Standard Operating Procedure
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Protocols for Calculating the Diatom Total Phosphorus Index (DTPI) and Diatom Total Nitrogen Index (DTNI) for Wadeable Streams and Rivers

Bureau of Land and Water Quality
Division of Environmental Assessment
Biological Monitoring Program
Standard Operating Procedure

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1. **Applicability.** The models are applicable to benthic diatom samples collected from rocks or logs in streams and river segments with open to partly open canopy and less than 1.25 meters in depth.

2. **Purpose**. This standard operating procedure describes two multiple regression models, the Diatom Total Phosphorus Index (DTPI) and Diatom Total Nitrogen Index (DTNI), that use benthic diatom community data to estimate concentrations of total phosphorus (TP) and total nitrogen (TN) in Maine streams and rivers. The DTPI and DTNI will be used to help determine attainment of water quality standards. The models will also be used to track water quality over time in response to increased pollution or restoration activities.

3. **Definitions**

   A. **Benthic Algae**. Algae growing on substrates on the stream bottom.

   B. **Diatom**. Algae in the class Bacillariophyceae.

   C. **Inference Model**. A statistical tool that uses species composition data collected from a waterbody to estimate the value of an environmental variable in the waterbody, such as pH or nutrient concentrations.

   D. **Regression Model**. A statistical model that uses one or more variables as input to predict the likely value for a dependent variable.

4. **Responsibilities**

   A. **Data Collection and Submission**. Algae must be collected by qualified personnel following Maine Department of Environmental Protection's (DEP) standard operating procedures (Danielson 2006) or comparable method. Algal samples must be processed and diatoms must be identified and enumerated following the protocols set forth the North American Water Quality Assessment (NAWQA) program of the U.S. Geological Survey (Charles et al. 2002) or comparable method. Data must be submitted in Electronic Data Deliverable (EDD) format for uploading into the Environmental Geographic Analysis Database (EGAD).

   B. **Model Calculations**. Data must be checked for quality assurance purposes by qualified DEP staff. Data can then be loaded into EGAD to run the model calculations.

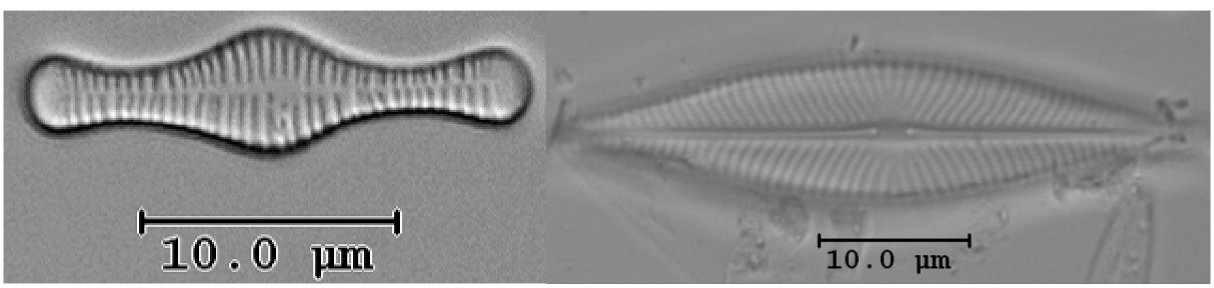
5. **Guidelines and Procedures**

   A. **Introduction.** Diatoms are commonly used to measure the impacts of nutrient enrichment on water quality. The availability of nutrients is one of the key factors determining which diatoms can survive in a stream. Some diatoms are usually only collected in low-nutrient streams, some are restricted to high-nutrient streams, and others have broad nutrient preferences. *Tabellaria flocculosa* is an example of a species that is most common in low nutrient streams and decreases in abundance with nutrient enrichment (Figure 1). In contrast, *Navicula trivialis* is an example of a high-nutrient diatom that increases in abundance with nutrient enrichment (Figure 1).

Diatom communities are better indicators of nutrient enrichment than water samples. Water samples can provide incomplete estimates of nutrient enrichment because they represent discrete moments in time. Nutrient concentrations, especially of phosphorus, can fluctuate in developed watersheds because of increased non-point source pollution and stream bank erosion following rain storms. Several water samples may not effectively represent the cumulative supply of nutrients over time because of the variation in concentrations. In contrast, diatom communities develop and are exposed to nutrients over a period of weeks or months. The cumulative supply of nutrients can influence which species can survive and can shape the overall community structure.

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

Figure 1. *Tabellaria flocculosa* (left) and *Navicula trivialis* (right).

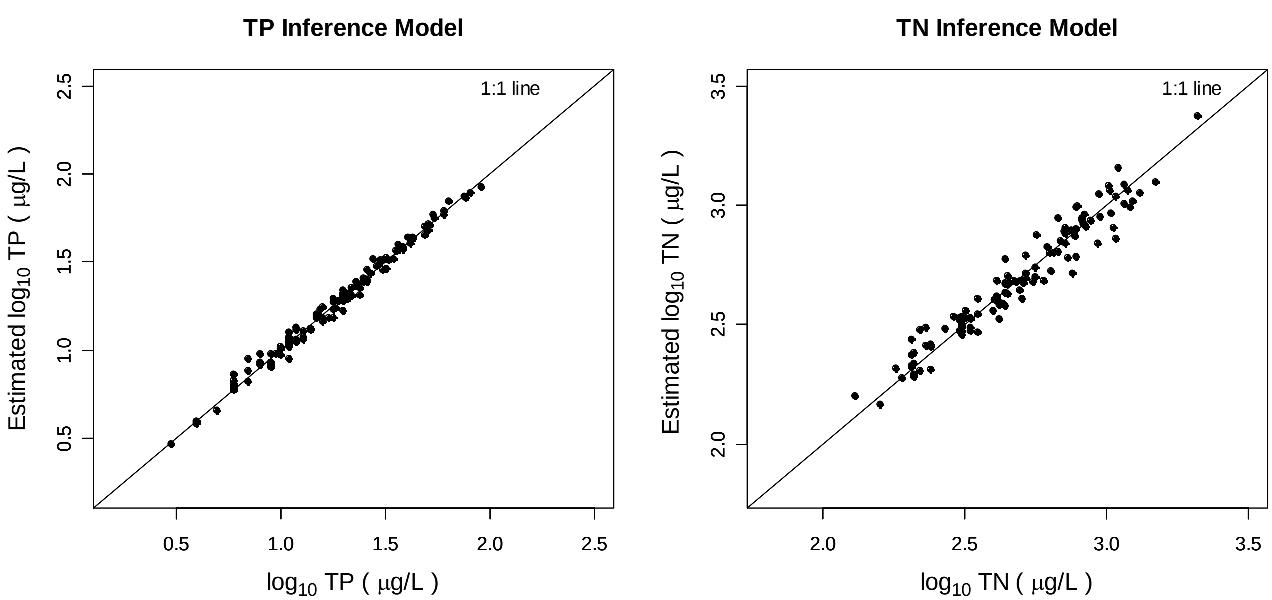


B. **Model Development.** The models were developed by assembling 123 samples from streams across the state. The streams ranged from low-nutrient streams to high-nutrient streams. Data included TN and TP concentrations from stream water and diatoms collected by scraping rocks in the streams. A variety of statistical models were tested and a multiple linear regression approach was ultimately selected because of its performance and ease of calculation. Linear regression uses a simple formula to describe a straight-line relationship between two variables: $Y = \beta\ x + \beta_0$. Y is the dependent or response variable that is predicted, x is the independent or explanatory variable, β is the coefficient for the explanatory variable, and β_0 is the constant. Multiple regression follows the same approach but uses more than one explanatory variable.

The DTPI and DTNI are regression models that use many species as independent variables in the calculations. A statistical technique called forward stepwise selection was used to identify the combination of species that provide the best estimate of the observed TP and TN concentrations. The statistical application took the diatom and nutrient data and iteratively added species and assigned the species coefficients (i.e., β). It selected the combination of species and their coefficients that best predicted the nutrient concentrations in a straight line with the least amount of scatter around the line.

Two measurements were used to measure how well the models fit a straight line. The r^2 value measures the strength of the association and the root mean square error (RMSE) measures the amount of scatter around the line. A perfect relationship would have an r^2 approaching 1 and a RMSE approaching 0. The worst relationship would have a r^2 approaching 0 and a very high RMSE. The adjusted r^2 and RMSE of the TP model were 0.90 and 0.10 respectively (Figure 2). The adjusted r^2 and RMSE of the TN model were 0.91 and 0.07 respectively. DTPI and DTNI models were tested with another set of 75 samples with r^2 values of 0.50 and 0.31 respectively. Overall, the performance of the Maine models is comparable to nutrient inference models developed for New Jersey (Ponader et al. 2007, Ponader et al. 2008), the Northern Piedmont Region of the U.S. (Potapova et al. 2004), and western U.S. (Stevenson et al. 2008).

Figure 2: TP and TN inference models for Maine streams and rivers.



C. **Data Preparation**

1) **Exclude Rare Species**. Rare species can reduce the predictive quality of inference models because calculating their nutrient preferences is difficult. The models were built using a subset of 180 of the most common diatom species (Table 1). New calculations need to be based on the same subset of 180 diatoms to be consistent with the way the models were developed. Including rare species would change the percent abundances of the common taxa. Therefore, any taxa that are present in a sample but are not included in Table 1 are excluded.

2) **Calculate Square Root of Percent Abundances.** Once species not included in Table 1 are removed, the next step is to convert the species counts to percent abundances as shown in Table 2. Diatom abundances are based on the density of cells per square centimeter of substrate sampled.

   i. Divide the abundance of each species in a sample by the total abundance of all species in the sample that are listed in Table 1.

   ii. The next step is to calculate the square root of the abundances. The models use the square roots of percent abundances to reduce the influence of a few ubiquitous and abundant diatoms such as *Achnanthidium minutissimum*.

D. **Diatom Total Phosphorus Index (DTPI)**

1) **Exclude Taxa without TP Coefficients.** Only include those species with TP coefficients in Table 1 when calculating the DTPI as shown in Table 2.

2) **Model Formula.** $TP^* = 1.322585 + \sum_i x_i \beta_i^{TP}$

   i. TP^* is the $\log_{10}$ TP (μg/L)

   ii. Σ is the symbol for summation.

   iii. x_i is the square root percent abundance of species *i*

   iv. β_i^{TP} is the TP coefficient of species *i* in Table 1

3) **Applicable Range.** Index values outside of the ranges specified below must be treated with caution since they are beyond the scope of the original models. In

addition, extreme values can be caused by atypical diatom communities. The applicable range for *TP** is between 0.4 and 2.1.

4) **Convert Results.** The final step is to convert *TP** from $\log_{10}$ units to normal units as shown in Table 2. This is accomplished by using the following formula:

$$\text{DTPI} = \text{Estimated TP } (\mu\text{g/L}) = 10^{TP^*}$$

E. **Diatom Total Nitrogen Index (DTNI)**

1) **Exclude Taxa Without TN Coefficients.** Only include those species with TN coefficients when calculating the DTNI (Table 1).

2) **Model Formula.** $TN^* = 2.245248 + \sum_i x_i \beta_i^{TN}$

   i. TN^* is the $\log_{10}$ TN (µg/L)

   ii. Σ is the symbol for summation.

   iii. x_i is the square root percent abundance of species *i*

   iv. β_i^{TN} is the TN coefficient of species *i* in Table 1

3) **Applicable Range.** Index values outside of the ranges specified below must be treated with caution since they are beyond the scope of the original models. In addition, extreme values can be caused by atypical diatom communities. The applicable range of *TN** is between 2.1 and 3.4.

4) C**onvert Results.** The final step is to convert *TN** from $\log_{10}$ units to normal units. This is accomplished by using the following formula:

$$\text{DTNI} = \text{Estimated TN } (\mu\text{g/L}) = 10^{TN^*}$$

Table 1 – List of 180 diatom species (and their DEP taxonomic codes) to be used in calculating square root percent abundances and the TP and TN coefficients used to calculate the DTPI and DTNI.

Species	Code	β_i^{TN}	β_i^{TP}
Achnanthes nollii Bock	ACnollii		
Achnanthes oblongella Østrup	ACoblong	0.173293	0.142281
Achnanthes subhudsonis var. kraeuselii (Cholnoky) Cholnoky	ACsubkra		
Achnanthidium deflexum (Rabenhorst) Lange-Bertalot et Ruppel	ADdeflex	0.040581	
Achnanthidium exiguum (Grunow) Czarnecki	ADexigua		
Achnanthidium minutissimum (Kützing) Czarnecki	ADminuti	0.018376	-0.028851
Achnanthidium rivulare Potapova et Ponader	ADrivula	0.050075	
Adlafia bryophila (Petersen) Lange-Bertalot	ALbryphl		-0.07318
Amphipleura pellucida (Kützing) Kützing	APpelluc		-0.167188
Amphora pediculus (Kützing) Grunow	AMpedcls	0.110615	
Asterionella formosa Hassal	ASformos		
Aulacoseira alpigena (Grunow) Krammer	AUalpige		
Aulacoseira ambigua (Grunow) Simonsen	AUambigu		0.14403
Aulacoseira granulata (Ehrenberg) Simonsen	AUgranul		
Brachysira brebissonii Ross	BRbrebis		
Brachysira microcephala (Grunow) Compère	BRmicroc		
Brachysira vitrea (Grunow) Ross	BRvitrea		
Caloneis bacillum (Grunow) Cleve	CAbacill	0.275167	
Cavinula cocconeiformis (Gregory ex Greville) Mann et Stickle	CJcoccon		
Chamaepinnularia bremensis (Hustedt) Lange-Bertalot	CKbremen		
Chamaepinnularia mediocris (Krasske) Lange-Bertalot	CKmedioc		
Cocconeis pediculus Ehrenberg	CCpedcls		0.097392
Cocconeis placentula var. euglypta (Ehrenberg) Grunow	CCplaeug	-0.043675	
Cocconeis placentula var. lineata (Ehrenberg) Van Heurck	CCplalin		
Craticula submolesta (Hustedt) Lange-Bertalot	CRsubmol	-0.063395	
Ctenophora pulchella (Ralfs ex Kützing) Williams et Round	CTpulche		
Cyclotella meneghiniana Kützing	CYmenegh		
Cyclotella michiganiana Skvortzow	CYmichig		
Cymbella affinis Kützing	CMaffins	-0.122131	
Cymbella cistula (Ehrenberg) Kirchner	CMcistul		
Cymbella delicatula Kützing	CMdelcat		-0.076764
Cymbella gracilis (Ehrenberg) Kützing	CMgracil	0.082538	
Cymbella naviculiformis Auerswald ex Héribaud	CMnavicu		0.200185
Cymbella tumida (Brébisson ex Kützing) Van Heurck	CMtumida		
Diatoma mesodon (Ehrenberg) Kützing	DAmesodo		
Diatoma moniliformis Kützing	DAmonili		
Diatoma tenuis Agardh	DAtenuis		

Table 1 – List of 180 diatom species (and their DEP taxonomic codes) to be used in calculating square root percent abundances and the TP and TN coefficients used to calculate the DTPI and DTNI (continued).

Species	Code	β_i^{TN}	β_i^{TP}
Discostella pseudostelligera (Hustedt) Houk et Klee	DOpseudo	-0.24269	
Discostella stelligera (Hustedt) Houk et Klee	DOstelli		
Encyonema minutum (Hilse) Mann	ENminutu		
Encyonema prostratum (Berkeley) Kützing	ENprostr		
Encyonema reichardtii (Krammer) Mann	ENreicha		
Encyonema silesiacum (Bleisch) Mann	ENsilesi		
Encyonopsis cesatii (Rabenhorst) Krammer	EScesati		
Encyonopsis microcephala (Grunow) Krammer	ESmicroc		-0.155503
Eucocconeis laevis (Østrup) Lange-Bertalot	EClaevis	-0.083052	
Eunotia arcus var. bidens Grunow	EUarcbid		
Eunotia bilunaris (Ehrenberg) Mills	EUbiluna		
Eunotia exigua (Brébisson ex Kützing) Rabenhorst	EUexigua	0.066465	
Eunotia flexuosa Brébisson ex Kützing	EUflexuo		
Eunotia implicata Nörpel, Lange-Bertalot et Alles	EUimplic		
Eunotia incisa Smith ex Gregory	EUincisa		
Eunotia minor (Kützing) Grunow	EUminor		
Eunotia muscicola var. tridentula Nörpel et Lange-Bertalot	EUmustri	-0.509509	-0.415916
Eunotia naegelii Migula	EUnaegel	0.120606	
Eunotia paludosa Grunow	EUpaludo	-0.133429	-0.327318
Eunotia pectinalis (Müller) Rabenhorst	EUpectin		
Eunotia pectinalis var. undulata (Ralfs) Rabenhorst	EUpecund		-0.053001
Eunotia praerupta Ehrenberg	EUpraeru		
Eunotia rhomboidea Hustedt	EUrhombo		
Eunotia soleirolii (Kützing) Rabenhorst	EUsoleir		
Eunotia subarcuatoides Alles, Nörpel et Lange-Bertalot	EUsubarc		
Fragilaria capucina Desmazières	FRcapuci		
Fragilaria capucina var. gracilis (Østrup) Hustedt	FRcapgra		0.02382
Fragilaria sepes Ehrenberg	FRsepes	0.046787	
Fragilaria tenera (Smith) Lange-Bertalot	FRtenera		
Fragilaria vaucheriae (Kützing) Petersen	FRvauche		
Fragilaria vaucheriae var. capitellata (Grunow) Ross	FRvaucap	0.091822	
Fragilariforma virescens (Ralfs) Williams et Round	FAviresc		
Frustulia amphipleuroides (Grunow) Cleve-Euler	FSamphip		
Frustulia crassinervia (Brébisson) Lange-Bertalot et Krammer	FScrassi		
Frustulia krammeri Lange-Bertalot et Metzeltin	FSkramme	0.079925	
Frustulia vulgaris (Thwaites) deToni	FSvulgar		
Geissleria decussis (Hustedt) Lange-Bertalot et Metzeltin	GAdecuss	-0.092402	
Gomphonema acuminatum Ehrenberg	GOacumin		
Gomphonema affine Kützing	GOaffine		
Gomphonema angustatum (Kützing) Rabenhorst	GOangust	0.08028	

Table 1 – List of 180 diatom species (and their DEP taxonomic codes) to be used in calculating square root percent abundances and the TP and TN coefficients used to calculate the DTPI and DTNI (continued).

Species	Code	β_i^{TN}	β_i^{TP}
Gomphonema angustum Agardh	GOangstm		
Gomphonema drutelingense Reichardt	GOdrutel		-0.112772
Gomphonema gracile Ehrenberg emend Van Heurck	GOgracil		
Gomphonema kobayasii Kociolek et Kingston	GOkobaya	0.107094	
Gomphonema micropus Kützing	GOmicrop		
Gomphonema minutum (Agardh) Agardh	GOminutu	0.057565	
Gomphonema olivaceoides Hustedt	GOolivco		
Gomphonema parvulum (Kützing) Kützing	GOparvul		0.035445
Gomphonema patrickii Kociolek et Stoermer	GOpatric		
Gomphonema pumilum (Grunow) Reichardt et Lange-Bertalot	GOpumilu		
Gomphonema pumilum var. rigidum Reichardt et Lange-Bertalot	GOpumilu		
Gomphonema rhombicum Fricke	GOrhombi		
Gomphonema spp.	GO		
Gomphonema truncatum Ehrenberg	GOtrunca		0.073149
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski	HPcapita		0.12347
Karayevia clevei (Grunow) Bukhtiyarova	KAclevei		
Karayevia laterostrata (Hantzsch) Bukhtiyarova	KAlatero		
Karayevia suchlandtii (Hustedt) Bukhtiyarova	KAsuchla		0.268543
Luticola mutica (Kützing) Mann	LUmutica		
Mayamaea agrestis (Hustedt) Lange-Bertalot	MYagrest		
Mayamaea atomus var. permitis (Hustedt) Lange-Bertalot	MYatoper		
Melosira varians Agardh	MEvarian		
Meridion circulare (Greville) Agardh	MDcircul		
Meridion circulare var. constrictum (Ralfs) Van Heurck	MDcircon		
Navicula angusta Grunow	NAangust		
Navicula antonii Lange-Bertalot	NAanton		
Navicula capitatoradiata Germain	NAcaprad	0.07829	
Navicula cryptocephala Kützing	NAcrypto	0.107229	0.176553
Navicula cryptotenella Lange-Bertalot ex Krammer et Lange-Bertalot	NAcryten	-0.047946	
Navicula cryptotenelloides Lange-Bertalot	NAcrytot		0.092992
Navicula gregaria Donkin	NAgregar		
Navicula lanceolata (Agardh) Ehrenberg	NAlanceo		
Navicula leptostriata Jörgansen	NAleptos		
Navicula menisculus Schumann	NAmenscl		
Navicula minima Grunow	NAminima		
Navicula notha Wallace	NAnotha	-0.070592	
Navicula radiosa Kützing	NAradios		
Navicula radiosafallax Lange-Bertalot	NAradiof		
Navicula rhynchocephala Kützing	NArhynch		

Table 1 – List of 180 diatom species (and their DEP taxonomic codes) to be used in calculating square root percent abundances and the TP and TN coefficients used to calculate the DTPI and DTNI (continued).

Species	Code	β_i^{TN}	β_i^{TP}
Navicula rostellata Kützing	NArostel		
Navicula schmassmanni Hustedt	NAschmas		-0.24594
Navicula schroeteri var. escambia Patrick	NAschroe		
Navicula tripunctata (Müller) Bory	NAtripun		
Navicula trivialis Lange-Bertalot	NAtrivia		0.170725
Navicula veneta Kützing	NAveneta		
Navicula viridula (Kützing) Kützing emend. Van Heurck	NAviridu		
Navicula viridulacalcis (Hustedt) Lange-Bertalot	NAvirlin		
Nitzschia acidoclinata Lange-Bertalot	NIacidoc	0.120971	
Nitzschia amphibia Grunow	NIamphib	-0.088765	
Nitzschia capitellata Hustedt	NIcapite		
Nitzschia dissipata (Kützing) Grunow	NIdissip		
Nitzschia dissipata var. media (Hantzsch) Grunow	NIdismed		
Nitzschia fonticola Grunow	NIfontic		
Nitzschia frustulum (Kützing) Grunow	NIfrustu		
Nitzschia gracilis Hantzsch ex Rabenhorst	NIgracil		
Nitzschia inconspicua Grunow	NIincons		0.144145
Nitzschia liebethruthii Rabenhorst	NIliebrt		
Nitzschia linearis (Agardh ex Wm. Smith) Wm. Smith	NIlinear		
Nitzschia palea (Kützing) Smith	NIpalea		0.055
Nitzschia paleacea Grunow ex Van Heurck	NIpaleac	0.164201	
Nitzschia perminuta (Grunow) Peragallo	NIpermin		
Nitzschia pumila Hustedt	NIpumila		
Nitzschia recta Hantzsch ex Rabenhorst	NIrecta		
Nitzschia supralitorea Lange-Bertalot	NIsupral		
Nitzschia tubicola Grunow ex Cleve et Grunow	NItubico		
Pinnularia gibba Ehrenberg	PIgibba		
Pinnularia obscura Krasske	PIobscur		
Pinnularia subcapitata Gregory	PIsubcap		
Pinnularia viridis (Nitzsch) Ehrenberg	PIviridi		
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot	PLfreque	0.115348	
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	PLlanceo		
Planothidium lanceolatum var. omissum (Reimer) Andresen, Stoermer et Kreis	PLlanceo		
Planothidium rostratum (Østrup) Lange-Bertalot	PLrostra		
Planothidium stewartii (Patrick) Lange-Bertalot	PLstewar		0.572415
Platessa conspicua (Mayer) Lange-Bertalot	PVconspi		
Psammothidium bioretii (Germain) Bukhtiyarova et Round	PSbioret		-0.123658
Psammothidium chlidanos (Hohn et Hellerman) Lange-Bertalot	PSchlida		
Psammothidium grischunum fo. daonensis (Lange-Bertalot ex Lange-Bertalot et Krammer) Bukhtiyarova et Round	PSgridao		

Table 1 – List of 180 diatom species (and their DEP taxonomic codes) to be used in calculating square root percent abundances and the TP and TN coefficients used to calculate the DTPI and DTNI (continued).

Species	Code	β_i^{TN}	β_i^{TP}
Psammothidium helveticum (Hustedt) Bukhtiyarova et Round	PShelvet		
Psammothidium marginulatum (Grunow) Bukhtiyarova et Round	PSmargin		
Psammothidium subatomoides (Hustedt) Bukhtiyarova et Round	PSsubato	0.07577	
Psammothidium ventralis (Krasske) Bukhtiyarova et Round	PSventra		
Pseudostaurosira brevistriata (Grunow) Williams et Round Round	PTbrevis	-0.131968	
Reimeria sinuata (Gregory) Kociolek et Stoermer	REsinuat		
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot	ROabbrev	0.027763	
Rossithidium linearis (Smith) Round et Bukhtiyarova	RMlinear		
Sellaphora pupula (Kützing) Meresckowsky	SEpupula		
Sellaphora seminulum (Grunow) Mann	SEseminu		
Stauroforma exiguiformis (Lange-Bertalot) Flower, Jones et Round	SQexigui		
Stauroneis anceps Ehrenberg	SSanceps		
Stauroneis kriegeri Patrick	SSkriege		
Staurosira construens Ehrenberg	STconstr		
Staurosira construens var. venter (Ehrenberg) Hamilton	STconsve		
Staurosira elliptica (Schumann) Williams et Round	STellipt		-0.194351
Staurosirella pinnata (Ehrenberg) Williams et Round	SLpinnat	0.099565	
Surirella amphioxys Smith	SUamphio	0.095076	
Surirella angusta Kützing	SUangust		
Surirella minuta Brébisson	SUminuta		
Synedra acus Kützing	SYacus		
Synedra rumpens Kützing	SYrumpen	0.019816	
Synedra ulna (Nitzsch) Ehrenberg	SYulna		
Synedra ulna var. oxyrhynchus (Kützing) Van Heurck	SYulnoxy		
Tabellaria flocculosa (Roth) Kützing	TAfloccu		-0.039732

Table 2. Example of calculating DTPI.

Species	Percent Abundance	Square root Percent Abundance (x_i)	TP coefficient (β_i^{TP})	Product
Constant				1.322585
Achnanthidium deflexum	0.2	0.404		
Achnanthidium minutissimum	82.8	9.102	-0.02885	-0.2626
Brachysira microcephala	2.9	1.715		
Cocconeis placentula var. lineata	0.3	0.572		
Cymbella aspera	not in Table 1			
Cymbella delicatula	0.8	0.904	-0.07676	-0.06939
Encyonema minutum	0.5	0.700		
Fragilaria capucina var. gracilis	2.9	1.715	0.02382	0.040851
Fragilaria vaucheriae var. capitellata	0.2	0.404		
Gomphonema acuminatum	0.3	0.572		
Gomphonema parvulum	2.6	1.617	0.035445	0.057311
Gomphonema truncatum	0.3	0.572	0.073149	0.041817
Navicula notha	0.5	0.700		
Nitzschia fonticola	not in Table 1			
Nitzschia inconspicua	0.2	0.404	0.144145	0.058267
Synedra ulna	5.1	2.251		
Tabellaria flocculosa	0.3	0.572	-0.03973	-0.02271
			*TP** = constant + sum of products =	1.166136
			DTPI = $10^{TP^*} = 10^{1.166136}$ =	14.7 µg/L

Table 3. Example of calculating DTNI.

Species	Percent Abundance	Square root Percent Abundance (x_i)	TN coefficient (β_i^{TN})	Product
Constant				2.204473
Achnanthidium deflexum	0.2	0.404	0.048112	0.019448
Achnanthidium minutissimum	82.8	9.102	0.016114	0.146667
Brachysira microcephala	2.9	1.715		
Cocconeis placentula var. lineata	0.3	0.572		
Cymbella aspera	not in Table 1			
Cymbella delicatula	0.8	0.904		
Encyonema minutum	0.5	0.700		
Fragilaria capucina var. gracilis	2.9	1.715		
Fragilaria vaucheriae var. capitellata	0.2	0.404		
Gomphonema acuminatum	0.3	0.572		
Gomphonema parvulum	2.6	1.617		
Gomphonema truncatum	0.3	0.572		
Navicula notha	0.5	0.700	-0.063641	-0.044558
Nitzschia fonticola	not in Table 1			
Nitzschia inconspicua	0.2	0.404	0.161569	0.065310
Synedra ulna	5.1	2.251		
Tabellaria flocculosa	0.3	0.572		
			*TN** = constant + sum of products =	2.391341
			DTNI = $10^{TN*} = 10^{2.391341}$ =	246.2 µg/L

References

Charles, D. F., C. Knowles, and R. S. Davis. 2002. Protocols for the analysis of algal samples collected as part of the U.S. Geological Survey National Water-Quality Assessment Program. 02-06, The Academy of Natural Sciences. Patrick Center for Environmental Research, Philadelphia, PA.

Danielson, T. J. 2006. Protocols for Sampling Algae in Wadeable Streams, Rivers, and Freshwater Wetlands (DEPLW0634). Maine Department of Environmental Protection, Augusta, ME.

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 diatom assemblages from artificial substrates. Hydrobiologia **610**:139-152.

Potapova, M. G., 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.

Stevenson, R. J., Y. Pan, K. Manoylov, C. A. Parker, D. P. Larsen, and A. Herlihy. 2008. Development of diatom indicators of ecological condition for streams in the western U.S. J. N. Am. Benthol. Soc **27**:1000-1016.