley, and the Inner and Outer Coastal Plains. Multivariate analysis showed that nutrient concentrations explain significant proportions of the variation in diatom species composition. Nutrient inference models and indices that we developed provide good measures of biological response to nutrient conditions.

The next step in the process of developing nutrient criteria was to establish impairment scores, based on the Diatom TP and TN Indices, that reflect protection of designated uses, primarily aquatic life and biotic integrity. This process is problematic, however, because a selection of these 'bright line' scores requires a re-assessment of available data, from both a technical and a policy perspective, with consensus of respected scientists a key step in translating obtuse technical jargon into clear water-quality goals. To that end, the U.S. EPA has required and supported state efforts to develop uniform assessments of aquatic resource condition and to set more uniform aquatic life protection and restoration goals. These efforts have led to a conceptual model that describes ecological changes, from pristine to completely degraded, that take place with increased anthropogenic degradation. This model, called the Biological Condition Gradient

(BCG) (Davies and Jackson 2006), promotes more consistent application of the Clean Water Act by identifying tiers or condition classes that can be operationally defined in a consistent manner.

The BCG approach defines categories of impairment due to human activities based on presence, absence, abundance, and relative abundance of several groups of taxa, as well as statements on system connectivity and ecosystem attributes (production, material cycling). The statements are consensus best-professional judgments based on years of experience of many biologists in a region, and reflect accumulated biological knowledge. In 2004, NJDEP received a grant from the U.S. EPA to work with their contractor Tetra Tech in performing a BCG assessment of New Jersey's large macroinvertebrate (AMNET) biomonitoring dataset (Gerritsen and Leppo 2005). A report was published describing the successful application of the BCG to streams in New Jersey and the development of operationally defined tiers for setting restoration goals and aquatic life protection criteria.

A similar approach was applied in this current project. Following EPA guidance (Gerritsen 2008), we defined ecological attributes for diatom taxa and assemblages that can be used with a set of rules to assign sites to BCG Categories. Algal taxonomists and ecologists at the ANSP performed most of the work to assign taxa to ecological categories; NJ DEP staff provided the primary data and expertise to help characterize levels of impairment of sites and evaluate how well diatom indicators define categories, and made recommendations for improvements. Two initial meetings and several smaller meetings and conference calls were held that included ANSP staff and aquatic biologists familiar with New Jersey streams. Their purpose was to help develop and guide the project. Participants included biologists from the NJDEP, USGS, USEPA, and the Delaware River Basin Commission. Their expertise included aquatic ecology, benthic algal sampling and monitoring, water quality, and phycology. A workshop of diatom experts was also convened to assess the overall development of diatom indicators, to help assign taxa to BCG Attributes, and to make expert judgments assigning a set of diatom assemblages (counts) to BCG Categories.

This project used data developed by ANSP for all its previous NJ DEP funded projects, as well as those associated with the USGS National Water Quality Assessment Program (NAWQA), in both northern and southern NJ.

The Biological Condition Gradient

The Biological Condition Gradient, as originally proposed by Davies and Jackson (2006) and being implemented by the US EPA (Gerritsen 2008), is a conceptual model relating biological response to a generalized gradient of stress caused by human activities. It is designed to apply to aquatic systems in the U.S, and has been tested and implemented primarily using benthic macroinvertebrates and fish. This is one of the first studies applying the approach to algae. The BCG is intended to provide a nationally consistent approach that will allow BCG status to be compared among different types of aquatic ecosystems and geographic regions.

Characteristics of biota are classified into BCG Attributes, in this study based primarily on response of diatom taxa to stress. Sites are classified into BCG Categories that represent their position along the condition gradient from undisturbed to extremely disturbed.

Taxonomic Composition Attributes

We used the same attribute categories as used for the NJ benthic invertebrate TALU study (Gerritsen and Leppo 2005), originally presented by Davies and Jackson (2006) and as defined in Gerritsen (2008), quoted below:

"Species differ in their sensitivity to pollution and disturbance. Sensitivity to pollution and tolerance to stressors are used to assign species to six of the ten attributes of the BCG. These six attributes have been found sufficient to assess sites on the BCG for free-flowing streams. … Only Attributes I through VII are discussed here because Attributes VIII through X have not yet been applied to bioassessment. Descriptions below are modified from Davies and Jackson (2006).

Attribute I: Historically documented, sensitive, long-lived or regionally endemic taxa refers to taxa known to have been supported in a waterbody or region prior to enactment of the Clean Water Act. Predictability of their occurrence is often low, requiring documented observation. Recorded occurrence may be highly dependent on sample methods, site selection and level of effort.

A critical issue for rare or endemic species is sampling. Routine monitoring, whether for fish or invertebrates, is inappropriate for determining presence/absence of rare species. Rare species require a sampling design that is targeted for finding them (broad survey of appropriate habitats; more intensive sampling only when the rare species are found, and other techniques; Green and Young 1993, Marchant 2002). Routine sampling may record occasional "lucky hits" of rare species, but lack of observation of rare species is unreliable as an indicator of absence, unless a targeted and documented sampling effort has been made to find the rare species. Information from natural heritage programs, state wildlife agencies, and the US Fish and Wildlife Service is likely to be more useful than routine monitoring data.

Attributes II through V: Sensitive and tolerant taxa – These are the taxa groups that form the backbone of bioassessment indexes of streams, for both macroinvertebrate and fish indexes.

Attribute II: Highly Sensitive Taxa: taxa that often occur in low numbers relative to total abundance at a site but may make up a large relative proportion of richness. These are the taxa that are the first to disappear following moderate disturbance or pollution …. In high-quality sites, they may be ubiquitous in occurrence or may be restricted to certain micro-habitats. Many of these species commonly occur at low densities, thus their occurrence is dependent on sample effort. They may have specialized food resource needs or feeding strategies and are generally intolerant to significant alteration of the physical or chemical environment.

In earlier descriptions of the BCG, these were called "sensitive-rare" taxa (Davies and Jackson 2006), but experience with calibrating the BCG showed that some highly sensitive species are found at many exceptional sites and some were occasionally highly abundant (e.g., Snook et al., 2007). The distinguishing characteristic was found to be sensitivity and not relative rarity, although some of these taxa may be uncommon in the data set (e.g., 1 or 2 occurrences in 100 samples).

Attribute III: Intermediate Sensitive Taxa, (or Sensitive and Common Taxa): taxa that are ordinarily common and abundant in natural communities …. They often have a broader range of tolerances than Highly Sensitive taxa, and usually occur in reduced abundance and reduced frequencies at disturbed or polluted sites. These are taxa that comprise a substantial portion of natural communities, and that often exhibit negative response (loss of population, richness) at mild pollution loads or habitat alteration.

Attribute IV: Taxa of Intermediate Tolerance: taxa that make up a substantial portion of natural communities; they may be early colonizers with rapid turn-over times. They may be eurythermal (having a broad thermal tolerance range), and many have generalist or facultative feeding strategies enabling utilization of diverse food types. They are readily collected with conventional sample methods. These species have little or no detectable response to a stress gradient … , and are often equally abundant in both reference and stressed sites. Some intermediate taxa may show an "intermediate disturbance" response, where densities and frequency of occurrence are highest at intermediate levels of stress.

Attribute V: Tolerant Taxa: Taxa that make up a low proportion of natural communities. These taxa often are tolerant of a greater degree of disturbance and stress than other organisms and are thus resistant to a variety of pollution or habitat induced stress. They may increase in number (sometimes greatly) under severely altered or stressed conditions, and may possess adaptations for highly enriched conditions, hypoxia, or toxic substances …. These are the last survivors in severely disturbed systems.

Attribute VI: Non-native or Intentionally Introduced Species: with respect to a particular ecosystem, any species that is not native to that ecosystem. Species introduced or spread from one region of the U.S. to another outside their normal range are non-native or non-indigenous, as are species introduced from other continents." (Gerritsen 2008). Because it is not possible to identify if diatom taxa are non-native or introduced, Attribute VI was redefined for this study to mean Very Tolerant, usually found in abundance only in highly stressed conditions.

Levels (Categories) of the Biological Condition Gradient

We used descriptions of BCG levels presented in Davies and Jackson (2006), and quoted from Gerritsen (2008), below.

"In most stream ecosystems it is possible to discriminate six levels in the condition gradient, ranging from undisturbed natural condition to severely degraded and almost devoid of natural life (Davies and Jackson 2006). The levels are described in terms of changes in the structure and function of native aquatic communities (but note that empirical applications of the BCG have so far not incorporated the functional or spatial attributes).

> 1. Natural structural, functional and taxonomic integrity is preserved within the range of natural variability.
>
> 2. Structure and function similar to natural community with some additional taxa and biomass; ecosystem level functions are fully maintained.
>
> 3. Evident changes in structure due to loss of some highly sensitive native taxa; shifts in relative abundance; ecosystem level functions fully maintained; sensitive-ubiquitous taxa are common and abundant.
>
> 4. Moderate changes in structure due to replacement of sensitive ubiquitous taxa by more tolerant taxa; ecosystem functions largely maintained; reproducing populations of some sensitive taxa are maintained; overall balanced distribution of all expected major groups.
>
> 5. Sensitive taxa markedly diminished; conspicuously unbalanced distribution of major taxonomic groups; ecosystem function shows reduced complexity & redundancy; organism condition shows signs of physiological stress; increased build-up or export of unused materials.
>
> 6. Extreme changes in structure and ecosystem function; wholesale changes in taxonomic composition; extreme alterations from normal densities; organism condition is often poor; ecosystem functions are severely altered." (Gerritsen 2008)

Though there are potentially six BCG Categories, NJ DEP, USGS, and ANSP biologists familiar with the study sites and environmental data determined at meetings at the beginning of the study that no sites were in natural condition and therefore could not be considered in BCG Categories 1 or 2. Also, they determined it was likely that none were so severely impaired as to be in BCG Category 6. Therefore, we used only BCG Categories 3, 4, and 5 in most of our analysis. The main reason BCG Category 1, 2 and 6 sites were not included in the study was that site selection was constrained to the set originally chosen for studies of how algal assemblages varied along a nutrient gradient. In the original site selection process the goal was to select sites as evenly spaced along TP and TN gradients as possible. Also, it was not possible to find largely undisturbed sites (BCG Categories 1 and 2) among the AMNET monitoring sites, and highly disturbed sites (BCG Category 6) were purposely avoided because non-nutrient stressors at these sites might confound the process of quantifying algae-nutrient relationships. It is highly likely that nutrient-impaired sites exist that would be considered in BCG Category 6, but they were not included in this study.

Project Implementation Stages

The following tasks describe the steps planned to implement this project.

Task 1. Hold first workshop with project participants and panel of experts on ecological condition of New Jersey streams. Review overall plans and approach for project. Characterize dominant stressor-response relationships. Identify datasets to help characterize impairment / disturbance gradient among study sites.

Task 2. Assemble and update ANSP NJAI diatom and environmental data.

Task 3. Assemble environmental data available from NJ DEP on ecological condition and impairment of NJ streams and their watersheds. Develop a stressor gradient for study sites and use it to assign sites a stressor gradient score.

Task 4. Review and analyze diatom assemblages from the NJ study sites to determine ecoregions or stream types for which it would be necessary to develop separate classification systems. At a minimum there would be systems for northern NJ and southern NJ (Coastal Plain). Classify sample sites based on "natural" ecological characteristics.

Task 5. Use ecological and stressor-gradient data derived from NJ datasets to assign diatom taxa found in NJ samples to BCG Attributes (Gerritsen and Leppo 2005).

Task 6. Convene workshop of diatom experts to 1) review assignment of taxa to BCG Attributes, 2) assign sites to BCG Categories based on their assessment of diatom assemblages, and 3) develop a basis for rules for assigning new diatom sample assemblages to BCG Categories, and 4) review the overall diatom-TALU process and make recommendations for improvements.

Task 7. Use NJ diatom data, including percents of diatoms in BCG Attributes to calculate BCG Categories for each site. Test and evaluate rules and metrics for doing this and make improvements. Identify which rules and guidelines are best for distinguishing BCG Categories based on impairment data, and position on the impairment / disturbance gradient. Also, evaluate relationships between BCG scores and diatom indices with the goal of determining nutrient concentration boundaries that correspond with the BCG boundaries. Work with NJ DEP to determine BCG Categories that correspond with poor, fair, good, and excellent. Take into account ecoregion differences. Examine relationships between BCG Category boundaries (above) and nutrient concentrations; agree on nutrient concentrations that could constitute nutrient guidance levels discuss variability and application in different ecoregions and implementation options.

Task 8. Hold additional workshops and meetings to review preliminary results and make recommendations on criteria development approaches and plans for preparation of final report.

Study Sites and Data Sources

Study sites

All 95 study sites are located in NJ and were sampled as part of the New Jersey Algal Indicators study (NJAI) (Ponader et al. 2007, 2008) (77 sites), or the USGS National Water Quality Assessment program (NAWQA) (18 sites). All of the NJAI sites are part of the NJ Ambient Biomonitoring Network (AMNET) monitoring program (NJ DEP 2006). Some of the NAWQA sites are located at NJ AMNET sites. The sites cover a range of stream and watershed sizes and chemistry (Appendices 7 and 8) are typical for the ecoregions studied. Sites were originally chosen to represent a gradient from low to high nutrient concentrations; ranges in other water chemistry and physical habitat characteristics were minimized. Sites with pH less than 5.5 were avoided. Site location information, including name, description, GPS coordinates, county, elevation, and Level III ecoregion (Omernik 1987, 1995) were obtained from the NJDEP and USGS.

Sites are located throughout NJ, in four ecoregions (Figure 1). Sites in the Atlantic Coastal Pine Barrens Ecoregion were categorized as Inner Coastal Plain (ICP) or Outer Coastal Plain (OCP) according to classifications used during the NJAI study, based on Wolfe (1977). Sites were also classified as being in either the northern NJ "zone" or the southern NJ "zone." The Atlantic Coastal Pine Barrens and the Middle Atlantic Coastal Plains were categorized as being in the southern NJ "zone," while all other NJ sites were assigned to the northern NJ "zone." Only a few sites from the Pinelands were included, primarily because diatoms were studied as part of previous Pinelands studies (Zampella 2007).

Environmental data

Environmental data were obtained from three main sources: the NJAI Study, the USGS NAWQA program, and NJ DEP's AMNET and other sampling programs. The composite dataset is included as Appendix 8, and is further described in the Appendix 1 (Data Dictionary) and Tables 1 and 2.

The NJAI Study provided data for 141 samples, 101 from Northern NJ and 40 from Southern NJ. The 33 parameters used included nutrient concentrations, and other water chemistry, substrate, land use, canopy cover, and biomass variables. Methods are described in Ponader et al. (2007, 2008). The web version of this dataset is available online at http://diatom.ansp.org/autecology/. It includes averages calculated across all samples from a single site and year in cases where multiple samples were collected; this was the norm for Southern NJ sites, where chemistry data were collected during diatometer deployment and retrieval. Supplemental, unpublished chloride, hardness, total Kjeldahl nitrogen (TKN), and ammonia data, also from the NJAI study, were available for several Northern NJ sites, and were averaged in the same fashion as the web-accessible data. NJAI substrate data for 98 Northern NJ samples and 16 Southern NJ natural-substrate samples were used.

NAWQA environmental data were downloaded from the NAWQA Data Warehouse (http://infotrek.er.usgs.gov/nawqa_queries/swmaster/index.jsp). Data collected from NAWQA sites in NJ and pertaining to the following parameter groups were downloaded in "serial" format: biological, major inorganics, nutrients, physical properties, and sample information. Analysis methods are documented in the Data Warehouse. Specific parameters included in our dataset can be found in Table 2. Environmental data were matched to NAWQA diatom data, which were taken from the Patrick Center's algal database, the North American Diatom Ecological Database (NADED). Data were matched by site and season. Environmental data that had a collection date closest to the diatom collection date were selected; in no case were collection dates more than 365 days apart. Seasons were defined according to the meteorological standard, as follows: winter spans the entire months of December, January, and February; spring spans March, April, and May; summer spans June, July, and August; and autumn spans September, October, and November. In cases where multiple measurements of the same environmental parameter were taken at the same site and on the same day, the first measurement was chosen. However, for stream width data, the measurements nearest in time to the corresponding diatom samples were selected, and not subject to any other timing criteria. Land-use data for NAWQA sites were provided by James Falcone of USGS and were collected between 2000 and 2002. Ultimately, environmental data corresponding to 19 NAWQA diatom samples from nine sites were incorporated into the environmental dataset.

We downloaded water chemistry data for 53 sites from the National Water Information System (NWIS) website (http://waterdata.usgs.gov/nwis/dv/?referred_module=sw). The NWIS database contains information for both NJ DEP and USGS sites, and therefore all the NJAI sites (Appendix 2). Daily surface-water parameters that were considered for use are listed in Table 1, and the dataset itself is displayed in Table 1, Appendix 9 (avg_nwis_data.xls). Only data collected between June and September were used, and data were averaged in cases where multiple values were available per site and parameter.

Habitat data for NJAI sites, generated by NJDEP's Ambient Biomonitoring Network (AMNET), were provided by Tom Miller of NJDEP (see http://www.state.nj.us/dep/wms/bfbm/downloads.html for relevant publications). These data constituted semi-subjective ratings of various habitat characteristics, sometimes featuring different scores for the left and right banks of the stream site (see the AMNET standard operating procedures document by Poretti, Bryson, and Miller (2008) for more information on these parameters). Left-bank and right-bank values for habitat parameters were averaged together. The habitat assessments made nearest in time to the corresponding diatom samples were used; in case of ties, the most recent sets of habitat measurements were used. No other temporal criteria were imposed.

We also used invertebrate metrics generated by the NJ Invertebrate TALU study (Gerritsen & Leppo 2005) in our analyses. Jeroen Gerritsen of TetraTech supplied these data for the NJAI sites, from which we extracted metrics calculated from 70 samples collected nearest in time to the corresponding diatom samples in our dataset. In case of ties, the most recent sets of invertebrate metrics were used. No other temporal criteria were imposed. The High Gradient Macroinvertebrate Index (HGMI, Jessup 2007) used in northern NJ and the Mid-Atlantic Coastal Plain Index (MACS; Maxted et al. 2000), used in southern NJ outside the Pinelands, were re-scaled to similar ranges of values. This was done by dividing their original ranges into four main categories, and then subdividing those category ranges into four subcategories to create a total of 16. Categorization of invertebrate metrics into the four main categories was performed according to Appendix B of NJDEP's AMNET standard operating procedures document (Poretti, Bryson, & Miller 2008). The 16 categories represent four assessment ratings (1-4 = Poor; 5-8 = Fair; 9-12 = Good; 13-16 = Excellent). Values for both rescaled metrics were combined into a new variable named NJ 16-Category Macroinvertebrate Index (NJMI-16-Cat).

After compiling environmental data, some processing was done before analysis. The percent forest and the percent wetlands land-use categories from NJAI were combined so they would be compatible with NAWQA's percent undeveloped category.

Diatom count data

All diatom counts were performed by analysts in the Patrick Center's Phycology Section, as part of either the NJAI or NAWQA studies, and were obtained from NADED. The current study used the same NJAI counts that were used in Ponader et al. (2007, 2008), with the addition of 16 natural-substrate samples collected from southern NJ sites. These additional samples were collected in conjunction with the diatometer samples at those same sites; results have not been published. The natural-substrate samples were collected to compare diatom assemblages with those from the diatometers. The NAWQA samples were collected from throughout NJ, excluding the Delaware River because it is much larger than the other study sites. Samples were collected from Richest Targeted Habitat (RTH) substrates using NAWQA protocols (Moulton et al, 2002). All samples were processed and analyzed according to USGS-approved protocols described in Charles et al. (2002). All taxon diatom names were updated to current taxonomy used at the ANSP as of June 2009 (NAWQA 2004-start taxonomic system; http://diatom.acnatsci.org/nawqa/taxalist.asp).

Data sets

Because sources of data contained different combinations of variables, and many variables had missing values, it was not possible to create one composite dataset to meet all needs. The main datasets used for data analysis are described below. Individual samples comprising each dataset are described in Appendix 2.

<u>201 sample diatom count dataset.</u> All available NJAI and NAWQA diatom samples described above, including multiple samples collected in the same sample reach. This dataset was used primarily for exploring patterns among assemblages and classifying sites based on assemblage composition. The main goal in creating this dataset was to include as many diatom counts as possible.

<u>140 sample diatom count and environmental datasets.</u> All diatom samples in the 201-sample set that have a corresponding basic set of environmental data. This dataset was used primarily to calculate environmental optima of diatom taxa and to help assign taxa to BCG Attributes. It was designed to include as many diatom counts as possible that had corresponding environmental data for basic set of parameters.

<u>77 sample NJAI diatom count and environmental dataset.</u> One diatom sample representing each NJAI study site, and corresponding environmental data.

73 sample diatom count and environmental datasets. One diatom sample representing NJAI and NAWQA sites for which there was also NWIS environmental data. This dataset had the most complete set of stressor-variables and was used to help develop and evaluate stressor gradients. The 57 diatom samples evaluated at the diatom expert-panel workshop were randomly selected from this dataset.

52 sample diatom count and environmental datasets. Subsets of the 73 sample datasets that had the most complete set of environmental data from all sources combined. This dataset was used primarily for multivariate analysis to examine and quantify relationships between diatom assemblages and as broad a set of environmental variables as possible to help assess which had the greatest influence on assemblage species composition.

Data analysis

Diatom data were converted to percent and log (+1) transformed prior to all analysis. All taxa were included in multivariate data analysis. All environmental parameters except pH were log-transformed.

We used Detrended Correspondence Analysis (DCA) of the 201 diatom count dataset, with detrending by 26 segments and down-weighting of rare taxa, to explore and classify patterns of diatom assemblage distributions. We used DCA because there was a strong horseshoe effect with CA. We also used DCA to assess the amount of variation among the diatom assemblages (ter Braak 1995). The gradient lengths of the first and second ordination axes were 5.07 and 3.36, respectively, both greater than 3.0, so we determined that underlying relationships between diatom distributions and environmental variables were better represented by unimodal than linear models (ter Braak and Prentice 1988). Principal Components Analysis (PCA) was used to examine and develop stressor gradients using primarily the 73-sample environmental dataset. Separate analyses were done with groups of variables representing water chemistry, land-use and habitat stressors to determine which individual stressor best represented the others in the group. The best representatives of each group were then combined to determine an overall stressor gradient. Forward selection in CCA was also run to identify the key variables within stressor-variable groups that explained most variation in diatom assemblages, and to compare with the PCA results. Multivariate analysis to determine the relative roles of environmental factors in explaining variation in diatom assemblage data was performed using Canonical Correspondence Analysis (CCA) and the 104, 73, and 52 sample datasets. The smaller datasets with larger number of environmental variables was used to identify a key set of the most important variables. The larger dataset with fewer variables was used to assess the relative importance of the key variables among a larger number of diatom samples. Relationships between abundance of individual diatom taxa and environmental stressor gradients were examined and plotted using PC-ORD. Diatom metrics were calculated using the Phyco-AIDE software application created in the PCER Phycology Section. The C2 program (Juggins 2003) was used to calculate abundance weighted mean (AWM) and tolerance values for diatom taxa.

CA and CCA ordinations were performed using CANOCO for Windows, version 4.5 (ter Braak and Šmilauer 2002). PCA and plots of taxa vs. environmental gradients were produced with PC-ORD version 5.10 (McCune and Mefford 2006). Diatom taxa abundance weighted mean values were calculated using C2 (Juggins 2003). Scatterplots and boxplots were made using SigmaPlot v. 11.

Project meetings and workshops

To maximize scientific accuracy and the usefulness of results for the NJ DEP, it was important to involve NJ DEP staff and outside diatom experts. Two workshops were held, plus several meetings at the beginning and ending phases of the project.

Project planning meetings and workshops with biologists from NJ DEP and federal agencies. An initial workshop was held December 12, 2008 at NJ DEP in Trenton to plan the approach for the project, agree on study sites, and identify data sources. It was attended by NJ DEP and Federal agency biologists, including Tom Belton, Kevin Berry, Tom Miller, Jim Kurtenbach, Bob Limbeck, Jon Kennen, Andrew Tuccillo, and Don Charles. A follow-up meeting was held February 4, 2009 to further refine the study and make it consistent with EPA's application of the BCG approach. Participants included Tom Belton, Kevin Berry, Tom Miller, Tom Vernam, Jon Kennen, Jeroen Gerritsen and Don Charles. Several other meetings and conference calls were held between ANSP and NJ DEP participants.

Workshop of diatom experts. One of the most important components of the BCG / TALU process is the involvement of outside experts familiar with the taxonomy and ecology of a group of biota and use of that group to make biological assessments of environmental conditions (Gerritsen 2008; Davies and Jackson 2006, Gerritsen and Jessup 2006, 2007; Snook et al. 2007). To obtain this expert input, we convened the "New Jersey Diatom TALU Workshop: Using the Biological Condition Gradient Approach" on August 6 and 7, 2009 at the Academy of Natural Sciences, Philadelphia, PA. Diatom expert participants were Hunter Carrick, Pennsylvania State University; Dean DeNicola, Slippery Rock University; Rex Lowe, Bowling Green State University; Kalina Manoylov, Georgia College and State University; Marina Potapova, Academy of Natural Sciences; Jerry Sgro, John Carroll University ; and Jan Stevenson, Michigan State University. All have PhD's and several with many years experience in diatom ecology and taxonomy research. Tom Belton, Danielle Donkersloot, and Patricia Ingelido of the NJ DEP also attended. The workshop was organized by Don Charles and facilitated by Jeroen Gerritsen of Tetra Tech, the principal investigator of the effort to develop NJ TALU approaches using benthic invertebrates (Gerritsen and Leppo 2005). Following an overview of the BCG process and detailed explanation and discussion of BCG Categories, diatom experts were asked to review sets of diatom counts and metrics derived from those counts. Metrics provided were number of taxa, diversity, % dominant taxa (>10% abundance), % dominant taxon, Siltation Index, and % of diatom valves in the autecological categories of pH, saprobic, Bahl's diatom tolerance, nitrogen uptake metabolism, oxygen requirement, and specific conductivity); community metrics are included in Appendix 5. Assignments of taxa to autecological categories were those assembled and evaluated by Porter (2008) and Porter et al. (2008). A total of 57 separate counts were evaluated, first, 30 from northern NJ and then 27 from the south. Samples were selected randomly from the 73-sample dataset. The only environmental data provided to the experts was the size of the watershed above the sampling site. After the experts reviewed each count independently, the facilitator polled them to determine the BCG Category they had assigned and tallied results on a flip-chart. Results were discussed as a group, particularly the criteria used, as well as taxonomy and indicator values of individual taxa. Participants were given an opportunity to change their assignment. The BCG scores of the seven experts were averaged to obtain a final score for each of the 57 sites. These "Average Diatom Workshop BCG Scores" were used in many data analyses because they provided finer-scale resolution than whole-number categories. Sites were assigned a BCG Category by rounding the average score to the nearest integer (BCG Category 2 = ave. workshop score < 2.5; 3 = 2.5 – 3.4; 4 = 3.5 – 4.4; 5 = > 4.5). Participants also reviewed preliminary assignment of taxa to BCG sites that had been completed at the ANSP prior to the workshop, and recommended changes. These changes were incorporated in the taxa attribute dataset (Appendix 4) and subsequent analyses. Toward the end of the workshop, participants were shown, and discussed, relationships between their average BCG site scores and several stressor variables. They also made recommendations for the development of decision rules that could be applied consistently when assigning diatom counts to BCG Categories, and for future steps to further develop the diatom BCG approach.

State Biologist Stressor Review Meeting. To provide an additional independent assessment of assignment of sites to impairment categories, Tom Belton and others of the NJ DEP convened a Diatom TALU Stressor Review Meeting on September 4, 2009. Participants included state biologists familiar with water quality conditions in the state and with many of the study sites. They reviewed 30 sites and ranked 27 of them on a scale of 1 - 10 according to their perceived impairment status; this measure is hereafter referred to as the State Biologist Impairment Score. They considered PCA-stressor scores for sites, nutrient levels, macroinvertebrate index scores, habitat sheet scores, and collective memories from visiting each site as part of NJ DEP routine monitoring programs.

Results

Diatom species composition and diversity

The 201 samples had a total of 561 diatom taxa (8490 records) (Appendices 4 and 9). Of these, 15 occurred in 100 or more samples, 98 in 25 or more, 173 (32%) in 10 or more, and 273 (50%) in 5 or more; 151 taxa occurred in only one sample. Most of the common taxa are pollution-tolerant. The number of valves counted per slide, diversity, percent dominance and other basic metrics are presented in Appendix 5. All counts were of 600 or more valves, except one, sample (GSN24343), which was not included in data analysis. In the 201-sample dataset, taxa richness, diversity, and sum of % dominant taxa were comparable among the RV+NH, NP and OCP ecoregions. Richness and diversity were higher for the ICP than the other regions. Most ICP samples had more than 60 taxa; nearly all samples from other regions had less than 55 taxa. There was no relationship between number of taxa and basin size. Percent *Achnanthidium minutissimum* was in many samples in all ecoregions, but generally in less than 10% abundance. Highest values (10 – 25%; one site had values > 70%)) were in the RV+HL. Siltation Index values ranged from 1 to 88; highest values were in the NP and lowest in the RV+NH. Diatom taxa abundance weighted means (AWM) values were calculated for several environmental factors using the 201-sample dataset (Appendix 4) to provide information for the diatom workshop and general reference during the study. The AWM values of the PCA-stressor scores were calculated using the 140-sample dataset for all taxa that occurred in at least 10 samples

(Appendix 4). AWM values ranged from 1 - 10.   Of the 182 taxa occurring in 10 or more sites, most taxa had mid-range scores. Only 8 taxa had AWM values of 3 and 4; 21 taxa had values from 7 to 9; and the remaining values were 5 and 6.

Site classification

Study sites and samples could be classified clearly into southern and northern NJ zones based on both diatom assemblages and environmental characteristics. The DCA of the 201 diatom-sample dataset showed two distinct groups of sites, one corresponding to sites in the northern NJ zone and one in the southern zone. There were no other clearly distinguishable groups. A PCA of "natural characteristics" in the 73-sample environmental dataset also demonstrated north-south differences. An initial PCA was run with only variables presumed not to be strongly influenced by human activities (basin size, stream width, pH-field, alkalinity, % bedrock, % boulder, % cobble, % gravel, % sand, % silt-clay, latitude and longitude). Scores for all variables had a correlation with axis 1 or 2 of greater than 0.6 except longitude and % bedrock. Basin size and stream width correlated strongly ($r > 0.8$) with axis 2. Because some variables correlated strongly with each other, another PCA was run with a representative subset (pH, stream width, % cobble, and % silt-clay) (Figure 2). These variables typify the major differences between the northern zone and southern zone for this study. Of all sites in this study, all in the northern zone, except one, had pH greater than 7.0; all sites in the south, except three, had pH less than 7.0 (Appendix 8). All northern sites were high-gradient streams with rock substrates; all southern sites were low-gradient with no rock substrate, only sand, silt and clay. Within each zone, basin size and stream width were important variables, but primarily because of a few rivers that were much larger than others; there was no basis for a separate classification based on stream or watershed size. There was limited basis for classifying based on ecoregions within the north and south zones. The ecoregion classifications were used to group sites in other data analyses.

Within the northern zone, there were sufficient differences in diatom assemblages and environmental characteristics to distinguish the NP from the RV+NH ecoregion. Though there were some differences between the latter two, they were not sufficient to keep them separate for data analysis. In the southern zone, there were significant differences between the ICP and OCP ecoregions. The ICP sites generally had higher nutrient concentrations, and somewhat higher pH and conductivity (Appendix 8), and many were turbid due to silt and clay (based on visual assessment).

Stressor gradient

A stressor gradient was defined based on water chemistry, physical habitat and land-use data for 73 sites. PCA showed that several stressor variables are important, that they can correlate with each other, and that they vary in importance among ecoregions. Defining a stressor gradient along which study sites could be arranged was necessary for both preliminary assignments of taxa to BCG Categories and to compare with assignments of sites to BCG Categories by diatom experts and NJ DEP biologists. Stressors were defined as water chemistry and physical habitat variables strongly influenced by human activities that potentially influence aquatic communities. They can result from point and non-point sources, habitat alteration, hydrologic modification, and other factors. They did not include biological factors. Nor did they include nutrient measures because results of the BCG calibration were to be used to help define nutrient-criteria categories.

The stressor gradient was developed in stages. First, a series of PCA were run on a set of physical habitat and land-use variables to determine a subset that best represented the others and explained most variation among the sites. Second, PCA's were run on water chemistry data for the same purpose. Third, the most explanatory variables from both groups were combined to develop a final stressor gradient. In all steps, separate analysis of sites from only the northern and only the southern zones were run to look for differences between the zones. The PCAs of physical habitat were done using the 73-site environmental dataset, and included land-use characteristics of the entire watershed above the sampling point (% forest plus wetland, % urban, and % agriculture) and physical habitat features of the immediate sampling locations (channel alteration, bank vegetative protection, riparian vegetative zone width, and % open). Other habitat measures, including overall score, were not included because they were not clearly measures of stress caused by human activity. The three land-use variables correlated most strongly with the first two axes; their environmental arrows typically divided the graph into thirds. All variables except % Ag and % open correlated strongly with the first axis ($r > 0.6$). Percent Ag correlated strongly with the axis 2. The habitat characteristics other than % open tended to correlate with each other and % forest. There were no clear north - south differences, but R+V and NH ecoregions had low scores on the % ag and % urban gradients. The initial PCAs of water chemistry were run using the 53 site environmental dataset. This dataset had a smaller number of samples than others in order to include as many chemistry variables as possible. Variables for which there was sufficient data included chloride, conductivity, dissolved oxygen (DO; mg/L, ave % saturation, and minimum % saturation), temperature (average and maximum), biochemical oxygen demand (BOD), turbidity, and bacteria counts (fecal coliforms). Variables that correlated closely with others (% ave and % minimum DO saturation and maximum temperature), or that had a few very high values compared with others (bacterial counts), were eliminated from further analysis. The remaining six variables correlated with axis 1 ($r > 0.5$), except turbidity, which correlated strongly ($r = 0.7$) with axis 2. Chloride and conductivity correlated most strongly with axis 1; DO, BOD, and temperature less so. If conductivity was removed from the analysis, Cl correlates most closely with axis 1. Among the northern zone sites, Cl and conductivity were the most important variables. Temperature, DO, BOD and turbidity correlated more strongly with axes in analysis of southern zone sites than northern zone sites.

The stressor gradient was derived from axis 1 scores of a PCA with a combined set of eight physical habitat and water chemistry variables derived from the previous PCAs (Figure 3; Appendix 4). The axis 1 scores were rescaled to create a PCA-stressor gradient ranging from 0 to 10. Axis 1 correlates most strongly with % forest+wetland and % urb ($r = 0.8$ for both), the bank vegetation variables, and Cl. Sites in the Piedmont ecoregion have the highest stressor scores, and tend to have highest % urban land-use and Cl concentrations. This is consistent with studies of Cl in groundwater in the northeastern U.S. (Mullaney et. al. 2009) indicating road salt and sewage treatment plants as primary sources. RV+NH sites have lowest stressor-scores, and are associated with high percent forest, riparian width, lowest temperatures and highest DO. Most ICP sites have higher % ag and are midway on the stressor gradient; they have higher temperatures and lower DO and poorer bank vegetation condition. The OCP sites have lower stressor scores than the ICP, and generally have greater % forest + wet and wider riparian vegetation width. Similar PCAs were run for northern and southern zone sites independently, and stressor scores were calculated using the same procedure as above (Appendix 4). Differences in stressor relationships reflected differences among ecoregions described above.

Diatom assemblage composition is responsive to the stressor variables used in the PCA, and is therefore potentially a good indicator of stress. Forward selection in CCA, using the 140-sample diatom and environmental datasets, showed that the eight environmental variables used in the stressor-gradient PCAs could each explain significant amounts of variability in assemblage composition, alone and in combination with 2-3 others. Land-use percents, Cl, and riparian vegetation explained the greatest amounts of variation. An implication of these results is that if human activities were managed to reduce the stress from these variables, ecological conditions represented by diatom assemblages could be improved. The benthic invertebrate metrics used in the NJ TALU study (Gerritsen and Leppo 2005) and the NJ 16-category Macroinvertebrate Index were analyzed using PCA to determine which metrics might best represent the others among the 70 sites that corresponded with those in this study. The several metrics used are listed in the Appendix 1, Data Dictionary under Data Source "NJ Invertebrate TALU." The NJMI-16-Cat correlated most strongly with axis 1 ($r = 0.95$) and was used to represent invertebrate scores in subsequent analyses. The PCA showed substantial differences among northern and southern ecoregions; sites in the RV + NH had the highest scores.

Assignment of taxa to BCG Attributes

Taxa were assigned to BCG Attributes based on their distribution along stressor gradients represented by percent land-use categories, Cl, conductivity, DO, temperature, and PCA stressor-scores (Appendix 4). This was done using the 201-sample dataset and PC-ORD to plot one taxon at a time vs. multiple stressor gradients. Assignments to BCG Attributes were based on matching distributions of taxa and descriptions of BCG Categories, as recommended by the US EPA (Gerritsen 2008). Taxa were assigned only to Attributes II-V; there was insufficient information to determine that a taxon was in attribute I (historically documented) or VI (non-native or intentionally introduced). Taxa were assigned to Attribute II (sensitive-rare) if they were most abundant in the low-stress sites and occurred there almost exclusively; usually they were less abundant taxa. Taxa were assigned to Attribute III (sensitive ubiquitous) if they were primarily in low-stress sites, and their relative abundance declined with increasing stress; they were typically taxa often found elsewhere in undisturbed sites. Taxa were assigned to Attribute IV (intermediate tolerance) if they were distributed throughout the length of the stress gradients; most species were assigned this Attribute. Taxa were included in Attribute V (tolerant taxa) if they were most abundant in the higher-stress sites and were in less abundance in the lower-stress sites. Of the 183 taxa that occurred in 10 or more samples in the 140-sample dataset, none were assigned to Attribute II, 56 were assigned to BCG Attribute III, 109 to Attribute IV, and 15 to Attribute V. Distributions of most taxa were the same for sites in both the northern and southern zones and the four main ecoregions. Some taxa, however, were limited primarily to one zone or region and potentially could be assigned to different BCG Attributes depending on ecoregion. The pre-workshop assignments of taxa made at ANSP were reviewed by experts before and during the diatom-expert workshop. Most of the assignments remained the same, but changes were recommended for 50 taxa, increases in BCG Attribute for 32 taxa and decreases for 18. These changes are incorporated in Appendix 4 and were used for all data analysis.

Assignment of sites to BCG Categories

The assignments of sites to BCG Categories provided by diatom experts at the ANSP workshop (Appendix 4) served as the basis for calibrating BCG decision models. In making their decisions, diatomists relied primarily on abundance of the more common taxa and their knowledge and experience about ecological conditions of sites where those were most often found. They gave relatively little weight to the metric values calculated from the counts. No sites were considered to be in a natural state (BCG Category 1), or to have undergone extreme changes (BCG Category 6); the majority was considered to have undergone moderate changes (BCG Category 4). Of the 57 diatom counts evaluated, 2 were in BCG Category 2, 10 in Category 3, 27 in Category 4, and 18 in Category 5. Though no sites had average assigned BCG Categories 1 or 6, individual diatomists occasionally assigned a site to these levels. Most experts envisioned a BCG Category 6 diatom assemblage as being heavily dominated by one or a few Very Tolerant taxa, typical of what is reported in the literature for sites below sewage treatment plant or industrial outfalls; no such assemblages were among those evaluated. Among northern zone ecoregions, the RV+NH had the lowest average BCG Category and the NP the highest. In the southern zone, ICP average BCG Categories were mostly 4 and 5, and OCP Categories were mostly 2 and 3 (Appendix 3).

Some general observations and recommendations of the workshop participants follow:

1. Most assignments of sites to BCG Categories were based on the dominant and relatively common taxa. Less common taxa were weighted more if there was uncertainty about the ecological characteristics of the most common taxa. Occurrence of rare taxa was not usually taken into account. A main reason was because one or a few valves of a taxon could have come from upstream, or for some other reason not represented site conditions. Less common taxa were taken into account more if they provided consistent information on site conditions, and especially if the common taxa provided uncertain or conflicting information. Planktonic species were not that common and not very useful in making BCG assignments.

2. Most participants did not use the metrics or autecological data. They started using them at first, but then stopped, in large part because they did not provide them much ecological information beyond what they already knew; they relied more on their own knowledge of taxa ecological characteristics and assessment of the count data.

3. There was more uncertainty when assigning sites in the southern zone compared to the north. This was primarily because many taxa in the south are "soft-water" taxa (typical of lower pH, lower conductivity, wetland-influenced) and usually associated with unimpaired conditions. There is not as much information generally available on how these taxa respond to impairment, including which are sensitive to disturbance and which are tolerant.

4. There is a potential big-river effect. When interpreting assemblage data, it is useful to know river size. Larger rivers can have a greater number of taxa, including taxa that might be typical of larger rivers in a region; they are also more likely to have generalist taxa (that are potential disturbance indicators) whose presence may not mean as much as if they were found in a smaller stream.

5. Diatom taxa may respond differently to stress due to urban land-use compared with agricultural; assemblages may have different "signatures." No relationships were specified at the workshop, but it is probably useful to take this observation into account in the future when developing rules and numeric guidance levels. Jan Stevenson says that in MI, urban land-use has a much bigger effect on diatoms than agriculture, at least non-row crop agriculture. Jerry Sgro mentioned studies suggesting that soil permeability can be an important factor.

6. It will be important to take into account major regions (north and south NJ) and the four ecoregions when developing decision rules and numeric guidance levels for nutrients.

7. Operational rules for assigning sites to BCG levels based can probably be based on percentages of taxa in attribute categories, in a manner similar to the benthic invertebrate TALU study (Gerritsen and Leppo 2005). Taxa in BCG Attributes II, III, and V should be given more weight in making assignments than those in Attribute IV.

8. In the future, revised assignments of taxa to BCG Categories should take into account additional sample data, including data from outside NJ.

The average diatom workshop BCG scores were compared with corresponding PCA stressor-scores, benthic invertebrate TALU BCG Category, NJMI-16-Cat, and the State Biologist Impairment Scores to assess consistency among the relationships. Overall there was general agreement, though some relationships were not strong, with some sites being assigned substantially different values by the different approaches. All sites with PCA-Stressor Score greater than 5 were in BCG Categories > 4.0 (Figure 4). The relationship between BCG scores and PCA-stressor scores was strongest for BCG Categories above 4.0. Sites in the RV+NH had the lowest PCA-Stressor and average BCG Category scores. The relationship between the PCA-Stressor and the NJMI-16-Cat was stronger than with the diatom BCG scores (Figure 5), and indicates that the PCA Stressor Score is a reasonable measure of stress affecting aquatic biota, including a group other than diatoms. The boundary between impaired (Fair and Poor ratings) and unimpaired (Excellent and Good ratings) indicated by the NJMI-16-Cat corresponded with PCA Stressor Score in the range of 5 to 6. If that PCA Stressor score dividing-line is applied to the relationship with average diatom BCG score, all RV+NH are on the left of the line and ICP and most NP sites are on the right; OCP sites are on both sides. Comparison of macroinvertebrate BCG Category and average diatom BCG scores (Figure 6) shows that sites are more likely to be assigned a lower BCG Category based on diatoms than on benthic invertebrates. More than twice as many sites fall above the 1:1 line as below. Agreement between Average Diatom Workshop BCG Scores and State Biologist Impairment Scores showed generally good agreement; exceptions were that state biologists classified some sites in the RV+NH in relatively better condition than the diatom experts (Figure 7).

Diatom workshop BCG scores were generally greater for sites with higher percents of non-forest land-use (Figure 8 a,b,c). For example, all sites with BGC scores greater than 4.0 had < 50% forest + wetland land-use. The importance of land-use stressors varies among ecoregions. In the RV + NH, all categories are important; all but 4 sites have BCG scores < 4.0 and less than 10% ag and < 20 % urban land-use. In the NP, sites with BCG score < 4.5 have >45% forest + wetland and < 20% urb land-use; there are no clear relationships with % ag. In the OCP, only 2 sites are in a BCG Category > 4.0, and most sites have > 50% forest + wetland and < 20 %

agriculture; there appears to be little relationship with % urban land-use. In the ICP, sites with BCG < 4.0 have > 50% forest and < 10% urb and < 20% ag land-use.

A key step in the BCG calibration process is to develop decision rules to assign sites to BCG Categories based on diatom count data, particularly the percents of specimens in BCG Attributes. Participants at the diatom expert-panel workshop recommended basing decision-rules primarily on these relationships. Rules must be based on a thorough examination and understanding of how percents in BCG Attributes vary with site BCG Categories (Figure 9 a-d; summarized in Table 3). Though these relationships are strong and expected, they are not, on their own, sufficient to unequivocally assign new samples to BCG Categories. Additional criteria would need to be used, possibly diatom metrics, indicator taxa, water chemistry characteristics, or land-use. Alternatively, a fuzzy logic approach, as used in the NJ benthic invertebrate TALU process (Gerritsen and Leppo 2005), would be useful for dealing with and quantifying the uncertainty in making assignments. There were potentially sufficient differences between northern and southern NJ zones, and individual ecoregions within them, to develop separate sets of rules for these regions. Sample size and lack of representation along the full BCG gradient pose significant limitations, however.

Nutrients and the Biological Condition Gradient

Nutrient concentrations were purposefully not included in the stressor gradient analysis, assignment of taxa to BCG Attributes, and assignment of sites to BCG Categories. Analysis of relationships of nutrients to other stressors and diatom data was done subsequent to these analyses as part of the process of developing nutrient criteria options. TP concentrations ranged from about 15 to over 700 µg/L, though most values were less than 200 µg/L; TN ranged from about 0.5 to over 8 mg / L, though most values were less than 4 mg/L (Figure 10; Appendix 8). The TN:TP ratio was generally consistent throughout the range of TP and TN concentrations, except for some high values in the 20 – 50 µg/L TP range (Figure 10). Also, ratios were lower in the ICP ecoregion, especially at higher TP concentrations, and for NP sites with TP concentrations > 200 µg/L. There was a noticeable difference in the relationship between TP and SRP concentration between northern NJ sites and the ICP sites (Figure 11). The TP:SRP ratio was about 4: 3 for the northern zone and 4:1 for the ICP. The relatively lower SRP concentrations in the ICP are possibly due to PO4 being adsorbed on silt and clay particles; concentrations of these particles can be high in the ICP, based on visual observations made at the time of sampling, and are consistent with the high clay content of the soils in this area and percent of agricultural land-use in the watersheds. Both TP and TN increase with decreasing % Forest + Wetland; TN is most closely related to % Urb land-use in the northern zone and % Ag in the south. Concentrations of TP and TN increase with PCA stressor score (Figure 12 and 13) with highest concentrations of both (> 50 ug / L TP and 1.5 – 2.0 mg / L TN) above a PCA-Stressor Score of 5. These relationships indicate that higher nutrient concentrations are associated with other measures of stress, and that sites with lower stress measures have lower nutrient concentrations.

The proportions of taxa in BCG Attributes vary consistently with TP (Figures 14a-e) and TN and can be used as a basis for assigning samples to nutrient categories. Sensitive taxa (BCG Attributes 2 and 3) are associated with low nutrient concentrations, Intermediate Tolerant taxa with moderate to low concentrations, and Tolerant taxa with higher nutrient concentrations. ICP samples have a somewhat different pattern than the other three ecoregions in that high TP concentrations are associated with higher proportions of Sensitive taxa and lower proportions of Tolerant taxa.

Proportions of sites in BCG Categories also vary consistently with TP and TN concentration (Figure 10.9 and 10.10). Sites with lower average BCG scores are associated with lower nutrient concentrations and vice versa. ICP sites have higher TP concentration for BCG scores greater than 4.0 compared with other ecoregions, but TN relationships are comparable.

Nutrient criteria options

Options for nutrient criteria were developed by examining TP and TN concentrations associated with boundaries between BCG Categories (Figures 15 and 16). The NJ DEP decided to use the boundary between BCG Category 4 and 5 to distinguish sites supporting (unimpaired) or not supporting (impaired) the interim goals of the Clean Water Act, based on Jackson and Davies (2006). This boundary was used to identify nutrient concentrations associated with unimpaired sites (BCG Categories 2-4). Because each ecoregion had different ranges of TP and TN, it was most appropriate to examine each separately. There are no BCG Category 5 sites in the RV+NH or OCP, and all sites, except two, have TP concentrations < 50 µg/L. In the NP, all sites in BCG Categories less than 5 have a TP concentration < 50 µg/L. In the ICP, there are only three sites with BCG greater than 4, and two have TP concentrations > 100 µg/L; several ICP sites in BCG Categories 3 and 4 have TP concentrations > 50 µg/L.

Because of the unique relationship between TP and SRP in the ICP, we also examined the correlation between SRP and BCG Categories (Figure 17). The differences in BCG Category-SRP relationships between the ICP and NP were less than the BCG Category-TP relationships. Most sites with BCG of 5 had SRP concentrations > 25 µg/L; most sites in Categories 2 – 4 had SRP < 25 µg/L. Six ICP and RV+NH sites in Category 4 had SRP concentrations ranging from about 25 – 150 µg/L. Most sites in BCG Categories 2-4, in all ecoregions, have TN < 1.5 - 2. Sites in BCG Category 5 can have concentrations of less than 1 to > 6 mg / L.

In addition to establishing nutrient guidance numbers, it is necessary to evaluate the diatom indicator chosen to provide the measure of those values. The Diatom TP and TN Indices (Ponader et al. 2007 and 2008) are the best indicators to use because they are based on a direct relationship between the index values and measured TP and TN concentrations. The Diatom TP and TN Indices tend to vary linearly with Average Diatom Workshop BCG Score (Figure 18a,b), and distinguish reasonably well between Diatom Workshop BCG Categories (Figures 19a,b). Diatom TP Index values of 33.3, 46.6, 56.6, and 66.6 correspond with TP concentrations of 10, 25, 50, and 100 µg/L of TP, respectively. These would be appropriate index values to use for determining the nutrient guidance levels described in the paragraph above and elsewhere. In considering options for selecting index values to support nutrient guidance levels, it is important to take into account differences in the northern and southern zone. Diatom inference models and indices were developed separately for these two regions and have a somewhat different relationship with BCG Categories. These differences pertain to issues of inference model development and the relative tendency to over-predict nutrient concentrations at low nutrient values and underpredict at higher nutrient values. This is more of an issue for southern than northern sites (Ponader et al 2007, 2008). For northern sites, the BCG 4-5 Category boundary is associated with an index value near 56.6, corresponding with a TP concentration of about 50 µg/L. For southern sites, a lower index value of about 33.3 may be more appropriate to protect high quality sites in the OCP. Except for three sites, an index value of 56.6 (50 µg/L) would be appropriate for the ICP.

In addition to comparing TP and TN indices with BCG Categories, we evaluated relationships between BCG Categories and three other useful diatom nutrient indicators, % High- and % Low-TP and TN indicators (Potapova and Charles, 2007), percents of diatom valves in the BCG Attributes, and the Siltation Index. Percent of High- and Low- TP and TN indicators relate closely enough with BCG Category boundaries (Figure 20a-d) that they could be used to help inform decisions about whether BCG-based nutrient guidance numbers are met. These indicators were developed using USGS NAWQA program samples collected from throughout the US, and in addition to being good indicators of nutrient conditions demonstrate that national-level indicators show the same patterns as NJ diatom indicators. Nearly all sites in the RV+NH (all in BCG Categories < 5) have > 10% Low-TP diatom valves and < 20% High TP valves. NP sites in BCG Category 5 have < 10 % Low TP and all but four have > 50% High TP (all have > 40% High TP. All OCP sites except two have % Low TP > 5% and < 30% High TP. The ICP sites have < 30% Low TP metric, and many are less than 10%. High TP %'s in the ICP range between 30 and about 70%, and over 40% for the two sites in BCG Category 5. In general, the % High TP metric is better for distinguishing BCG Categories than the %Low-TP metric. Also, the %High- and %Low- TP metrics (Potapova and Charles 2007) developed using the entire USA calibration set had closer associations with BCG Categories than the metrics based on the Eastern Plains Calibration set when considering all NJ sites together. The Eastern Plains -based metrics may have closer associations with BCG Categories for southern NJ. The % High TP metric correlates closely with % BCG Attribute V (Tolerant taxa) indicating that Tolerant taxa are also good indicators of nutrient conditions. A Siltation Index of < 30 is associated with TP concentrations < 50 µg/L in northern NJ; most SI values > 40 have TP > 50 (Figure 21a). This indicates that higher percentages of motile taxa are associated with higher nutrient conditions in the north, and that the SI may provide a simple preliminary indicator of whether a site meets the desired nutrient guidance levels. The SI is also a good indicator of BCG Category in the northern zone. All sites with a SI < 30 are in a Diatom Workshop BCG Category < 5 (Figure 21b). Also, the SI correlates with % BCG Attribute V taxa ($r^2 = 0.71$).

Discussion

In general, results show that diatom assemblages are responsive to a variety of stressors affecting NJ streams and that they contain sufficient ecological information to assign sites to BCG Categories. These relationships correspond with nutrient concentrations and can be used to help develop regulatory guidelines for nutrients. There are several issues related to limitations and uncertainties in these relationships and they are discussed in the following sections.

Site classification

Classification of sites into northern and southern NJ based on natural characteristics is strongly supported by the multivariate analysis of diatom and environmental data (Figure 1), and is consistent with other studies (e.g., Kennen and Ayers 2002) and NJ monitoring program designs (NJDEP 2006). Further subdivision by ecoregion is moderately well supported by differences in natural characteristics, but strongly supported by differences in land-use and types of stressors. The RV+NH ecoregion has lower level of disturbance than the NP, and the OCP has less land use disturbance and lower nutrients than the ICP.

Stressor gradient

The PCA-stressor gradient represented human-influenced land-use, habitat and water chemistry characteristics. It also generally corresponded well with nutrient conditions and the Biological Condition Gradient Categories. Though there were limitations in stressor data (e.g., missing and insufficient data, variation in time of year samples taken), and uncertainty in the relative importance of human influence compared with natural variability, the PCA-Stressor Scores provide an adequate measure of stress for the BCG process. This is in part because many key stress measures co-vary with each other. Some stressor variables found to influence diatom assemblages in other studies were not available for this study, but may have been partially represented by other variables that were included. For example, Kennon and Ayres (2002) showed that Atrazine concentration and 2-year peak flow correlate most strongly with axis 1 in a CCA of diatom assemblages from 36 NJ streams. These variables may be at least partially represented by % ag and % urb in analyses done in this study. It is interesting that land-use variables explain most of the variation in other stress variables, and represent so well the suite of specific environmental factors that act directly to influence diatom community composition. It also suggests the importance of land-development and non-point sources in addition to point-source factors. The differences in combination of natural characteristics and importance of stressors (e.g., urbanization and Cl in the north and agricultural land-use in the south, especially the ICP) among the ecoregions suggest the potential value of tailoring nutrient criteria to each. The agreement between the Average Diatom Workshop BCG Scores and the State Biologists Impairment Scores (Figure 7) was generally good, but not strong, reflecting differences in approaches, available data and criteria deemed most important in defining stress. The state biologists focused most on local site conditions and benthic macroinvertebrate assemblages; their scores represented both measures of stress and biological condition. The PCA Stressor Score correlated better with the NJMI-16-Cat (Figure 5) and Benthic Invertebrate BCG Category (NomTier). This relationship provides additional evidence that the PCA-Stressor Scores correlate with biological condition, and suggests that benthic invertebrates are strong indicators of impairment compared with diatoms.

One of the most important issues in defining a stressor gradient is determining what constitutes a stressor, and which variables to include in the analysis. Several approaches have been used in other studies. In many cases, choice of variables is limited by the information available. Land-use is usually found to be a key indicator. The stressors used in this study are typical of those used in other studies. Another issue is dealing with variables that can be stressors because they influence biota and can be strongly influenced by human activities, but that also have a wide range of natural variation. For example, in this study, conductivity correlates with several stressor characteristics, but also varies naturally among ecoregions. It was not included as a stressor variable, but because of strong correlation with Cl, primarily in the north, the human-influenced component of conductivity was represented in the stressor gradient. Another example is nutrient concentrations. They were not included in the PCA stressor analysis, but correlated with other factors that were, and therefore increase in value with PCA-Stressor Score (Figures 12 and 13).

Assignment of taxa to BCG Attributes

Assignment of taxa to BCG Attributes was first done using relationships based on the full set of 201 diatom samples and accompanying environmental data. It was then modified based on opinions expressed at the diatom-expert workshop. There were few major discrepancies between these two approaches, though many minor ones. One of the biggest differences was that the initial assignments for taxa common in coastal plain sites were generally considered more representative of "cleaner" conditions than the sites where they were found. In the future, taxa assignments could be improved and made more quantitative by using a larger calibration dataset, including sites in states neighboring NJ, and accounting for differences among the ecoregions. This would be particularly important for some of the *Eunotia* and other soft-water taxa that were very abundant in several southern NJ sites. Though generally associated with low-nutrient conditions, some can be abundant at high nutrient levels (Ponader et al. 2008, Charles et al. 2006). Because diatom analysis of all samples was done at the ANSP using similar protocols, there were no significant within dataset issues due to taxonomic identifications. All counts were reviewed prior to analysis and some names in older counts were updated to newer names (most included in Appendix 6). There were potential issues at the diatom expert-panel workshop based on differences in synonyms that were used in the counts and that experts were more familiar with. The issues with the taxa most-used for BCG assignments were discussed and resolved by workshop participants, particularly with the help of Marina Potapova.

The distribution of percent abundance of BCG Attributes among sites (Figure 9) is consistent with definitions (see intro) of the BCG Categories. The two BCG Category 2 sites have primarily Sensitive taxa (Attributes II and III). The BCG Category 3 sites have both Sensitive and Intermediate Tolerant taxa in moderate abundance. In BCG Category 4 sites, Intermediate and Tolerant taxa are common, but Sensitive taxa are also present. In the BCG Category 5 sites, Intolerant taxa are most abundant, intermediate tolerant taxa common, and sensitive taxa markedly diminished. BCG Attribute V correlates well and linearly with the Siltation Index and % High TP metric; it is the best BCG Attribute for indicating overall stress and nutrients. These patterns are generally consistent for all ecoregions.

The Siltation Index (proportion of motile diatoms) might be considered as a candidate for BCG Attribute VIII, an indicator of ecosystem function. A major potential cause for the increase in motile diatoms is increased nutrients that lead to the build-up in thickness of algal mats, favoring taxa that can move to near the surface of the mat where light levels are sufficient for photosynthesis (Passy 2007). An increase in physical structure of periphyton growth alters ecosystem structure and function by influencing the composition of invertebrates feeding on algae and energy flow pathways (Yallop and Kelly 2006). The Siltation Index correlates closely with BCG, and generally with nutrient concentrations (Figure 21a,b) and % Attribute V. Another advantage of the Siltation Index is that it requires taxa to be identified to genus level only, so the analysis could be done by analysts that have limited but basic knowledge of diatom taxonomy.

Assignments of sites to BCG Categories

The assignment of sites by Diatom Workshop participants to BCG Categories tends to categorize sites in somewhat better condition (lower BCG scores) compared to assignment of sites based on invertebrates (Figure 6), and as suggested by State Biologist Scores (Figure 7). This raises the questions of whether the extent of impairment is being underestimated, whether guidelines for assigning sites to categories were properly followed, whether guidelines could be revised to make assignments more consistent with those based on invertebrates, and whether assignments of taxa to BCG Attributes should be re-examined. Other than the comparisons among approaches (Figures 6 and 7), there are no apparent independent ways to assess accuracy and appropriateness of assignments. Also, other than developing a purely mathematical relationship, there does not appear to be a straightforward way to adjust diatom-based BCG Categories to be comparable to invertebrate-based BCG Categories. Relationships between invertebrate and diatom indicators are comparable in strength to those shown by Horwitz and Flinders (2006) and Horwitz et al. (2008) in their integrated assessment of biological water quality indicators. But results are expressed in different kinds of numbers so cannot be used to calibrate or compare directly with results from the current study. There is no obvious evidence that site-assignment guidelines were not consistently followed. Diatom experts were instructed to assign sites to BCG Categories by following BCG definitions (quoted in the Introduction to this report). The distributions of percents of BCG Attributes among BCG Categories (Figure 9) are consistent with those guidelines, with the exception of ICP sites. The averages of BCG scores assigned by each participant were within 0.3 units of each other, indicating no undue influence of a few experts on group results. Based on Diatom Workshop discussions, it may be appropriate to reconsider some of the guidelines used to assign sites based on percents of BCG Attributes. For example, the role of percent sensitive taxa (BCG Attributes II and III) could be re-evaluated; though there is substantial reduction in percents in higher BCG Categories, there are almost always usually some, which may cause hesitancy in assigning sites to the highest BCG Categories, even if the percent of Tolerant taxa is high. Workshop participants also recommended improving quantitative ecological data for diatom taxa, especially the common taxa in the southern zone that are potentially good indicators of high nutrients. This is important because if these taxa were assumed to be indicators of lower nutrients because they are generally thought of by experts as soft-water low-nutrient indicators (e.g., some *Eunotia* species), this could lead to underestimating BCG Category assignments. This would be particularly relevant to this study because of the tendency of sites in the ICP with high BCG Categories to have lower Tolerant and Very Tolerant taxa (BCG Attributes IV and V) compared with other ecoregions, especially the NP.

The best approach for assigning sites to BCG Categories is probably to apply a fuzzy logic algorithm to the percents of BCG Attributes, as was done in the NJ benthic invertebrate BCG study (Gerritsen and Leppo 2005). A fuzzy logic output (http://en.wikipedia.org/wiki/Fuzzy_logic) would provide the degree of membership of a site in each individual BCG Category, as compared with most current rule-based approaches that attempt to assign a site to only one BCG Category, with or without an error estimate associated with that assignment. Other approaches, including use of the various metrics tested did not seem to provide a better basis for making classifications. There was no correlation between Average Diatom Workshop BCG Scores and taxa richness, diversity, or sum % dominant taxa. None of these could be used to reliably assign sites to BCG Categories. Percent *Achnanthidium* *minutissimum* also did not generally correlate with BCG Categories; however, no site with an average BCG score greater than 4.5 had a value > 8%. The Siltation Index generally varied with BCG score (Figure 21b). Nearly all sites with average BCG score greater than 4.5 had a Siltation Index greater than 30; those with a BCG score < 3.5 had a Siltation Index less than 30. But the SI correlated closely with percent Tolerant taxa (Attribute V) ($R^2 = 0.71$; $p< 0.001$), so would probably not contribute more than using the BCG Attributes alone (compare figures 9d and 21b).

The boundary between BCG Category 4 and 5 is used by the NJ DEP to distinguish between impaired and unimpaired conditions, based on Davies and Jackson (2006). Another approach is to select boundaries based on "threshold" responses where there are substantial changes in BCG Category values along gradients of stress or ecological condition measures (e.g., Stevenson et al. 2008). Examination of relationships of BCG scores with PCA-Stressor Score (Figure 4), percent land-use (Figure 8), and some nutrient relationships suggest that a cutoff at Average Diatom Workshop BCG Score 4.0 or lower might be considered. This may be a useful approach for specific ecoregions that have few sites in BCG Categories above 5, but have evidence of ecological change in lower BCG Category ranges.

Nutrient criteria options

Using BCG boundaries to set nutrient criteria is a reasonable, appropriate approach that uses proscribed procedures. It provides an objective way to establish categories for use in a regulatory framework that is based on ecological theory. It requires the assumption that there is a reasonably good relationship between the BCG and nutrient concentrations, but recognizes that there are limitations to this relationship because the BCG status of sites will be determined to varying degrees by factors other than nutrient concentrations. In this study, nutrient-BCG relationships are consistent with magnitude of nutrient sources and stressors within ecoregions. They also show that reductions in nutrient concentration would result in lower BCG Categories, especially for sites in regions with BCG Categories greater than 4 – 5 (Figures 15 and 16). Also, relationships between Diatom TP / TN Indices and BCG Categories (Figure 18) show that lower diatom index values are associated with lower BCG scores.

New Jersey's current TP numerical criterion for streams is 100 µg/L (Cohen et al. 2009). Based on the BCG approach used in this study, this value is too high. It will not protect sites from becoming impaired, as defined as sites being classified as BCG Categories 5 or 6 (average BCG score > 4.5). The results of this study support a general statewide criterion of no higher than 50 µg/L TP to maintain or restore most sites to unimpaired condition (BCG Category less than 5 or 6). To further ensure the ability to maintain or restore all sites to a BCG Category <5, a lower criterion would be necessary in the NP (35 µg/L) and ICP (25 µg/L). Lower concentrations are also supported for the ecoregions that have most sites in lower BCG Categories. A level of 25 µg/L would be supported for rivers and streams in the RV+NH and ecoregion; a value of 25 µg/L or lower is supported for the OCP.

The ICP is different from the other ecoregions in that diatom assemblages and BCG Categories indicate lower nutrient conditions than do measured TP and TN values. Reasons for this are unclear and should be further investigated. In particular, it is important to know if these different relationships are a function of study methods, or if they accurately represent ecological conditions. One consideration is that the ICP is one of the most fertile agricultural regions in the state and that many soils and geological deposits in the region have high P levels, mostly due to glauconite and other high-phosphorus minerals (Tedrow 1986). But many streams in the area also have high turbidity due to clays and silts which can absorb phosphate-P and so reduce the dissolved P readily available to algae. This may be the reason for the high TP: SRP ratio in this ecoregion (Figure 11). On the other hand, because of the high clay soils in many areas, runoff does not infiltrate as readily as in areas with sandier soils, so P may not be as readily transferred to surface waters. Soil conditions may also influence seasonality of TP concentrations; if concentrations are significantly lower in seasons other than late summer and fall when samples were collected, this could help explain why diatoms are indicating lower nutrient conditions. If there are streams in this ecoregion that have natural high biologically-available TP they could logically require higher nutrient criteria concentrations.

If an option of 50 µg/L TP were chosen as a nutrient criterion, it would not provide sufficient protection for sites with currently much lower values. For example, if a site with a current TP of 25 µg/L or less had concentrations increase to 50 µg/L, there would be appreciable biological change, at least in diatom assemblages (e.g., Figure 18). Given that natural background concentrations of TP for much of NJ have been estimated at < 30 µg/L (Smith et al. 2003), there may be many stream reaches with relatively low amounts of watershed disturbance that would not be well protected. Since there are many such stream reaches in the RV+NH and the OCP, a TP criterion of no more than 25 µg/L should be considered for these ecoregions.

Recommendations for future research

The scientific basis, applicability, and procedures for using diatoms as the basis of numeric nutrient criteria can be improved by further study. Additional sampling could be done to represent a wider range of nutrient concentrations, especially to provide more even distributions within individual ecoregions. In particular, more impaired sites should be added in the RV+NH and OCP, and more less-impaired sites in the NP and ICP. More sites should be sampled that are in as close to natural conditions and severely impaired conditions (e.g., below STP and industrial outfalls) as possible to help better identify taxa in Attributes II and VI, which will in turn help better assign sites to BCG Categories. Water chemistry, including nutrients, and diatoms should be sampled more frequently to provide better quantification of site nutrient conditions and temporal variability. The common forms of N and P should be measured. Further investigation of the relationships between P, N, turbidity, and DOC in the ICP and OCP would be useful. Indicator Species Analysis should be tested as a way to more objectively assign taxa to BCG Attributes and nutrient categories.

The BCG decision rules proposed here will be further tested by analyzing diatom samples from 40 sites being collected by the NJ DEP in summer 2010. Also, the fuzzy-logic approach (Gerritsen 2008) for assigning sites to BCG levels and selecting nutrient criteria boundaries should be tested and evaluated.

Conclusions

The BCG approach using diatom assemblages was an effective means to develop nutrient criteria options. The BCG procedures described by Davies and Jackson (2006) and Gerritsen (2008) were used to assign sites to BCG Categories that were distributed along a stressor gradient. The stressor gradient was developed without including nutrient concentrations. The distributions of BCG sites along corresponding TP and TN gradients were evaluated and boundaries between BCG Categories were used to select nutrient criteria options. Diatom TP and TN Indices correlate with the nutrient and BCG Categories and can be used in a regulatory framework to determine if sites meet nutrient standards. Procedures developed as part of this study will be further evaluated and improved using sets of test samples collected in 2009 and 2010.

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References

Charles, D. F., C. A. Knowles and R. S. Davis, editors. 2002. Protocols for the analysis of algal samples collected as part of the U.S. Geological Survey National Water-Quality Assessment Program. Report No. 02-06. PCER, ANSP, Philadelphia, PA. 124 pp. http://diatom.ansp.org/nawqa/pdfs/ProtocolPublication.pdf

Charles, D.F., F.W. Acker, D.D. Hart, C.W. Reimer, and P.B. Cotter. 2006. Large-scale regional variation in diatom-water chemistry relationships: rivers of the eastern USA. Hydrobiologia 561:27-57.

Cohen, S., S. Lubow, and J. Pflaumer. 2009. New Jersey nutrient criteria enhancement plan. New Jersey Department of Environmental Protection, Water Monitoring and Standards. Trenton, N.J. 29pp.

Davies, S.P. and S.K. Jackson. 2006. The Biological Condition Gradient: A descriptive model for interpreting change in aquatic ecosystems. Ecological Applications 16: 1251 - 1266.

Flinders, C. A., R. J. Horwitz, and T.J. Belton. 2008. Relationship of fish and macroinvertebrate communities in the mid-Atlantic uplands: implications for integrated assessments. Ecological Indicators 8: 588-598.

Gerritsen, J. and E.W. Leppo. 2005. Biological condition gradient for tiered aquatic life use in New Jersey. Tetra Tech, Inc., Owings Mills, MD. 156 pp.

Gerritsen, J. and B.K. Jessup. 2006. Identification of the Biological Condition Gradient for freestone (non-calcareous) streams of Pennsylvania. Prepared for the U.S. EPA Office of Science and Technology, U.S. EPA Region 3, and Pennsylvania DEP.

Gerritsen, J. and B.K. Jessup. 2007. Identification of the Biological Condition Gradient for high-gradient streams of Connecticut. Prepared for the U.S. EPA Office of Science and Technology, and Connecticut DEP.

Gerritsen, J. 2008. The Biological Condition Gradient: Model development and calibration. Prepared for U.S. EPA Office of Science and Technology. Tetra Tech, Inc., Owings Mills, MD

Horwitz, R.J. and C. Flinders. 2006. Bioassessment Integration Study: Systems ecology evaluation of US EPA Rapid Bioassessment Protocols in New Jersey (macroinvertebrates, periphyton, fish and habitat. Report no. 06-06. Patrick Center for Environmental Research, Academy of Natural Sciences. Philadelphia, PA 229 pp.

Jessup, B. 2007. Development of the New Jersey High Gradient Macroinvertebrate Index (HGMI). Tetra Tech, Inc., Owings Mills, MD.

Juggins, S., 2003. C2 User Guide. Software for ecological and paleoecological data analysis and visualization. University of Newcastle, Newcastle upon Tyne, UK, 69 pp.

Kennen, J.G. 1999. Relation of macroinvertebrate community impairment to catchment characteristics in New Jersey streams. Journal of the American Water Resources Association 35: 939-955.

Kennen, J.G. and M.A. Ayers. 2002. Relation of environmental characteristics to the composition of aquatic assemblages along a gradient of urban land use in New Jersey, 1996-98: U.S. Geological Survey Water-Resources Investigations Report 02-4069, 77 pp.

Mullaney, J.R., D.L. Lorenz and A.D. Arntson. 2009. Chloride in groundwater and surface water in areas underlain by the glacial aquifer system, northern United States. U.S. Geological Survey Scientific Investigations Report 2009-5086, 41 pp.

New Jersey Department of Environmental Protection. 2006. Ambient Biological Monitoring Network. http://www.state.nj.us/dep/wms/brochure/AMNET.pdf

Maxted, J.R., M.T. Barbour, J. Gerritsen, V. Poretti, N. Primrose, A. Silvia, D. Penrose, and R. Renfrow. 2000. Assessment framework for mid-Atlantic coastal plain streams using benthic macroinvertebrates. Journal of the North American Benthological Society 19:128-144.

McCune, B. and M. J. Mefford. 2006. PC-ORD. Multivariate Analysis of Ecological Data. Version 5.10. MjM Software, Gleneden Beach, Oregon, U.S.A.

Moulton II, S.R., J.G. Kennen, R.M. Goldstein, and J.A. Hambrook. 2002. Revised Protocols for Sampling Algal, Invertebrate, and Fish Communities as Part of the National Water-Quality Assessment Program. U.S. Geological Survey Open-File Report 02-150. 75 pp.

Newall, P. and C.J. Walsh. 2005. Response of epilithic diatom assemblages to urbanization influences. Hydrobiologia 532: 53-67.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000) Ann. Assoc. Am. Geograph. 77, 118–125.

Omernik, J.M. 1995. Ecoregions. A spatial framework for environmental management. In: Davis, W.S., Simon, T.P. (Eds.), Biology Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis, Boca Raton, FL, pp. 49–62.

Passy, S.I. 2007. Diatom ecological guilds display distinct and predictable behavior along nutrient and disturbance gradients in running waters. Aquatic Botany 86: 171-178.

Ponader K.C., D.F. Charles and T.J. Belton. 2007. Diatom-based TP and TN inference models and indices for monitoring nutrient enrichment of New Jersey streams. Ecological Indicators 7:79-93.

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

Poretti, V., D. Bryson, and T. Miller. 2007. Standard Operating procedures: AMNET Bio-monitoring using benthic macroinvertebrates: Field, lab, and assessment methods. NJDEP, Trenton, NJ. 44 pp.

Porter, S.D. 2008. Algal attributes—An autecological classification of algal taxa collected by the National Water-Quality Assessment Program: U.S. Geological Survey Data Series 329, available only online at http://pubs.usgs.gov/ds/ds329/.

Porter, S.D., D.K. Mueller, N.E. Spahr, M.D. Munn, and N.M. Dubrovsky. 2008. Efficacy of algal metrics for assessing nutrient and organic enrichment in flowing waters. Freshwater Biology 53: 1036–1054.

Potapova, M., D.F. Charles, K.C. Ponader and D.M. Winter. 2004. Quantifying species indicator values for trophic diatom indices: a comparison of approaches. Hydrobiologia 517: 25-41.

Potapova, M. and D.F. Charles. 2007. Diatom metrics for monitoring eutrophication in rivers of the United States. Ecological Indicators 7: 48-70.

Potapova, M., J.F. Coles, E.M.P. Giddings, and H. Zappia. 2005. A comparison of the influences of urbanization in contrasting environmental settings on stream benthic algal assemblages. American Fisheries Society Symposium. 41: 333-359.

Snook, H., S.P. Davies, J. Gerritsen, B.K. Jessup, R. Langdon, D. Neils and E. Pizutto. 2007. The New England Wadeable Stream Survey (NEWS): Development of common assessments in the framework of the Biological Condition Gradient. Prepared for the USEPA Office of Science and Technology, USEPA Office of Watersheds, Oceans, and Wetlands, and New England Interstate Water Pollution Control Commission.

Smith, R.A., R.B. Alexander, and G.E. Schwarz. 2003. Natural background concentrations of nutrients in streams and rivers of the conterminous United States. Environmental Science and Technology. 37: 3039 - 3047.

Stevenson, R.J., B.H. Hill, A.T. Herlihy, L.L. Yuan, and S.B. Norton. 2008. Algae-P relationships, thresholds, and frequency distributions guide nutrient criterion development. Journal of the North American Benthological Society 27: 783-799.

Tedrow, J.C. 1986. Soils of New Jersey. New Jersey Agricultural Experiment Station publication no. A-15134-1-82. R.E. Kreiger Publishing, Malabar, Fl. 480 pp.

ter Braak, C.J.F. 1995. Ordination. In: Jongman, R.H.G., ter Braak, C.J.F.,van Tongeren, O.F.R. (Eds.), Data Analysis in Community and Landscape Ecology. Cambridge University Press, Cambridge, UK, pp. 91–169.

ter Braak, C.J.F. and S. Juggins. 1993. Weighted averaging partial least squares regression (WA-PLS): an improved method for reconstructing environmental variables from species assemblages. Hydrobiolgia 269/270: 485–502.

ter Braak, C.J.F. and I.C. Prentice. 1988. A theory of gradient analysis. Advances in Ecological Research 18: 221–317.

ter Braak, C.J.F. and P. Šmilauer. 2002. CANOCO reference manual and CanoDraw for Windows. User's guide: Software for canonical community ordination. Version 4.5. Microcomputer Power, Ithaca, NY.

Wolfe, P.E., 1977. The Geology and Landscapes of New Jersey. Crane, Russak and Company Inc, New York, NY. 351 pp.

Yallop, M.L. and M.G. Kelly. 2006. From pattern to process: understanding stream phytobenthic assemblages and implications for determining "ecological status." Nova Hedwigia, Beiheft 130: 357-372.

Zampella, R.A., K.J. Laidig and R.L. Lowe. 2007. Distribution of diatoms in relation to land use and pH in blackwater Coastal Plain streams. Environmental Management 39: 369 - 384.

Zampella, R. A., N. A. Procopio, R. G. Lathrop, and C. L. Dow. 2007 Relationship of land-use/land-cover patterns and surface-water quality in the Mullica River Basin. Journal of the American Water Resources Association 43:594-604.

Tables

Table 1. All NWIS environmental parameters that were considered during this study. The NWIS dataset itself is displayed in Appendix 9. Data were obtained from http://waterdata.usgs.gov/nwis/dv/?referred_module=sw.

Parameter	Column Heading in Appendix 9	USGS Parameter Code
Biochemical oxygen demand, water, unfiltered, 5 days at 20 degrees Celsius, milligrams per liter	bod_mgl	310
Cadmium, water, unfiltered, micrograms per liter	cd_uf_ugl	1027
Calcium, water, filtered, milligrams per liter	ca_f_mgl	915
Chloride, water, filtered, milligrams per liter	clde_f_mgl	940
Chlorophyll a, water, fluorometric method, corrected, micrograms per liter	chla_w_ugl	32209
Chromium, water, unfiltered, recoverable, micrograms per liter	cr_uf_ugl	1034
Copper, water, filtered, micrograms per liter	cu_f_ugl	1040
Dissolved oxygen, water, unfiltered, milligrams per liter	do_mgl	300
Dissolved oxygen, water, unfiltered, percent of saturation	do_pc	301
Enterococci, m-E MF method, water, colonies per 100 milliliters	entero_cols_100ml	31649
Escherichia coli, m-TEC MF method, water, colonies per 100 milliliters	ecoli_cols_100ml	31633
Fecal coliform, EC broth method, water, most probable number per 100 milliliters	fecal_mpn_100ml	31615
Lead, water, unfiltered, recoverable, micrograms per liter	pb_uf_ugl	1051
Magnesium, water, filtered, milligrams per liter	mg_f_mgl	925

Parameter	Column Heading in Appendix 9	USGS Parameter Code
Organic carbon, water, filtered, milligrams per liter	foc_mgl	681
Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	sp_cond_uscm	95
Sulfate, water, filtered, milligrams per liter	so4_f_mgl	945
Suspended sediment concentration, milligrams per liter	sus_sed_mgl	80154
Temperature, water, degrees Celsius	temp_w_c	10
Turbidity, water, unfiltered, field, nephelometric turbidity units	turb_ntu	61028
Zinc, water, unfiltered, recoverable, micrograms per liter	zn_uf_ugl	1092

Table 2. All NAWQA Data Warehouse (http://infotrek.er.usgs.gov/nawqa_queries/swmaster/index.jsp) parameters that were added to the environmental dataset (see Appendix 1), along with their descriptions, parameter codes, and short names, and the corresponding environmental dataset column heading. See text for further details.

Parameter Code	Parameter Short Name	Parameter Group	Report Units	Description	Corresponding Column Name
39036	Alkalinity_ wf_fixedEP	Major Inorganics	mg/l CaCO3	Alkalinity, water, filtered, fixed endpoint (pH 4.5) titration, field, milligrams per liter as calcium carbonate	alk_mgl
00418	Alkalinity_ wf_fixedEP	Major Inorganics	mg/l CaCO3	Alkalinity_ water_ filtered_ fixed endpoint (pH 4.5) titration_ field_ milligrams per liter as calcium carbonate	alk_mgl
39086	Alkalinity_ wf_inflect	Major Inorganics	mg/l CaCO3	Alkalinity, water, filtered, incremental titration, field, milligrams per liter as calcium carbonate	alk_mgl
00610	Ammonia_ wu	Nutrients	mg/l as N	Ammonia_ water_ unfiltered_ milligrams per liter as nitrogen	nh3n_mgl
00310	BOD_ 5 day_ 20 deg	Physical Property	mg/l	Biochemical oxygen demand_ water_ unfiltered_ 5 days at 20 degrees Celsius_ milligrams per liter	bod_mgl
00915	Calcium_ wf	Major Inorganics	mg/l		ca_f_mgl
00940	Chloride_ wf	Major Inorganics	mg/l	Chloride_ water_ filtered_ milligrams per liter	clde_mgl
00300	Dissolved oxygen	Physical Property	mg/l	Dissolved oxygen_ water_ unfiltered_	do_mgl

Parameter Code	Parameter Short Name	Parameter Group	Report Units	Description	Corresponding Column Name
				milligrams per liter	
50468	E coli_ Defined Substr	Biological	MPN/100 ml		ecoli_mpn_100ml
31649	Enterococci_ m-E MF me	Biological	cfu/100ml	Enterococci, m-E MF method, water, colonies per 100 milliliters	entero_cfu_100ml
31615	Fecal coliform_ EC bro	Biological	MPN/100 ml	Fecal coliform, EC broth method, water, most probable number per 100 milliliters	fecal_mpn_100ml
00900	Hardness_ water	Physical Property	mg/l CaCO3	Hardness_ water_ milligrams per liter as calcium carbonate	har_mgl
00631	NO3+NO2_ wf	Nutrients	mg/l as N	Nitrate plus nitrite_ water_ filtered_ milligrams per liter as nitrogen	no3n_mgl
00681	Organic carbon_ wf	Major Inorganics	mg/l	Organic carbon_ water_ filtered_ milligrams per liter	doc_mgl
00671	Orthophosphate_ wf	Nutrients	mg/l as P	Orthophosphate_ water_ filtered_ milligrams per liter as phosphorus	op_p_ugl
00400	pH	Physical Property	std units	pH_ water_ unfiltered_ field_ standard units	ph_field
00665	Phosphorus_ wu	Nutrients	mg/l	Phosphorus_ water_ unfiltered_ milligrams per liter as phosphorus	tp_ugl
00935	Potassium_ wf	Major Inorganics	mg/l		k_f_mgl
00930	Sodium_ wf	Major Inorganics	mg/l		na_f_mgl

Parameter Code	Parameter Short Name	Parameter Group	Report Units	Description	Corresponding Column Name
00095	Specific cond at 25C	Physical Property	uS/cm @25C	Specific conductance_ water_ unfiltered_ microsiemens per centimeter at 25 degrees Celsius	cond_fie_uscm
00945	Sulfate_ wf	Major Inorganics	mg/l		so4_f_mgl
00010	Temperature_ water	Physical Property	deg C	Temperature_ water_ degrees Celsius	temp_w_c
00600	Total nitrogen_ wu	Nutrients	mg/l	Total nitrogen_ water_ unfiltered_ milligrams per liter	tn_mgl
62855	Total nitrogen_ wu	Nutrients	mg/l	Total nitrogen (nitrate + nitrite + ammonia + organic-N), water, unfiltered, analytically determined, milligrams per liter	tn_mgl
00076	Turbidity	Physical Property	NTU	Turbidity_ water_ unfiltered_ nephelometric turbidity units	turb
99872	Turbidity_ wu_ Hach210	Physical Property	NTU	Turbidity_ water_ unfiltered_ laboratory_ Hach 2100AN_ nephelometric turbidity units	turb
61028	Turbidity_ wu_field	Physical Property	NTU	Turbidity, water, unfiltered, field, nephelometric turbidity units	turb

Table 3. Percent of diatoms in BCG attributes by BCG categories assigned to 57 samples at the NJ TALU Diatom Expert Workshop. Based on data in Figure 9.

	BCG Attributes – Diatom Taxa				
	II	III	IV	V	VI
BCG Categories	Sensitive - rare	Sensitive -ubiquitous	Intermediate tolerance	Tolerant	Very tolerant
2 Minimal change	ID	> 35%	< 10%	0 – 15%	none
3 Evident change	0 – 30%	15 – 75%	25 – 70%	0 – 15%	< 2%
4 Moderate change	0 – 10%, but can be up to 30%	1 – 60%; mostly < 30%	20 -70%; can be less, but always > 5	5 – 70%	0 – 5%
5 Major change	< 1%:, usually none	1 – 15%	10 – 50%	25 – 80%	0 – 15%

Footnotes: Data for BCG category 2 are based on only two samples. ID = insufficient data.

Figures

16. Average Diatom Workshop BCG Score vs. TN, by ecoregion (panels a - d). Includes sites with TN < 8 mg/L.

17. Soluble reactive phosphorus (SRP) vs. Average Diatom Workshop BCG Score for 57 study sites, by ecoregion.

18. Average Diatom Workshop BCG Score vs. a) Diatom TN Index and b) Diatom TP Index for 51 study sites, by ecoregion. The concentration range of TP and TN corresponding with the index values are shown on the right vertical axes. Horizontal reference lines on the TP plot represent TP index values of 33.3 and 56.6, and correspond to TP values of 25 and 50 µg/L, respectively. The horizontal reference line on the TN plot represents a TN Index value of 59, corresponding to a TN value of 1.5 mg/L. All diatom index values are from Ponader et al. (2007, 2008) and are based on bootstrapped inference models. The relationships for only the northern ($r^2 = 0.65$) and the southern sites ($r^2 = 0.60$) are each higher than for all sites together ($r^2 = 0.49$).

19. Diatom Workshop BCG Category vs. Diatom TP and TN Index values. The concentration ranges of TP and TN corresponding with the index values are shown on the right vertical axes. Plot a) represents TP Index values for all 51 sites in northern and southern NJ; plot b) represents only the 31 sites in the northern zone. Plot c) represents the 26 sites from northern NJ; sufficient measured TN data were not available to develop a Diatom TN Index for the southern zone. All index values are from Ponader et al. (2007, 2008) and are based on bootstrapped inference models.

20. Percent High- and % Low-TN (a,b) and TP (c,d) metrics (Potapova and Charles 2007) vs. Average Diatom Workshop BCG Score for 57 sites, by ecoregion.

21. Siltation Index vs. a) TP and b) Average Diatom Workshop BCG Score, for 57 sites, by ecoregion.

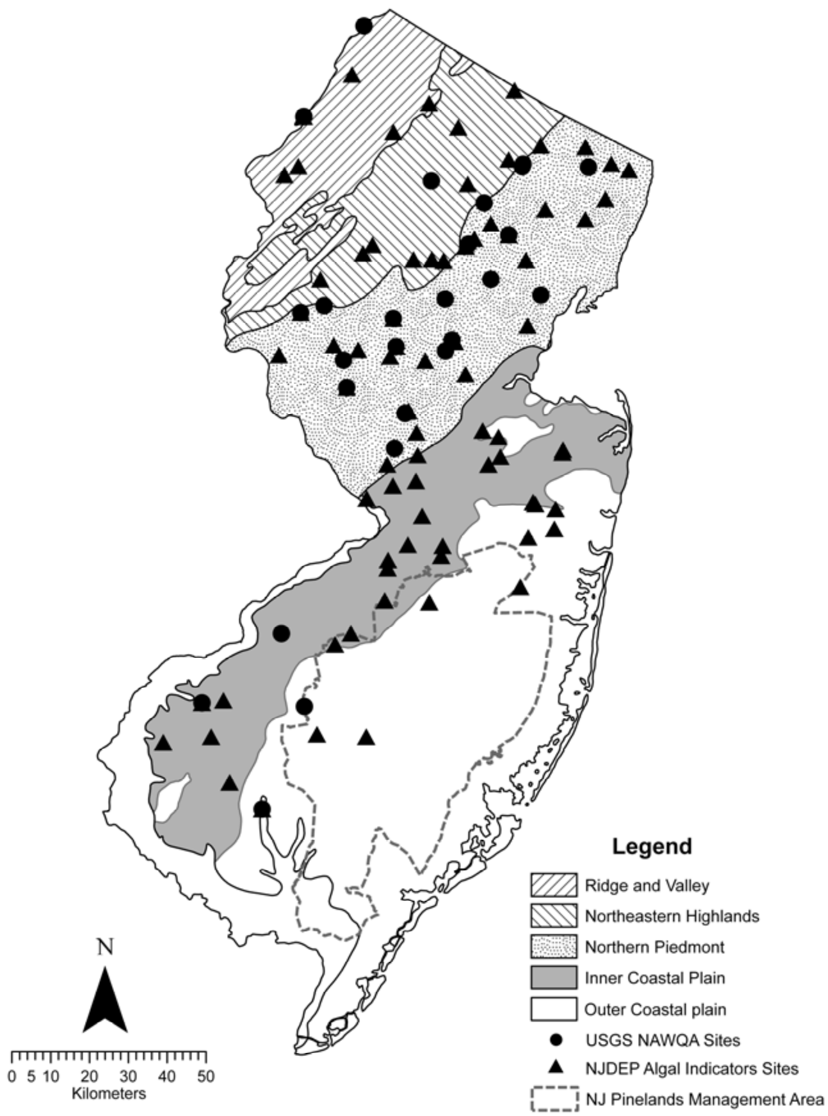


Figure 1. Location of 95 NJAI and NAWQA study sites and New Jersey ecoregions.

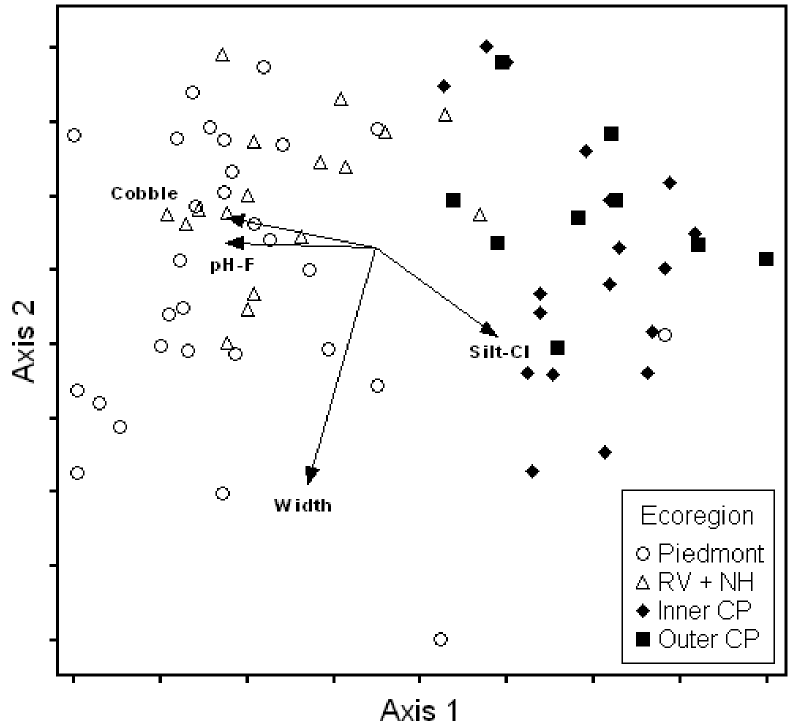


Figure 2. Principal Components Analysis (PCA) of four environmental variables and 73 sites, grouped by ecoregion. Northern NJ sites are on the left; southern NJ on the right. One northern site groups with the southern sites; it is located near the N-S boundary and has characteristics of southern sites.

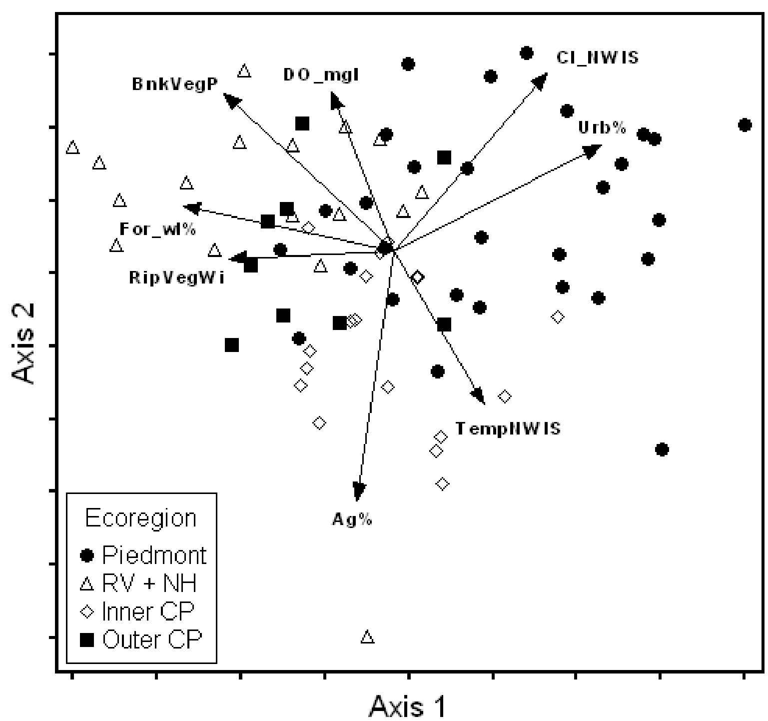


Figure 3. Principal Components Analysis of land-use, water chemistry and physical habitat variables for 73 study sites. Symbols represent ecoregions. Axis 1 was used to calculate PCA-Stressor Scores.

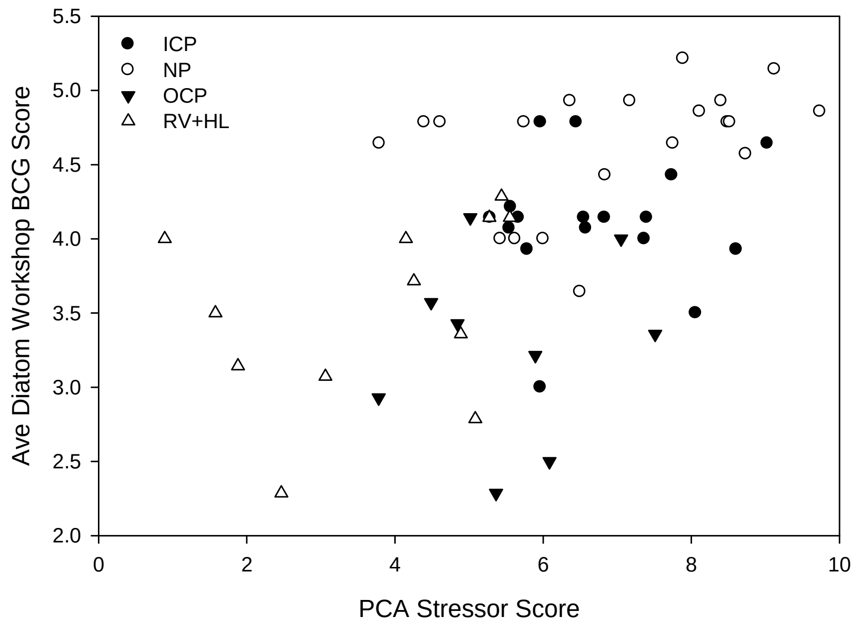


Figure 4. PCA-Stressor Score vs. Average Diatom Workshop BCG Score, by ecoregion, for 57 study sites.

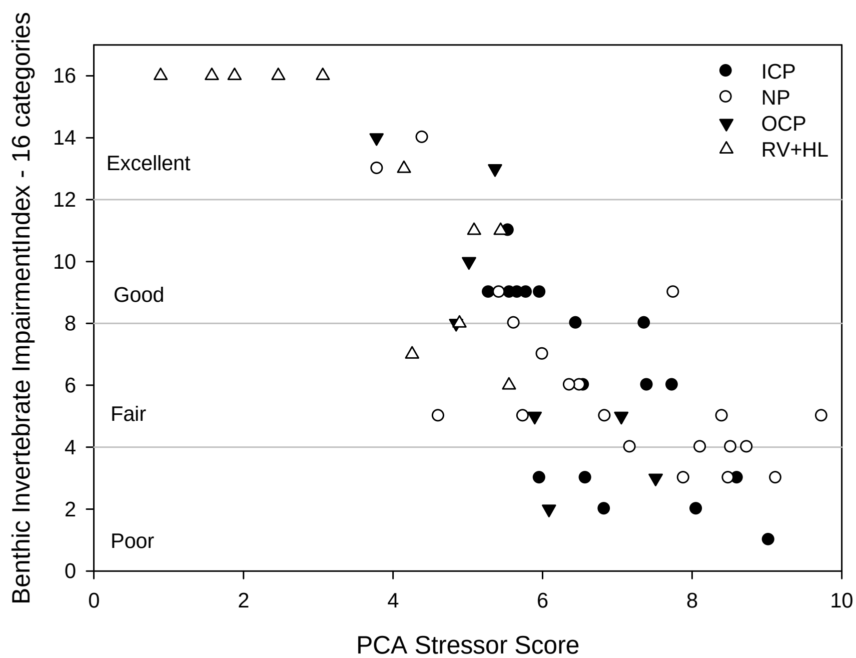


Figure 5. PCA-Stressor Score vs. Benthic Invertebrate Impairment Index (NJMI-16-Cat) for 57 study sites. Symbols represent ecoregions.

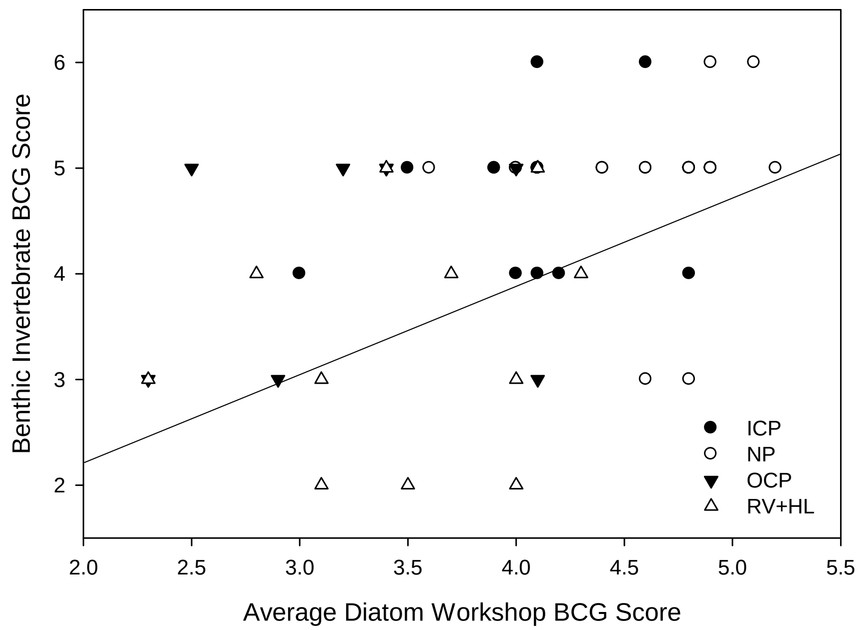


Figure 6. Diatom Workshop BCG Category vs. Benthic Macroinvertebrate BCG Category based on NJ TALU study (Gerritsen and Leppo 2005), for 57 study sites. Invertebrate BCG variable named NomTier in TALU study (Appendix 1).

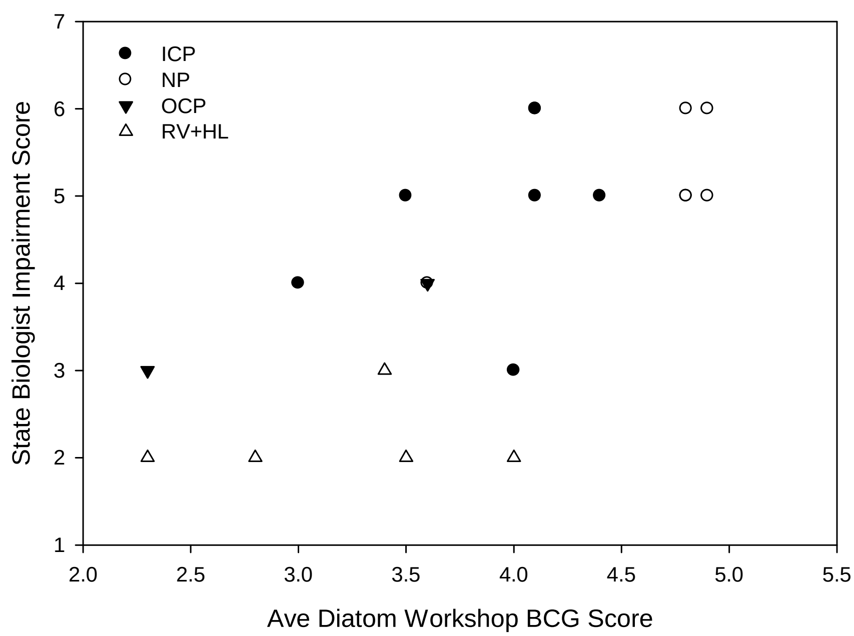
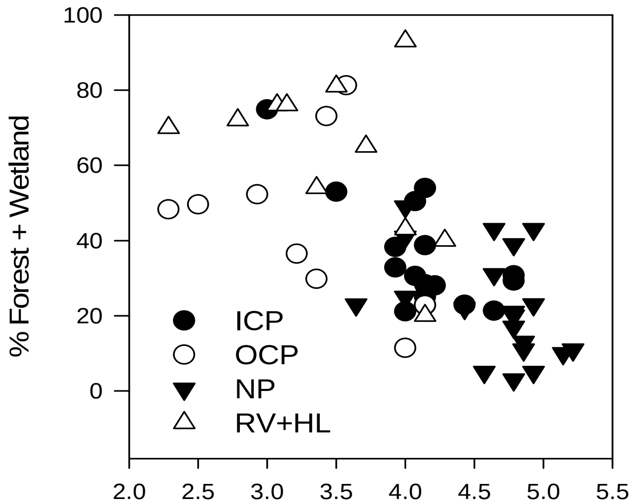
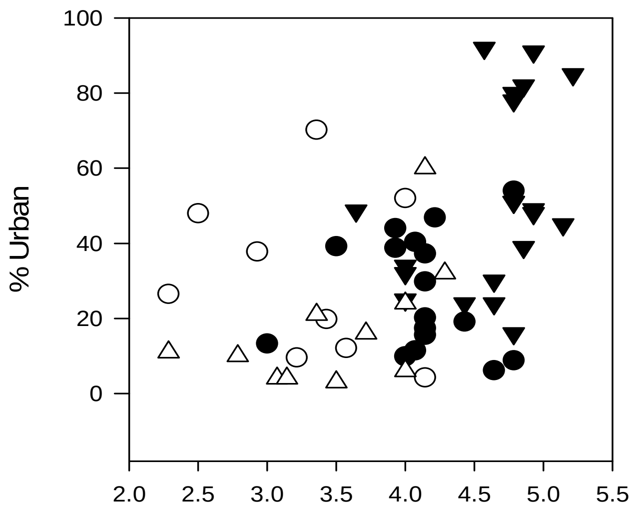


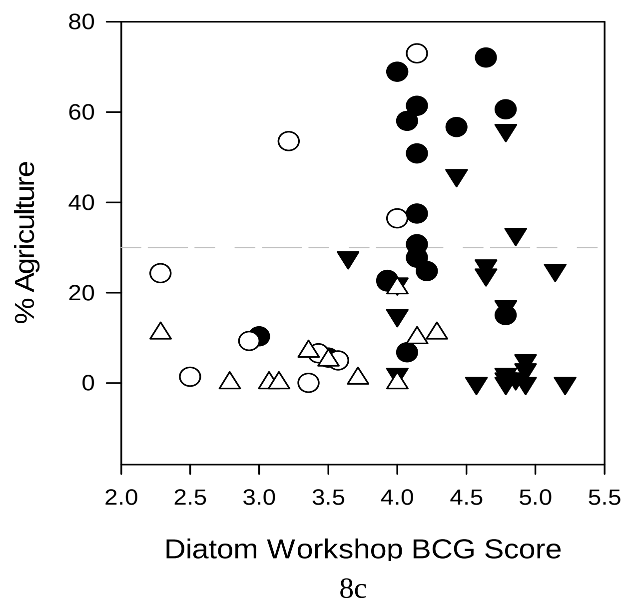
Figure 7. Average Diatom Workshop BCG Score vs. State Biologist Impairment Score for 27 study sites.



8a



8b



8c

Figure 8 a-c. Percent a) forest + wetland, b) urban and c) agricultural land-use vs. Average Diatom Workshop BCG Score. Symbol types represent ecoregions.

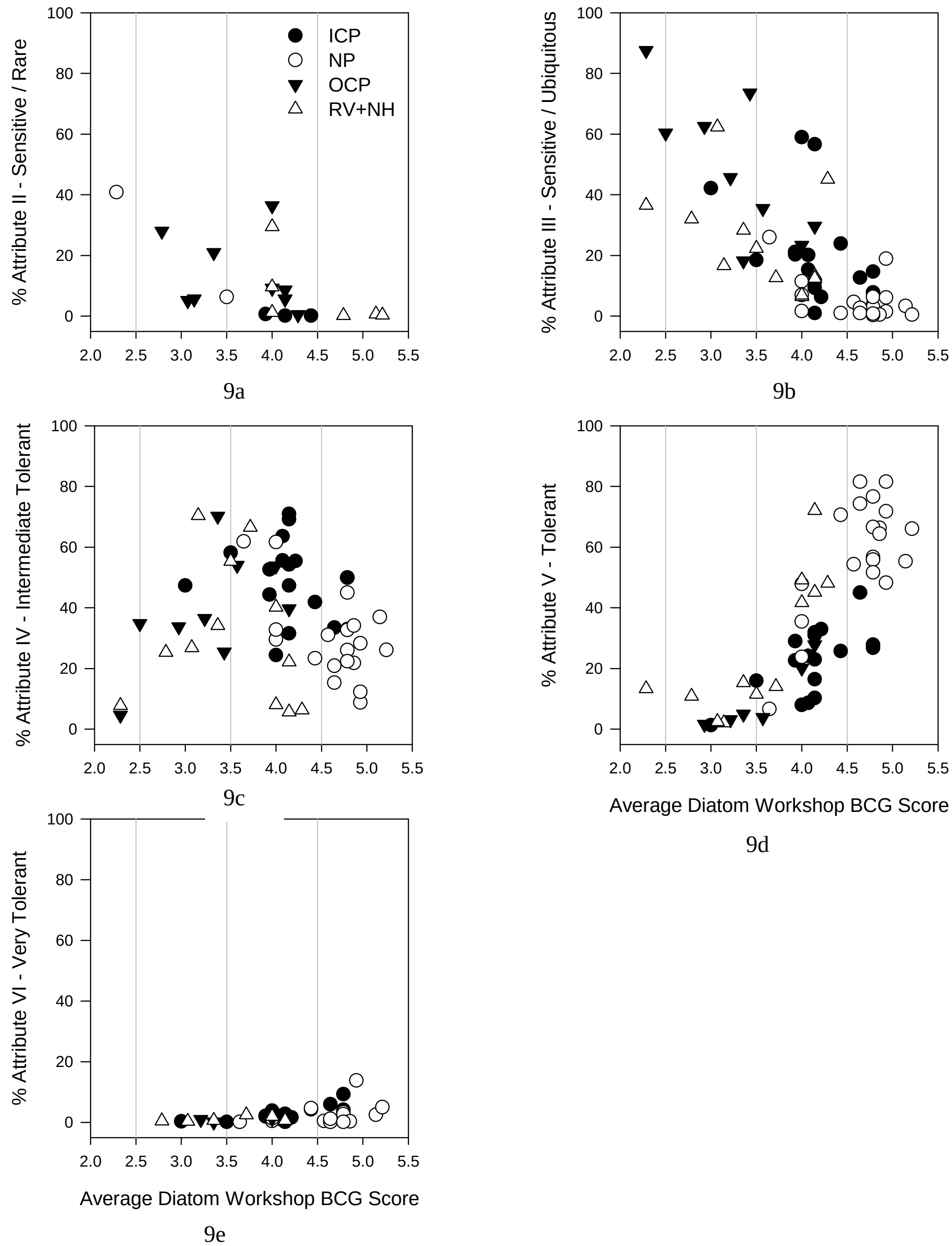


Figure 9 a-e. Percent of diatom valves in BCG Attributes II - VI (panels a - e) vs. BCG levels for 57 study sites.

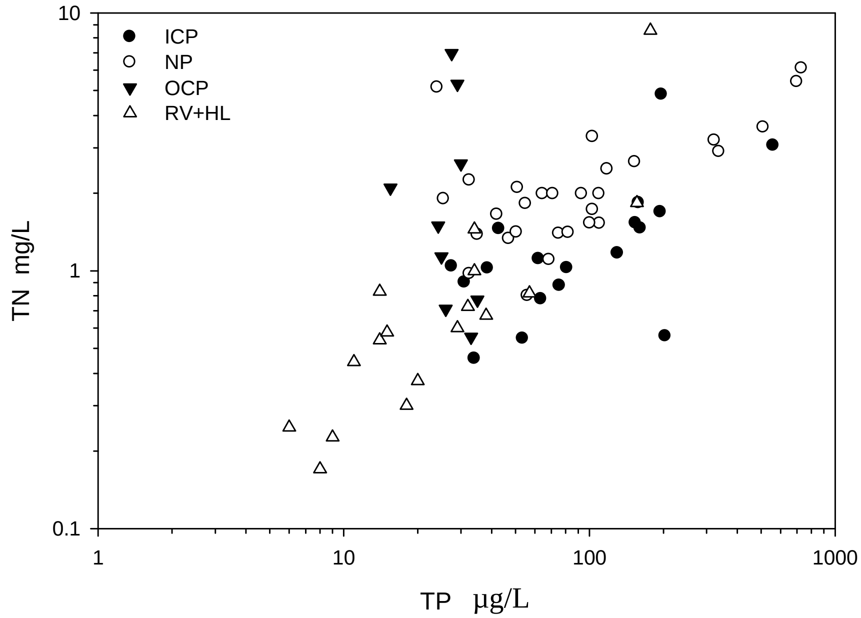


Figure 10. Total P vs. total N for 73 study sites, by ecoregion.

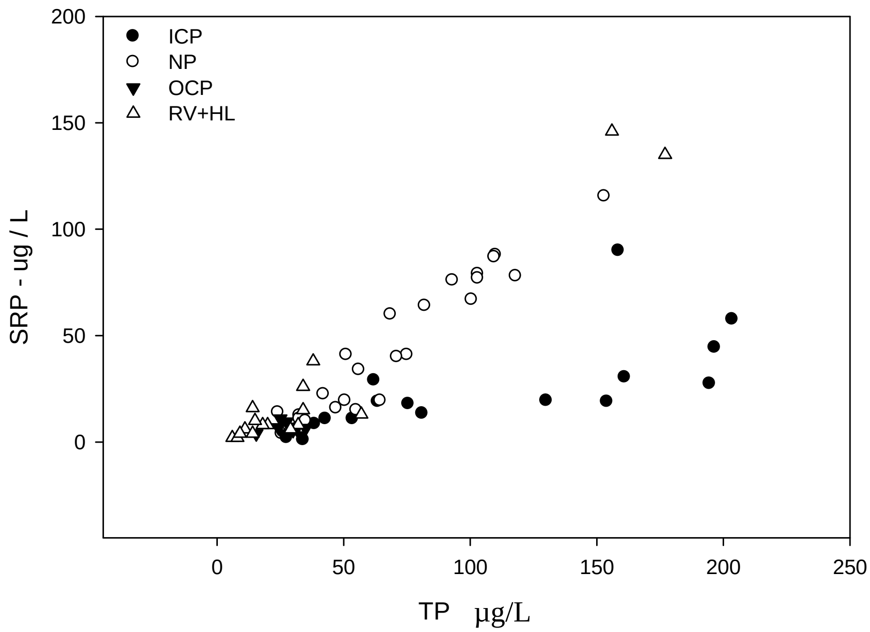


Figure 11. Total P vs. soluble reactive phosphorus (SRP) for 73 study sites, by ecoregion. Includes only sites with TP < 250 µg/L.

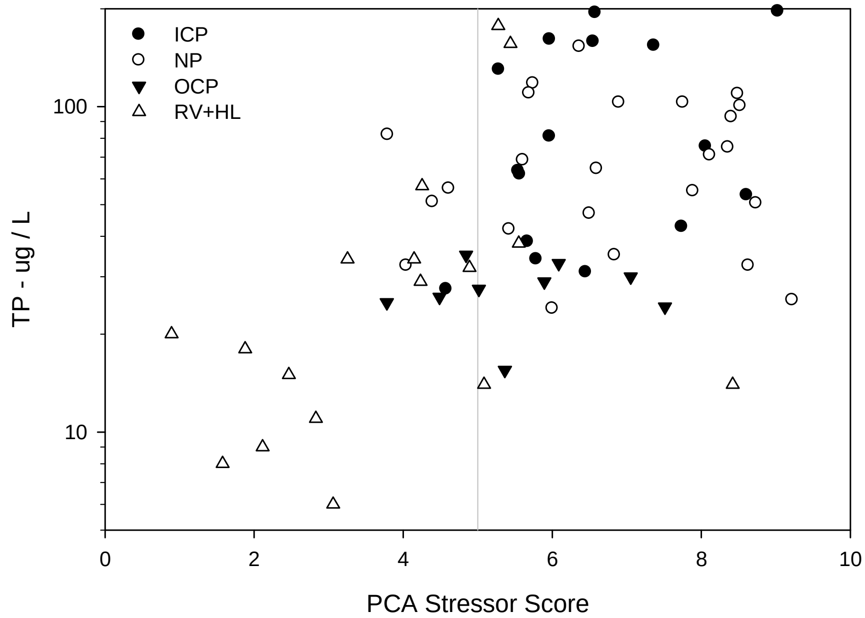


Figure 12. PCA-Stressor Score vs. TP for 73 study sites, by ecoregion. Includes sites with TP < 200 µg/L.

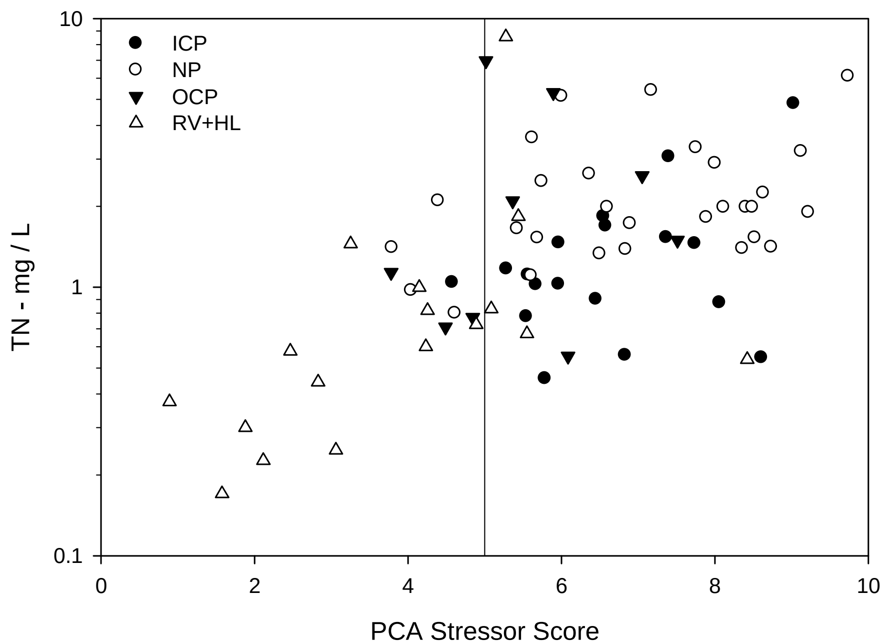


Figure 13. PCA-Stressor Score vs. TN for 73 study sites, by ecoregion. Includes sites with TN < 10 mg/L.

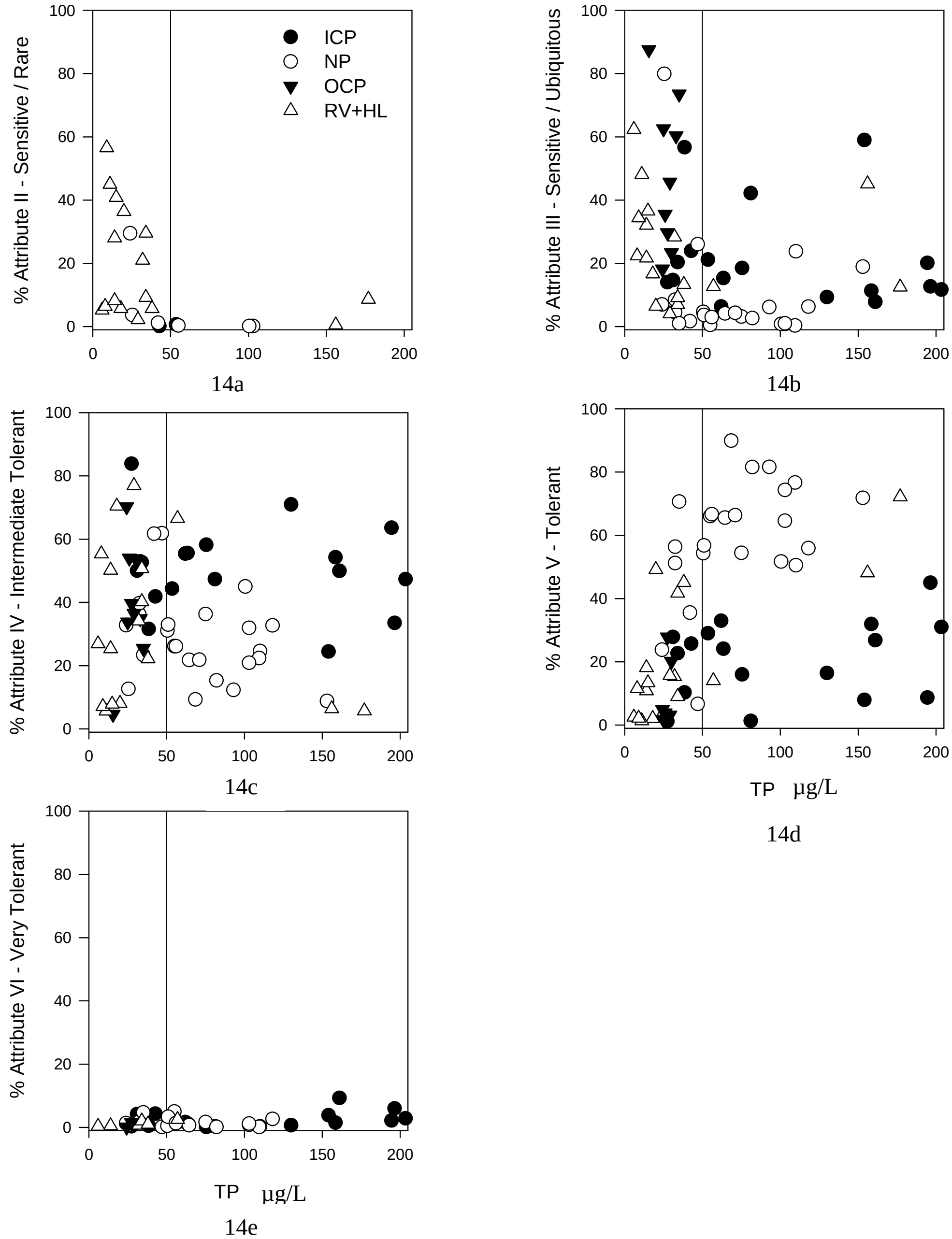
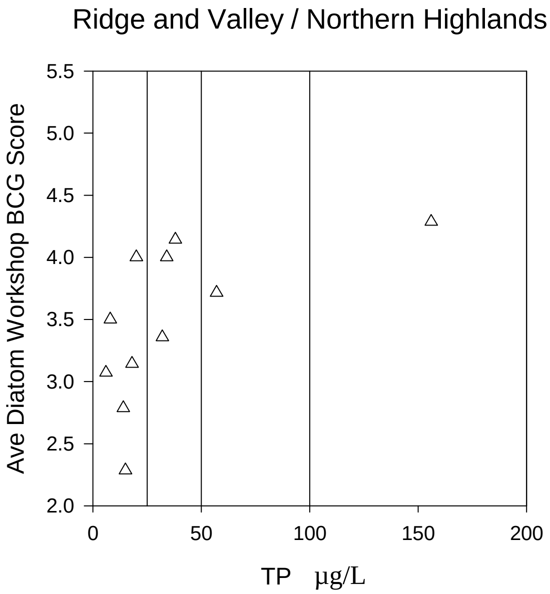
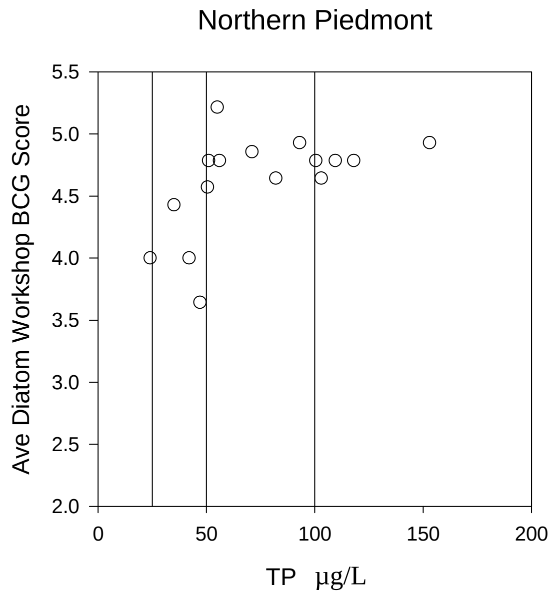


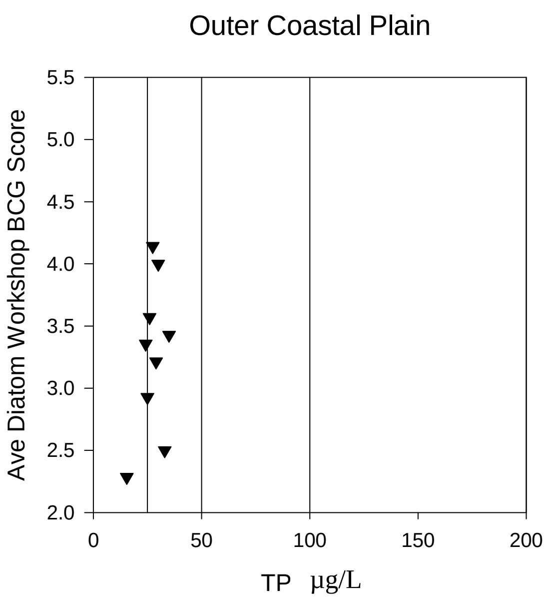
Figure 14 a - e. Percent of diatom valves in BCG Attributes II - VI (panels a - e) vs. TP for 57 study sites. Includes sites with TP < 200 µg/L.



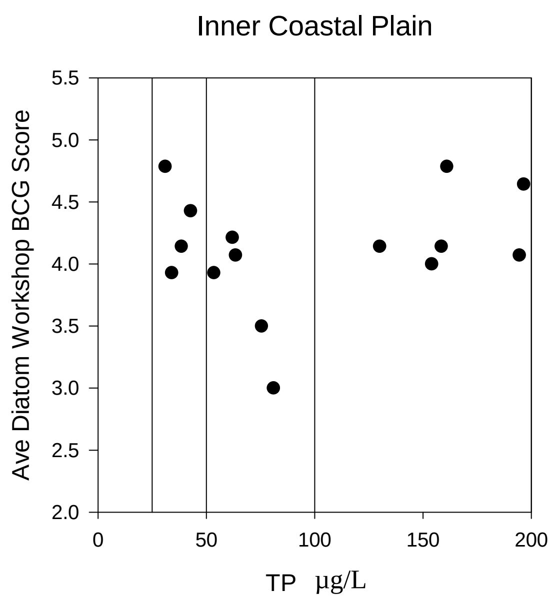
15a



15b

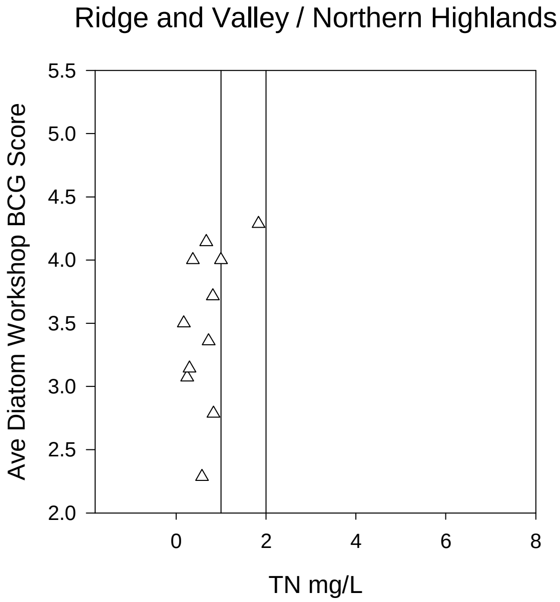


15c

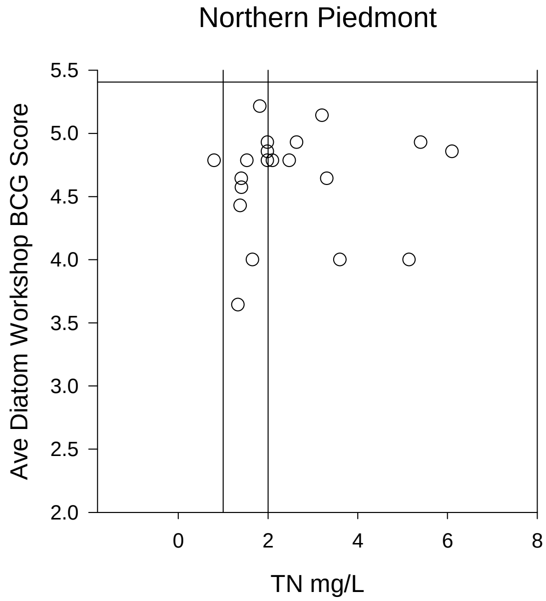


15d

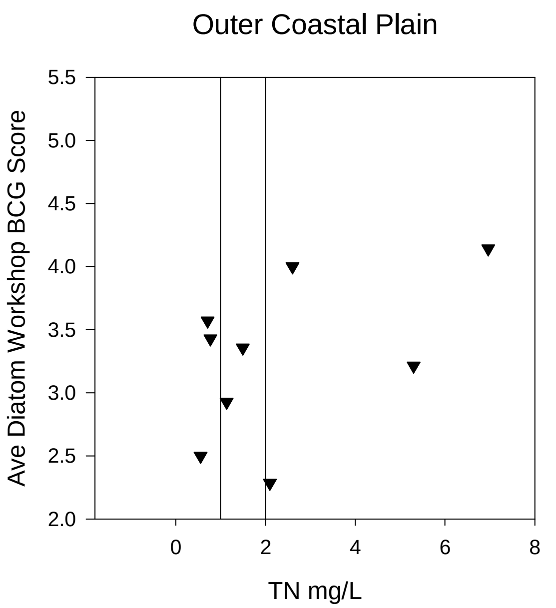
Figure 15 a - d. Average Diatom Workshop BCG Score vs. TP, by ecoregion. Includes sites with TP < 200 µg/L.



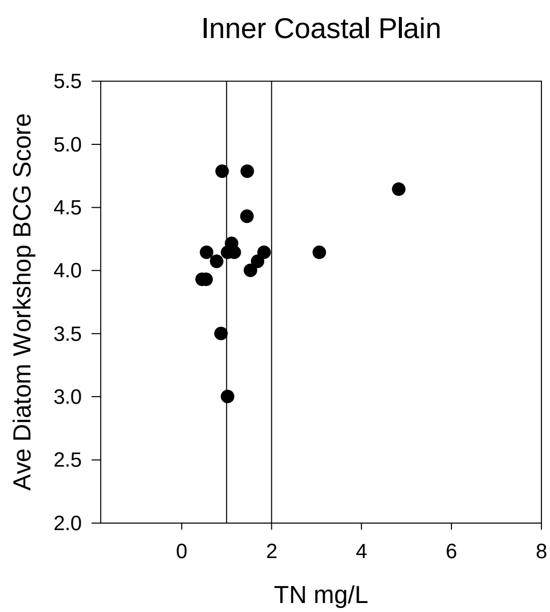
16a



16b



16c



16d

Figure 16 a - d. Average Diatom Workshop BCG Score vs. TN, by ecoregion. Includes sites with TN < 8 mg/L.

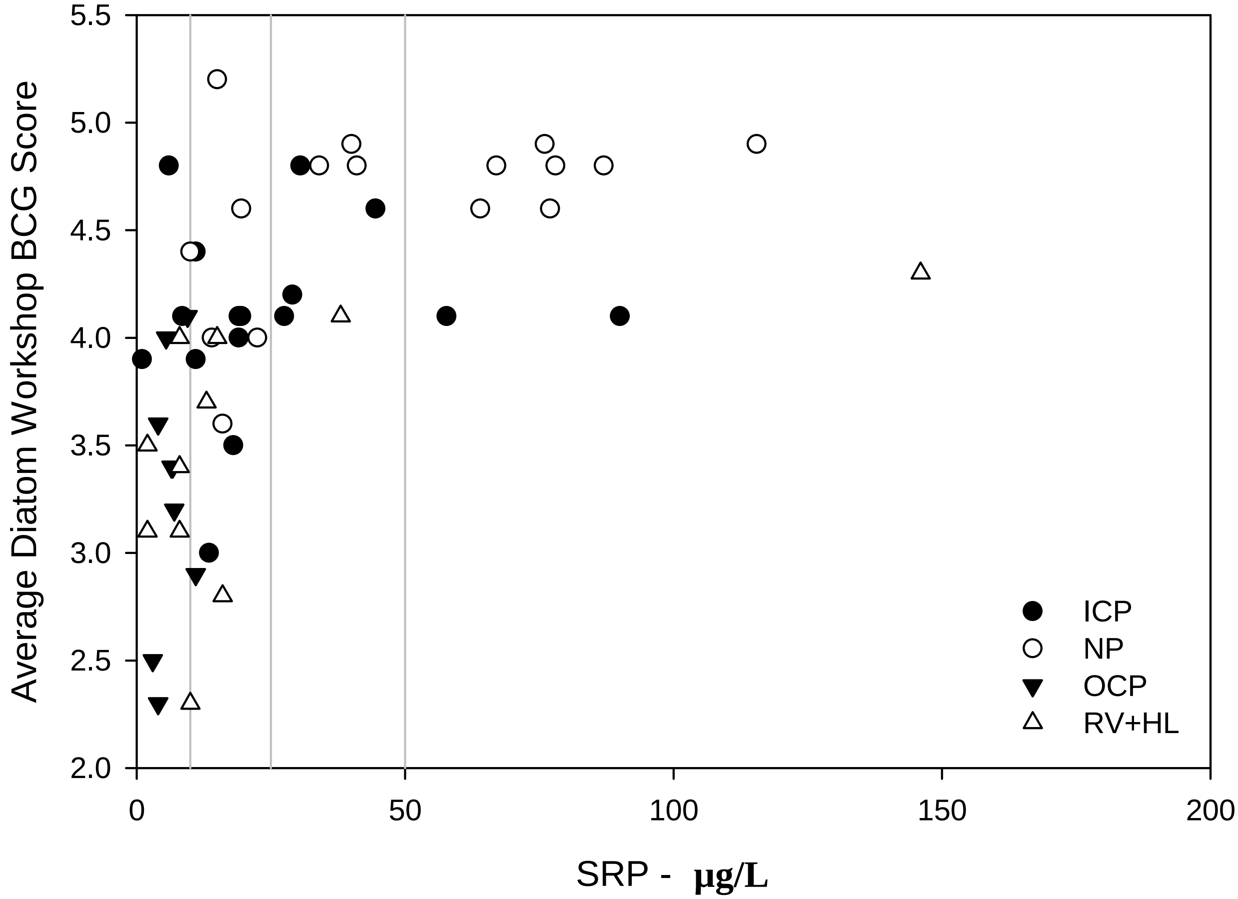
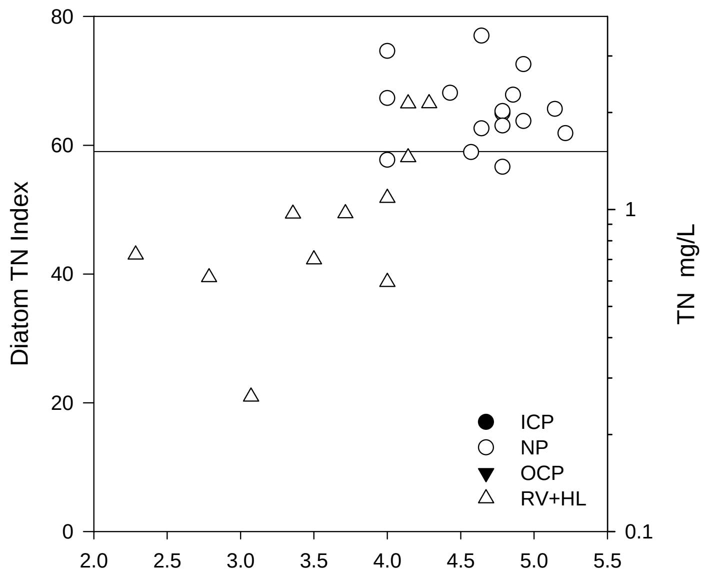
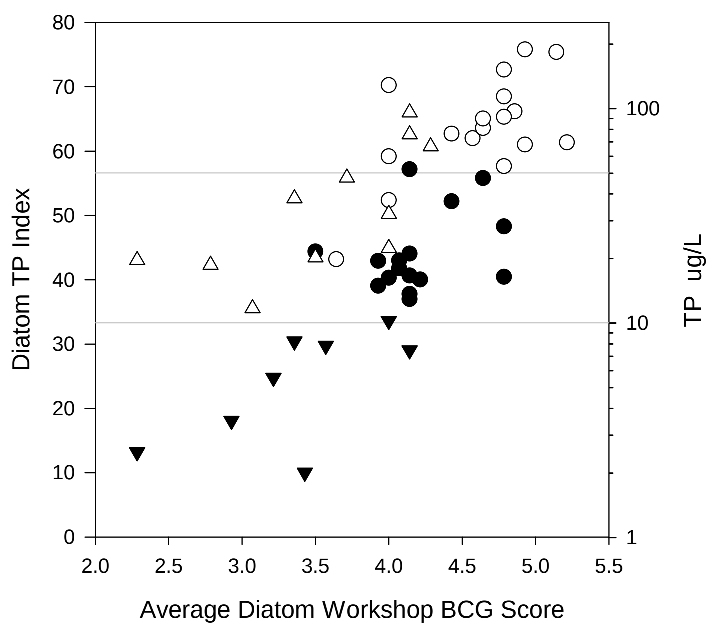


Figure 17. Soluble reactive phosphorus (SRP) vs. Average Diatom Workshop BCG Score for 57 study sites, by ecoregion.

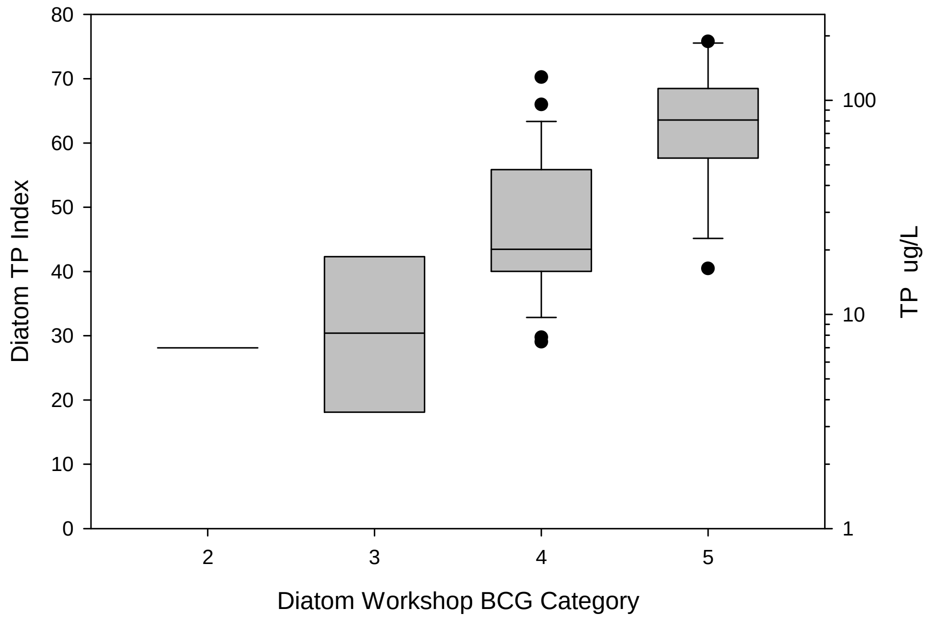


18a

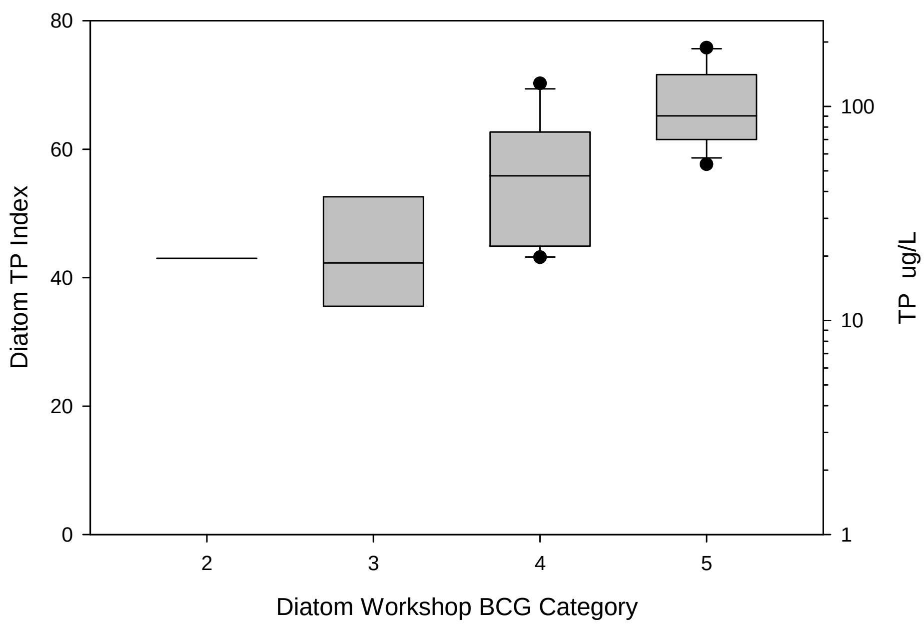


18b

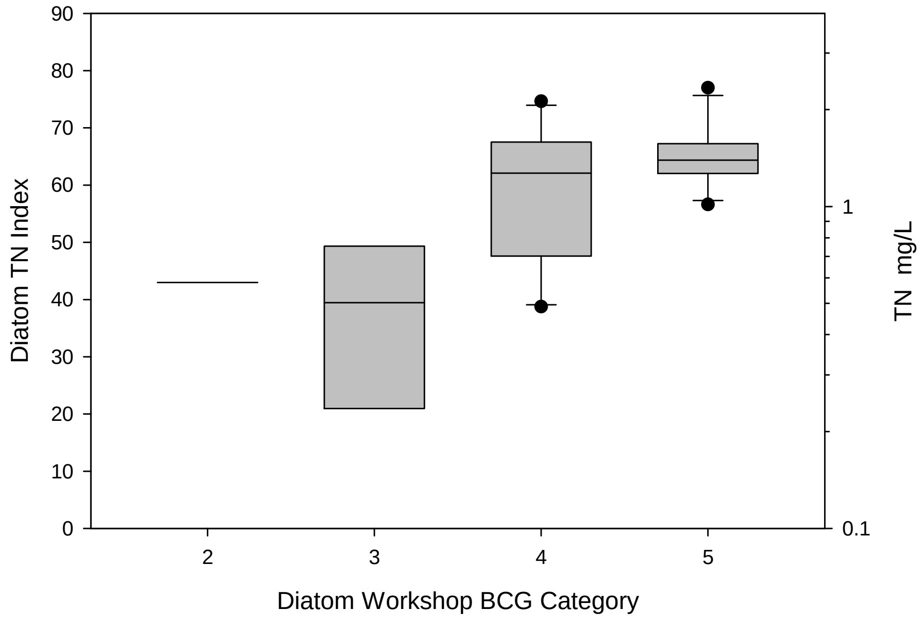
Figure 18 a - b. Average Diatom Workshop BCG Score vs. a) Diatom TN Index and b) Diatom TP Index for 51 study sites, by ecoregion. The concentration range of TP and TN corresponding with the index values are shown on the right vertical axes. Horizontal reference lines on the TP plot represent TP index values of 33.3 and 56.6, and correspond to TP values of 25 and 50 µg/L, respectively. The horizontal reference line on the TN plot represents a TN Index value of 59, corresponding to a TN value of 1.5 mg/L. All diatom index values are from Ponader et al (2007, 2008) and are based on bootstrapped inference models. The relationships for only the northern (r^2 = 0.65) and the southern sites (r^2 = 0.60) are each higher than for all sites together (r^2 = 0.49).


Diatom TP Index
TP ug/L
Diatom Workshop BCG Category
0
10
20
30
40
50
60
70
80
1
10
100
2
3
4
5

19a


Diatom TP Index
TP ug/L
Diatom Workshop BCG Category
0
20
40
60
80
1
10
100
2
3
4
5

19b



19c

Figure 19 a **-** c. Diatom Workshop BCG Category vs. Diatom TP and TN Index values. The concentration range of TP and TN corresponding with the index values are shown on the right vertical axes. Plot a represents TP Index values for all 51 sites in northern and southern NJ; b) represents only the 31 sites in the northern zone. Plot c) represents the 26 sites from northern NJ; sufficient measured TN data were not available to develop a Diatom TN Index for the southern zone. All index values are from Ponader et al (2007, 2008) and are based on bootstrapped inference models.

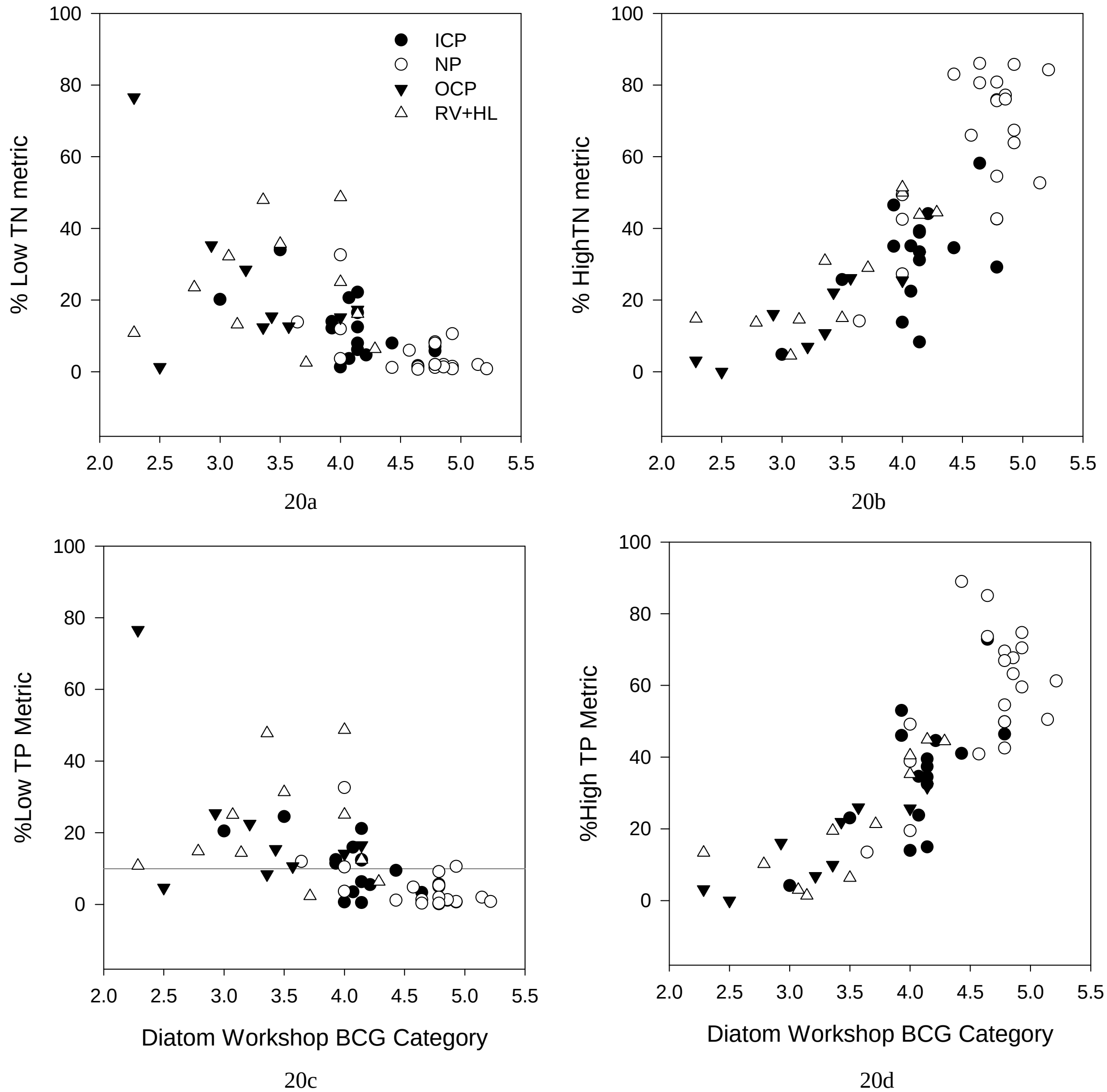
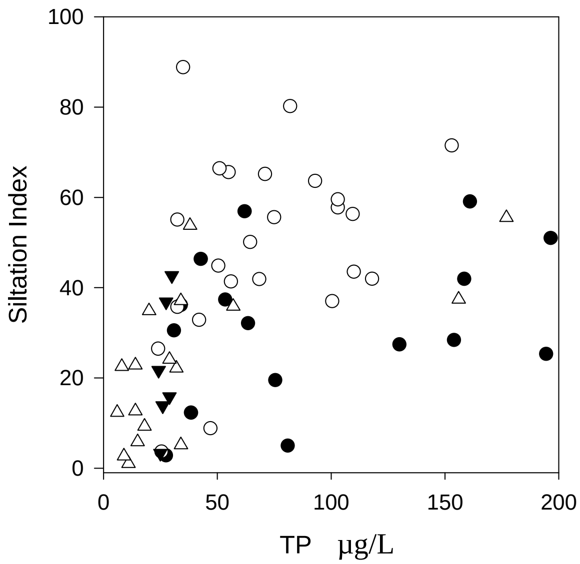
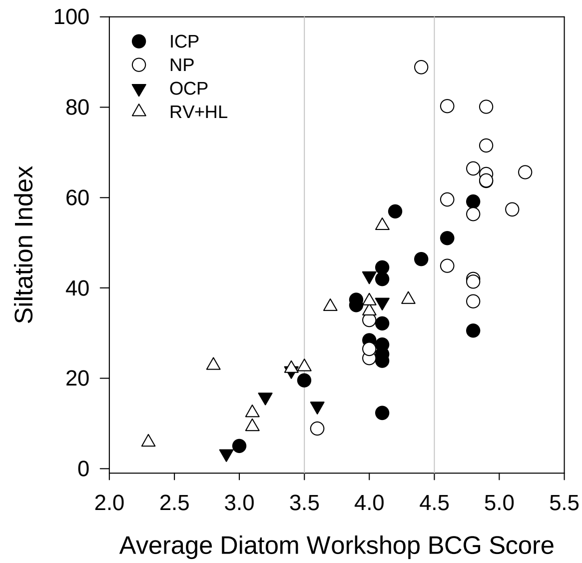


Figure 20 a - d. Percent High- and % Low-TN (a,b) and TP (c,d) metrics (Potapova and Charles 2007) vs. Average Diatom Workshop BCG Score for 57 sites, by ecoregion.



21a



21b

Figure 21 a - b. Siltation Index vs. a) TP and b) Average Diatom Workshop BCG Score for 57 sites, by ecoregion.

Appendices

Included in report

1. Data dictionary for site location and environmental variables. Descriptions of fields in Appendix 8, "Location and environmental data for 201 study samples." Sources of data for some fields are indicated in the "data_source" column. "Data_source" values: "NJAI" = NJ Algal Indicators study (Ponader et al. 2007 for Northern NJ; Ponader et al. 2008 for Southern NJ); "NJ Invertebrate TALU" = NJ Invertebrate TALU study (Gerritsen & Leppo 2005); "NADED" = North American Diatom Ecological Database, administered by the Patrick Center; "NAWQA Data Warehouse" = NAWQA Data Warehouse website, http://infotrek.er.usgs.gov/nawqa_queries/swmaster/index.jsp; "NAWQA GIS database" = database of spatial data provided by James Falcone of USGS; "AMNET" = habitat and other data collected during AMNET sampling, and provided by Tom Miller of NJDEP (see http://www.state.nj.us/dep/wms/bfbm/downloads.html for relevant publications).

2. Site and sample codes, labels, ecoregions, and membership in study datasets [(140, 131, 77 and 73-sample datasets)] for 201 samples. Abbreviated column headings: Dtm. TALU site ID = site identifier used for this study; Lvl. 3 Eco. = Omernik Level III Ecoregion (NP = Northern Piedmont; NEH = Northeastern Highlands; NECZ = Northeastern Coastal Zone; ACPB = Atlantic Coastal Pine Barrens; CARV = Central Appalachian Ridges and Valleys; MACP = Mid-Atlantic Coastal Plain); Sub-Eco. = Sub-ecoregion (ICP = Inner Coastal Plain; OCP = Outer Coastal Plain); Dtm. Cllctn. Date = diatom sample collection date; Dtm. Smpl. ID = identifier of diatom sample; "Label" = unique identifier for samples during data analysis and workshop proceedings.

3. Site codes, PCA-Stressor Scores, average BCG Category site scores determined at the diatom expert-panel workshop, and State Biologist Impairment Scores for 73 study sites. Includes statewide N-S Zone specific scores. See text for more information.

4. List of 192 diatom taxa occurring in the 201-sample dataset, and ecological data. Includes name, authority, NADED ID, number of samples in which taxa occurred, total number of valves counted in all samples, BCG Attribute to which taxa were assigned before and during the diatom expert-panel workshop, and optima (AWM) and tolerance of taxa for PCA-Stressor Score, land-use categories, dissolved oxygen, temperature, and Benthic Macroinvertebrate Impairment Score (NJMI-Cat-16). Field names are documented in Appendix 1.

5. Diatom metrics for 201-sample dataset.

6. Diatom taxa synonyms. Name used in current dataset and corresponding name used in earlier sample and data analysis (Ponader et al. 2007, 2008).

7. State Biologist Diatom TALU Stressor Review Meeting (September 4, 2009). Assignments of 27 sites to stressor categories.

The Appendices below are unprintable and can be found as separate excel files.

8. Location and environmental data for 201 study samples. Each record contains environmental data pertaining to a single diatom sample. See text for more information. Data dictionary for descriptions of all fields is Appendix 1. (Filename: Location and environ data.xls)

9. Environmental data downloaded from NWIS (http://waterdata.usgs.gov/nwis/dv/?referred_module=sw) for NJ Algal Indicator sites; both their NJDEP and USGS site codes are listed. Descriptions of the parameters are displayed in Table 1. All of the displayed data were collected between June and September, and are averaged in cases where multiple values were available per site and parameter. (Filename: Appendix 9 Avg NWIS environ data.xls)

10. List of 546 diatom taxa occurring in the 201-sample dataset , and ecological data. Includes name, authority, NADED ID, number of samples in which taxa occurred, total number of valves counted in all samples, BCG Category to which taxa were assigned before and during the diatom expert-panel workshop, and optima (AWM) and tolerance of taxa for PCA stressor score, land-use categories, dissolved oxygen, temperature, [CCA stressor score], and Benthic Macroinvertebrate Impairment Score (NJMI-Cat-16). Documentation of field names are in a separate spreadsheet tab. See text for further explanation. (Filename: Appendix 10 List of 546 diatom taxa and ecol data.xls)

Appendix 1

Data dictionary for site location and environmental variables. Descriptions of fields in Appendix 10, "Location and environmental data for 201 study samples." Sources of data for some fields are indicated in the "data_source" column.

"Data_source" values:
"NJAI" = NJ Algal Indicators study (Ponader et al. 2007 for Northern NJ; Ponader et al. 2008 for Southern NJ);
"NJ Invertebrate TALU" = NJ Invertebrate TALU study (Gerritsen and Leppo 2005);
"NADED" = North American Diatom Ecological Database, administered by the Patrick Center;
"NAWQA Data Warehouse" = NAWQA Data Warehouse website, http://infotrek.er.usgs.gov/nawqa_queries/swmaster/index.jsp;
"NAWQA GIS database" = database of spatial data provided by James Falcone of USGS; "AMNET" = habitat and other data collected during AMNET sampling, and provided by Tom Miller of NJDEP (see http://www.state.nj.us/dep/wms/bfbm/downloads.html for relevant publications).
[appdx_1_site_and_stressor_data.xls - "Data Dictionary" tab]

Field Name	Description	Data Source
afdm_gm2	ash-free dry mass, g/m2	various
algae_sample_type	Collection method of algae sample: "HC" = hand collection; "RTH" = richest-targeted habitat, "DTH" = depositional-targeted habitat; "Indiv" = individual habitat; "Diatomet" = diatometer	NADED
alk_mgl	alkalinity, filtered, mg/L CaCO3	various
ASPT	Average score per taxon (BMWP divided by no. taxa)	NJ Invertebrate TALU
ASPT-Abun	ASPT abundance-weighted	NJ Invertebrate TALU
Att1pct	Percent individuals attribute 1	NJ Invertebrate TALU
Att1TaxR	Total taxa assigned to BCG Attribute 1	NJ Invertebrate TALU
Att23pct	Percent individuals attribute 2 and 3	NJ Invertebrate TALU
Att23tax	Sum of taxa assigned to BCG Attributes 2 and 3	NJ Invertebrate TALU

Field Name	Description	Data Source
Att23taxpct	Percent of taxa assigned to BCG Attributes 2 and 3	NJ Invertebrate TALU
Att2pct	Percent individuals attribute 2	NJ Invertebrate TALU
Att2TaxR	Total taxa assigned to BCG Attribute 2	NJ Invertebrate TALU
Att3pct	Percent individuals attribute 3	NJ Invertebrate TALU
Att3TaxR	Total taxa assigned to BCG Attribute 3	NJ Invertebrate TALU
Att4pct	Percent individuals attribute 4	NJ Invertebrate TALU
Att4TaxR	Total taxa assigned to BCG Attribute 4	NJ Invertebrate TALU
Att5pct	Percent individuals attribute 5	NJ Invertebrate TALU
Att5TaxR	Total taxa assigned to BCG Attribute 5	NJ Invertebrate TALU
Att6pct	Percent individuals attribute 6	NJ Invertebrate TALU
Att6TaxR	Total taxa assigned to BCG Attribute 6	NJ Invertebrate TALU
avg_wi_m	section width, m for NJAI samples	NJAI
basn_km2	basin area, km2	various
BMWP	Biomonitoring Working Party Score (British index consisting of sum of intolerance scores)	NJ Invertebrate TALU
bod_mgl	biochemical oxygen demand, unfiltered, 5 day incubation at 20 degrees C, mg/L O2	various
bod_qual	qualifier field for bod_mgl; see table	various

Field Name	Description	Data Source
	'qualifier_codes'	
chla_be_mgm2	chlorophyll a, benthic, mg/m2	various
chla_dt_mgm2	chlorophyll a, diatometer, mg/m2	NJAI
cl_na_ratio	[clde_mgl]/[na_f_mgl]; only used values collected simultaneously.	(calculated)
cl_so4_ratio	[clde_mgl]/[so4_f_mgl]; only used values collected simultaneously.	(calculated)
clde_mgl	chloride, filtered, mg/L	various
close	Whether nominal and 2nd tier are close. "Tie" = exact tie, "yes" = memberships within 0.2	NJ Invertebrate TALU
collection_year	year diatom sample was collected	(computed)
color		NJAI
cond_fie_uscm	specific conductivity at 25 C, uS/cm, field	various
corresp_algae_sample_code	algae sample code from naded.samples.code	NADED
county		NADED
CricPct	Percent of individuals that are Cricotopus (tolerant midge genus)	NJ Invertebrate TALU
diatom_collection_date		NADED
do_mgl	dissolved oxygen, unfiltered, mg/L	various
doc_mgl	dissolved organic carbon, filtered, mg/L	various
elevation_feet		NADED
EphemPct	percent of individuals that are Ephemeroptera (mayflies)	NJ Invertebrate TALU
flow_est	estimate of flow, levels 1-3	various
hab_date	NJDEP habitat sample date	AMNET

Field Name	Description	Data Source
hab_gradient	"H" = high gradient, "L" = low gradient; see Poretti, Bryson, & Miller (2008)	AMNET
hab_gradient_no	Numeric form of "hab_gradient;" high = 1, low = 2	(computed)
hab_param_1	See Poretti, Bryson, & Miller (2008)	AMNET
hab_param_10_avg	Average of "hab_param_10left" and "hab_param_10right"	(computed)
hab_param_10left	Riparian Vegetative Zone Width; see Poretti, Bryson, & Miller (2008)	AMNET
hab_param_10right	Riparian Vegetative Zone Width; see Poretti, Bryson, & Miller (2008)	AMNET
hab_param_2	See Poretti, Bryson, & Miller (2008)	AMNET
hab_param_3	See Poretti, Bryson, & Miller (2008)	AMNET
hab_param_4	See Poretti, Bryson, & Miller (2008)	AMNET
hab_param_5	Channel Flow Status; See Poretti, Bryson, & Miller (2008)	AMNET
hab_param_6	Channel Alteration; See Poretti, Bryson, & Miller (2008)	AMNET
hab_param_7	See Poretti, Bryson, & Miller (2008)	AMNET
hab_param_8left	Bank Stability; see Poretti, Bryson, & Miller (2008)	AMNET
hab_param_9_avg	Average of "hab_param_9left" and "hab_param_9right"	(computed)
hab_param_9left	Bank Vegetative Protection; see Poretti, Bryson, & Miller (2008)	AMNET
hab_param_9right	Bank Vegetative Protection; see Poretti, Bryson, & Miller (2008)	AMNET
hab_rating	Categorization of "hab_score;" see Poretti, Bryson, & Miller (2008)	AMNET

Field Name	Description	Data Source
hab_rating_no	Numeric form of "hab_rating;" "poor" = 1, "marginal" = 2, "suboptimal" = 3, "optimal" = 4	(computed)
hab_round	Round of AMNET sampling during which samples were taken	AMNET
hab_score	See Poretti, Bryson, & Miller (2008)	AMNET
har_mgl	hardness, mg/L as CaCO3	various
har_qual	qualifier field for har_mgl; see table 'qualifier_codes'	various
HBI	Hilsenhoff Biotic Index	NJ Invertebrate TALU
HydPct	Percent of individuals that Hydropsychidae (net-spinning caddisflies)	NJ Invertebrate TALU
inv_date	invertebrate sampling date	NJ Invertebrate TALU
inv_metric_category	Value of "macs_category" if from a southern NJ site; value of "nj_hgmi_category" if from a northern NJ site	(computed)
inv_metric_subcategory	Value of "macs_subcategory" if from a southern NJ site; value of "nj_hgmi_subcategory" if from a northern NJ site	(computed)
inv_pinelands	"yes" = in Pinelands protection area, but may not be Pinelands biotype	NJ Invertebrate TALU
k_f_mgl	Potassium, water, filtered, mg/L.	NAWQA Data Warehouse
latitude_decimal	latitude of site, in decimal degrees	NADED
longitude_decimal	longitude of site, in decimal degrees	NADED
lu_ag_pc	land use %agriculture	various

Field Name	Description	Data Source
lu_fo_pc	land use %forest (or %undeveloped for nawqa sites)	various
lu_fo_wl_pc	combined % wetland-% forest land use values	(calculated)
lu_is_pc	land use %impervious surface	NAWQA GIS database
lu_ur_pc	land use %urban	various
lu_wl_pc	land use %wetland	NJAI
lvl_3_ecoregion	Omernik Level III Ecoregion	NADED
MACS	Mid-Atlantic Coastal Plain index (Maxted et al. 2000; coastal plain sites only)	NJ Invertebrate TALU
macs_category	Numeric categorization of "MACS" values from 1 to 4, 1 being "poor" and 4 being "excellent;" Categories taken from Poretti, Bryson, & Miller (2008)	(computed)
macs_subcategory	Division of each "macs_category" into four subcategories of equal width.	(computed)
main_source	Study responsible for algae sample and bulk of environmental data; "njai_north" = NJAI study of Northern NJ; "njai_south" = NJAI study of Southern NJ; "nawqa" = NAWQA, and "nj_nawqa_np" = NAWQA data taken from the Northern Piedmont study (Potapova et al. 2004) data compilation	
Memb	Degree of membership in nominal tier	NJ Invertebrate TALU
Memb_2	degree of membership in 2nd tier	NJ Invertebrate TALU
na_f_mgl	Sodium, water, filtered, mg/L.	NAWQA Data Warehouse
nawqa_study_unit	Four-letter abbreviation for the NAWQA	NADED

Field Name	Description	Data Source
	study unit that houses the site	
nh4n_mgl	NH4, mg/L as N	various
nh4n_qual	qualifier field for nh4n_mgl; see table 'qualifier_codes'	
NJ_HGMI	New Jersey High Gradient Macroinvertebrate Index (NJ multimetric index for non-coastal plain)	NJ Invertebrate TALU
nj_hgmi_category	Numeric categorization of "NJ_HGMI" values from 1 to 4, 1 being "poor" and 4 being "excellent;" Categories taken from Poretti, Bryson, & Miller (2008)	(computed)
nj_hgmi_subcategory	Division of each "nj_hgmi_category" into four subcategories of equal width.	(computed)
nj_talu_site_code	NJDEP site code if available, otherwise USGS site code (intended to help identify unique and duplicated sites)	
nj_zone	"north"/"south" flag for NJAI samples; see report text for definitions	(computed)
njdep_site_code	Alpha-numeric site identifier used by NJDEP	NADED
njis	NJ Impairment Score	AMNET
njis_imp_no	Numeric form of "njis_impairment;" 1 = severe, 2 = moderate, 3 = non-impaired	(computed)
njis_impairment	NJ Impairment Score category	AMNET
no3n_mgl	NO3, mg/L as N	various
no3n_qual	qualifier field for no3n_mgl; see table 'qualifier_codes'	various
NomTier	Nominal BCG tier assigned to sample from fuzzy-set model	NJ Invertebrate TALU
OligoPct	Percent of individuals that are oligochaetes	NJ Invertebrate TALU

Field Name	Description	Data Source
op_p_qual	qualifier field for op_p_ugl; see table 'qualifier_codes'	various
op_p_ugl	orthophosphate, filtered, µg/L as P	various
open_pc	canopy %open	NJAI
ph_field	pH, unfiltered, field	various
sample_label	Alpha-numeric code used by ANSP during data analysis and workshop discussion	(computed)
sec_l_m	section length, m for NJAI samples	NJAI
section_no	section number for NJAI samples	NJAI
site_name	Name of site, provided by NJDEP/USGS	NADED
so4_f_mgl	Sulfate, water, filtered, mg/L.	NAWQA Data Warehouse
source_client_site_code	client site code where data originally stored	NADED
su_bo_pc	substrate %boulder	NJAI
su_br_pc	substrate %bedrock	NJAI
su_cb_pc	substrate %cobble	NJAI
su_gr_pc	substrate %gravel	NJAI
su_sd_pc	substrate %sand	NJAI
su_si_cl_pc	combined % silt-% clay substrate values	NJAI
sub_ecoregion	If "lvl_3_ecoregion" is "atlantic coastal pine barrens," then this field notes whether the site falls in the "inner coastal plain" or "outer coastal plain" according to (reference used in NJAI papers); otherwise, same as "lvl_3_ecoregion"	NJAI
TaxaR100	Taxa estimated from rarefaction for samples > 200 individuals (not a	NJ Invertebrate

Field Name	Description	Data Source
	randomized subsample; coastal plain sites only)	TALU
temp_w_c	water temperature, field, degrees C	various
Tier_2d	Second (runner-up) tier	NJ Invertebrate TALU
tkn_mgl	TKN, unfiltered, mg/L	various
tn_mgl	TN, unfiltered, mg/L	various
TotalInd	Total individuals in standard NJ subsample. Target subsample = 100 organisms, but in 1993-94, many samples were counted to completion	NJ Invertebrate TALU
TotalTax	total number of distinct invertebrate taxa	NJ Invertebrate TALU
tp_ugl	TP, unfiltered, µg/L	various
TubPct	Percent of individuals that are Tubificidae	NJ Invertebrate TALU
turb	turbidity	various
turb_qual	qualifier field for turb; see table 'qualifier_codes'	various
usgs_site_code	Alpha-numeric site identifier used by NAWQA	NADED
waterbody_name	Name of waterbody at site, provided by NJDEP or USGS	NADED

Appendix 2

Site codes, PCA stressor scores, average BCG level site scores determined at diatom expert-panel workshop, and NJ DEP biologist stressor scores for 73 study sites. Includes statewide N-S Zone specific scores. See text for more information. [appdx_2_site_scores.xls]

NJDEP site ID	USGS site ID	Diatom TALU site ID	NJ Zone	Stressor Score	Stressor Categ.	Zone Stressor Score	Avg. Wkshp. Score	NJDEP Score
AN0006	01439830	AN0006	north	2.115	2	0.007		
AN0008	01440000	AN0008	north	1.577	2	1.318	3.5	2
AN0016	01443276	AN0016	north	8.421	5	5.763		
AN0029	01443600	AN0029	north	2.468	2	2.610	2.3	2
AN0032A	01443700	AN0032A	north	4.234	3	4.811		
AN0081	01458570	AN0081	north	4.394	3	3.403	4.8	5
AN0111	01463661	AN0111	north	8.113	5	6.023	4.9	5
AN0115	01463850	AN0115	north	9.218	5	3.028		
AN0118	01464020	AN0118	north	9.124	5	8.804	5.1	
AN0121	01464420	AN0121	south	5.284	3	5.049	4.1	6
AN0129	01464515	AN0129	south	7.737	4	1.578	4.4	5
AN0132	01464527	AN0132	south	5.966	3	4.499	4.8	5
AN0136	01464540	AN0136	south	6.576	4	4.902	4.1	6
AN0139	01464578	AN0139	south	7.364	4	3.047	4.0	3

NJDEP site ID	USGS site ID	Diatom TALU site ID	NJ Zone	Stressor Score	Stressor Categ.	Zone Stressor Score	Avg. Wkshp. Score	NJDEP Score
AN0149A	01465965	AN0149A	south	4.489	3	7.004	3.6	4
AN0151A	0146700260	AN0151A	south	5.963	3	7.780	3.0	4
AN0166	01465865	AN0166	south	8.060	5	5.152	3.5	5
AN0169	01465882	AN0169	south	5.543	3	6.174	4.1	5
AN0192	01393960	AN0192	north	4.610	3	10.013	4.8	6
AN0195	01395000	AN0195	north	8.356	5	9.077		
AN0207	01377500	AN0207	north	8.000	5	8.024		
AN0209	01378387	AN0209	north	7.888	4	6.880	5.2	
AN0211	01378560	AN0211	north	8.735	5	9.469	4.6	
AN0213	01378660	AN0213	north	5.552	3	4.727	4.1	
AN0215	01378780	AN0215	north	0.893	2	0.583	4.0	
AN0231	01379580	AN0231	north	7.173	4	6.441	4.9	6
AN0234	01381498	AN0234	north	6.365	4	7.514	4.9	
AN0235	01381515	AN0235	north	5.743	3	6.183	4.8	
AN0237	01443470	AN0237	north	6.597	4	7.176		
AN0245	01446000	AN0245	north	1.882	2	0.960	3.1	

NJDEP site ID	USGS site ID	Diatom TALU site ID	NJ Zone	Stressor Score	Stressor Categ.	Zone Stressor Score	Avg. Wkshp. Score	NJDEP Score
AN0255	01383505	AN0255	north	4.255	3	4.334	3.7	
AN0259	01382170	AN0259	north	3.061	3	3.346	3.1	
AN0265	01382800	AN0265	north	5.085	3	6.026	2.8	2
AN0267	01387811	AN0267	north	5.689	3	6.691		
AN0274	01389500	AN0274	north	5.621	3	6.437	4.0	
AN0281	01390470	AN0281	north	8.631	5	9.674		
AN0291	01391550	AN0291	north	9.738	5	9.802	4.9	
AN0299	01367715	AN0299	north	4.888	3	4.787	3.4	3
AN0313	01396219	AN0313	north	3.253	3	3.073		
AN0315	01396270	AN0315	north	5.439	3	6.774	4.3	
AN0318	01396550	AN0318	north	2.830	2	2.851		
AN0321	01396660	AN0321	north	4.146	3	4.148	4.0	2
AN0326	01397000	AN0326	north	5.422	3	5.498	4.0	
AN0333	01398000	AN0333	north	6.836	4	5.909	4.4	
AN0339	01398090	AN0339	north	5.605	3	5.995		
AN0341	01398102	AN0341	north	6.894	4	8.046		

NJDEP site ID	USGS site ID	Diatom TALU site ID	NJ Zone	Stressor Score	Stressor Categ.	Zone Stressor Score	Avg. Wkshp. Score	NJDEP Score
AN0346	01398260	AN0346	north	5.275	3	5.885		
AN0370	01399780	AN0370	north	3.791	3	3.540	4.6	
AN0374	01398900	AN0374	north	4.040	3	4.540		
AN0384	01400808	AN0384	north	6.498	4	6.048	3.6	4
AN0396	01401400	AN0396	north	6.002	4	4.730	4.0	
AN0405	01401700	AN0405	north	7.754	4	8.594	4.6	
AN0413	01402730	AN0413	north	8.489	5	8.624	4.8	
AN0424	01403385	AN0424	north	8.521	5	8.174	4.8	
AN0429	01404165	AN0429	north	8.402	5	8.180	4.9	
AN0439	01405340	AN0439	south	5.666	3	4.151	4.1	
AN0440	01405390	AN0440	south	4.577	3	6.781		
AN0448	01405195	AN0448	south	6.449	4	5.803	4.8	
AN0470	01407320	AN0470	south	5.562	3	6.142	4.2	
AN0488	01407868	AN0488	south	6.829	4	6.160	4.1	
AN0489	01407871	AN0489	south	8.606	5	1.302	3.9	
AN0490	01407900	AN0490	south	5.786	3	5.794	3.9	

NJDEP site ID	USGS site ID	Diatom TALU site ID	NJ Zone	Stressor Score	Stressor Categ.	Zone Stressor Score	Avg. Wkshp. Score	NJDEP Score
AN0503	01408100	AN0503	south	7.514	4	8.940	3.4	
AN0510	01408136	AN0510	south	4.846	3	8.047	3.4	
AN0532	01408460	AN0532	south	6.087	4	9.990	2.5	
AN0575	0140941075	AN0575	south	7.052	4	4.286	4.0	
AN0623	01410820	AN0623	south	3.781	3	7.704	2.9	
AN0673	01475090	AN0673	south	7.399	4	4.721	4.1	
AN0683	01477120	AN0683	south	6.550	4	4.234	4.1	
AN0686	01477440	AN0686	south	5.895	3	7.310	3.2	
AN0694	01482530	AN0694	south	9.026	5	0.000	4.6	
AN0740	01411500	AN0740	south	5.364	3	4.827	2.3	3
AN0744	01411680	AN0744	south	5.017	3	6.323	4.1	

Appendix 3

Site and sample codes, labels, ecoregions, and membership in study datasets [(140, 131, 77 and 73-sample datasets)] for 201 samples. Abbreviated column headings: Dtm. TALU site ID = site identifier used for this study; Lvl. 3 Eco. = Omernik Level III Ecoregion (NP = Northern Piedmont; NEH = Northeastern Highlands; NECZ = Northeastern Coastal Zone; ACPB = Atlantic Coastal Pine Barrens; CARV = Central Appalachian Ridges and Valleys; MACP = Mid-Atlantic Coastal Plain); Sub-Eco. = Sub-ecoregion (ICP = Inner Coastal Plain; OCP = Outer Coastal Plain); Dtm. Cllctn. Date = diatom sample collection date; Dtm. Smpl. ID = identifier of diatom sample; "Label" = unique identifier for samples during data analysis and workshop proceedings. [appdx_3_sample_sets.xls]

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
01379000	north	NP	NP	7/8/1996	GS028073	N1Q6			
01379500	north	NP	NP	10/3/1996	GS028083	N2Q6			
01379680	north	NEH	NEH	9/25/1996	GS028093	N3Q6			
01380500	north	NP	NP	9/25/1996	GS028103	N4Q6			
01381500	north	NP	NP	9/30/1996	GS028123	N5Q6			
01387041	north	NP	NP	9/24/1996	GS028153	N6Q6			
01387042	north	NP	NP	10/8/1996	GS028163	N7Q6			
01390500	north	NECZ	NECZ	7/3/1996	GS028183	N8Q6			
01390500	north	NECZ	NECZ	7/8/1997	GS028413	N8Q7X			
01390500	north	NECZ	NECZ	7/9/1997	GS028423	N8Q7Y			
01390500	north	NECZ	NECZ	7/10/1997	GS028433	N8Q7Z			

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
01390500	north	NECZ	NECZ	7/21/1998	GS028583	N8Q8			
01393400	north	NP	NP	10/3/1996	GS028203	N9Q6			
01396535	north	NP	NP	9/11/1996	GS028223	N10Q6			
01397295	north	NP	NP	9/11/1996	GS028253	N11Q6			
01401000	north	NP	NP	7/11/1996	GS028303	N12Q6			
01401000	north	NP	NP	7/3/1997	GS028473	N12Q7			
01401000	north	NP	NP	7/24/1998	GS028603	N12Q8			
01401600	north	NP	NP	9/10/1996	GS028313	N13Q6			
01403300	north	NP	NP	7/10/1996	GS028323	N14Q6			
01403300	north	NP	NP	7/22/1997	GS028483	N14Q7			
01403300	north	NP	NP	7/23/1998	GS028613	N14Q8			
01403900	north	NP	NP	7/2/1996	GS028333	N15Q6			
01403900	north	NP	NP	7/17/1997	GS028493	N15Q7			
01403900	north	NP	NP	7/22/1998	GS028623	N15Q8			
01410784	south	ACPB	ACPB	7/21/1997	GS028503	S16Q7			
01438399	north	CARV	CARV	8/29/2001	GSN87393	N17Q1			

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
01467150	south	MACP	MACP	8/23/1999	GSN00428	S18Q9			
01467150	south	MACP	MACP	7/24/2000	GSN23742	S18Q0			
01467150	south	MACP	MACP	8/6/2001	GSN87479	S18Q1			
AN0006	north	CARV	CARV	8/7/2002	NJ000121	N006A21	X	X	X
AN0008	north	CARV	CARV	9/1/1999	GSN00407	N008Q9			
AN0008	north	CARV	CARV	8/1/2000	GSN24343	N008Q0			
AN0008	north	CARV	CARV	8/15/2001	GSN87410	N008Q1			
AN0008	north	CARV	CARV	8/7/2002	NJ000124	N008A21	X	X	X
AN0016	north	CARV	CARV	8/6/2002	NJ000127	N016A21	X	X	X
AN0029	north	CARV	CARV	8/8/2002	NJ000129	N029A21	X	X	X
AN0032A	north	CARV	CARV	8/8/2002	NJ000132	N032AA21	X	X	X
AN0081	north	NP	NP	9/14/2000	NJ000001	N081A01	X	X	X
AN0081	north	NP	NP	9/14/2000	NJ000002	N081A02	X		
AN0081	north	NP	NP	9/14/2000	NJ000003	N081A03	X		
AN0109	north	NP	NP	9/16/2003	NJ000380	N109A32		X	
AN0111	north	NP	NP	9/25/2000	NJ000004	N111A01	X	X	X

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0111	north	NP	NP	9/25/2000	NJ000005	N111A02	**X**		
AN0115	north	NP	NP	8/9/2000	NJ000006	N115A01	**X**	**X**	**X**
AN0115	north	NP	NP	8/9/2000	NJ000007	N115A02	**X**		
AN0115	north	NP	NP	8/9/2000	NJ000008	N115A03	**X**		
AN0115	north	NP	NP	8/26/2001	NJ000086	N115A11			
AN0118	north	NP	NP	10/3/2000	NJ000009	N118A01	**X**	**X**	**X**
AN0118	north	NP	NP	10/3/2000	NJ000010	N118A02	**X**		
AN0118	north	NP	NP	10/3/2000	NJ000011	N118A03	**X**		
AN0121	south	ACPB	ICP	9/5/2003	NJ000205	S121A31	**X**	**X**	**X**
AN0124	south	ACPB	ICP	9/16/2003	NJ000360	S124A32		**X**	
AN0129	south	ACPB	ICP	9/9/2003	NJ000235	S129A31	**X**	**X**	**X**
AN0132	south	ACPB	ICP	9/5/2003	NJ000225	S132A31	**X**	**X**	**X**
AN0136	south	ACPB	ICP	9/16/2003	NJ000345	S136A31	**X**	**X**	**X**
AN0139	south	ACPB	ICP	9/5/2003	NJ000215	S139A31	**X**	**X**	**X**
AN0149A	south	ACPB	OCP	9/14/2004	NJ000404	S149A41H	**X**		
AN0149A	south	ACPB	OCP	9/14/2004	NJ000405	S149A42H	**X**		

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0149A	south	ACPB	OCP	9/14/2004	NJ000450	S149AA41	X	X	X
AN0149A	south	ACPB	OCP	9/14/2004	NJ000455	S149AA42	X		
AN0151A	south	ACPB	ICP	9/5/2003	NJ000195	S151AA31	X	X	X
AN0166	south	ACPB	ICP	9/4/2003	NJ000180	S166A31	X	X	X
AN0169	south	ACPB	ICP	9/5/2003	NJ000190	S169A31	X	X	X
AN0192	north	NP	NP	8/22/2001	NJ000089	N192A11	X	X	X
AN0195	north	NP	NP	9/19/2000	NJ000015	N195A01	X	X	X
AN0195	north	NP	NP	9/19/2000	NJ000016	N195A02	X		
AN0195	north	NP	NP	9/19/2000	NJ000017	N195A03	X		
AN0207	north	NP	NP	8/23/2001	NJ000092	N207A11	X	X	X
AN0209	north	NP	NP	8/23/2001	NJ000095	N209A11	X	X	X
AN0211	north	NP	NP	9/28/2000	NJ000018	N211A01	X	X	X
AN0211	north	NP	NP	9/28/2000	NJ000019	N211A02	X		
AN0211	north	NP	NP	9/28/2000	NJ000020	N211A03	X		
AN0211	north	NP	NP	8/24/2001	NJ000098	N211A11			
AN0213	north	NEH	NEH	8/14/2002	NJ000135	N213A21	X	X	X

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0215	north	NEH	NEH	9/15/2000	NJ000021	N215A01	X	X	X
AN0215	north	NEH	NEH	9/15/2000	NJ000022	N215A02			
AN0215	north	NEH	NEH	9/15/2000	NJ000023	N215A03			
AN0215	north	NEH	NEH	10/4/2002	NJ000168	N215A21			
AN0231	north	NP	NP	10/22/1997	GS028783	N231Q7			
AN0231	north	NP	NP	8/22/2001	NJ000101	N231A11	X	X	X
AN0234	north	NP	NP	9/27/2000	NJ000027	N234A01	X	X	X
AN0234	north	NP	NP	9/27/2000	NJ000028	N234A02	X		
AN0234	north	NP	NP	9/27/2000	NJ000029	N234A03	X		
AN0234	north	NP	NP	8/21/2001	NJ000102	N234A11			
AN0234	north	NP	NP	10/4/2002	NJ000171	N234A22			
AN0235	north	NP	NP	8/21/2001	NJ000105	N235A11	X	X	X
AN0237	north	NP	NP	8/22/2001	NJ000108	N237A11	X	X	X
AN0245	north	NEH	NEH	8/14/2002	NJ000138	N245A21	X	X	X
AN0255	north	NEH	NEH	8/12/2002	NJ000141	N255A21	X	X	X
AN0259	north	NEH	NEH	8/13/2002	NJ000144	N259A21	X	X	X

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0265	north	NEH	NEH	8/13/2002	NJ000147	N265A21	X	X	X
AN0267	north	NP	NP	9/26/2000	NJ000033	N267A01	X	X	X
AN0267	north	NP	NP	9/26/2000	NJ000034	N267A02	X		
AN0267	north	NP	NP	9/26/2000	NJ000035	N267A03	X		
AN0274	north	NP	NP	10/2/2000	NJ000036	N274A01	X	X	X
AN0274	north	NP	NP	8/24/2001	NJ000111	N274A11			
AN0281	north	NP	NP	9/20/2000	NJ000037	N281A01	X	X	X
AN0281	north	NP	NP	9/20/2000	NJ000038	N281A02	X		
AN0281	north	NP	NP	9/20/2000	NJ000039	N281A03	X		
AN0291	north	NP	NP	9/29/2000	NJ000040	N291A01	X	X	X
AN0291	north	NP	NP	9/29/2000	NJ000041	N291A02	X		
AN0291	north	NP	NP	9/29/2000	NJ000042	N291A03	X		
AN0299	north	NEH	NEH	8/6/2002	NJ000150	N299A21	X	X	X
AN0313	north	NEH	NEH	8/15/2002	NJ000153	N313A21	X	X	X
AN0315	north	NEH	NEH	8/16/2002	NJ000156	N315A21	X	X	X
AN0318	north	NEH	NEH	9/13/2000	NJ000043	N318A01	X	X	X

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0318	north	NEH	NEH	9/13/2000	NJ000044	N318A02	X		
AN0318	north	NEH	NEH	9/13/2000	NJ000045	N318A03	X		
AN0318	north	NEH	NEH	8/3/2002	NJ000159	N318A21			
AN0321	north	NEH	NEH	7/1/1996	GS028243	N321Q6			
AN0321	north	NEH	NEH	9/13/2000	NJ000046	N321A01	X	X	X
AN0321	north	NEH	NEH	9/13/2000	NJ000047	N321A02	X		
AN0321	north	NEH	NEH	9/13/2000	NJ000048	N321A03	X		
AN0321	north	NEH	NEH	8/3/2002	NJ000162	N321A21			
AN0326	north	NP	NP	9/14/2000	NJ000049	N326A01	X	X	X
AN0326	north	NP	NP	9/14/2000	NJ000050	N326A02	X		
AN0326	north	NP	NP	9/14/2000	NJ000051	N326A03	X		
AN0333	north	NP	NP	7/9/1996	GS028263	N333Q6			
AN0333	north	NP	NP	7/16/1997	GS028463	N333Q7			
AN0333	north	NP	NP	7/20/1998	GS028593	N333Q8			
AN0333	north	NP	NP	8/20/2001	NJ000112	N333A11	X	X	X
AN0339	north	NP	NP	9/7/2000	NJ000052	N339A01	X	X	X

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0339	north	NP	NP	9/7/2000	NJ000053	N339A02	X		
AN0339	north	NP	NP	9/7/2000	NJ000054	N339A03	X		
AN0341	north	NP	NP	9/12/2000	NJ000055	N341A01	X	X	X
AN0341	north	NP	NP	9/12/2000	NJ000056	N341A02	X		
AN0341	north	NP	NP	9/12/2000	NJ000057	N341A03	X		
AN0346	north	NEH	NEH	8/16/2002	NJ000165	N346A21	X	X	X
AN0370	north	NP	NP	9/13/1996	GS028283	N370Q6			
AN0370	north	NP	NP	9/7/2000	NJ000058	N370A01	X	X	X
AN0370	north	NP	NP	9/7/2000	NJ000059	N370A02	X		
AN0370	north	NP	NP	9/7/2000	NJ000060	N370A03	X		
AN0374	north	NP	NP	9/10/1996	GS028293	N374Q6			
AN0374	north	NP	NP	9/11/2000	NJ000061	N374A01	X	X	X
AN0374	north	NP	NP	9/11/2000	NJ000062	N374A02	X		
AN0374	north	NP	NP	9/11/2000	NJ000063	N374A03	X		
AN0374	north	NP	NP	8/20/2001	NJ000115	N374A11			
AN0374	north	NP	NP	10/4/2002	NJ000172	N374A21			

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0384	north	NP	NP	9/16/2003	NJ000365	N384A31	X	X	X
AN0396	north	NP	NP	9/6/2000	NJ000067	N396A01	X	X	X
AN0396	north	NP	NP	9/6/2000	NJ000068	N396A02	X		
AN0396	north	NP	NP	9/6/2000	NJ000069	N396A03	X		
AN0405	north	NP	NP	9/8/2000	NJ000070	N405A01	X	X	X
AN0405	north	NP	NP	9/8/2000	NJ000071	N405A02	X		
AN0405	north	NP	NP	9/8/2000	NJ000072	N405A03	X		
AN0405	north	NP	NP	8/26/2001	NJ000118	N405A11			
AN0413	north	NP	NP	9/12/2000	NJ000073	N413A01	X	X	X
AN0413	north	NP	NP	9/12/2000	NJ000074	N413A02	X		
AN0413	north	NP	NP	9/12/2000	NJ000075	N413A03	X		
AN0424	north	NP	NP	9/18/2000	NJ000077	N424A01	X	X	X
AN0424	north	NP	NP	9/18/2000	NJ000078	N424A02	X		
AN0424	north	NP	NP	9/18/2000	NJ000079	N424A03	X		
AN0429	north	NP	NP	9/18/2000	NJ000080	N429A01	X	X	X
AN0429	north	NP	NP	9/18/2000	NJ000081	N429A02	X		

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0429	north	NP	NP	9/18/2000	NJ000082	N429A03	X		
AN0439	south	ACPB	ICP	9/10/2003	NJ000295	S439A31	X	X	X
AN0440	south	ACPB	ICP	9/10/2003	NJ000275	S440A31	X	X	X
AN0448	south	ACPB	ICP	9/15/2003	NJ000335	S448A31	X	X	X
AN0451	south	ACPB	ICP	9/10/2003	NJ000290	S451A32		X	
AN0466	south	ACPB	ICP	9/15/2003	NJ000330	S466A32		X	
AN0470	south	ACPB	ICP	9/10/2003	NJ000265	S470A31	X	X	X
AN0488	south	ACPB	ICP	9/9/2003	NJ000245	S488A31	X	X	X
AN0489	south	ACPB	ICP	9/9/2003	NJ000255	S489A31	X	X	X
AN0490	south	ACPB	ICP	9/15/2003	NJ000315	S490A31	X	X	X
AN0503	south	ACPB	OCP	9/15/2004	NJ000408	S503A41H	X		
AN0503	south	ACPB	OCP	9/15/2004	NJ000409	S503A42H	X		
AN0503	south	ACPB	OCP	9/15/2004	NJ000490	S503A41	X	X	X
AN0503	south	ACPB	OCP	9/15/2004	NJ000495	S503A42	X		
AN0510	south	ACPB	OCP	9/15/2004	NJ000410	S510A41H	X		
AN0510	south	ACPB	OCP	9/15/2004	NJ000500	S510A41	X	X	X

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0532	south	ACPB	OCP	9/15/2004	NJ000413	S532A41H	X		
AN0532	south	ACPB	OCP	9/15/2004	NJ000414	S532A42H	X		
AN0532	south	ACPB	OCP	9/15/2004	NJ000505	S532A41	X	X	X
AN0532	south	ACPB	OCP	9/15/2004	NJ000510	S532A42	X		
AN0575	south	ACPB	OCP	9/14/2004	NJ000415	S575A41H	X		
AN0575	south	ACPB	OCP	9/14/2004	NJ000416	S575A42H	X		
AN0575	south	ACPB	OCP	9/14/2004	NJ000470	S575A41	X	X	X
AN0575	south	ACPB	OCP	9/14/2004	NJ000475	S575A42	X		
AN0623	south	ACPB	OCP	9/14/2004	NJ000417	S623A41H	X		
AN0623	south	ACPB	OCP	9/14/2004	NJ000418	S623A42H	X		
AN0623	south	ACPB	OCP	9/14/2004	NJ000480	S623A41	X	X	X
AN0623	south	ACPB	OCP	9/14/2004	NJ000485	S623A42	X		
AN0673	south	ACPB	ICP	8/20/2003	NJ000175	S673A31	X	X	X
AN0683	south	ACPB	ICP	8/24/1999	GSN00449	S683Q9			
AN0683	south	ACPB	ICP	7/25/2000	GSN23714	S683Q0			
AN0683	south	ACPB	ICP	8/7/2001	GSN87496	S683Q1			

Dtm. TALU Site ID	NJ Zone	Lvl. 3 Eco.	Sub-eco.	Dtm. Cllctn. Date	Dtm. Smpl. ID	Label	140-Smpl. Set	77-Smpl. Set	73-Smpl. Set
AN0683	south	ACPB	ICP	9/11/2003	NJ000305	S683A31	X	X	X
AN0686	south	ACPB	OCP	9/13/2004	NJ000419	S686A41H	X		
AN0686	south	ACPB	OCP	9/13/2004	NJ000440	S686A41	X	X	X
AN0686	south	ACPB	OCP	9/13/2004	NJ000445	S686A42	X		
AN0694	south	ACPB	ICP	9/29/2003	NJ000385	S694A31	X	X	X
AN0740	south	ACPB	OCP	9/18/1998	GS028723	S740Q8			
AN0740	south	ACPB	OCP	9/13/2004	NJ000420	S740A41H	X		
AN0740	south	ACPB	OCP	9/13/2004	NJ000421	S740A42H	X		
AN0740	south	ACPB	OCP	9/13/2004	NJ000460	S740A41	X	X	X
AN0740	south	ACPB	OCP	9/13/2004	NJ000465	S740A42	X		
AN0744	south	ACPB	OCP	9/13/2004	NJ000422	S744A41H	X		
AN0744	south	ACPB	OCP	9/13/2004	NJ000423	S744A42H	X		
AN0744	south	ACPB	OCP	9/13/2004	NJ000430	S744A41	X	X	X
AN0744	south	ACPB	OCP	9/13/2004	NJ000435	S744A42	X		

Appendix 4

List of 192 diatom taxa occurring in the 201-sample dataset, and ecological data. Includes name, authority, NADED ID, number of samples in which taxa occurred, total number of valves counted in all samples, BCG category to which taxa were assigned before and during the diatom expert-panel workshop, and optima (AWM) and tolerance of taxa for PCA stressor score, land-use categories, dissolved oxygen, temperature, [CCA stressor score?], and [metric benthic invertebrate subcategory-score]. Documentation of field names are in separate tables and appendices [specify names]. See text for further explanation. [appndx_4_taxa_info.xls]

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	%For. +Wet. Opt.	%Urb. Opt.	%Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
Achnanthes deflexa	2126	131	7	3	2	4.78	2.70	61.0	8.9	9.3	19.6	431	5.1	20.0	7.95	0.84	11.0
Achnanthidium pyrenaicum	1023	2336	40	3	2	5.22	2.42	38.4	29.1	17.7	25.8	209	6.5	19.3	8.31	0.98	10.4
Cymbella affinis	23073	116	5		2	5.93	2.20	43.3	29.1	9.4	39.2	634	4.4	20.9	7.96	0.61	6.7
Epithemia adnata	32003	11	2		2	2.96	4.36	68.0	6.6	16.6	17.0	259	7.5	18.9	7.18	1.37	13.8
Epithemia sorex	32006	21	2		2	1.58	1.49	81.0	3.0	5.0	15.0	290	9.0	18.0	7.62	1.62	16.0
Navicula notha	46044	25	12	4	2	7.01	1.74	36.9	34.1	25.2	28.3	216	6.1	20.6	4.90	3.39	6.0
Rossithidium pusillum	189003	1605	16	3	2	3.81	1.71	59.0	19.4	6.7	19.7	207	6.9	17.1	8.13	1.01	12.9
Achnanthes subhudsonis var. kraeuselii	2132	3517	67	4	3	5.04	1.75	44.9	28.5	14.0	36.2	235	6.5	19.3	8.54	0.82	10.4
Achnanthidium minutissimum	1010	5255	151	4	3	5.97	2.13	37.0	35.9	18.8	26.4	202	6.1	19.5	6.47	2.36	8.3

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	%For. +Wet. Opt.	%Urb. Opt.	%Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
Amphora ovalis	7001	24	10	3	3	5.97	2.34	41.8	31.2	13.1	67.6	518	5.5	22.5	8.44	0.74	9.3
Aulacoseira crassipunctata	10001	65	10	4	3	5.66	0.75	46.9	15.0	37.3	17.0	133	6.3	20.1	4.23	1.06	6.4
Aulacoseira italica	10019	118	8	4	3	6.82	2.05	30.5	39.0	19.7	37.9	229	5.8	21.2	6.91	1.94	7.3
Aulacoseira subarctica	10015	157	15	3	3	6.49	2.00	37.4	33.1	22.7	37.0	194	5.9	21.4	5.88	2.67	6.6
Chamaepinnularia evanida	212003	64	17	4	3	6.17	1.30	38.9	32.6	28.0	21.2	160	6.2	20.4	3.94	1.24	7.2
Discostella stelligera	2506003	29	13	3	3	6.02	2.47	39.5	35.5	15.8	26.1	166	5.8	21.0	6.58	2.27	7.4
Encyonema auerswaldii	110018	62	9		3	6.10	3.17	41.5	22.0	32.8	23.3	207	5.5	21.5	5.99	2.32	7.5
Encyonema minutum	110004	591	76	3	3	5.24	2.01	40.2	27.7	24.4	24.8	197	6.4	19.9	7.38	2.02	10.3
Eunotia bilunaris var. mucophila	33211	180	11	3	3	5.32	1.04	43.6	28.6	27.0	18.3	97	5.6	19.4	3.96	0.77	8.8
Eunotia carolina	33007	245	5	3	3	5.00	0.56	52.9	21.0	25.1	15.5	97	6.2	20.5	4.03	0.79	11.5
Eunotia circumborealis	33210	195	22	3	3	5.33	1.16	48.3	29.4	21.5	22.4	116	5.8	19.3	4.25	1.11	8.1
Eunotia exigua	33015	475	53	3	3	6.18	1.38	37.3	36.5	24.6	24.5	145	5.8	19.7	4.26	1.52	6.8

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	%For. +Wet. Opt.	%Urb. Opt.	%Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
Eunotia implicata	33168	610	44	3	3	5.65	1.76	42.2	30.8	23.2	21.3	117	5.6	19.2	4.61	1.68	7.8
Eunotia incisa	33026	2104	29	3	3	5.41	1.06	43.0	27.5	28.8	19.6	112	5.8	19.5	3.99	1.11	9.2
Eunotia pectinalis var. undulata	33041	570	39	3	3	5.98	1.27	42.2	32.1	24.6	19.8	126	5.8	20.1	4.38	1.08	6.2
Eunotia pirla	33103	1142	37	4	3	6.13	1.16	37.3	28.4	33.6	20.7	133	5.6	20.7	4.36	1.06	7.1
Eunotia rhomboidea	33051	574	28	4	3	5.86	1.18	42.9	33.4	23.1	19.2	110	5.7	19.5	4.03	1.04	6.6
Eunotia soleirolii	33056	1031	22	3	3	5.21	1.16	49.7	28.0	21.6	21.7	111	5.9	19.2	4.08	1.05	8.8
Fragilaria capucina	34006	87	20	3	3	4.66	2.25	53.2	20.5	15.2	30.7	182	5.5	19.8	7.19	1.78	10.9
Fragilaria crotonensis	34017	102	19	3	3	5.37	1.20	42.6	30.3	26.4	26.0	115	5.7	18.9	3.79	1.14	7.9
Fragilariforma constricta	192002	76	11	3	3	5.67	1.01	43.3	26.1	29.8	16.0	105	6.1	19.8	3.84	0.87	8.7
Fragilariforma strangulata	192007	106	15	3	3	5.47	1.24	42.2	30.4	26.7	22.9	116	5.9	19.0	3.88	0.64	9.1
Fragilariforma virescens	192008	340	38	3	3	6.01	1.13	41.9	25.4	31.6	19.6	152	6.1	19.6	4.06	1.13	6.0
Frustulia vulgaris	35011	174	54	3	3	6.51	1.78	36.6	39.9	19.6	27.3	186	5.8	20.5	5.52	2.31	6.3
Frustulia	35014	23	10	4	3	7.37	1.23	36.5	29.5	32.8	29.2	194	6.1	22.0	4.32	2.47	5.4

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	% For. + Wet. Opt.	% Urb. Opt.	% Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
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Gomphonema acuminatum	37001	37	11	3	3	5.18	1.38	38.3	9.8	49.4	16.5	157	6.2	19.3	4.33	1.26	8.6
Gomphonema affine	37002	77	14	3	3	5.73	1.46	43.6	34.2	19.5	23.8	151	5.7	19.7	4.84	1.70	6.7
Gomphonema rhombicum	37080	238	7	3	3	7.74	1.49	22.9	19.1	56.6	26.0	174	3.8	22.7	5.68	1.62	6.0
Gomphonema sp. 2 ANS NEW JERSEY KCP	37277	486	13	3	3	3.62	1.41	63.2	11.8	9.9	25.1	216	7.7	19.2	8.11	1.00	13.8
Gomphonema truncatum	37022	51	10	3	3	5.12	1.00	46.8	34.1	10.4	47.2	247	6.1	19.7	8.23	1.90	8.8
Karayevia clevei	125001	63	21	3	3	5.18	1.60	46.9	28.5	12.7	45.8	264	5.7	18.7	7.89	1.80	9.3
Navicula angusta	46002	26	10	4	3	6.43	1.35	34.2	32.1	17.5	40.6	230	6.3	19.5	7.15	2.48	6.6
Navicula cryptocephala	46014	660	85	4	3	6.27	1.69	36.0	33.7	25.1	28.5	179	5.6	20.0	5.38	2.26	6.8
Navicula integra	46363	87	20	3	3	6.39	1.04	38.0	37.2	23.4	26.4	186	5.7	21.7	4.92	1.69	6.9
Neidium ampliatum	47066	37	19	3	3	6.00	0.93	42.1	31.2	25.7	21.1	152	6.1	20.3	4.37	0.94	6.8
Nitzschia liebethruthii	48156	222	53	3	3	5.99	2.06	33.4	35.8	20.8	38.7	266	6.3	20.1	7.72	2.03	8.6

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Nitzschia nana	48307	81	24	3	3	6.08	1.24	35.8	28.8	35.0	22.7	163	6.0	19.7	4.14	1.46	6.7
Pinnularia subrostrata	52184	55	16	3	3	5.76	0.95	46.1	21.9	31.2	19.4	138	6.2	20.7	4.33	0.72	7.6
Placoneis elginensis	194005	88	24	3	3	5.77	1.24	41.0	22.0	35.9	20.2	128	5.5	20.2	4.72	1.40	7.4
Psammothidium bioretii	186001	93	20	3	3	4.94	1.86	44.1	19.2	34.5	16.8	167	6.7	18.8	4.71	2.08	9.3
Psammothidium helveticum	186003	650	29	3	3	5.65	1.27	40.2	33.6	25.7	22.1	116	5.6	19.1	4.12	1.23	7.7
Psammothidium marginulatum	186005	211	18	3	3	6.09	1.14	39.5	34.6	25.3	19.1	144	5.9	20.0	4.23	1.05	6.0
Psammothidium ventralis	186009	57	11	3	3	5.67	1.02	43.9	24.6	27.6	19.0	135	6.3	19.0	4.95	2.30	6.8
Pseudostaurosira brevistriata	73001	117	18		3	6.52	2.02	35.9	27.6	22.9	37.3	245	6.0	19.7	6.83	2.57	7.4
Rossithidium linearis	189002	991	19	4	3	9.12	1.49	10.0	45.0	25.0	54.8	291	6.5	21.3	7.89	1.62	3.0
Stauroforma exiguiformis	193001	299	12	3	3	5.04	0.90	45.3	23.3	30.7	20.1	104	6.0	18.9	4.03	0.98	10.3
Stauroneis anceps	62002	43	16	3	3	5.95	1.17	44.6	24.2	30.6	21.7	170	6.2	20.2	4.01	0.88	5.8

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	%For. +Wet. Opt.	%Urb. Opt.	%Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
Stauroneis kriegeri	62008	134	11	3	3	6.03	0.98	30.1	9.9	59.5	20.7	191	6.2	18.8	3.89	0.91	6.3
Stauroneis phoenicenteron	62015	31	14	3	3	6.04	1.31	46.1	29.8	22.7	22.0	145	5.6	21.6	5.24	1.56	7.4
Tabellaria flocculosa	67004	159	28	4	3	6.21	1.34	42.0	30.2	25.9	22.1	148	6.1	20.2	4.60	1.74	5.8
Tabellaria quadriseptata	67008	551	4	4	3	6.38	0.53	37.9	49.2	12.1	11.0	63	4.8	19.9	3.79	0.72	2.9
Achnanthidium exiguum	1024	233	50	4	4	7.00	1.87	32.1	47.8	12.9	35.9	242	5.4	21.1	6.83	2.27	5.8
Amphora inariensis	7010	559	28	4	4	4.98	1.39	36.8	35.7	16.7	40.8	336	6.5	17.8	7.49	2.17	9.4
Amphora montana	7042	25	11	4	4	7.33	1.19	24.8	38.7	30.6	37.2	285	5.7	20.7	6.31	3.27	6.2
Amphora pediculus	7043	2032	94	5	4	6.67	2.01	30.1	48.0	12.7	48.6	361	6.3	20.4	8.67	1.15	8.0
Aulacoseira ambigua	10008	119	9	3	4	4.87	2.50	42.6	20.6	28.0	13.1	129	5.1	20.4	6.05	1.59	10.2
Aulacoseira granulata	10018	784	31	4	4	6.64	1.64	36.1	34.0	21.7	38.1	212	5.6	21.4	5.96	2.55	6.2
Caloneis bacillum	12001	374	85	5	4	6.96	1.87	28.3	46.5	16.5	39.0	291	5.8	20.3	7.33	2.19	6.4

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Caloneis hyalina	12009	69	20	4	4	6.75	1.30	31.8	32.7	34.7	23.8	178	5.7	21.1	3.90	1.62	5.8
Capartogramma crucicula	14001	88	16	4	4	6.47	1.09	41.0	38.2	20.2	16.2	118	5.6	19.7	4.62	1.23	4.5
Cocconeis fluviatilis	16010	179	13	4	4	7.01	1.29	26.8	34.4	31.4	28.3	198	4.6	21.5	6.46	2.07	5.8
Cocconeis pediculus	16011	1047	64	3	4	5.68	2.31	43.5	29.6	15.6	31.1	301	7.3	20.0	8.43	1.25	9.9
Cocconeis placentula	16004	281	18	4	4	6.06	0.65	33.0	31.3	32.7	24.3	161	4.7	20.3	5.08	1.98	7.0
Cocconeis placentula var. euglypta	16005	1357	29	3	4	4.31	1.94	54.1	19.7	10.6	21.3	219	6.2	18.5	7.59	1.41	11.2
Cocconeis placentula var. lineata	16003	5701	138	3	4	6.37	1.89	32.5	39.9	18.8	39.6	282	6.8	20.5	8.25	1.81	8.5
Craticula molestiformis	21015	38	13	4	4	6.62	2.01	28.9	24.2	39.4	29.1	226	6.3	21.1	7.53	2.67	7.7
Ctenophora pulchella	201001	28	10	4	4	6.79	0.92	35.8	35.0	28.1	20.5	169	5.4	21.9	4.56	1.78	5.2
Cymbella naviculiformis	23016	83	17	4	4	6.29	1.63	44.6	43.1	10.7	22.2	123	5.7	20.0	4.70	1.11	5.4
Cymbella tumida	23068	101	25	3	4	4.87	1.68	46.1	30.6	10.1	46.5	303	6.0	20.0	7.86	1.05	9.6

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Diadesmis contenta	197002	40	17	4	4	6.09	1.88	36.1	37.2	20.2	24.4	211	6.1	20.2	5.14	2.81	7.0
Diatoma vulgaris	27013	237	42	3	4	5.44	2.11	38.4	34.1	18.4	41.6	286	7.1	20.8	8.76	0.61	10.9
Discostella pseudostelligera	2506002	285	48	4	4	7.09	1.64	23.9	48.7	19.0	45.5	291	5.4	20.1	6.77	2.60	6.2
Encyonema silesiacum	110005	273	34	4	4	5.47	1.49	43.8	24.3	28.9	21.2	131	5.9	19.4	4.79	1.50	8.2
Eunotia bilunaris	33185	659	55	4	4	6.00	1.36	39.4	34.3	25.5	23.7	137	5.6	20.0	4.28	1.39	6.9
Eunotia formica	33021	310	42	4	4	5.98	1.67	38.7	30.3	23.7	23.4	153	5.8	19.8	5.39	1.95	7.3
Eunotia naegelii	33036	531	6	4	4	6.24	0.87	38.8	47.5	12.9	12.5	68	4.9	19.8	3.84	0.77	3.6
Eunotia pectinalis var. minor	33040	1223	34	4	4	5.85	1.34	43.1	32.8	23.4	20.4	123	5.8	19.6	4.13	1.27	7.1
Eunotia sp. 9 NAWQA EAM	33244	510	12	4	4	6.16	0.70	42.5	22.0	34.7	16.9	122	5.2	22.0	4.86	1.06	5.5
Fragilaria capucina var. gracilis	34098	696	45	4	4	6.04	1.53	39.1	33.9	25.2	24.9	152	5.7	20.0	4.65	1.84	7.0
Fragilaria vaucheriae	34030	330	75	4	4	6.25	1.36	40.7	32.7	21.8	26.2	180	5.7	20.1	5.40	2.30	6.3
Frustulia amphipleuroides	35036	28	16	4	4	6.76	2.53	30.3	53.0	8.9	46.6	308	6.0	20.9	8.07	1.67	6.9

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Frustulia crassinervia	35024	73	26	4	4	6.47	1.53	34.7	38.2	24.7	19.7	135	5.7	20.2	4.30	1.47	5.6
Frustulia krammeri	35039	178	35	4	4	6.11	1.28	41.3	37.0	21.0	22.1	138	5.8	20.2	4.48	0.99	6.1
Geissleria acceptata	210001	51	17	4	4	5.90	2.24	32.4	38.8	15.7	37.4	373	6.0	19.0	8.65	0.68	9.2
Geissleria decussis	210003	390	53	3	4	5.76	2.00	33.3	31.1	31.1	26.0	210	6.1	19.6	6.07	2.35	9.1
Gomphonema angustatum	37003	104	20	5	4	7.57	2.13	21.2	33.5	24.8	20.8	240	4.9	20.1	8.36	1.22	6.5
Gomphonema gracile	37007	256	43	4	4	5.94	1.36	37.5	33.0	28.2	26.2	164	5.7	19.7	4.72	1.89	7.2
Gomphonema kobayasii	37197	2728	91	5	4	6.86	1.90	27.3	44.1	17.5	39.9	309	6.0	20.9	8.13	1.81	7.4
Gomphonema parvulum	37010	4455	172	4	4	6.16	1.78	36.0	35.3	23.4	27.6	185	5.9	20.1	5.96	2.42	7.7
Gomphonema patrickii	37193	91	12	4	4	7.54	1.58	20.3	43.5	20.3	33.9	190	5.1	20.2	7.27	1.79	6.3
Gomphonema pumilum	37096	48	8		4	3.10	2.42	62.6	13.8	13.3	13.2	192	7.9	18.2	8.25	1.37	14.2
Gyrosigma acuminatum	38001	43	19	4	4	7.14	1.85	25.8	39.0	23.6	36.5	334	5.4	21.1	8.12	1.65	6.6

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Hantzschia distinctepunctata	40007	36	13	4	4	6.52	1.15	33.5	40.8	25.1	27.5	214	6.0	20.6	3.57	1.47	6.2
Lemnicola hungarica	188001	68	19	3	4	5.83	1.14	37.4	24.4	37.3	23.6	133	5.1	20.2	4.85	1.34	8.2
Melosira varians	44073	1592	117	4	4	6.21	1.93	34.5	38.7	18.2	41.3	277	6.6	20.4	7.88	2.06	8.4
Meridion circulare	45001	299	58	4	4	5.94	1.46	40.2	33.5	23.2	24.8	166	6.0	19.6	5.03	2.08	7.0
Navicula antonii	46893	162	20	3	4	4.28	1.61	54.5	19.9	12.2	32.2	230	7.0	19.9	8.19	1.00	12.0
Navicula arvensis	46003	51	15	4	4	7.33	1.63	24.5	38.6	31.9	34.4	208	5.4	21.1	5.34	2.85	6.2
Navicula capitatoradiata	46661	369	43	3	4	5.05	1.55	41.5	24.7	23.3	31.4	241	7.6	20.5	8.64	0.84	10.9
Navicula cf. kriegerii NAWQA KM	93165	240	18	4	4	5.88	1.20	41.3	38.4	19.6	18.5	108	5.5	19.6	4.18	1.08	6.8
Navicula cryptotenella	46527	962	98	3	4	5.59	2.17	40.1	33.4	15.1	32.6	256	6.4	19.9	8.11	1.47	9.7
Navicula lanceolata	46859	630	88	4	4	6.93	1.76	27.9	50.5	11.2	55.6	349	6.0	20.2	8.32	1.64	7.1
Navicula longicephala	46507	176	35	4	4	6.04	1.25	38.9	31.4	26.4	26.0	153	6.0	19.6	4.75	1.94	7.4
Navicula peregrina	46289	148	12	4	4	6.19	0.60	41.5	39.4	4.8	89.9	349	4.9	20.0	8.90	0.67	6.3

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Navicula perminuta	46538	482	48	4	4	6.39	2.26	26.9	46.6	16.0	48.4	335	6.0	20.4	8.63	0.86	8.6
Navicula rhynchocephala	46154	393	51	4	4	6.17	1.28	40.0	35.5	22.2	23.1	141	5.8	19.8	4.45	1.55	6.3
Navicula rostellata	46896	383	64	4	4	6.66	1.83	29.8	41.3	21.4	39.0	267	6.1	20.8	7.06	2.49	7.5
Navicula subminuscula	46562	1373	72	3	4	6.40	1.96	29.4	38.7	22.2	40.0	290	7.0	20.9	8.80	1.14	8.8
Navicula symmetrica	46400	470	71	4	4	6.45	1.80	30.1	39.7	20.9	40.7	285	5.9	20.6	7.77	2.12	7.8
Navicula tenelloides	46401	239	44	4	4	6.25	1.83	35.1	34.7	25.4	27.7	195	5.9	20.0	4.84	2.19	7.2
Navicula viridula	46408	138	9	4	4	7.47	0.24	22.8	16.4	60.3	19.8	195	5.2	19.4	4.80	0.81	6.0
Neidium affine	47001	18	10	4	4	6.66	1.62	26.1	47.8	25.8	26.8	128	4.9	20.0	4.52	2.46	5.9
Neidium alpinum	47006	120	28	4	4	5.89	1.12	41.3	32.1	25.4	20.4	136	5.8	19.7	4.18	1.12	7.1
Nitzschia archibaldii	48417	134	28	4	4	5.80	2.26	37.9	34.4	18.6	32.7	245	6.6	20.1	7.38	2.21	8.5
Nitzschia capitellata	48006	278	48	4	4	6.54	1.40	31.8	35.9	26.1	31.4	214	5.7	20.8	6.01	2.43	6.2
Nitzschia clausii	48137	60	17	4	4	6.79	1.12	32.4	25.5	36.0	25.7	188	5.9	21.0	5.71	2.10	5.9

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Nitzschia dissipata	48008	493	77	4	4	6.24	1.76	35.3	39.9	17.7	40.3	266	5.5	20.1	7.15	2.29	8.1
Nitzschia filiformis	48145	32	10	4	4	6.88	1.45	35.0	44.6	18.6	28.3	205	5.8	20.8	5.51	2.20	5.6
Nitzschia fonticola	48011	408	54	3	4	5.65	2.03	43.7	25.7	23.3	32.2	208	6.4	20.6	6.60	2.39	9.0
Nitzschia gessneri	48422	422	12	4	4	5.90	1.34	28.3	27.4	44.0	25.4	151	5.8	18.9	4.27	1.66	7.6
Nitzschia gracilis	48015	27	14	4	4	6.82	1.79	31.9	48.9	14.8	34.8	207	5.5	20.6	6.76	2.49	6.0
Nitzschia linearis	48023	87	31	4	4	5.86	2.10	36.5	40.3	17.1	29.6	225	6.4	20.5	6.17	2.63	8.0
Nitzschia paleacea	48165	40	14	4	4	6.01	1.22	31.5	31.4	33.2	20.4	187	6.7	20.5	6.22	2.51	7.2
Nitzschia recta	48029	191	60	4	4	6.57	1.66	34.0	36.4	20.7	27.3	194	5.7	19.8	6.33	2.38	6.4
Nitzschia sociabilis	48225	126	28	4	4	6.32	1.35	35.2	27.3	29.6	31.6	215	5.6	20.5	5.69	2.40	6.6
Nitzschia tubicola	48349	141	33	4	4	6.59	1.26	34.3	32.6	29.8	26.4	185	5.6	20.8	4.74	1.85	5.4
Nupela neglecta	92013	363	8	5	4	8.20	1.18	8.9	79.1	3.7	62.7	497	6.2	20.2	8.77	1.28	4.6
Parlibellus protracta	214002	33	11	4	4	6.15	1.04	28.6	40.9	27.7	48.5	304	5.1	20.2	5.45	2.31	6.8
Pinnularia	52194	66	16	4	4	5.87	1.54	35.5	31.8	28.4	29.2	124	5.5	19.5	4.84	1.80	7.9

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	% For. + Wet. Opt.	% Urb. Opt.	% Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
interrupta																	
Pinnularia microstauron	52045	236	44	4	4	6.65	1.24	35.3	35.3	27.5	22.2	160	5.8	21.0	4.96	1.93	5.6
Pinnularia obscura	52049	75	21	4	4	5.93	1.37	33.2	34.1	31.2	22.7	155	5.9	19.4	4.23	1.94	7.2
Pinnularia subcapitata	52059	84	23	4	4	6.61	1.15	37.5	36.6	23.7	18.7	139	5.8	21.0	4.79	1.93	5.6
Placoneis clementis	194004	142	31	4	4	6.30	1.04	39.6	32.4	26.9	20.1	142	5.7	20.3	4.68	1.40	5.7
Planothidium apiculatum	155019	326	18	4	4	5.89	1.11	46.2	36.3	16.8	17.0	115	5.8	20.0	4.47	1.49	5.8
Planothidium lanceolatum	155003	1946	146	4	4	6.51	2.05	28.4	43.9	18.9	33.4	263	6.2	19.8	7.72	2.08	7.7
Planothidium rostratum	155018	72	16	4	4	5.91	2.47	38.7	24.2	24.9	30.3	355	4.3	21.4	7.01	2.00	9.6
Psammothidium subatomoides	186008	1116	52	4	4	6.12	1.63	38.3	33.0	25.4	20.2	132	5.8	19.7	4.56	1.82	7.0
Sellaphora pupula	170006	558	93	4	4	6.84	1.48	33.4	41.2	20.7	34.5	213	5.4	20.7	5.97	2.47	6.0
Stauroneis prominula	62069	65	14	4	4	6.02	1.25	37.8	33.4	28.3	22.7	135	6.0	18.5	3.89	0.87	5.7

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	% For. + Wet. Opt.	% Urb. Opt.	% Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
Stauroneis smithii	62007	93	21	4	4	6.13	1.53	36.2	29.0	33.0	28.3	206	5.8	20.7	4.42	1.44	7.7
Staurosira construens	172001	113	26	4	4	6.24	1.71	32.9	40.5	19.1	37.2	280	5.8	20.2	7.40	2.24	7.4
Staurosira construens var. venter	172006	187	33	4	4	6.93	1.46	34.0	49.0	8.3	69.7	289	4.1	20.1	8.37	1.82	6.3
Staurosirella pinnata	175005	660	76	4	4	6.31	1.89	37.1	39.8	15.9	36.5	264	5.6	20.4	6.75	2.30	7.0
Surirella amphioxys	65069	36	16	4	4	5.95	1.72	39.9	32.0	26.6	22.9	125	5.7	19.9	4.30	2.08	7.9
Surirella angusta	65002	79	38	4	4	6.63	1.44	27.9	36.4	31.3	30.4	216	6.0	20.1	5.65	2.68	6.4
Synedra rumpens	66016	177	33	4	4	5.90	1.80	45.2	35.4	11.6	28.8	164	6.3	18.8	5.71	2.46	6.9
Tryblionella apiculata	185023	29	13	4	4	6.94	1.87	24.5	50.6	16.2	59.5	304	6.4	19.8	7.53	2.47	6.5
Tryblionella debilis	185002	35	13	4	4	6.64	0.93	30.6	27.3	41.5	23.3	184	5.4	21.3	4.10	1.17	6.3
Tryblionella levidensis	185026	18	10	4	4	6.43	1.87	27.3	38.2	21.3	34.9	245	6.4	20.2	7.42	2.01	7.4
Achnanthes oblongella	2105	209	21	5	5	5.74	1.06	42.4	30.3	26.7	16.9	131	6.1	19.8	3.92	1.00	7.8
Amphora	7075	105	30	5	5	7.14	1.42	32.4	47.2	14.1	29.3	201	5.5	20.7	6.52	2.15	5.4

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	% For. + Wet. Opt.	% Urb. Opt.	% Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
copulata																	
Bacillaria paradoxa	76001	652	56	4	5	6.80	1.59	27.2	50.6	12.2	57.8	334	5.9	20.3	7.39	2.40	6.2
Cyclotella atomus	20001	161	23	4	5	7.61	1.62	29.4	44.9	18.6	72.2	352	4.8	21.3	7.75	2.69	5.3
Cyclotella meneghiniana	20007	629	93	4	5	6.70	1.89	32.4	42.7	17.0	46.7	284	5.7	20.6	7.21	2.48	6.5
Diadesmis confervacea	197001	374	33	3	5	6.66	1.38	33.3	39.6	23.1	31.8	186	5.0	21.3	5.96	2.13	6.3
Gomphonema minutum	37178	489	58	5	5	6.04	2.15	35.7	33.9	20.2	30.9	268	7.2	20.3	8.41	1.42	9.0
Hippodonta capitata	213001	142	48	4	5	6.94	1.60	31.0	45.8	18.4	34.0	221	5.5	20.7	6.28	2.46	6.1
Luticola goeppertiana	130006	330	29	4	5	7.53	1.40	22.0	56.6	10.0	64.7	325	4.5	20.0	8.29	1.45	5.3
Luticola mutica	130002	130	35	4	5	6.38	1.14	34.4	35.4	29.4	21.1	153	5.8	20.2	4.03	1.52	5.8
Mayamaea agrestis	211001	59	17	4	5	6.86	1.59	22.3	42.7	27.9	30.7	251	6.6	20.3	7.72	2.66	7.0
Mayamaea atomus	211003	151	44	3	5	5.83	1.83	30.6	32.0	30.4	30.1	249	6.8	20.8	7.95	2.38	10.0
Navicula canalis	46317	105	27	5	5	7.10	1.66	24.7	39.8	20.2	45.1	334	6.3	20.1	8.24	1.24	6.4

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	% For. + Wet. Opt.	% Urb. Opt.	% Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
Navicula erifuga	46648	103	26	4	5	6.53	1.70	33.0	42.2	14.9	51.8	374	6.0	20.5	7.20	2.50	6.8
Navicula germainii	46616	879	89	4	5	6.38	1.70	33.6	36.6	22.5	37.0	248	6.3	20.4	6.96	2.48	7.6
Navicula gregaria	46023	2374	115	4	5	6.53	1.89	30.1	43.8	16.7	46.1	296	6.1	20.3	8.25	1.76	8.0
Navicula ingenua	46362	135	23	4	5	7.73	1.26	17.1	61.8	9.6	62.2	419	5.2	20.8	8.45	1.47	4.8
Navicula minima	46039	6105	167	4	5	6.61	1.96	29.4	44.3	18.2	39.3	273	6.2	20.3	7.69	2.16	7.6
Navicula recens	46649	651	36	5	5	6.73	1.74	36.3	39.6	14.3	48.8	298	6.7	20.8	8.81	1.14	7.9
Navicula tripunctata	46104	390	51	5	5	6.43	2.25	35.3	44.6	10.4	46.3	380	6.3	20.5	8.73	0.81	9.0
Navicula veneta	46504	31	11	4	5	6.65	3.01	35.0	50.4	8.2	53.1	333	6.2	20.9	7.70	2.04	8.5
Nitzschia amphibia	48004	2895	134	4	5	6.66	1.79	28.5	44.2	17.7	44.7	310	6.4	20.3	8.35	1.66	7.9
Nitzschia frustulum	48013	675	48	4	5	6.14	1.23	32.2	33.3	29.0	31.4	251	6.3	20.0	6.12	2.84	6.7
Nitzschia inconspicua	48122	6563	112	4	5	6.54	1.84	29.0	45.5	16.3	44.6	311	6.7	20.3	8.77	1.03	8.4
Nitzschia palea var. debilis	48228	400	31	5	5	6.52	1.35	31.8	29.8	37.4	25.1	166	5.4	20.4	4.15	1.63	6.2
Planothidium frequentissimum	155017	1595	104	5	5	6.87	2.00	26.8	49.2	15.6	40.8	293	6.1	20.2	7.79	2.11	7.1

Taxon Name	NADED ID	Abund	Freq.	Init. BCG Cat.	Final BCG Cat.	PCA Str. Opt.	PCA Str. Tol.	%For. +Wet. Opt.	%Urb. Opt.	%Ag. Opt.	Cl- Opt.	Cond. Opt.	DO Opt.	Temp. Opt.	CCA Str. Opt.	CCA Str. Tol.	Inv. Cat. Opt.
Platessa conspicua	2508001	1674	78	5	5	7.09	1.75	24.4	54.6	11.8	49.4	327	6.4	20.0	8.36	1.51	7.0
Reimeria sinuata	55002	3281	117	4	5	5.81	2.25	34.9	38.9	17.2	34.5	280	7.3	19.9	8.62	1.11	10.2
Rhoicosphenia abbreviata	57002	5858	134	4	5	6.26	2.04	32.5	41.2	15.5	38.4	305	6.6	20.0	8.64	1.03	8.7
Sellaphora seminulum	170014	3684	135	4	5	6.82	1.76	28.2	44.8	20.0	39.1	265	6.0	20.1	7.25	2.43	6.8
Stephanodiscus hantzschii	64010	27	10	4	5	7.72	1.61	22.3	52.7	19.3	59.6	405	5.4	19.6	7.75	2.98	6.1
Synedra ulna	66024	914	107	4	5	5.79	1.61	38.3	31.5	25.1	28.6	192	6.3	20.2	6.39	2.59	8.4
Thalassiosira weissflogii	70008	76	16	4	5	7.38	1.71	23.4	37.5	30.3	48.2	334	6.3	20.6	7.10	2.86	4.0
Nitzschia palea	48025	1923	145	5	6	6.50	1.70	31.2	38.7	22.8	36.8	233	6.0	20.2	6.74	2.52	7.1

Appendix 5

Diatom metrics for 201-sample dataset. Dtm. Smpl. ID = Diatom Sample ID; Smpl. Label = Diatom Sample Label (used for workshops); Dtm. TALU Site ID = Site identifier used for NJ Diatom TALU study; Total Taxa = Total number of diatom taxa found; Total Valves = Total number of diatom valves counted; %Dom. Taxon = Relative abundance of the most abundant diatom taxon; Sum %Dom. Taxa = Combined relative abundances of all taxa with relative abundances greater than 10%; %Ach. min. = relative abundance of *Achnanthidium minutissimum* (Kützing) Czarnecki (NADED ID 1010); SW Div. = Shannon-Wiener diversity index using base 2 logarithm; SW Div. (ln); Shannon-Wiener diversity index using natural logarithm; Siltation = Siltation Index

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	%Dom. Taxon	Sum %Dom. Taxa	%Ach. min.	SW Div.	SW Div. (ln)	Siltation
GS028073	N1Q6	01379000	44	605	44.0	44.0		3.39	2.35	22.48
GS028083	N2Q6	01379500	36	614	21.2	51.8		3.81	2.64	84.85
GS028093	N3Q6	01379680	46	600	49.0	49.0	0.50	3.23	2.24	18.83
GS028103	N4Q6	01380500	33	600	37.0	72.0	3.00	2.67	1.85	1.17
GS028123	N5Q6	01381500	46	600	49.7	49.7	0.17	3.09	2.14	28.83
GS028153	N6Q6	01387041	46	600	62.7	62.7	2.33	2.53	1.76	6.50
GS028163	N7Q6	01387042	35	600	51.0	68.5	7.00	2.73	1.89	9.17
GS028183	N8Q6	01390500	31	609	39.9	70.0		3.07	2.13	10.51
GS028203	N9Q6	01393400	31	600	36.3	60.0	6.50	3.06	2.12	76.33
GS028223	N10Q6	01396535	21	600	70.3	70.3		1.81	1.25	6.17
GS028243	N321Q6	AN0321	22	600	42.5	58.2	1.17	2.83	1.96	19.50
GS028253	N11Q6	01397295	20	600	34.0	77.8	0.17	2.86	1.99	17.33

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
GS028263	N333Q6	AN0333	15	600	54.2	81.5		2.26	1.57	58.50
GS028283	N370Q6	AN0370	18	600	34.0	71.8		2.65	1.84	16.67
GS028293	N374Q6	AN0374	32	600	19.8	45.2		3.96	2.74	50.67
GS028303	N12Q6	01401000	17	600	47.8	81.0		2.00	1.38	6.67
GS028313	N13Q6	01401600	24	600	28.7	74.3		3.17	2.20	51.83
GS028323	N14Q6	01403300	26	600	23.0	54.0	2.00	3.42	2.37	28.83
GS028333	N15Q6	01403900	21	601	24.8	70.5		3.18	2.21	48.75
GS028413	N8Q7X	01390500	46	600	44.2	55.0	4.67	3.25	2.25	10.50
GS028423	N8Q7Y	01390500	38	600	20.2	59.2	11.33	3.80	2.64	23.83
GS028433	N8Q7Z	01390500	44	600	12.7	12.7	8.67	4.45	3.09	37.50
GS028463	N333Q7	AN0333	32	600	26.3	64.7	0.17	3.64	2.52	45.50
GS028473	N12Q7	01401000	34	600	18.7	33.0		4.02	2.78	52.67
GS028483	N14Q7	01403300	30	601	37.8	60.4	0.50	2.99	2.07	80.87
GS028493	N15Q7	01403900	37	603	36.0	36.0	0.66	3.71	2.57	60.20
GS028503	S16Q7	01410784	54	604	21.0	56.5	2.15	4.07	2.82	9.93
GS028583	N8Q8	01390500	35	604	24.2	43.4	0.83	3.64	2.52	25.50

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
GS028593	N333Q8	AN0333	34	604	22.0	54.6		3.76	2.61	32.28
GS028603	N12Q8	01401000	40	610	30.2	48.5	0.82	3.73	2.59	29.34
GS028613	N14Q8	01403300	45	601	13.3	13.3	0.33	4.53	3.14	50.25
GS028623	N15Q8	01403900	36	603	11.4	22.2	1.16	4.29	2.97	38.31
GS028723	S740Q8	AN0740	48	600	24.2	37.8	0.33	4.19	2.90	4.33
GS028783	N231Q7	AN0231	43	613	38.2	38.2	3.43	3.86	2.68	37.19
GSN00407	N008Q9	AN0008	32	602	28.4	55.5	3.99	3.29	2.28	6.48
GSN00428	S18Q9	01467150	67	600	17.0	17.0	0.83	5.02	3.48	56.17
GSN00449	S683Q9	AN0683	76	610	8.9		1.80	5.40	3.74	41.80
GSN23714	S683Q0	AN0683	35	118	12.7	12.7	3.39	4.52	3.13	38.14
GSN23742	S18Q0	01467150	60	600	17.5	27.8	4.00	4.59	3.18	46.17
GSN24343	N008Q0	AN0008	11	32	31.3	71.9	3.13	2.80	1.94	21.88
GSN87393	N17Q1	01438399	20	601	38.1	67.7	1.00	2.59	1.80	6.16
GSN87410	N008Q1	AN0008	19	500	69.8	87.4	0.40	1.64	1.14	0.20
GSN87479	S18Q1	01467150	74	601	13.8	26.0	1.66	4.94	3.43	41.10
GSN87496	S683Q1	AN0683	78	600	18.0	18.0	3.83	5.12	3.55	41.17

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000001	N081A01	AN0081	35	601	21.8	21.8		4.16	2.88	66.39
NJ000002	N081A02	AN0081	40	606	16.8	29.9	0.33	4.25	2.95	56.44
NJ000003	N081A03	AN0081	47	601	14.3	27.0	1.16	4.49	3.11	52.91
NJ000004	N111A01	AN0111	58	600	24.0	36.7	0.67	4.43	3.07	65.17
NJ000005	N111A02	AN0111	71	600	12.2	12.2	1.00	5.28	3.66	51.00
NJ000006	N115A01	AN0115	14	601	77.7	77.7	77.70	1.44	1.00	3.66
NJ000007	N115A02	AN0115	13	600	87.3	87.3	87.33	0.90	0.63	3.17
NJ000008	N115A03	AN0115	15	601	79.4	79.4	79.37	1.26	0.87	1.33
NJ000009	N118A01	AN0118	26	600	29.5	62.7		3.27	2.26	57.33
NJ000010	N118A02	AN0118	30	602	27.9	70.9	0.66	3.08	2.14	66.61
NJ000011	N118A03	AN0118	58	600	27.5	68.0	1.00	3.95	2.74	41.50
NJ000015	N195A01	AN0195	63	601	16.1	16.1	2.16	5.14	3.56	55.57
NJ000016	N195A02	AN0195	50	601	18.0	48.9		4.20	2.91	60.90
NJ000017	N195A03	AN0195	51	603	14.8	14.8		4.74	3.29	58.71
NJ000018	N211A01	AN0211	34	602	22.8	33.6	3.32	4.06	2.81	44.85
NJ000019	N211A02	AN0211	22	601	48.6	75.0	0.17	2.38	1.65	10.98

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000020	N211A03	AN0211	36	601	25.0	56.6		3.52	2.44	21.96
NJ000021	N215A01	AN0215	18	608	36.3	66.8	5.76	2.64	1.83	34.87
NJ000022	N215A02	AN0215	37	601	18.1	42.8	13.31	4.13	2.86	20.13
NJ000023	N215A03	AN0215	42	608	11.8	33.2	11.02	4.40	3.05	23.36
NJ000027	N234A01	AN0234	29	603	16.6	69.5	0.17	3.53	2.45	71.48
NJ000028	N234A02	AN0234	49	603	20.1	33.2	0.33	4.49	3.11	61.03
NJ000029	N234A03	AN0234	42	601	40.3	53.9	0.67	3.53	2.45	41.43
NJ000033	N267A01	AN0267	41	602	21.6	60.8	0.17	3.53	2.45	43.52
NJ000034	N267A02	AN0267	46	601	16.0	40.3		4.23	2.93	54.24
NJ000035	N267A03	AN0267	45	600	40.8	40.8		3.67	2.55	33.67
NJ000036	N274A01	AN0274	36	602	23.3	46.5		3.82	2.65	24.42
NJ000037	N281A01	AN0281	25	602	28.9	66.4	8.14	3.32	2.30	35.71
NJ000038	N281A02	AN0281	26	601	23.3	43.4	2.33	3.40	2.36	24.79
NJ000039	N281A03	AN0281	38	601	24.0	52.2	10.48	3.89	2.69	39.43
NJ000040	N291A01	AN0291	37	601	15.8	31.3		4.14	2.87	63.73
NJ000041	N291A02	AN0291	56	601	14.6	27.1	0.33	4.68	3.24	42.60

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000042	N291A03	AN0291	42	601	15.0	15.0		4.47	3.10	59.90
NJ000043	N318A01	AN0318	16	603	44.9	83.6	7.63	1.90	1.32	1.00
NJ000044	N318A02	AN0318	18	602	60.8	87.9	3.16	1.74	1.20	2.66
NJ000045	N318A03	AN0318	19	603	44.3	80.9	6.97	2.07	1.44	2.65
NJ000046	N321A01	AN0321	41	607	9.7		5.93	4.52	3.13	37.07
NJ000047	N321A02	AN0321	46	601	9.5		7.99	4.74	3.28	41.60
NJ000048	N321A03	AN0321	49	600	17.3	17.3	8.33	4.60	3.19	33.17
NJ000049	N326A01	AN0326	35	600	27.2	41.5	1.33	3.87	2.68	32.83
NJ000050	N326A02	AN0326	33	600	32.2	62.2		3.44	2.38	23.67
NJ000051	N326A03	AN0326	28	603	35.0	61.5	0.83	3.10	2.15	36.82
NJ000052	N339A01	AN0339	21	602	46.7	75.9		2.58	1.79	41.86
NJ000053	N339A02	AN0339	22	601	30.1	54.6		3.32	2.30	37.94
NJ000054	N339A03	AN0339	20	600	29.7	72.2		2.86	1.99	53.00
NJ000055	N341A01	AN0341	39	601	16.3	54.6		4.04	2.80	57.74
NJ000056	N341A02	AN0341	35	604	20.5	31.8		3.97	2.75	56.79
NJ000057	N341A03	AN0341	38	602	22.9	45.8		3.92	2.71	47.34

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000058	N370A01	AN0370	32	601	51.7	69.6		2.70	1.87	80.20
NJ000059	N370A02	AN0370	43	603	12.3	12.3	1.82	4.48	3.10	57.05
NJ000060	N370A03	AN0370	31	604	23.2	47.4	0.33	3.81	2.64	54.30
NJ000061	N374A01	AN0374	39	605	10.1	10.1		4.54	3.15	55.04
NJ000062	N374A02	AN0374	28	605	31.4	51.4		3.50	2.43	63.31
NJ000063	N374A03	AN0374	31	600	12.5	35.3		4.33	3.00	57.00
NJ000067	N396A01	AN0396	51	601	29.5	29.5	3.16	4.40	3.05	26.46
NJ000068	N396A02	AN0396	48	600	29.2	43.0	4.33	4.17	2.89	24.83
NJ000069	N396A03	AN0396	50	600	23.5	43.7	6.67	4.17	2.89	16.50
NJ000070	N405A01	AN0405	44	603	19.4	49.3	0.33	3.99	2.76	59.54
NJ000071	N405A02	AN0405	23	600	23.2	57.3	0.83	3.33	2.31	61.00
NJ000072	N405A03	AN0405	44	600	20.0	38.8	0.33	3.94	2.73	46.00
NJ000073	N413A01	AN0413	28	604	19.9	47.2	0.33	3.66	2.53	56.29
NJ000074	N413A02	AN0413	43	601	23.8	58.2		3.98	2.76	45.09
NJ000075	N413A03	AN0413	36	602	17.8	31.4		4.13	2.86	48.84
NJ000077	N424A01	AN0424	44	600	29.3	43.8		3.71	2.57	37.00

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000078	N424A02	AN0424	37	600	28.8	42.7	0.17	3.69	2.56	53.00
NJ000079	N424A03	AN0424	32	601	25.8	67.1		3.23	2.24	52.41
NJ000080	N429A01	AN0429	18	602	34.7	53.5	6.15	3.06	2.12	63.62
NJ000081	N429A02	AN0429	15	603	32.8	64.3	9.12	2.62	1.82	77.78
NJ000082	N429A03	AN0429	22	602	18.9	59.5	5.81	3.46	2.39	56.15
NJ000086	N115A11	AN0115	20	600	44.0	82.7	38.67	2.10	1.46	3.17
NJ000089	N192A11	AN0192	42	602	20.1	34.4		4.29	2.98	41.36
NJ000092	N207A11	AN0207	49	601	11.8	22.6	5.49	4.54	3.15	59.73
NJ000095	N209A11	AN0209	37	601	34.6	34.6	0.33	3.73	2.59	65.56
NJ000098	N211A11	AN0211	50	600	19.3	19.3	3.17	4.52	3.13	48.17
NJ000101	N231A11	AN0231	63	601	13.8	13.8	0.67	5.03	3.49	80.03
NJ000102	N234A11	AN0234	45	602	12.8	24.4	0.83	4.47	3.10	64.29
NJ000105	N235A11	AN0235	54	603	15.4	30.3	0.83	4.54	3.14	41.96
NJ000108	N237A11	AN0237	41	601	19.6	34.8	4.16	4.01	2.78	50.08
NJ000111	N274A11	AN0274	44	600	16.3	47.7	0.83	4.13	2.86	47.17
NJ000112	N333A11	AN0333	32	599	38.7	51.4		3.39	2.35	88.81

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000115	N374A11	AN0374	35	602	21.4	21.4	0.50	4.01	2.78	50.50
NJ000118	N405A11	AN0405	47	600	15.7	30.7	0.67	4.28	2.96	44.33
NJ000121	N006A21	AN0006	18	600	54.3	77.2	8.33	2.14	1.48	2.67
NJ000124	N008A21	AN0008	46	600	16.8	45.0	16.83	4.28	2.97	22.50
NJ000127	N016A21	AN0016	38	600	21.5	56.0	21.50	3.64	2.52	12.67
NJ000129	N029A21	AN0029	18	600	40.8	79.2	9.67	2.43	1.68	5.83
NJ000132	N032AA21	AN0032A	39	602	35.5	50.5	1.99	3.51	2.43	24.09
NJ000135	N213A21	AN0213	47	601	21.3	32.1	10.82	4.35	3.02	53.74
NJ000138	N245A21	AN0245	51	584	36.6	36.6	3.42	3.70	2.56	9.25
NJ000141	N255A21	AN0255	44	600	33.0	44.5	2.00	3.95	2.74	35.83
NJ000144	N259A21	AN0259	37	600	40.3	59.0	18.67	3.31	2.29	12.33
NJ000147	N265A21	AN0265	49	600	25.7	25.7	9.33	4.32	2.99	22.83
NJ000150	N299A21	AN0299	38	601	26.5	44.8	26.46	3.59	2.49	22.13
NJ000153	N313A21	AN0313	39	600	29.5	64.8	4.00	3.39	2.35	5.17
NJ000156	N315A21	AN0315	16	601	42.4	68.2	2.33	2.41	1.67	37.44
NJ000159	N318A21	AN0318	21	602	60.8	75.2	7.14	2.09	1.45	1.00

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000162	N321A21	AN0321	39	600	11.3	22.0	9.83	4.22	2.93	26.00
NJ000165	N346A21	AN0346	25	602	27.4	77.1	0.50	3.01	2.08	55.48
NJ000168	N215A21	AN0215	27	601	21.1	48.6	9.82	3.57	2.47	20.47
NJ000171	N234A22	AN0234	51	600	14.0	14.0		4.67	3.24	50.50
NJ000172	N374A21	AN0374	36	603	47.4	47.4	0.66	3.26	2.26	18.91
NJ000175	S673A31	AN0673	57	600	23.7	36.5		4.18	2.90	23.83
NJ000180	S166A31	AN0166	83	600	8.0		2.50	5.38	3.73	19.50
NJ000190	S169A31	AN0169	76	601	6.3		1.83	5.61	3.89	32.11
NJ000195	S151AA31	AN0151A	71	600	31.8	44.0		4.22	2.93	5.00
NJ000205	S121A31	AN0121	58	602	23.6	45.0	1.16	4.31	2.98	27.41
NJ000215	S139A31	AN0139	44	602	54.3	54.3	0.33	3.15	2.18	28.41
NJ000225	S132A31	AN0132	76	601	9.3			5.34	3.70	59.07
NJ000235	S129A31	AN0129	76	602	10.0		3.82	5.30	3.67	46.35
NJ000245	S488A31	AN0488	58	600	9.3		6.00	5.17	3.58	44.50
NJ000255	S489A31	AN0489	60	600	12.5	12.5	8.83	5.00	3.46	37.33
NJ000265	S470A31	AN0470	72	601	8.2		1.33	5.39	3.74	56.91

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000275	S440A31	AN0440	24	600	74.7	87.0		1.54	1.07	2.83
NJ000290	S451A32	AN0451	67	601	12.6	12.6	6.66	5.21	3.61	28.62
NJ000295	S439A31	AN0439	38	602	46.7	46.7	1.83	3.34	2.31	12.29
NJ000305	S683A31	AN0683	71	601	11.0	21.3	1.66	5.23	3.62	41.93
NJ000315	S490A31	AN0490	61	600	26.3	26.3	8.00	4.59	3.18	36.17
NJ000330	S466A32	AN0466	64	606	10.1	10.1	0.99	5.00	3.47	60.40
NJ000335	S448A31	AN0448	70	600	15.3	29.5	3.67	4.82	3.34	30.50
NJ000345	S136A31	AN0136	83	601	18.0	45.9	1.00	4.84	3.35	25.29
NJ000360	S124A32	AN0124	57	600	25.2	39.3	2.83	4.38	3.03	47.83
NJ000365	N384A31	AN0384	73	600	28.3	45.0	3.83	4.25	2.95	8.83
NJ000380	N109A32	AN0109	93	600	9.7		6.83	5.68	3.93	24.17
NJ000385	S694A31	AN0694	47	600	10.8	21.0	0.67	4.60	3.19	51.00
NJ000404	S149A41H	AN0149A	68	600	12.7	25.3	12.67	5.02	3.48	15.83
NJ000405	S149A42H	AN0149A	67	601	15.8	30.0	14.14	4.84	3.35	10.48
NJ000408	S503A41H	AN0503	67	601	21.0	33.4	2.83	4.62	3.20	22.13
NJ000409	S503A42H	AN0503	63	600	19.8	31.0	1.50	4.65	3.22	25.33

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000410	S510A41H	AN0510	78	600	13.3	25.3	12.00	5.09	3.53	18.83
NJ000413	S532A41H	AN0532	43	600	22.0	33.5		4.14	2.87	5.17
NJ000414	S532A42H	AN0532	35	600	26.8	51.7		3.76	2.61	6.50
NJ000415	S575A41H	AN0575	56	600	15.8	27.7	5.83	4.68	3.25	20.33
NJ000416	S575A42H	AN0575	54	603	17.2	30.3	7.79	4.49	3.11	21.06
NJ000417	S623A41H	AN0623	58	599	17.2	31.4		4.42	3.06	5.01
NJ000418	S623A42H	AN0623	45	600	25.5	48.0	0.67	4.11	2.85	3.33
NJ000419	S686A41H	AN0686	72	601	20.6	20.6	4.66	4.94	3.42	6.49
NJ000420	S740A41H	AN0740	49	602	36.0	46.3	2.49	3.81	2.64	8.31
NJ000421	S740A42H	AN0740	52	600	20.8	32.0	2.33	4.31	2.99	11.83
NJ000422	S744A41H	AN0744	65	602	9.8		4.82	5.05	3.50	25.91
NJ000423	S744A42H	AN0744	71	601	8.2		7.99	5.23	3.63	24.46
NJ000430	S744A41	AN0744	55	600	20.5	45.0	7.17	4.30	2.98	36.83
NJ000435	S744A42	AN0744	41	603	21.4	54.4	3.65	3.88	2.69	38.14
NJ000440	S686A41	AN0686	85	600	10.7	10.7	4.83	5.55	3.85	15.83
NJ000445	S686A42	AN0686	78	603	8.1		4.31	5.58	3.86	26.37

Dtm. Smpl. ID	Smpl. Label	Dtm. TALU Site ID	Total Taxa	Total Valves	% Dom. Taxon	Sum % Dom. Taxa	% Ach. min.	SW Div.	SW Div. (ln)	Siltation
NJ000450	S149AA41	AN0149A	74	600	20.0	34.2	5.50	4.85	3.36	13.83
NJ000455	S149AA42	AN0149A	38	600	30.8	59.5	0.33	3.44	2.38	1.83
NJ000460	S740A41	AN0740	11	602	74.9	74.9	1.00	1.41	0.98	
NJ000465	S740A42	AN0740	11	603	64.5	82.6	2.65	1.72	1.19	
NJ000470	S575A41	AN0575	55	600	17.0	17.0	1.67	4.71	3.26	42.67
NJ000475	S575A42	AN0575	40	600	23.3	36.2	3.00	4.10	2.84	29.00
NJ000480	S623A41	AN0623	38	601	22.6	58.1	0.33	3.60	2.50	3.33
NJ000485	S623A42	AN0623	29	600	35.8	82.2		2.61	1.81	0.50
NJ000490	S503A41	AN0503	72	604	13.6	24.0	2.15	5.02	3.48	21.69
NJ000495	S503A42	AN0503	54	598	23.6	36.6	1.34	4.30	2.98	13.55
NJ000500	S510A41	AN0510	17	601	58.4	80.4	8.32	1.95	1.35	
NJ000505	S532A41	AN0532	16	600	52.0	84.2		1.94	1.35	
NJ000510	S532A42	AN0532	13	601	50.1	86.2		1.82	1.26	0.17

Appendix 6

Diatom taxa synonyms. Name used in current dataset and corresponding name used in earlier sample and data analysis (Ponader et al. 2007, 2008.

Current Name	Previous Name
Achnanthidium caledonicum (Lange-Bertalot) Lange-Bertalot	Achnanthes minutissima var. scotica (Carter) Lange-Bertalot sensu Krammer et Lange-Bertalot 1991
Achnanthidium exiguum (Grunow) Czarnecki	Achnanthidium exiguum var. heterovalvum (Krasske) Czarnecki
Achnanthidium rivulare Potapova et Ponader	Achnanthidium sp. 10 NAWQA MP
Achnanthidium subatomus (Hustedt) Lange-Bertalot	Achnanthes biasolettiana var. subatomus Lange-Bertalot
Aulacoseira italica (Ehrenberg) Simonsen	Aulacoseira crenulata (Ehrenberg) Thwaites
Aulacoseira lacustris (Grunow) Krammer	Aulacoseira lirata var. lacustris (Grunow) Ross
Chamaepinnularia evanida (Hustedt) Lange-Bertalot	Navicula evanida Hustedt
Cocconeis pseudolineata (Geitler) Lange-Bertalot	Cocconeis placentula var. pseudolineata Geitler
Craticula molestiformis (Hustedt) Lange-Bertalot	Navicula biconica Patrick
Cymbella elginensis Krammer	Cymbella turgida Gregory
Cymbella tropica Krammer	Cymbella sp. 1 ANS POTO
Cymbella tumida (Brébisson ex Kützing) Van Heurck	Encyonema paludosa var. subsalina (Cleve) Krammer
Cymbella tumida (Brébisson ex Kützing) Van Heurck	Encyonema tumida (Brébisson ex Kützing) Mann
Discostella pseudostelligera (Hustedt) Houk et Klee	Cyclotella pseudostelligera Hustedt

Current Name	Previous Name
Discostella stelligera (Hustedt) Houk et Klee	Cyclotella stelligera (Cleve et Grunow) Van Heurck
Encyonema auerswaldii Rabenhorst	Cymbella caespitosa Brun
Encyonema triangulum (Ehrenberg) Kützing	Cymbella triangulum (Ehrenberg) Cleve
Fallacia lenzii (Hustedt) Lange-Bertalot	Navicula lenzii Hutedt in A.S.
Fragilaria capucina Desmazières	Fragilaria capucina var. lanceolata Grunow
Fragilaria capucina var. gracilis (Østrup) Hustedt	Fragilaria capucina var. 1 NAWQA UM 1996 UCOL
Fragilaria capucina var. gracilis (Østrup) Hustedt	Fragilaria capucina var. 2 NAWQA UM 1996 UCOL
Fragilaria rhabdosoma Ehrenberg	Fragilaria bidens Heiberg
Fragilaria sepes Ehrenberg	Fragilaria nanana Lange-Bertalot
Fragilaria vaucheriae (Kützing) Petersen	Fragilaria intermedia (Grunow) Grunow
Fragilariforma constricta var. trinodis (Hustedt) Hamilton	Fragilariforma constricta fo. trinodis (Hustedt) Hamilton
Frustulia krammeri Lange-Bertalot et Metzeltin	Frustulia rhomboides (Ehrenberg) deToni
Gyrosigma wormleyi (Sullivan) Boyer	Gyrosigma parkerii (Harrison) Elmore
Karayevia suchlandtii (Hustedt) Bukhtiyarova	Kolbesia suchlandtii (Hustedt) Kingston
Navicula cf. kriegerii NAWQA KM Krasske	Achnanthes bahusiensis (Grunow) Lange-Bertalot
Navicula cf. kriegerii NAWQA KM Krasske	Navicula bahusiensis (Grunow) Grunow
Navicula cryptotenella Lange-Bertalot in Krammer et	Achnanthes expressa Carter

Current Name	Previous Name
Lange-Bertalot	
Navicula cryptotenella Lange-Bertalot in Krammer et Lange-Bertalot	Navicula sp. 1 ANS HDSN
Navicula kotschyi Grunow	Navicula savannahiana Patrick
Navicula kotschyi Grunow	Navicula texana Patrick
Navicula wallacei Reimer	Fallacia cf. ecuadoriana NAWQA KM Lange-Bertalot et Rumrich
Nitzschia archibaldii Lange-Bertalot	Nitzschia cf. archibaldii CODY Lange-Bertalot
Nitzschia capitellata Hustedt	Nitzschia diserta Hustedt
Nitzschia fonticola Grunow	Nitzschia sp. 1 ANS WRC
Nitzschia homburgienis Lange-Bertalot	Nitzschia thermalis var. minor Hilse
Nitzschia intermedia Hantzsch ex Cleve et Grunow	Nitzschia tarda Hustedt
Nitzschia palea (Kützing) Smith	Nitzschia accomodata Hustedt
Nitzschia palea (Kützing) Smith	Nitzschia palea var. sumatrana Hustedt
Nitzschia subtilis Grunow	Nitzschia linearis var. subtilis Hustedt
Nupela carolina Potapova et Clason	Nupela sp. 3 NAWQA MP
Nupela neglecta Ponader, Lowe et Potapova	Nupela sp. 1 ANS NEW JERSEY KCP
Planothidium daui (Foged) Lange-Bertalot	Achnanthes cf. grana ROBERTS Hohn et Hellerman

Current Name	Previous Name
Planothidium stewartii (Patrick) Lange-Bertalot	Achnanthes stewartii Patrick
Platessa conspicua (Mayer) Lange-Bertalot	Achnanthes conspicua Mayer
Platessa hustedtii (Krasske) Lange-Bertalot	Achnanthes rupestoides Hohn
Psammothidium ventralis (Krasske) Bukhtiyarova et Round	Achnanthes sublaevis Hustedt
Pseudostaurosira parasitica (Smith) Morales	Synedra parasitica (Smith) Hustedt
Pseudostaurosira parasitica var. subconstricta (Grunow) Morales	Synedra parasitica var. subconstricta (Grunow) Hustedt
Puncticulata bodanica (Grunow in Schneider) Håkansson	Cyclotella bodanica Grunow
Reimeria sinuata (Gregory) Kociolek et Stoermer	Reimeria lacus-idahoensis Kociolek et Stoermer
Staurosira construens Ehrenberg	Fragilaria construens var. 1 ANS LLB
Staurosira construens var. venter (Ehrenberg) Hamilton	Staurosira construens var. pumila (Grunow) Kingston
Surirella helvetica Brun	Surirella linearis var. helvetica (Brun) Meister
Synedra delicatissima var. angustissima Grunow	Synedra acus var. angustissima Grunow
Synedra rumpens Kützing	Fragilaria capucina var. rumpens (Kützing) Lange-Bertalot
Synedra rumpens Kützing	Fragilaria cf. capucina NAWQA LJM Desmazières

Appendix 7

NJDEP Diatom TALU Stressor Review Meeting (September 4, 2009)

* Scores from 1 (best) to 10 (worst): assume 1 as pristine or non-degraded almost impossible to meet.

AN006
Good site: stormwater pipes, filamentous algae, macroinvertebrates (good 5.89) ((Good stoneflies Score 3

AN008
Excellent, Forested, DO 9.74 and Ph 8.44 was high (a lot of alkalinity, cl), more upstream AG influenced Rt. 615 Score = 2

AN0016
Wetlands, a lot of weeds and grasses, Macros = filter feeders (indicate high nutrients), unusual sandy site. Sluggish flow, brown color to water - unusual), Score = 5

An0029
Cornfield nearby (AG), nitrate higher (Ag), Excellent macros, shaded and water temp low in august, Score = 2-3

An032A
Rural, fair macros, moderate epts, conductivity/hardness high (Road). Higher siltation index than others Score = 5 (Jack 6)

An0081
Cat 1 stream, excellent macros, Ag area, and bank stability bad with r pap to shore up bank. Low TP but high nitrogen, well shaded, bugs excellent Score = 6, (Jack 5)

An 109
High siltation, and High Ah, Low nut but N/P more evenly distributed, (no good sites on Assunpink) fair to poor for macros, high silt (Score = 8, 7, 7)

An0111
Siltation high, good canopy, slow, poor bank stability, lot of silt and sand, flashy, erosion, Chl a 64 in middle, Moile low. Score = 7, 7

An0115
Right behind a strip mall and baseball field, high Chl a, macro lower fair, Score 7-8

Ano118
Tidal (remove)

ANo121
80%clay, high siltation high tp N/P ration is 3 – 1, Poor bank stability, erosion control netting on bank, Steep banks, Score 8

Ano 124
Not a great site, High nutrients, motile 50%, Flow says 3 –high but believe in a wetland area, lots of clay and sand. Colored water Score = 5

An129
TP- TMDL done, Macro fair, storm drains, Allentown stp upstream, motiles are high, unstable erodable stream banks, Lot of Ag, high siltation Score = 7.

An132
Good canopy lots of TP (0.2), Ag area, highest motile species, clay bottom, fair macros, Score = 6.

An133
Shaded, high sand, (No sense of site)

An136
Poor bugs, poor bank stability, suburban area, silt moderate, high TP but N/T 4:1, Score 8-9 (mostly chironomids and worms)

An139
TP_ TMDL done, A lot of gravel, macro is good, TP is high, dark water (15) near PB (outside 3.mi buffer for Pineland AMNET), Score = 4-5

An149A
Highest sand, used PB index, tp low, color is 20 (dark), suburban area, fair amount erosion, west lakeshore drive, adjacent to pumping station (Browns Mills), Mirror Lake lead investigator Score = 5

AN151 A
Almost identical to last site for bugs, ammonia is high (2Xnitrate), low TP, possibly Sybron Chemical on same road, good macros, Score = 5-6 (NH4)

AN166
PB, poor bugs, low do 4.43, colored, storm sewers, suburban, Score = 6, 7-8, 7.

An0169
Colored water, wide deep stream, fair for bugs, mud and silt, DO low 4.86, ph 6.41, rural, (substrate AMNET poor, TDI 90 % sand) Score = 7 (a lot of worms in mud.).

Ano192
Runs through a parking lot, some of highest chloride levels seen, (250 cl DW Std), golf course upstream, above a reservoir, , highest conductivity, land use does not jibe with river type, suspect golf course, poor bugs – chironomids, banks unstable. Score = 9, 9-10.

ANo195
Nitrate really high (compared to TP 20X), 4911 (Chl a 128 mg/l), moderate canopy, banks fair, storm sewers present, fair macros, Score = 5, 7 (Chl a high)

An237
Storm sewers, boulders, cobble, a lot of snags, narrow, bugs fair, downstream of lake and Rt. 80 and 238, Chl a 43 (not real high), shaded (water temp 19.8 in august), high canopy cover, bank fair. Score = 5.

Ano231
High conductivity, bugs poor, worm and Chiron, a lot of wastewater, storm sewers , eroding, 50%substrate, 100% open canopy, water murky and brown, high tp an nitrate but ammonia is low (stp result). Score = 10, 9 (not concrete)

ANo 299
Hardness high, high filamentous algae, railroad tracks along bank, AH is high, Chl a 72, Bugs are good with sensitive species present, fast flowing, bank stable. Score = 4

ANo 321
Filamentous algae, trout stocked ph 9, banks stable, and bugs good, rocky, real sensitive species. Score = 3, 4.

ANO 740
Bugs good, macrophytes, filamentous algae, geese, USG weir creates lowest number of taxa, really lake, brown water, pg 5.98, % Parvin Stare Park upstream, Ag. Score = 4

An0265
Bugs high side good (excellent), storm sewers, macrophytes, trout prod'n, land use commercial (runs through main street in Butler Boro), bank stability fair, fast water, a few sensitive species , Score 4, 3

AN0384
Fair bugs, storm sewers, macrophytes,