The Diatom Pollution Tolerance Index: Assigning Tolerance Values

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Abstract

Pollution tolerance indices are metrics that summarize the pollution sensitivity of diatom taxa in a particular community. The assemblage becomes an indicator of the relative health of the stream evaluated. The Environmental Resource Management Division of the Watershed Protection Department has adopted the Kentucky pollution tolerance index for use in its Environmental Integrity Index. Preliminary data have shown a relationship between this index and percent impervious cover (R^2=0.34), which is an indication that the metric is not adequately reflecting degradation due to non-point source pollution associated with impervious cover. However, only one-third of the taxa found in Central Texas are assigned indicator values using the Kentucky PTI. The purpose of this report was to assign indicator scores for the Austin-area taxa through literature survey and calculation methods in order to make recommendations for improvement to the EII diatom PTI. The diatom taxa database was evaluated, and nomenclature was updated across the historical records. The new calculation method resulted in 99% of Austin-area taxa represented with indicator values. These new values were calculated across historical data, resulting in a final adjusted R^2 of 0.44 with impervious cover. This improvement satisfactorily justifies continued use of the metric as an indicator of degradation, along with other EII components.

Introduction

Most government bioassesment programs that examine diatom community structure employ a version of a pollution tolerance index (PTI), similar to the Hilsenhoff Biotic Index for invertebrates (Barbour et al. 1999). These indices rate diatom taxa by their sensitivities to increased environmental degradation, using diatom communities as a measure of environmental health. Barbour et al. (1999) outline the diatom pollution tolerance index as one of several recommended metrics. Oklahoma (1993), Montana (1992), and Kentucky (1991) all use some form of a pollution tolerance index (PTI) in their diatom bioassesment programs. Most of these indices are based upon Lange-Bertalot (1979), who separates taxa into three categories based on: (1) tolerance to or (3) sensitivity to pollution. The middle category (2) is reserved for taxa without strong associations. The relative abundance of each taxa (n_i/N) is then multiplied by its tolerance value (t_i), and summed over all data (Eq. 1). The result for each sample is a composite value representing the pollution tolerance of the community sampled. Tolerance values have been assigned using Lange-Bertalot's designations, other autecological surveys, and water quality data.

Eq. 1 $$PTI = \frac{\sum (n_i t_i)}{N}$$

Where PTI is the total PTI value for the sample, n_l is the number of organisms of that taxonomic breakdown (species in this instance) and t_l is the tolerance value for that taxon. N is the total number of organisms found at the site.

Oklahoma's pollution tolerance index is based on Lange-Bertalot (1979) and Descy (1979). However, the pollution tolerance categories are reversed, with Category 1 being most sensitive, and Category 3 being most tolerant. In addition, upper levels of the Oklahoma protocol use a diatom PTI based only on the most dominant taxa, rather than all taxa found. The taxa lists for Oklahoma were not available, and were not used in this study.

Montana (Bahls 1992) adapted the Lange-Bertalot category concept, and filled in indicator values for taxa from various water quality criteria, including Lowe (1974). In addition, Montana water quality data were used to indicate sensitivity to pollution. Bahls (1992) used the following autecological criteria to categorize the tolerance of diatoms: nutrients, organics, salts, temperature, toxics, substrate stability, and suspended solids. Obscure diatom taxa were assigned an average tolerance value by genus.

The Kentucky Division of Water (Metzmeier 1991) rated taxa on a scale of 1 to 4, with 4 being the most sensitive. This method diverges from the other classifications by breaking up the large, ubiquitous "2" category between the extremes of sensitive or tolerant. Metzmeier accomplished this with literature surveys and multivariate statistics using Kentucky water quality data. Diatoms without supporting habitat information were not given pollution tolerance scores (2001).

A wealth of information exists on diatom habitat and pollution tolerances. However, problems arise in data comparison. For example, there is a difference of scale in comparing the pollution tolerance values assigned by these different studies. In addition, taxa habitat preferences may differ by region, resulting in different authors assigning different values for the same taxa. In addition to the state surveys, works such as Lowe (1974) and Van Dam (1994) have assigned indicator values to diatom taxa based on broad regional surveys. These values are specific to environmental parameters such as pH, salinity, and trophic status. Many scientists are also calibrating diatom taxa to specific optima and tolerance values using multivariate statistics and water quality data. These methods have gained popularity due to the qualitative nature of their approach (Barbour et al. 1999; Jongman et al. 1995; Porter pers.comm; ter Braak and Van Dam 1989).

The Environmental Resource Management Division has adopted the Kentucky PTI for use in its Environmental Integrity Index survey. Preliminary data have shown a relationship between this diatom PTI and percent impervious cover (R^2=0.34). However, only one-third of the taxa found in Central Texas are assigned indicator values in the Kentucky PTI. The purpose of this report was to assign PTI scores for the Austin-area taxa through literature survey and calculation methods and make recommendations for improvement of the EII diatom PTI.

Materials and Methods

The protocols for diatom pollution tolerance indices are described by Montana (1992), Kentucky (1991), Oklahoma (1993), and the EPA Rapid Bioassesment Protocol. In addition, several diatomists and aquatic ecologists working with diatom bioassessment were consulted. Unique sources of diatom indicator values were compared to prepare the most comprehensive, but non-repetitive, list of pollution tolerance values. The Kentucky PTI values and an updated Montana PTI list (2001) were evaluated for Austin-area taxa. In addition, nitrogen uptake metabolism, oxygen requirements, saprobity, and trophic state indicator values were used from Van Dam (1994). Since Lowe (1974) and Lange-Bertalot (1979) were used in the development of the Kentucky and Montana PTIs, they were not individually applied in this assessment.

The first task in preparing a comprehensive PTI value list was to ensure the validity of the taxa list. Up-to-date taxonomic information was supplied by Bahls (2001) and Morales (2001). Supplementary information was gathered from Round et al. (1990), Krammer and Lange-Bertalot (1986), and Winsborough (pers. comm.). The naming conventions adopted for use in the ERM database follow the U.S. Geological Service's National Water Quality Assessment Program (Morales 2001) most completely, with Bahls (2001) used as a secondary reference. Database tables were queried to list a primary (most current) taxa name and database number with all synonymous taxa names, authorship information, and references. This information was linked to the historical data records to eliminate redundancy and confusion due to frequent changes in naming conventions. Once a complete taxa list was updated for generic and species level name changes, the process of assigning PTI values was undertaken.

The major difficulty with comparing indicator values was the variety of scales used by different authors. The parameters used from Van Dam (1994) had either four, five, or seven categories (Table 1). In addition, taxa sensitivity was scored from sensitive (1) to tolerant (4, 5, or 6), and possibly ubiquitous (7). The Montana and Kentucky values were scored in the opposite direction, from tolerant (1) to sensitive (3, 4). In addition, Metzmeier changed the Kentucky scale by splitting the middle category (2) into two numbers, and transforming the scale into four values (1-4). The scales used to categorize these diatoms were standardized as follows.

Table 1. Original indicator values from Van Dam (1994) for selected parameters. Each parameter column is assigned values independently.

#	Nitrogen Uptake Metabolism	Oxygen Requirements	Saprobity				Trophic State
				Wq class	O_2 % sat	BOD_5^{20} mg/L	
1	N-autotroph, low tolerance for organic N	Continuously high (~100% saturation)	Oligo-	I, I-II	>85	<2	Oligotrophic
2	N-autotroph, elevated tolerance for organic N	Fairly high (>75% saturation)	β-meso-	II	70-85	2-4	Oligo-Mesotrophic
3	Facultative N- heterotroph needing periodically elevated N concentrations	Moderate (>50% saturation)	α-meso	III	25-70	4-13	Mesotrophic
4	Obligate N – heterotroph Needing constantly elevated N concentrations	Low (>30% saturation)	A-meso/poly	III-IV	10-25	13-22	Meso-Eutrophic
5		Very low (~10% saturation)	Poly-	IV	<10	>22	Eutrophic
6							Hypereutrophic
7							Ubiquitous

The Montana PTI values were scaled to the Kentucky designations (Table 2) by converting the high value from 3 to 4. The twos and threes were then assigned values of 2.49, an average of the two middle categories, but a more conservative estimate. The average of these two numbers was calculated to assess differences due to calculation method.

Table 2. Assignment of pollution tolerance values for Kentucky and Montana pollution tolerance indices. The MT PTI was scaled to allow relative comparison with KY values.

Sensitivity	KY PTI	MT PTI	Scaled MT PTI
Tolerant	1	1	1
Moderate	2	2	2.49
	3		
Sensitive	4	3	4

The Van Dam values were first scaled to match Metzimer's category designations. (Table 3). Nitrogen uptake metabolism was not changed. The first two values in oxygen requirements (1,2) were combined to change the Category 1 to 75% saturation or higher. The other values were scaled accordingly. The first two saprobity categories (1,2) were also combined to yield a slightly broader sensitive designation. The other values were adjusted downward accordingly. The trophic status category required the most scaling. The seventh category represented taxa that were rather ubiquitous, and was dropped. Additionally, the first two categories (1,2) were combined to yield a larger oligotrophic designation. The remaining highest categories (5,6) were also combined to provide a eutrophic/hypertrophic category.

Table 3. Scaled Van Dam indicator values. All parameters changed to a scale of 1 to 4, with the low values being the most sensitive. Compare with Table 1 to illustrate changes.

#	Nitrogen Uptake Metabolism	Oxygen Requirements	Saprobity				Trophic State
				Wq class	O_2 sat	BOD_5^{20}	
1	N-autotroph, low tolerance for organic N	high (>75% saturation)	Oligo- β-meso-	I, II	70-85	<2-4	Oligotropic Oligo/meso-
2	N-autotroph, elevated tolerance for organic N	Moderate (>50% saturation)	α-meso -	III	25-70	4-13	Mesotrophic
3	Facultative N- heterotroph needing periodically elevated N concentrations	Low (>30% saturation)	A-meso/poly	III-IV	10-25	13-22	Meso-eutrophic
4	Obligate N – heterotroph Needing constantly elevated N concentrations	Very low (~10% saturation)	Poly-	IV	<10	>22	Eutrophic hypereutropic

These indicator values (IV), were scaled from 1 through 4, with low numbers indicating the most pollution-sensitive taxa. The indicator values were then inverted (Table 4), to align all indicator scales from tolerant (1) to sensitive (4).

Old Van Dam Value	Scaled Van Dam Value
1	4
2	3
3	2
4	1

The four Van Dam parameter values averaged into a single value, and then compared to the average of the PTI values. These numbers were also evaluated against the current ERM database values when possible, to determine the proximity of the values. The Van Dam means were averaged with the PTI means and medians to determine the final PTI values for each taxon. In the approximately twenty cases where synonymous names yielded different PTI values, the taxa were individually checked against the literature. These cases were mostly due to one name having more published PTI values; therefore, the value representing the most information was chosen.

In accordance with Bahls (1992), taxa lacking information in the literature were assigned PTI values. The PTI values for these taxa were averaged at the generic level, and assigned to species within their respective genera. These final diatom PTI values were calculated with all historical EII data, and the results were analyzed both by watershed and site. In addition, statistical regressions were performed on this data using percent impervious cover as a surrogate for anthropogenic development.

Results

Approximately 289 (67%) of the 429 taxa collected by ERM did not originally have PTI indicator values, and were left out of the diatom PTI calculations (Table 4). With this data set, a regression of diatom PTI values for sites against percent impervious cover showed a modest relationship (R^2=0.34). After taxonomic revision, the total number of taxa names identified in the database was 478. It is important to note that all valid taxa with PTI information were integrated into this new list, even if the species have not yet been found in this area. This accounts for the slightly higher number of taxa on the revised list. Of the 478 new taxa, 81% were unique taxa and 19% were synonyms. The prior lack of correlation between different names of the same taxa complicated analysis of this data, and had obscured observable trends. Linking the changes in names to taxa records was crucial to establish a consistent diatom database that could be analyzed for trends in community composition. All calculations performed on data, and references to data in the database, will refer to the most currently accepted taxon name in the future. Approximately 70 taxa names were added as name changes as the PTI database was updated. The new total taxa list (427) was split into 387 primary taxa and 91 synonyms. Of these taxa, twenty diatoms had different PTI values calculated for synonymous taxa. Sixteen of these differences resulted from the older name being used by Van Dam et al. (1994). In these instances, the older name was used to calculate the PTI value (using all sources). In four instances, PTI values were different based on different information between Kentucky and Montana PTI. In three cases, it also appeared to be related to the older name. Since the Kentucky values most often correlated with Van Dam values as well, the taxa names with the most information were used to calculate the PTI value for all synonyms. A total of 299 of the 387 primary taxa were scored using the PTI calculation method. Eighty-nine taxa were not represented in the literature, or were represented at an insufficient level of resolution. These missing taxa were checked for taxonomic changes and PTI scores were applied, if found. If taxa were still missing PTI values, a value was assigned based on the mean PTI value for its genus. Eighty-three taxa were assigned PTI values in this manner. After all taxa names were calculated and compared, there was only one PTI value for any one primary taxon name, with that PTI value assigned to its synonyms. Six taxa currently do not have adequate information in the literature to assign PTI values. Those taxa are as follows: *Cymbellopsis* sp., *Encyonemopsis silesiacum*, *Encyonemposis grunowii*, *Gomphosphenia recheltii* (G. *grovei*), *Mayamaya cf. atomus*, *Terpsinoe musica*, and *Terpsinoe americana*. As more information becomes available, these taxa will be assigned PTI values.

Table 4. Statistics for diatom taxa lists.

Statistic	Old List	New List
Number of taxa	429	478
Unique taxa	429	387 (91 synonyms)
Total number of PTI values	138	382
Number of species PTI values	138	299
Number of generic PTI values	0	83
Percent total taxa w/ PTI values	33%	99%

To maintain consistency, this calculation method was applied to all diatom taxa found in the ERM diatom taxa list. Scores were calculated for this metric with both the old and new PTI value lists. The results of these calculations are illustrated in the following figures. The old PTI calculations are listed in Table 4 and Figures 1 and 3. The new PTI distribution appears more skewed; however, the classes are represented differently in the two graphs (Figures 1, 2). The new method produces a tighter fit in the regression to impervious cover. In addition, the R^2 increased with the new PTI values (Figures 3, 4).

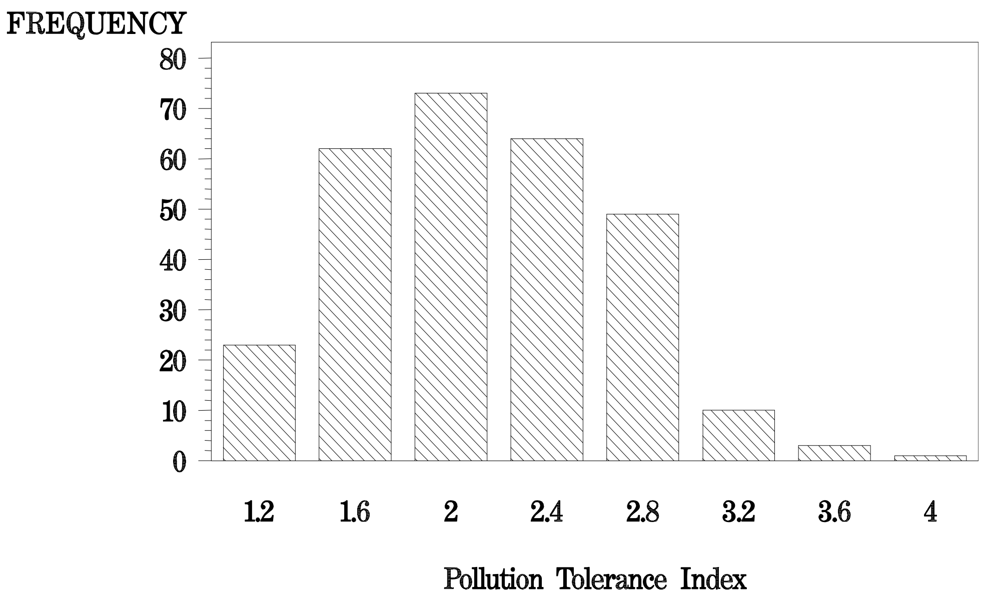

Figure 1. Frequency plot of EII PTI calculations by site using old PTI values.

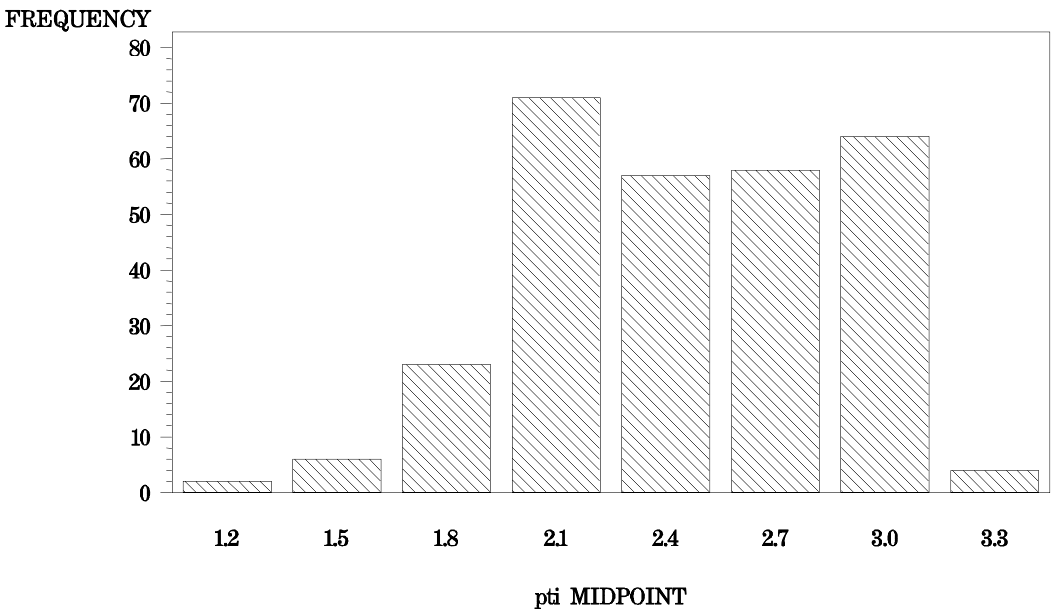

Figure 2. Frequency plot of EII PTI calculations by site using the revised PTI values.

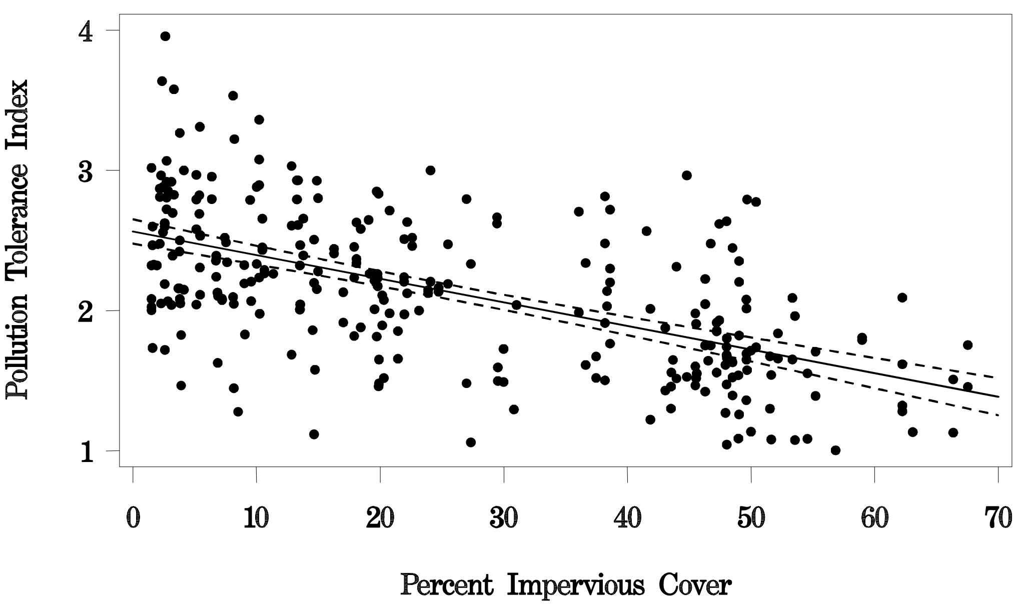

Figure 3. Regression of EII PTI calculations and percent impervious cover with site data, R^2=0.34. These calculations were performed using old PTI values.

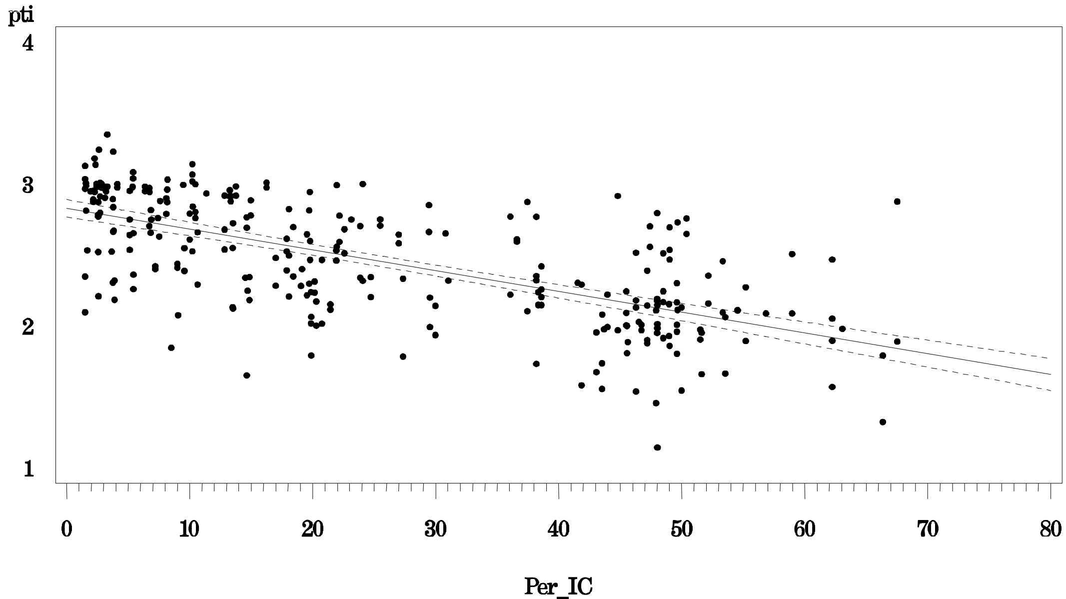

Figure 4. Regression of EII PTI calculations and percent impervious cover with site data, R^2=0.44. These calculations were performed using revised PTI values

Discussion

The revised calculation method for pollution tolerance values has increased the reliability of this metric. All taxa are now represented with indicator values, providing a more certain indication of the diatom community. The original Kentucky PTI index contained indicator values for only 138 (33%) of the 429 taxa found in this region. The revised PTI calculation now has calculated indicator values for 337 (84%) taxa. Generic values are calculated for an additional 23% of the taxa, yielding 99% of taxa contributing to the pollution tolerance index. This is an improvement of 66% of taxa identified. In addition, the data show a stronger relationship to impervious cover, as a surrogate for anthropogenic impacts. The R^2 value for the pollution tolerance index has risen over its several iterations to the present method. The old calculation method yielded a final EII R^2 of 0.34, while the final method with generic taxa values 0.44. The new calculation method has produced a more robust periphyton index, and will be useful in assessing impact to the biological communities in Central Texas creeks. In addition, the literature survey and taxonomic revision updated this index to current research levels on a national level.

Many of these final values differed from Metzmeier's (1991) pollution tolerance rating for the Kentucky study. However, the values are now the average of a wider range of studies, rather than a specific ecoregion. The most rigorous, complete method of determining indicator values for ERM-collected diatom taxa would qualitatively compare diatom and water quality data from this region. Using multivariate programs such as CALIB and WA-CALIB, taxa optima as well as tolerances of particular diatoms can be determined and used to improve resolution of community analysis. Further information regarding these procedures can be found in Jongman et al. (1995). Porter (2001) especially recommends this approach. However, Wu and Stevenson (2001) comment that adjusting already established PTIs and metrics is an acceptable method to establish a periphyton monitoring program. Until parameters can be definitively linked to variables in the blackland prairie and Edwards plateau ecoregions, this averaging of values from different studies will provide the best insight into the information contained within the diatom community in Central Texas. The possibility of expanding to this more quantitative regional approach should be a future consideration of this program.

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Appendix: Revised Taxa list and PTI values.

No.	DESCRIPTION	PTI	Genus
1407	*ACHNANTHES AMOENA*	3	Achnanthes
565	*ACHNANTHES BIASOLETTIANA*	3	Achnanthes
955	*ACHNANTHES BUTTERFASSIANA*	3	Achnanthes
1408	*ACHNANTHES CURTISSIMA*	3	Achnanthes
1410	*ACHNANTHES DELICATULA*	2	Achnanthes
956	*ACHNANTHES DUTHEII*	3	Achnanthes
566	*ACHNANTHES EXIGUA*	3	Achnanthes
1409	*ACHNANTHES GRISCHUNA*	3	Achnanthes
568	*ACHNANTHES LANCEOLATA*	2	Achnanthes
569	*ACHNANTHES LANCEOLATA SUBSP. DUBIA*	2	Achnanthes
2039	*ACHNANTHES LEVANDERI*	4	Achnanthes
570	*ACHNANTHES LINEARIS*	4	Achnanthes
574	*ACHNANTHES SCOTICA*	3	Achnanthes
1133	*ACHNANTHES* SP.1	3	Achnanthes
1478	*ACHNANTHES THERMALIS*	4	Achnanthes
2040	*ACHNANTHIDIUM MINUTISSIMUM*	3	ACHNANTHIDIUM
1476	*AMPHIPLEURA LINDHEIMERI*	2	Amphipleura
575	*AMPHIPLEURA PELLUCIDA*	3	Amphipleura
578	*AMPHORA CF. NORMANI*	3	Amphora
1519	*AMPHORA COFFEAEFORMIS*	2	Amphora
1412	*AMPHORA LIBYCA*	3	Amphora
577	*AMPHORA MONTANA*	3	Amphora
579	*AMPHORA OVALIS*	3	Amphora
581	*AMPHORA PEDICULUS*	3	Amphora
582	*AMPHORA VENETA*	2	Amphora
2041	*ANOMOEONEIS SERIANS VAR. ACUTA*	2	Anomoeoneis
583	*ANOMOEONEIS SPHAEROPHORA*	2	Anomoeoneis
2649	*AULACOSEIRA AMBIGUA*	3	AULACOSEIRA
958	*AULACOSEIRA GRANULATA*	3	AULACOSEIRA
959	*AULACOSEIRA GRANULATA VAR. ANGUSTISSIMA*	3	AULACOSEIRA
1168	*BACILLARIA PARADOXA*	2	Bacillaria
1413	*BRACHYSIRA BREBISSONII*	4	BRACHYSIRA
584	*BRACHYSIRA VITREA*	3	BRACHYSIRA
586	*CALONEIS ALPESTRIS*	3	Caloneis
587	*CALONEIS BACILLUM*	3	Caloneis
588	*CALONEIS HYALINA*	2	Caloneis
1172	*CALONEIS LEPTOSOMA*	4	Caloneis
591	*CALONEIS MACEDONICA*	2	Caloneis
1414	*CALONEIS MOLARIS*	2	Caloneis
1415	*CALONEIS SCHUMANNIANA*	3	Caloneis
592	*CALONEIS SILICULA*	3	Caloneis
585	*CALONEIS* SP.1	3	Caloneis
1240	*CALONEIS TENUIS*	3	Caloneis
2043	*CALONEIS WESTII*	3	Caloneis
2044	*CAMPYLODISCUS CLYPEUS*	2	Campylodiscus
960	*CAMPYLODISCUS HIBERNICUS*	2	Campylodiscus
593	*COCCONEIS PEDICULUS*	3	Cocconeis
594	*COCCONEIS PLACENTULA*	3	Cocconeis

1425	*CRATICULA ACCOMODA*	1	CRATICULA
689	*CRATICULA CUSPIDATA*	2	CRATICULA
2647	*CRATICULA DECUSSIS*	3	CRATICULA
691	*CRATICULA HALOPHILA*	2	CRATICULA
961	*CYCLOSTEPHANOS INVISITATUS*	2	CYCLOSTEPHANOS
2673	*CYCLOTELLA ATOMUS*	2	Cyclotella
1516	*CYCLOTELLA BODANICA*	4	Cyclotella
595	*CYCLOTELLA MENEGHINIANA*	2	Cyclotella
2470	*CYCLOTELLA OCELLATA*	3	Cyclotella
596	*CYCLOTELLA PSEUDOSTELLIGERA*	2	Cyclotella
597	*CYCLOTELLA STELLIGERA*	3	Cyclotella
614	*CYMATOPLEURA ELLIPTICA*	3	Cymatopleura
615	*CYMATOPLEURA SOLEA*	2	Cymatopleura
599	*CYMBELLA AFFINIS*	3	Cymbella
600	*CYMBELLA AMPHICEPHALA*	4	Cymbella
601	*CYMBELLA ASPERA*	4	Cymbella
603	*CYMBELLA CISTULA*	3	Cymbella
604	*CYMBELLA CYMBIFORMIS*	4	Cymbella
605	*CYMBELLA DELICATULA*	4	Cymbella
1443	*CYMBELLA DESCRIPTA*	4	Cymbella
2471	*CYMBELLA HAUCKII*	3	Cymbella
606	*CYMBELLA HUSTEDTII*	4	Cymbella
607	*CYMBELLA INCERTA*	4	Cymbella
608	*CYMBELLA LAEVIS*	3	Cymbella
1441	*CYMBELLA LEPTOCEROS*	4	Cymbella
1247	*CYMBELLA NORVEGICA*	4	Cymbella
612	*CYMBELLA PUSILLA*	1	Cymbella
1098	*CYMBELLA* SP.1 *(GRACILE)*	3	Cymbella
598	*CYMBELLA* SP.2	3	Cymbella
1137	*CYMBELLA* SP.3	3	Cymbella
2045	*CYMBELLA SPECIES (NO STRIAE)*	3	Cymbella
1248	*CYMBELLA SUBAEQUALIS*	4	Cymbella
962	*CYMBELLA TUMIDULA*	4	Cymbella
2472	*CYMBELLOPSIS SP.*		CYMBELLOPSIS
616	*DENTICULA ELEGANS*	3	Denticula
618	*DENTICULA KUETZINGII*	3	Denticula
619	*DENTICULA KUETZINGII VAR. RUMRICHAE*	3	Denticula
1170	*DENTICULA SUBTILIS*	3	Denticula
686	*DIADESMIS CONFERVACEA*	2	DIADESMIS
1495	*DIATOMA MONILIFORMIS*	2	Diatoma
622	*DIATOMA VULGARIS*	3	Diatoma
617	*DIPLONEIS ELLIPTICA*	3	Diploneis
2645	*DIPLONEIS FINNICA*	3	Diploneis
2674	*DIPLONEIS MARGINESTRIATA*	4	Diploneis
625	*DIPLONEIS OBLONGELLA*	4	Diploneis
1418	*DIPLONEIS OVALIS*	4	Diploneis
626	*DIPLONEIS PARMA*	3	Diploneis
627	*DIPLONEIS PSEUDOVALIS*	2	Diploneis
628	*DIPLONEIS PUELLA*	3	Diploneis
623	*DIPLONEIS* SP.*1*	3	Diploneis
629	*DIPLONEIS SUBCONSTRICTA*	3	Diploneis

621	*DIPLONEIS SUBOVALIS*	3	Diploneis
1416	*ENCYONEMA BREHMII*	3	ENCYONEMA
963	*ENCYONEMA AUERSWALDII*	2	ENCYONEMA
2046	*ENCYONEMA CARINA*	3	ENCYONEMA
2047	*ENCYONEMA EVERGLADIANUM*	3	ENCYONEMA
1446	*ENCYONEMA GAEUMANNII*	3	ENCYONEMA
964	*ENCYONEMA GRACILE*	3	ENCYONEMA
2643	*ENCYONEMA HUSTEDTII*	3	ENCYONEMA
1099	*ENCYONEMA MESIANA*	2	ENCYONEMA
610	*ENCYONEMA MINUTUM*	2	ENCYONEMA
1417	*ENCYONEMA NEOGRACILE*	4	ENCYONEMA
1119	*ENCYONEMA OBSCURUM*	3	ENCYONEMA
1262	*ENCYONEMA PROSTRATUM*	3	ENCYONEMA
634	*ENCYONEMA SILESIACA*	3	ENCYONEMA
611	*ENCYONEMA SILESIACUM*	3	ENCYONEMA
965	*ENCYONEMA SP.1*	3	ENCYONEMA
631	*ENCYONEMA SP.2*	3	ENCYONEMA
632	*ENCYONEMA SP.3*	3	ENCYONEMA
633	*ENCYONEMA SP.5*	3	ENCYONEMA
966	*ENCYONEMA SP.6*	3	ENCYONEMA
613	*ENCYONEMA TRIANGULUM*	3	ENCYONEMA
2675	*ENCYONEMOPSIS GRUNOWII*		ENCYONEMOPSIS
2049	*ENCYONEMOPSIS SILESIACUM*		ENCYONEMOPSIS
602	*ENCYONOPSIS CESATII*	3	ENCYONOPSIS
609	*ENCYONOPSIS MICROCEPHALA*	3	ENCYONOPSIS
1166	*EPITHEMIA ADNATA*	3	Epithemia
635	*EPITHEMIA ARGUS*	3	Epithemia
1249	*EPITHEMIA SOREX*	3	Epithemia
636	*EPITHEMIA TURGIDA*	3	Epithemia
567	*EUCOCCONEIS FLEXELLA*	4	EUCOCCONEIS
637	*EUNOTIA ARCUS*	4	Eunotia
1429	*EUNOTIA BILUNARIS*	3	Eunotia
640	*EUNOTIA CF. MONODON*	3	Eunotia
2050	*EUNOTIA FLEXUOSA*	4	Eunotia
1135	*EUNOTIA FORMICA*	4	Eunotia
1419	*EUNOTIA MINOR*	3	Eunotia
639	*EUNOTIA MONODON*	4	Eunotia
1449	*EUNOTIA PALUDOSA*	4	Eunotia
1250	*EUNOTIA PECTINALIS*	3	Eunotia
2474	*EUNOTIA PRAERUPTA*	4	Eunotia
1389	*FALLACIA MONOCULATA*	2	FALLACIA
706	*FALLACIA PYGMAEA*	2	FALLACIA
983	*FALLACIA SUBHAMULATA*	2	FALLACIA
642	*FRAGILARIA ARCUS*	4	Fragilaria
1258	*FRAGILARIA CAPITATA (DILITATA)*	3	Fragilaria
644	*FRAGILARIA CAPUCINA*	3	Fragilaria
647	*FRAGILARIA CAPUCINA VAR. MESOLEPTA*	2	Fragilaria
645	*FRAGILARIA CAPUCINA VAR.INCOGNITA*	3	Fragilaria
967	*FRAGILARIA CYCLOPUM*	3	Fragilaria
1420	*FRAGILARIA DELICATISSIMA*	3	Fragilaria
651	*FRAGILARIA FASCICULATA*	3	Fragilaria

968	*FRAGILARIA PARASITICA*	4	Fragilaria
1518	*FRAGILARIA PULCHELLA*	3	Fragilaria
641	*FRAGILARIA SP.1*	3	Fragilaria
969	*FRAGILARIA SP.2*	3	Fragilaria
2150	*FRAGILARIA TENERA*	4	Fragilaria
1261	*FRAGILARIA ULNA*	3	Fragilaria
653	*FRAGILARIA VAUCHERIAE*	2	Fragilaria
648	*FRAGILLARIA CAPUCINA VAR. VAUCHERIAE*	3	Fragilaria
654	*FRUSTULIA VULGARIS*	3	Frustulia
2676	*FRUSTULIA WEINHOLDII*	4	Frustulia
655	*GOMPHONEMA ACUMINATUM*	3	Gomphonema
656	*GOMPHONEMA AFFINE*	3	Gomphonema
658	*GOMPHONEMA ANGUSTATUM*	2	Gomphonema
657	*GOMPHONEMA ANGUSTUM*	3	Gomphonema
659	*GOMPHONEMA AUGUR*	3	Gomphonema
660	*GOMPHONEMA CLAVATUM*	3	Gomphonema
661	*GOMPHONEMA CLEVEI*	3	Gomphonema
663	*GOMPHONEMA GRACILE*	3	Gomphonema
1421	*GOMPHONEMA GROVEI*	3	Gomphonema
970	*GOMPHONEMA GROVEI VAR. LINGULATUM*	3	Gomphonema
666	*GOMPHONEMA INSIGNE*	3	Gomphonema
665	*GOMPHONEMA INTRICATUM VAR. VIBRIO*	3	Gomphonema
971	*GOMPHONEMA MINUTUM*	3	Gomphonema
667	*GOMPHONEMA PARVULUM*	1	Gomphonema
668	*GOMPHONEMA PSEUDOAUGUR*	2	Gomphonema
972	*GOMPHONEMA RHOMBICUM*	3	Gomphonema
1422	*GOMPHONEMA SP.1*	3	Gomphonema
669	*GOMPHONEMA SPENCERII*	3	Gomphonema
670	*GOMPHONEMA TRUNCATUM*	3	Gomphonema
2475	*GOMPHOSPHENIA REICHELTII (G. GROVEII)*		GOMPHOSPHENIA
1450	*GYROSIGMA ATTENUATUM*	3	Gyrosigma
2476	*GYROSIGMA EXILIS*	2	Gyrosigma
671	*GYROSIGMA NODIFERUM*	3	Gyrosigma
672	*GYROSIGMA OBSCURUM*	2	Gyrosigma
973	*GYROSIGMA SCALPROIDES*	2	Gyrosigma
673	*GYROSIGMA SPENCERII*	2	Gyrosigma
674	*HANTZSCHIA AMPHIOXYS*	3	Hantzschia
710	*KOBAYASIELLA SUBTILISSIMA*	4	KOBAYASIELLA
1385	*LUTICOLA GOEPPERTIANA*	2	LUTICOLA
699	*LUTICOLA MUTICA*	2	LUTICOLA
1162	*MASTOGLOIA BALTICA*	3	Mastogloia
676	*MASTOGLOIA CF. SMITHII (COARSE)*	2	Mastogloia
974	*MASTOGLOIA ELLIPTICA*	2	Mastogloia
675	*MASTOGLOIA GREVILLEI*	2	Mastogloia
677	*MASTOGLOIA SMITHII*	3	Mastogloia
678	*MASTOGLOIA SMITHII VAR. AMPHICEPHALA*	2	Mastogloia
679	*MASTOGLOIA SMITHII VAR. LACUSTRIS*	3	Mastogloia
2638	*MAYAMAEA CF. ATOMUS*		MAYAMAEA
1423	*MELOSIRA LINEATA*	3	Melosira
1471	*MELOSIRA VARIANS*	2	Melosira
681	*MERIDION CIRCULARE*	3	Meridion

1424	*NAVICULA ABSOLUTA*	3	Navicula
1426	*NAVICULA ANGUSTA*	3	Navicula
1427	*NAVICULA ARVENSIS*	1	Navicula
1428	*NAVICULA ATOMUS*	2	Navicula
1381	*NAVICULA BACILLOIDES*	2	Navicula
2051	*NAVICULA CAPITATA*	2	Navicula
687	*NAVICULA CAPITATA VAR. HUNGARICA*	3	Navicula
684	*NAVICULA CARI*	2	Navicula
975	*NAVICULA CINCTA*	2	Navicula
976	*NAVICULA CONCENTRICA*	3	Navicula
2152	*NAVICULA CONSTANS VAR. SYMMETRICA*	4	Navicula
688	*NAVICULA CRYPTOCEPHALA*	3	Navicula
1382	*NAVICULA CRYPTOTENELLA*	3	Navicula
1383	*NAVICULA DECUSSIS*	3	Navicula
2052	*NAVICULA DUERRENBERGIANA*	1	Navicula
690	*NAVICULA EIDRIGIANA*	2	Navicula
1384	*NAVICULA ERIFUGA*	2	Navicula
1173	*NAVICULA EXILIS*	2	Navicula
984	*NAVICULA GREGARIA*	2	Navicula
713	*NAVICULA HUFLERI VAR. LEPTOCEPHALA*	2	Navicula
1386	*NAVICULA INGENUA*	2	Navicula
1136	*NAVICULA JAAGII*	2	Navicula
717	*NAVICULA KOTSCHYI*	3	Navicula
1387	*NAVICULA KRIEGERII*	2	Navicula
693	*NAVICULA LIBONENSIS*	2	Navicula
1388	*NAVICULA LONGICEPHALA*	2	Navicula
696	*NAVICULA MENISCULUS*	2	Navicula
697	*NAVICULA MINIMA*	1	Navicula
1160	*NAVICULA MINUSCULA*	3	Navicula
978	*NAVICULA MUTICA VAR. MUTICA*	2	Navicula
695	*NAVICULA MUTICOPSIS*	2	Navicula
700	*NAVICULA OBLONGA*	3	Navicula
701	*NAVICULA PLACENTULA (PSEUDANGLICA)*	2	Navicula
703	*NAVICULA PSEUDOBRYOPHILA*	2	Navicula
1498	*NAVICULA PSEUDOLANCEOLATA*	3	Navicula
702	*NAVICULA PUMULA*	2	Navicula
707	*NAVICULA RADIOSA*	3	Navicula
1475	*NAVICULA RECENS*	2	Navicula
1390	*NAVICULA REICHARDTIANA*	3	Navicula
709	*NAVICULA RHYNCHOCEPHALA*	3	Navicula
1431	*NAVICULA SALINICOLA*	1	Navicula
1472	*NAVICULA SANCTAECRUCIS*	2	Navicula
980	*NAVICULA SCHROETERII*	2	Navicula
977	*NAVICULA SOEHRENSIS VAR. HASSIACA*	4	Navicula
682	*NAVICULA SP.1*	2	Navicula
683	*NAVICULA SP.2*	2	Navicula
981	*NAVICULA SP.2 (CF. TEXANA)*	2	Navicula
1393	*NAVICULA SP.3*	2	Navicula
1394	*NAVICULA SP.4*	2	Navicula
1395	*NAVICULA SP.5*	2	Navicula
1392	*NAVICULA SP.6*	2	Navicula

982	*NAVICULA STANKOVICII*	2	Navicula
712	*NAVICULA STROEMII*	3	Navicula
1252	*NAVICULA SUBLUCIDULA*	2	Navicula
714	*NAVICULA SUBMINISCULA*	2	Navicula
2637	*NAVICULA SUECORUM VAR DISMUTICA*	2	Navicula
715	*NAVICULA SYMMETRICA*	2	Navicula
985	*NAVICULA TENELLOIDES*	2	Navicula
1396	*NAVICULA TRIDENTULA*	3	Navicula
716	*NAVICULA TRIPUNCTATA*	3	Navicula
694	*NAVICULA TRIVIALIS*	2	Navicula
718	*NAVICULA VENETA*	2	Navicula
986	*NAVICULA VIRIDULA*	2	Navicula
1473	*NAVICULA VIRIDULA VAR. ROSTELLATA*	3	Navicula
719	*NAVICULA VULPINA*	3	Navicula
720	*NEIDIUM AMPLIATUM*	4	Neidium
725	*NITZSCHIA ACICULARIS*	2	Nitzschia
2477	*NITZSCHIA ACUMINATA*	2	Nitzschia
987	*NITZSCHIA AGNITA*	1	Nitzschia
726	*NITZSCHIA AMPHIBIA*	2	Nitzschia
988	*NITZSCHIA AMPHIBIOIDES*	2	Nitzschia
727	*NITZSCHIA ANGUSTATA*	3	Nitzschia
736	*NITZSCHIA CF. PUNCTATA*	2	Nitzschia
1257	*NITZSCHIA CF. SINUATA VAR. DELOGNEI*	2	Nitzschia
1253	*NITZSCHIA CLAUSII*	2	Nitzschia
2636	*NITZSCHIA COMMUNIS*	1	Nitzschia
1117	*NITZSCHIA COMPRESSA*	1	Nitzschia
1254	*NITZSCHIA DEBILIS*	3	Nitzschia
730	*NITZSCHIA DISSIPATA*	3	Nitzschia
989	*NITZSCHIA FILIFORMIS*	2	Nitzschia
731	*NITZSCHIA FILIFORMIS VAR. CONFERTA*	2	Nitzschia
990	*NITZSCHIA FONTICOLA*	3	Nitzschia
732	*NITZSCHIA FRUSTULUM*	2	Nitzschia
1397	*NITZSCHIA GRACILIFORMIS*	2	Nitzschia
991	*NITZSCHIA INCONSPICUA*	2	Nitzschia
1255	*NITZSCHIA LACUNARUM*	2	Nitzschia
1398	*NITZSCHIA LIBETRUTHII*	2	Nitzschia
733	*NITZSCHIA LINEARIS*	3	Nitzschia
734	*NITZSCHIA MICROCEPHALA*	2	Nitzschia
1399	*NITZSCHIA NANA*	3	Nitzschia
735	*NITZSCHIA PALEA*	1	Nitzschia
1400	*NITZSCHIA PALEACEA*	2	Nitzschia
1401	*NITZSCHIA PELLUCIDA*	2	Nitzschia
1402	*NITZSCHIA PUMILA*	2	Nitzschia
1434	*NITZSCHIA RECTA*	3	Nitzschia
1116	*NITZSCHIA REVERSA*	2	Nitzschia
1403	*NITZSCHIA SCALPELLIFORMIS*	1	Nitzschia
1256	*NITZSCHIA SERPENTIRAPHE*	2	Nitzschia
1163	*NITZSCHIA SIGMA*	2	Nitzschia
1167	*NITZSCHIA SIGMOIDEA*	3	Nitzschia
2479	*NITZSCHIA SINUATA*	3	Nitzschia
992	*NITZSCHIA SINUATA VAR. TABELLARIA*	3	Nitzschia

737	*NITZSCHIA SOLITA*	1	Nitzschia
722	*NITZSCHIA SP.1*	2	Nitzschia
723	*NITZSCHIA SP.2*	2	Nitzschia
724	*NITZSCHIA SP.3*	2	Nitzschia
738	*NITZSCHIA TROPICA*	2	Nitzschia
1447	*NITZSCHIA VERMICULARIS*	3	Nitzschia
993	*NITZSCHIA VITREA*	1	Nitzschia
1134	*PINNULARIA ACROSPHAERIA*	4	Pinnularia
2634	*PINNULARIA APPENDICULATA*	4	Pinnularia
1435	*PINNULARIA BOREALIS*	3	Pinnularia
1444	*PINNULARIA BRAUNII*	4	Pinnularia
744	*PINNULARIA CF. VIRIDIS*	3	Pinnularia
739	*PINNULARIA GIBBA*	3	Pinnularia
1436	*PINNULARIA LUNDII*	3	Pinnularia
740	*PINNULARIA MAIOR*	3	Pinnularia
741	*PINNULARIA MESOGONGYLA*	3	Pinnularia
742	*PINNULARIA MICROSTAURON*	3	Pinnularia
1171	*PINNULARIA SP.1*	3	Pinnularia
743	*PINNULARIA STOMATOPHORA*	4	Pinnularia
1437	*PINNULARIA SUBROSTRATA*	3	Pinnularia
745	*PINNULARIA VIRIDIS*	3	Pinnularia
745	*PINNULARIA VIRIDIS*	3	Pinnularia
1169	*PLACONEIS ELGINENSIS*	3	PLACONEIS
1517	*PLACONEIS GASTRUM*	3	PLACONEIS
2053	*PLACONEIS PLACENTULA*	3	PLACONEIS
979	*PLACONEIS PSEUDANGLICA*	3	PLACONEIS
2480	*PLAGIOTROPIS LEPIDOPTERA VAR. PROBOSCIDEA*	2	Plagiotropis
994	*PLEUROSIGMA DELICATULUM*	2	Pleurosigma
1438	*PLEUROSIGMA SALINARUM*	4	Pleurosigma
1499	*PLEUROSIRA LAEVIS*	2	PLEUROSIRA
573	*PSAMMOTHIDIUM ABUNDANS F. ROSENSTOCKII*	4	PSAMMOTHIDIUM
2671	*PSAMMOTHIDIUM MARGINULATUM*	4	PSAMMOTHIDIUM
1411	*PSAMMOTHIDIUM SUBATOMOIDES*	4	PSAMMOTHIDIUM
643	*PSEUDOSTAUROSIRA BREVISTRIATA*	4	PSEUDOSTAUROSIRA
746	*REIMERIA SINUATA*	3	Reimeria
2056	*REIMERIA SINUATA VAR. DELOGNEI*	3	Reimeria
747	*RHOICOSPHENIA CURVATA*	3	Rhoicosphenia
2153	*RHOPALODIA BREBISSONII*	1	Rhopalodia
748	*RHOPALODIA GIBBA*	3	Rhopalodia
2482	*RHOPALODIA GIBBERULA*	2	Rhopalodia
1477	*RHOPALODIA GIBBERULA VAR. VANHEURCKII*	2	Rhopalodia
1520	*RHOPALODIA OPERCULATA*	1	Rhopalodia
692	*SELLAPHORA LAEVISSIMA*	2	SELLAPHORA
704	*SELLAPHORA PUPULA*	2	SELLAPHORA
705	*SELLAPHORA RECTANGULARIS*	2	SELLAPHORA
711	*SELLAPHORA SEMINULUM*	1	SELLAPHORA
1496	*STAURONEIS ANCEPS*	3	Stauroneis
749	*STAURONEIS LAUENBURGIANA*	3	Stauroneis
2057	*STAURONEIS OBTUSA*	4	Stauroneis
750	*STAURONEIS PHOENICENTERON*	3	Stauroneis
2058	*STAURONEIS PSEUDOSUBOBTUSOIDES*	3	Stauroneis

751	*STAURONEIS SMITHII*	3	Stauroneis
995	*STAURONEIS SP.1*	3	Stauroneis
649	*STAUROSIRA CONSTRUENS*	3	STAUROSIRA
2631	*STAUROSIRA CONSTRUENS VAR VENTER*	3	STAUROSIRA
650	*STAUROSIRA CONSTRUENS VAR. VENTER*	3	STAUROSIRA
652	*STAUROSIRELLA PINNATA*	3	STAUROSIRA
2630	*STEPHANODISCUS MEDIUS*	2	Stephanodiscus
1404	*STEPHANODISCUS PARVUS*	2	Stephanodiscus
752	*SURIRELLA ANGUSTA*	2	Surirella
753	*SURIRELLA BIFRONS*	2	Surirella
754	*SURIRELLA BISERIATA*	3	Surirella
1439	*SURIRELLA BREBISSONII*	2	Surirella
755	*SURIRELLA ELEGANS*	3	Surirella
996	*SURIRELLA MINUTA*	2	Surirella
997	*SURIRELLA OVALIS*	2	Surirella
1405	*SURIRELLA PATELLA*	2	Surirella
756	*SURIRELLA SPIRALIS*	3	Surirella
1497	*SURIRELLA TENERA*	3	Surirella
757	*SYNEDRA BICEPS*	3	Synedra
759	*SYNEDRA CAPITATA*	3	Synedra
760	*SYNEDRA DILATATA*	3	Synedra
1251	*SYNEDRA NANA*	4	Synedra
761	*SYNEDRA RADIANS*	2	Synedra
762	*SYNEDRA TENERA*	2	Synedra
758	*SYNEDRA ULNA*	2	Synedra
1259	*TERPSINOE AMERICANA*		Terpsinoe
998	*TERPSINOE MUSICA*		Terpsinoe
999	*THALASSIOSIRA WEISSFLOGII*	2	Thalassiosira
729	*TRYBLIONELLA APICULATA*	2	TRYBLIONELLA
728	*TRYBLIONELLA CALIDA*	2	TRYBLIONELLA
2635	*TRYBLIONELLA HUNGARICA*	2	TRYBLIONELLA
1433	*TRYBLIONELLA LEVIDENSIS*	2	TRYBLIONELLA
2478	*TRYBLIONELLA LITTORALIS*	2	TRYBLIONELLA