



METHOD DESCRIPTION OF THE ASSESSMENT OF LAKES AND RESERVOIRS WITH PHYTOPLANKTON AND THE PHYTO-SEE-INDEX IN GERMANY. USER HANDBOOK.

OFFICIAL EXCERPT OF ORIGINAL HANDBOOK

HANDBUCH FÜR DIE SEENBEWERTUNG MITTELS PLANKTON – PHYTO-SEE-INDEX (TEIL A)



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1 BASIS OF THE METHOD AND THE HISTORY OF ITS DEVELOPMENT

In accordance with the European Water Framework Directive (EU-WRRL, 2000, EU 2008), the sensitivity of phytoplankton to environmental pressures of eutrophication is used to assess the ecological status of German lakes.

In Germany the Phyto-See-Index (PSI) has been used since 2008. The European Commission has published the agreed classification systems of the member states – including the Phyto-See-Index - as the result of the intercalibration process in the Official Journal of the European Union (Europäische Kommission 2008, 2013).

Since then, the Phyto-See-Index has been further developed (for details, see Annex III) with a considerable expansion for lakes in the German central highlands as well as for artificial and heavily modified lakes (AWB und HMWB), groups which include reservoirs and flooded quarry/gravel pits. For the special case of strongly acidic mining lakes, a biodiversity index (Leßmann & Nixdorf 2009) was adopted as a new component of the Phyto-See-Index.

The Phyto-See-Index compares the current ecological status to a predetermined reference status, which is harmonised for ecoregions Europe-wide (Poikâne et al. 2010, 2014; Järvinen et al. 2013).

Further required components of the Phyto-See-Index are:

- I) German lake sampling standard (Nixdorf et al. 2008, 2010),
- II) Profile documents describing German lake types and in the cover letter instructions for assigning lake types (Riedmüller et al. 2013b),
- III) German taxa list for phytoplankton (HTL; Mischke & Kusber Mai 2009) and
- IV) Assessment tool PhytoSee for the calculation of the Phyto-See-Index (Chapter 4).

Please note that an update for the German coding list will be available at end of the year 2017, including currently accepted names also for indicator taxa.



1.1 ASSESSMENT SYSTEM AND PARAMETERS – AN OVERVIEW

The German system for assessing lakes using phytoplankton distinguishes between ecologically relevant lake types and delivers a multi-metric index value, the Phyto-See-Index (PSI). This places the assessed lake into one of five EU-WFD defined ecological status classes. The Trophic-Index according LAWA was used for calibration the assessment system against eutrophication during method development.

1.1.1 LAKE TYPE AND THE CALCULATION OF THE PHYTO-SEE-INDEX

The assessment of a lake is strongly dependent on its lake type. Classification by lake type takes into account a lake's theoretical trophic status under minimal anthropogenic influence, its "reference state" (see Tables 1 und 2).

Table 1 Position of the reference trophic states of the German Phytoplankton-Lake types (see Table 4; Table 5) along the LAWA-Trophic-Index gradient (for the placement in trophic classes see Table 2). Lake types are ordered by ecoregion and reference trophic state. EQ = ecological quality in the range 1-5.

Phyto-plankton-lake type/ sub-type	Trophic reference value for calculation of EQ	Trophic reference status Upper boundary	High/ Good boundary EQ 1.5	Good/ Moderate boundary EQ 2.5	Moderate / Poor boundary EQ 3.5	Poor / Bad boundary EQ 4.5
Alpine and Pre-alpine						
4	0.75	oligo	1.25	1.75	2.25	2.75
3	1.00	oligo	1.50	2.00	2.50	3.00
2	1.25	meso 1	1.75	2.25	2.75	3.25
1	2.00	meso 2	2.50	3.00	3.50	4.00
Central Highland						
7 and 9	1.00	oligo	1.50	2.00	2.50	3.00
5 and 8	1.25	meso 1	1.75	2.25	2.75	3.25
6.1	1.75	meso 2	2.25	2.75	3.25	3.75
6.2	2.00	meso 2	2.50	3.00	3.50	4.00
6.3	2.25	eu 1	2.75	3.25	3.75	4.25
North German Lowland*						
13	1.25	meso 1	1.75	2.25	2.75	3.25
10.1	1.50	meso 1	2.00	2.50	3.00	3.50
10.2	1.75	meso 2	2.25	2.75	3.25	3.75
14	1.75	meso 2	2.25	2.75	3.25	3.75
11.1	2.00	meso 2	2.50	3.00	3.50	4.00
11.2	2.25	eu 1	2.75	3.25	3.75	4.25
12	2.50	eu 2	3.00	3.50	4.00	4.50

* AWB, HMWB and special types in the North-German-Lowlands are denoted by the suffix "k" after lake type number.

The reference state, as required by the EU-WFD, provides a guidance value or upper reference point for the assessment process. For the Phyto-See-Index, a trophic reference value of 0.5 is smaller (i.e. more oligotrophic) than the assumed boundary between High and Good status. Additionally, different assessment parameters are identified as sensitive to eutrophication for each lake type, and are defined here for the described Phyto-See-Index.



In the above described preliminary studies, the national (German) lake typology for phytoplankton assessment (Table 4 lake types) was based on Mathes et al. (2002) and further developed according to the associated trophic reference values. These reference conditions have been intercalibrated, within the European framework, for widely distributed lakes within a given ecoregion (Poikane et al. 2010; 2014; Järvinen et al. 2013). In Table 2 it can be seen that many lakes would be oligotrophic in their reference condition, while for others their reference condition would be eutrophic.

Table 2 Value ranges for the trophic classification LAWA-Index acc. to LAWA (1999, 2014).

Classification-/Trophic-Index	Trophic class
0.5-1.5	oligotrophic
> 1.5 – 2.0	mesotrophic 1
> 2.0 – 2.5	mesotrophic 2
> 2.5 – 3.0	eutrophic 1
> 3.0 – 3.5	eutrophic 2
> 3.5 – 4.0	polytrophic 1
> 4.0 – 4.5	polytrophic 2
> 4.5	hypertrophic

For the updated Phyto-See-Index, reference conditions and lake typology have been newly defined for central (German) highland lakes and for lowland riverine lakes (lake type 12), and for the alpine lakes (lake types 1 and 3).

1.1.2 PARAMETERS FOR THE CALCULATION OF THE PHYTO-SEE-INDEX

In the Phyto-See-Index, one or more assessment parameters are used as components in 3-4 biological metrics. The Phyto-See-Index comprises three compulsory metrics "Biomass", "Algal Class" and "Phytoplankton-Taxa-Seen-Index" (PTSI). A special group of strongly acidic lakes are assessed using a biodiversity index in place of the PTSI, and additionally the metric "Algal Class" is not applied. As an optional additional value, the metric "DI-PROF" can be used for assessment of taxonomic composition in natural lowland lakes - the empty shells (frustules) of planktonic diatoms in the surface sediment are used to calculate a trophic value.

The metrics are calibrated against a general trophic classification gradient, corresponding to eutrophication pressure, so as to produce an ecological status classification that reflects deviation from reference conditions. This is achieved using calibrated assessment functions for the assessment parameters, or metrics, that produce assessment values between 0.5 and 5.5. These resulting fine scaled assessment values can then be placed into the five EU-WFD-defined ecological status classes (see Table 3).

As a scale of environmental impact, the current value of the German LAWA-Trophic-Index (1999) and the total phytoplankton biovolume were used, in addition to the total phosphorus concentration (TP), for calibration, particularly for data with a TP concentration above 150 µg/L. Documentation of the selection and development of the metrics can be found in the listed research reports.

The metrics are composed of several assessment parameters obtained by sampling phytoplankton. The assessment parameters are based on measurements made according to defined sampling methodologies, for example, chlorophyll-a concentrations follow the DIN standard, and phytoplankton biovolume and taxonomic composition follow the



Utermöhl-method (Utermöhl 1958) for counting phytoplankton cells of specific taxa (converted to taxon specific biovolumes).

For each assessment parameter, either the annual mean (PTSI), the seasonal mean for the period March to November, or in some cases the late summer mean for the period July to October is calculated.

The following assessment parameters are used for the metrics and are presented as an overview here. Full assessment details can be found in the following chapters, where step-by-step instructions are given.

1) Metric "Biomass":

The metric "Biomass" is the mean outcome of the individual assessment of the following three parameters:

- a) Total biovolume of phytoplankton from the epilimnion, or in clear-water lakes the euphotic zone, of the lake (seasonal mean)
- b) Chlorophyll-a concentration (seasonal mean)
- c) Chlorophyll-a maximum value, if this is 25% greater than the seasonal mean

2) Metric "Algal Class":

Summed biovolumes of the Cyanobacteria, the Chlorophyceae, and the Cryptophyceae; and for Chrysophyceae and Dinophyceae their percentage composition of the total biovolume, are calculated as seasonal or late summer means depending on the lake type. Their deviation from the reference trophic condition is taken into account by transforming the assessment value into a calibrated value using a lake type specific assessment function. The arithmetic mean of the 2 to 4 assessment parameters (depending on lake type) gives an Algal Class assessment value between 0.5 and 5.5.

3) Metric PTSI (Phytoplankton-Taxa-Seen (*Lake*)-Index):

The use of PTSI (annual value) allows assessment of the trophic state of lakes (oligotrophic to hypertrophic), on the basis of their taxonomic composition (in accordance with the EU-WFD). The difference is calculated between the PTSI-annual-value and the trophic reference condition for the corresponding lake type. A deviation of more than 0.5 results in a downgrading of one ecological status class, a deviation of more than 1.0 results in a downgrading of two status classes, and so on (Table 3). Depending on the defined status classes, a PTSI assessment value between 0.5 and 5.5 is produced.

For the PTSI metric, six different indicator lists are defined (see Chapter 2.3), which each contain more than 150 trophic-scored indicator taxa. For each indicator taxon a trophic anchor value (TAW) and a weighting factor are given, these use the "Stenoecy" (stenoecy factor = SF) as a measure of the "constancy" of the taxon to the trophic gradient. The biovolumes of all indicator taxa recorded in a water sample are assigned to an "abundance class" before they are used with their taxon-specific TAW and SF (s. Table 33). The PTSI is first calculated for each sample and then a "PTSI annual value" is calculated as the arithmetic mean.



4) Optional additional parameter: DI-PROF (Diatom-Profundal-Index from Schönfelder 2006):

For natural lakes in the north German lowland (lake types 10 - 14) the three compulsory metrics of the PSI can be supplemented with the metric "DI-PROF", especially when there are too few recorded indicator taxa for the PTSI metric.

Dominance values are calculated using the prepared shells of planktonic diatom indicator taxa, collected from the profundal zone. These values are then transformed using taxon-specific trophy-, index- and weighting-factors. Assessment is made in two stages: 1. A trophic classification on the basis of all DI-PROF-indicator taxa detected in the profundal sediment sample. 2. A comparison of the trophic classification against the lake type specific reference condition (Schönfelder 2006). The deviance from the reference condition is given numerically as the DI-PROF-assessment-value (also DI-PROF-Score) between 0.5 and 5.5.

5) Biodiversity index following Leßmann & Nixdorf (2009):

In conditions of pollution by acidic geogenic groundwater, such as in the acidic mining lakes, a biodiversity index is used in place of the PTSI taxa list: the Shannon Index, and as additional parameter the Evenness-Index, are calculated from the number of identified taxa and their dominance distribution.

A relatively high biodiversity is assumed to indicate a good ecological potential, which is reduced by both increasing acidity and eutrophication. The assessment is made by comparing the calculated Shannon Index with previously determined class boundaries and gives the ecological status class as an integer value (no continuous gradient of values between status classes).

1.1.3 UNITS OF THE PHYTO-SEE-INDEX AND THE ECOLOGICAL QUALITY RATIO

The output from all metrics (with the exception of the biodiversity index for acidic lakes) and the combined final PSI, lie in the range from 0.5 to 5.5, whereby a value of 0.5 indicates the best possible, and 5.5 the worst possible status. The values lie in the range of ecological status classes 1 to 5, and can be interpreted as ecological quality (EQ) scores, in conformance with the EU-WFD.

Because all five status classes are equally wide (equidistant), the Phyto-See-Index-values (PSI) can be converted to normalised ecological quality ratios (EQR) with the following formula:

$$\mathbf{EQR = -0.2 \times PSI + 1.1}$$

In Table 3, ranges of the German Phyto-See-Index are shown that correspond to the five status classes of the EU-WFD (2000) and to the normalised ecological quality ratios (EQR).

Table 3 Index values of PSI and status classes for the derivation of EQR.

PSI (EQ)	Status class	Normalised EQR	Indicator colour
0.5–1.50	1 = (H = high)	0.81–1.0	Blue
1.51–2.50	2 = (G = good)	0.61–0.8	Green
2.51–3.50	3 = (M = moderate)	0.41–0.6	Yellow
3.51–4.50	4 = (P = poor)	0.21–0.4	Orange
4.51–5.50	5 = (B = bad)	0.00–0.2	Red



The combination of the separate metrics into the Phyto-See-Index is done using weighting factors (see chapter 2.6).

For natural lakes, their ecological status is determined using the Phyto-See-Index. In accordance with the EU-WFD, for HMWB and AWB the ecological potential is used (see chapter 1.2.6).

1.2 GUIDELINES FOR SAMPLING, ANALYSIS PROCEDURES DURING DATA COLLECTION AND DETERMINATION OF THE LAKE TYPE

The German system for the assessment of lakes with phytoplankton requires specific methods to be followed during data collection (Nixdorf et al. 2008, 2010).

- 1) Sampling
- 2) Sample preservation and storage
- 3) Microscopic analysis and cell counting protocol (following Utermöhl 1958; DIN EN 15204 2006). There is a specified taxonomic resolution and coding of the recorded taxa according to the provided harmonised taxa list for phytoplankton (HTL, Mischke & Kusber 2009).

The specified methods should be followed precisely during data collection.

In addition to the respective standards, a checklist for the estimation of errors during phytoplankton identification and for the resulting Phyto-See-Index is listed in the handbook for quality control (chapter 8 in the German Handbook).

1.2.1 DATA COLLECTION AND PREPARATION

In this chapter, the required data and their preparation and use (mean value calculations, conversion to an assessment value etc.) are summarised. For guidance on sampling and microscopic analysis consult the instructions in Nixdorf et al. (2010).

1.2.2 REQUIREMENTS FOR THE PHOTOMETRIC ANALYSIS OF CHLOROPHYLL-A CONCENTRATION

For each survey year, the chlorophyll-a concentration must be measured photometrically in 6 samples (March/April to October/November) following the German DIN 38409-H60 (see chapter 4.1) taken from the same mixed sample in which phytoplankton will be counted (see chapter 2.2.3). The samples can come from either the epilimnion, or in clearwater lakes the euphotic zone. At least four samples must be taken during the period from May to September.

1.2.3 REQUIREMENTS FOR THE MICROSCOPIC ANALYSIS

A minimum of six Lugol-solution fixed samples are required per studied year, taken from the epilimnion or for clearwater lakes from the euphotic zone. The microscopic analysis of the Lugol fixed samples follows the Utermöhl-method, with the counting of at least two transects across the bottom of a sedimentation chamber of diameter 25–25.5 mm at high magnification, and the counting of at least half a chamber at a lesser magnification, in order to obtain



a sufficiently large sample. At least 10 dominant taxa should be counted per sample, with a pre-defined number of objects to be counted. These must be combined with the counts of non-dominant taxa when converting to biovolumes.

In order to detect additional important indicator taxa, further analysis of diatom slides prepared from six pelagic samples is recommended. Omitting this step will increase the risk of identifying too few taxa for the PTSI metric to be used, and therefore failure to obtain a valid Phyto-See-Index. Particularly in oligotrophic and slightly mesotrophic lakes, the phytoplankton are often dominated by centric diatoms (Bacillariophyceae), that cannot be reliably identified to species level. Whereas for the Alpine and Pre-alpine lakes, diatom slides are usually prepared from pelagic and supplementary non-Lugol-fixed samples, for lowland lakes an additional profundal sample is often taken, from which a preparation of diatom skeletons (frustules) can be made so that the DI-PROF metric can be calculated following Schönfelder (2006).

All recorded taxa must be identified using the proper numeric taxa codes from the harmonized taxa list (HTL, Mischke & Kusber 2009, with modifications for some taxa, see Appendix I). Alternatively, the program PhytoSee can automatically translate taxa coded using the German DV-numbering system for aquatic organisms (based on Mauch et al. 2003 updated following Internet-Version Sept 2007 and 2011) into codes from the HTL.

The quantitative list of recorded taxa must contain the values for biovolumes, and if possible also the cell counts per ml. The required taxonomic level of taxa identification is marked in the harmonised taxa list.

1.2.4 RAW DATA REQUIRED TO CALCULATE THE PHYTO-SEE-INDEX

The metrics that make up the Phyto-See-Index require some parameters that come directly from the raw sample data while others must be calculated.

As long as the raw data are supplied in a digital format matching the provided template, all further calculation can be made automatically by the Access based assessment tool "PhytoSee", and the results can be exported in a table format. To import the data into PhytoSee, the raw data must be organised into a specific three table format. A detailed format template is provided with PhytoSee tool. The required arrangement and formatting of the raw data, a description of the mandatory fields, and user instructions for PhytoSee can be found in chapter 3.

The mandatory fields and optional fields are arranged in three import tables: "Gewässername_SeeNr" (Waterbody-name_LakeNo), "Probendaten_Seen" (sample-data lakes) and "Taxon_BV_Seen" (Taxon_BV_Lakes).

The mandatory data fields are: a sample-station ID code, sample-station name and a code identifying the lake type for phytoplankton analysis. The recorded-taxa list requires a sample ID number, the taxon-ID-code (from the harmonised taxa list, or the German DV-number system for aquatic organisms), and the taxon biovolume. The sample list requires the sample ID number, the date of sampling, and the chlorophyll-a concentration for each sampled station. Additional information that will aid the interpretation of the PSI can be entered in non-mandatory fields, for example the total phosphorus concentration and Secchi-depth. Lakes with special characteristics, or of special types, should be indicated in the field "Gewässerart_Sondertyp" (*lake type special*) (see chapter 3.2.1).

In cases where multiple stations are sampled within the same waterbody, and when they are labelled with unique station ID numbers and names, separate PSI values will be calculated for each station. A single mean "waterbody" PSI value per year will be calculated as the mean of the separate station values. An aggregation of multiple stations from a single waterbody should only be made when all stations belong to the same lake type, otherwise they should be



treated as separate waterbodies, e.g. when a lake contains two basins of different depths such that one is dimictic while the other is polymictic. The identification of waterbodies is the responsibility of the appropriate authorities in the corresponding German state.

The results of the optional DI-PROF index for natural lowland lakes (Schönfelder 2006) can be entered in a separate table and included in the Phyto-See-Index calculation. Inclusion of DI-PROF index values is valuable when too few indicator taxa have been identified for the PTSI to be calculated (providing a DI-PROF sample was prepared). In addition to an Excel-Workbook (Ilka Schönfelder unpublished), a simple Access program is available to calculate the DI-PROF index (DI-PROF_Berech_kl.mdb). The dominance scores of the taxa must be present in addition to their DV ID numbers, coded according to a specific (and not the latest) version of the German DV-number system for aquatic organisms (DV-Coding following Mauch et al. 2003; Version March 2007, available online).

1.2.5 DETERMINING THE LAKE TYPE

Preconditions for use of the phytoplankton-based assessment method are that:

- The lake is larger than 50 ha (i.e. EU-WFD relevant lakes). Experience shows that the PSI method gives plausible assessment values for small lakes between 5 - 50 ha, but they must be indicated as "small lakes" (< 50 ha) when reported.
- The lake should not be a marshland-lake or have high salt content.
- The lake must be correctly assigned to one of the 16 defined German phytoplankton lake types.

The EU-WFD requires that lakes are classified into types according to geographical (ecoregion), physical (mean lake depth, lake volume), and chemical (alkalinity, water colour) criteria. In Germany, this classification is further extended using national criteria.

The typology for the current assessment method is based on the German LAWA lake typology of (Mathes et al. 2002). A small number of new lake types are distinguished and few lake types have been merged. These are described in the lake type profiles document (Riedmüller et al. 2013b)

For example, in Mathes et al. (2002) the lake types for German central highland lakes (5, 7, 8, and 9) are distinguished by their Volume Quotient ($VQ = \text{catchment area (m}^2\text{)}/\text{lake volume (m}^3\text{)}$), whereas for phytoplankton-based assessment the Volume-Depth-Quotient (VTQ^1) is used (Riedmüller & Hoehn 2011).

The morphometric and hydrological parameters listed in Table 4 are required to assign a lake to a lake type. A short description of each lake type is given in Table 5. A lake's ecoregion, its thermal stratification in summer (mostly stratified or polymictic), water hardness (alkalinity), the size of its catchment relative to volume (VQ und VTQ), and its theoretical water residence time (calculated from the surface outflow and lake volume) play an important role in assigning a lake to its lake type.

When assigning lake types to polymictic lowland lakes, these additional criteria should be followed in order:

1. A lowland polymictic riverine lake with a residence time of between 3 and 30 days should be classified as type 12, regardless of its mean depth or VQ.

¹VTQ ($1/\text{m}^2$) = catchment area (m^2)/lake volume (m^3) \times mean depth (m)



2. A lowland polymictic lake with mean depth less than or equal to 3 m should be classified as type 11.2 (very shallow), regardless of its VQ. In any case, shallow lakes typically have VQ-values greater than 1.5 m⁻¹.
3. For lakes with a residence time of more than 30 days and a mean depth greater than 3 m, the VQ criteria is used to distinguish between types 11.1 (VQ > 1.5) and 14 (VQ ≤ 1.5).

Descriptions for phytoplankton-based lake-(sub)-types (Table 5) are used in the assessment tool PhytoSee version 5.1 and later, and are slightly modified from those used in version 5.0.

Table 4 German lake types for phytoplankton (Riedmüller et al. 2013b) and their corresponding types according to Mathes et al. (2002). Green = required classification criteria. Red = ancillary classification criteria.

Phyto-plankton lake type	Lake type MATHES	Eco-region	Calcium content	Stratification	VQ-boundaries (m ² /m ³ → m ⁻¹)	VTQ-boundaries (m ⁻²)	mean depth	τ theoretical residence time
1	1	AVA	calc.	polymictic	any VQ		≤ 3 m	
2	2	VA		dimictic	> 1.5		3-15 m	
3	3	VA			≤ 1.5		3-15 m	
4	4	A		any VQ		> 15 m		
5	5/7*	MG	calc.	dimictic	> 1.5	> 0.18	< 8 m	
7	5/7*				≤ 1.5	≤ 0.18	> 8 m	
8	8/9*		calc.	dimictic	> 1.5	> 0.18	< 8 m	
9	8/9*				≤ 1.5	≤ 0.18	> 8 m	
6.1	6		calc. or soft-water	polymictic	< 10	≤ 2	> 5 m	0.5-1 a
6.2					10 – 20	2 – 6	2 – 5 m	0.1 – 0.5 a
6.3		> 20			> 6	< 2 m	3-30 d	
10.1	10	TL	calc.	dimictic	1.5-15			1-10 a
10.2					> 15			0.1-1 a
13	13			≤ 1.5			10-100 a	
11.1	11		polymictic	> 1.5			> 30 d	
11.2				> 1.5		≤ 3 m	> 30 d	
12	12		> 1.5			3-30 d		
14	14	≤ 1.5				< 10 a		

AVA = Alpine (A) and Prealpine (VA) ecoregion, MG = central highlands, TL = North German lowlands, calc. = calcareous. VQ (Volume quotient) = Catchment area / lake volume. VTQ (Volume-Depth-Quotient) = VQ/mean depth. τ = mean theoretical water residence time in days (d) or years (a).

A lake type can include a large proportion of German lakes (see Seen-Steckbriefe (lake profiles) Riedmüller et al. 2013b), whose true individual reference conditions cannot be covered by a single simplified reference trophic range as used here.

The classification of sometimes highly variably responding lakes into a set of types can only reflect an approximation of the true situation. It is common that "obligatory" type-criteria information such as bathymetry are missing or out of date. In these cases, local expert opinion can be used to interpret the ancillary classification criteria in Table 4 and be given as grounds for classification as a particular type. Lakes that are near to type boundaries, such as with a VQ of 1.45, can be re-classified as type 13 rather than 10.1 if this better fits the ancillary type-criteria.



In the north German lowland region in particular, there are only a small number of reference lakes to be found, so that paleolimnological examination of lake sediments is required to reconstruct their reference trophic state. This can be achieved, for example, by determining the taxonomic composition of diatoms whose shells are found preserved in sediment cores, and using a TP-Diatom transfer function to infer the historical nutrient conditions (for examples see Hübener 2006, 2009; Hofmann & Schaumburg 2005a,b,c; Voigt 1996). Paleolimnological results have, for polymictic lakes, partially supported the proposals made here (see chapter 4.1.5 in Mischke et al. 2010), but sometimes the reconstructed TP concentrations are higher than those accepted in the current document on background and orientation values for TP (Riedmüller et al. 2013a).

Table 5 Descriptions of the lake types for phytoplankton (PP) following Riedmüller et al. (2013b) including sub-types.

Sub-type PP*	Description of the phytoplankton-based lake types
1	Natural, artificial and heavily modified Pre-alpine lakes, calcareous, polymictic
2	Natural, artificial and heavily modified Pre-alpine lakes, calcareous, large catchment area, dimictic
3	Natural, artificial and heavily modified Pre-alpine lakes, calcareous, relatively small catchment area, dimictic
4	Natural, artificial and heavily modified Alpine lakes, calcareous, dimictic
5	Natural, artificial and heavily modified Central Highland lakes, calcareous, relatively large catchment area, dimictic
7	Natural, artificial and heavily modified Central Highland lakes, calcareous, relatively small catchment area, dimictic
6.1	Natural, artificial and heavily modified Central Highland lakes, relatively small catchment area, polymictic
6.2	Natural, artificial and heavily modified Central Highland lakes, moderately large catchment area, polymictic
6.3	Natural, artificial and heavily modified Central Highland lakes, relatively large catchment area, polymictic
8	Natural, artificial and heavily modified Central Highland lakes, low calcium, relatively large catchment area, dimictic
9	Natural, artificial and heavily modified Central Highland lakes, low calcium, relatively small catchment area, dimictic
10.1	Natural Lowland lakes, calcareous, relatively large catchment area, dimictic
10.2	Natural Lowland lakes, calcareous, very large catchment area, dimictic
13	Natural Lowland lakes, calcareous, relatively small catchment area, dimictic
11.1	Natural Lowland lakes, calcareous, relatively large catchment area, polymictic, residence time > 30 d, mean depth > 3 m
11.2	Natural Lowland lakes, calcareous, relatively large catchment area, polymictic, residence time > 30 d, mean depth ≤ 3 m
12	Natural Lowland lakes, calcareous, relatively large catchment area, polymictic, residence time 3-30 d
14	Natural Lowland lakes, calcareous, relatively small catchment area, polymictic

*for acidic mining lakes with pH 3 - 6 further lake-sub-types are available in the PSI: 7s, 10.1s und 13s

The latest revision in assessing lakes in the Alpine region resulted in revised reference conditions and subsequent boundary classification. The assumed reference conditions for lake types (Table 1) might become under revision in case of new insights from current lake data and from paleolimnological results and for harmonisation with the considerations of the European countries.



1.2.5.1 SPECIAL CONDITIONS AND SPECIAL LAKE TYPES

When undertaking phytoplankton surveys, special conditions in a lake can cause particularly unusual nutrient conditions and trophic dynamics, or make it difficult to assign a lake to a unique type.

Some examples are given in Riedmüller et al. (2013b; 2015) that demonstrate the validity of lake type specific background and orientation TP values. They are listed here, without explaining the underlying processes, but to show the effect on the Phyto-See-Index in comparison with total phosphorus concentration (TP):

Special condition or variant	Effect on Phyto-See-Index (PSI)²
A Macrophyte dominated lakes ³	PSI values are better than expected given TP
B Lakes with nutrient enriched sediment due to historical eutrophication	PSI values are worse than expected given TP
C Lakes which, because of their position in lake chains, deliver a higher retention performance	PSI values are better than expected given TP
D Lakes with unstable stratification behaviour	PSI values do not correspond well with the lake type classification
E Lakes in which the hydraulic residence time and discharge vary strongly over the year	PSI values do not correspond well with the lake type classification
F Lakes with strongly divided basins	PSI differs strongly between sampling stations. Consider splitting into multiple waterbodies.
G Lakes that are strongly influenced by humic substances and/or with degraded moorland in their catchments	PSI values are better than expected given TP. Lake type should be indicated as "dystrophic lake"
H Marshland/wetland/fen	PSI for taxonomic composition does not fit. Identify as a special type.
I Recently restored lakes that are still characterised by grazing resistant algae, such as cyanobacteria	PSI values are worse than expected given TP
J Lakes with a large proportion of zooplanktivorous fishes and a reduced zooplankton community	PSI values are worse than expected given TP
K Lakes with strong nitrogen limitation	PSI values are better than expected given TP

If one or more of these special conditions is present (A - K), PSI based assessment should be carried out and considered in the context of the prevailing nutrient and limnological conditions and the lake should be indicated as a "special-

²) when assessment is based on the closest matching defined phytoplankton-based lake type

³) macrophyte dominance is a component of the definition of reference state for many lake types, see Poikane et al. 2014



type" in the field "Gewässerart_Sondertyp" ("*waterbody-type_special*"). The procedure for Heavily Modified Water Bodies and Artificial Water Bodies (AWB) will be explained in the next chapter.

In the case of G: In lowland Germany there are only six natural lakes larger than 50 ha that are strongly influenced by humic substances, so this lake type is undefined. When a lake is strongly humic it should be indicated as a "dystrophic lake", and, where appropriate, additionally as a lowland marsh/moor and/or a "small lake" (< 50 ha). In the soft-water, stratified central German highland lakes of types 8 and 9 have been identified: a single natural humic lake (Titisee) and more than 20 humic reservoirs. These could be indicated as "brown-water-lakes" in the field "Gewässerart_Sondertyp" ("*waterbody-type_special*") for documentation.

In the case of I and J: The PhytoLoss module was developed to identify a strongly altered zooplankton grazing effect on the phytoplankton (see Deneke et al. 2015).



1.2.6 OVERALL STRATEGY FOR THE ASSESSMENT OF HEAVILY MODIFIED AND ARTIFICIAL WATERBODIES

When assessing a lake, in addition to lake type, it is also necessary to determine whether a lake is natural or rather counts as a Heavily Modified Water Body (HMWB) or an Artificial Water Body (AWB), for example if it has been dredged/excavated or dammed. The classification of a lake as a particular type, and its identification as a HMWB or AWB, is the responsibility of the person in charge in the public authorities of the German Federal States. In the lowland region, lakes identified as HMWB and AWB are assessed using a different PTSI indicator list and are given the suffix "k" after their lake type number, e.g. 13k for a gravel-pit lake with a relatively small catchment area. Assessment of the ecological potential of AWB and HMWB lakes is described in a document from the German Federal States Working Group for Lakes (LAWA-Expertenkreis Seen 2013).

Regarding excessive nutrient enrichment (eutrophication), HMWB and AWB should be assessed in terms of bio-components in an analogous way to natural lakes. As such, a calibrated PTSI indicator list is used for the lowland HMWB and AWB lakes, which receive the suffix "k" (e.g. 13k) to their lake type number.

In the case of pollution by acidic geogenic groundwater, the applicability of method-specific indicator lists for phytoplankton is reduced, so that in this case a biodiversity index is used in place of the metrics "PTSI" and "Algal Class" (following Leßmann & Nixdorf 2009). Concerning the metric "Biomass", which is used for neutral lakes, only the parameter "total biovolume" is used, which allows an assessment of pollutant loads (particularly nutrients) in acidic lakes. The suffix "s" (e.g. 13s) is added to the lake type number.

Strong fluctuations in water level can alter the trophic situation (or manifestation of trophy), and should therefore be taken into account during assessment as hydromorphological supporting elements. This also applies to changes in the stratification behaviour of reservoirs due to strong water extraction from the hypolimnion. Supporting elements are accounted for by relaxing the status assessment. Experience has shown that in this situation no standard method can be used, rather a lake's potential is determined on an individual basis by the LAWA expert group for lakes (LAWA-Expertenkreis Seen 2013). Parameters for the assessment of heavily modified and artificial lakes are identified in the present method description by the suffixes "HMWB" and "AWB".



2 STEP-BY-STEP CALCULATION OF THE GERMAN PHYTO-SEE-INDEX

The Phyto-See-Index for a studied lake is calculated from three metrics: "Biomass", "Algal Class" and PTSI. These metrics are determined from quantitative microscopic analysis of phytoplankton content (quantitative recorded-taxa-list) and photometric analysis (Chlorophyll-a concentration according to DIN) of water samples taken on at least six occasions. Optionally, the metric DI-PROF can be used, which is based on counts of planktonic diatom frustules in profundal sediment samples.

Assessment must always consider the lake type (see chapter 1.2.5). The assignment of a lake to a particular type is carried out according to the responsible authority of its German state or according to the criteria in Table 4.

All the following calculation steps, including those for the indices, can be carried out automatically by the assessment tool PhytoSee (version 5.0 and later), as long as the required data is correctly prepared for import into PhytoSee (see chapter 1.2).

The following step-by-step calculation of the Phyto-See-Index documents the extensions and modifications to the procedure that have been made since its previous description in Mischke et al. (2008).

2.1 METRIC "BIOMASS"

The metric "Biomass" is calculated from the following individual parameters:

- "Total biovolume" - vegetation period mean (Y1),
- "Chlorophyll-a" - vegetation period mean (Y2) and
- "Chlorophyll-a" - maximum value in the vegetation period (Y3)

The individual indices are averaged using the arithmetic mean (mean of Y1, Y2, Y3, see below).

2.1.1 TOTAL PHYTOPLANKTON BIOVOLUME

To calculate the seasonal mean for total phytoplankton biovolume, the raw data must be summed and averaged in a given sequence:

- a) Per sample total taxon biovolume: The biovolumes for all taxa in a sample are summed, with the exception of heterotrophic organisms. Heterotrophic taxa are marked in the harmonized phytoplankton taxa list (HTL) and are filtered out by the calculation tool.
- b) Seasonal-mean from samples taken during the vegetation period March–November

This seasonal-mean of total biovolume (x) is transformed using a lake type specific formula (see functions in Table 6) into the assessment value of parameter (Y1). For reference, the status class boundaries are also given in Table 6.



Table 6 Status-class boundaries for the parameter "Total Biovolume", and lake type specific assessment functions to calculate Y1, arranged by ecoregion in groups of equal reference status (Table 6a – 6e).

Lake type	1	2	3	4
As of: 10.01.2016	Pre-alpine lakes			Alpine lakes
Table 6a	Natural and HMWB and AWB lakes			
Parameter	Total Biovolume (mm³/l)			
Assessment-function	$Y1 = 1.5772 * \ln(x) - 0.0795$	$Y1 = 1.7109 * \ln(x) + 1.8296$	$Y1 = 1.6733 * \ln(x) + 2.3322$	$Y1 = 2.17 * \ln(x) + 2.9187$
H / G	2.72	0.82	0.61	0.52
G / M	5.13	1.48	1.11	0.82
M / P	9.68	2.65	2.01	1.31
P / B	18.24	4.76	3.65	2.07

Lake type	5 and 8	7, 7s and 9
As of: 23.11.2011	Stratified Central Highland Lakes	Stratified Central Highland Lakes
Table 6b	Natural and HMWB and AWB lakes	
Parameter	Total Biovolume (mm³/l)	
Assessment-function	$Y1 = 1.6841 * \ln(x) + 1.4139$	$Y1 = 1.6793 * \ln(x) + 1.9635$
H / G	1.1	0.8
G / M	1.9	1.4
M / P	3.5	2.5
P / B	6.2	4.5

Lake type	6.1	6.2	6.3
As of: 23.11.2011	Polymictic Central Highland Lakes		
Table 6c	Natural and HMWB and AWB lakes		
Parameter	Total Biovolume (mm³/l)		
Assessment-function	$Y1 = 1.9958 * \ln(x) + 0.1454$	$Y1 = 1.9958 * \ln(x) - 0.3546$	$Y1 = 1.9958 * \ln(x) - 0.8546$
H / G	1.9	2.5	3.3
G / M	3.4	4.2	5.4
M / P	5.5	6.9	8.9
P / B	8.6	11.4	14.6



Continuation of Table 6: Status-class boundaries for the parameter "total biovolume", lake type specific assessment functions to calculate Y1, arranged by ecoregion in groups of equal reference status (Table 6d – 6e)

Lake type	11.1 and 11.1k	11.2 and 11.2k	14, 14k, 10.2 and 10.2k
As of: 07.01.2013	Polymictic Lowland Lakes and Stratified Lowland Lakes with large VQ		
Table 6d	Natural and HMWB and AWB lakes		
Parameter	Total Biovolume (mm³/l)		
Assessment-function	$Y1 = 1.7906 * \ln(x) - 0.2384$	$Y1 = 1.7906 * \ln(x) - 0.738$	$Y1 = 1.7906 * \ln(x) + 0.2616$
H / G	2.64	3.49	2.00
G / M	4.61	6.10	3.49
M / P	8.07	10.67	6.10
P / B	14.1	18.64	10.67

Lake type	12 and 12k	10.1, 10.1k and 10.1s	13, 13k and 13s
As of: 07.01.2013	Lowland Riverine Lakes	Stratified Lowland Lakes	
Table 6e	Natural and HMWB and AWB lakes		
Parameter	Total Biovolume (mm³/l)		
Assessment-function	$Y1 = 1.7906 * \ln(x) - 1.2384$	$Y1 = 1.7906 * \ln(x) + 0.7616$	$Y1 = 1.7906 * \ln(x) + 1.2616$
H / G	4.61	1.51	1.14
G / M	8.07	2.64	2.00
M / P	14.10	4.61	3.49
P / B	24.65	8.07	6.10

Resulting values smaller than 0.5 are set to 0.5 and values larger than 5.5 are set to 5.5. The suffix "k" (e.g. 13k) is used to indicate artificial and heavily modified lakes and the suffix "s" (e.g. 13s) to indicate acidic mining lakes.

2.1.2 METRIC "CHLOROPHYLL-A SEASONAL MEAN"

To calculate the seasonal mean for total phytoplankton biovolume, the raw data must be summed and averaged in a given sequence:

- a) Calculate the mean of multiple samples when they have been taken on the same day (daily mean values).
- b) Calculate seasonal-mean values from daily mean values taken during the period March–November

This seasonal-mean of chlorophyll-a (x) is transformed using a lake type specific formula (see functions in table 7) into the assessment value of parameter (Y2). Assignment of a lake to a particular type is made either by following the recommendation of the responsible authorities or following the criteria in Table 4. For reference, the status class boundaries are also given in table 7.



Table 7 Status-class boundaries for the parameter chlorophyll-a seasonal-mean and lake type specific assessment functions to calculate Y2, arranged by ecoregion in groups of equal reference status (Table 7a –7e)

Lake type	1	2	3	4
As of: 10.01.2016	Pre-alpine lakes			Alpine lakes
Table 7a	Natural and HMWB and AWB lakes			
Parameter	Chlorophyll-a Seasonal Mean (µg/l)			
Assessment-function	$Y2 = 1.6063 * \ln(x) - 0.5962$	$Y2 = 1.6063 * \ln(x) - 0.5962$	$Y2 = 1.6063 * \ln(x) - 0.5962$	$Y2 = 1.6063 * \ln(x) + 0.4038$
H / G	10.84	4.02	3.0	2.52
G / M	19.44	7.2	5.38	4.05
M / P	34.86	12.92	9.64	6.50
P / B	62.52	23.16	17.3	10.43

Lake type	5 and 8	7 and 9
As of: 23.11.2011	Stratified Central Highland Lakes	Stratified Central Highland Lakes
Table 7b	Natural and HMWB and AWB lakes	
Parameter	Chlorophyll-a Seasonal Mean (µg/l)	
Assessment-function	$Y2 = 1.7129 * \ln(x) - 0.8799$	$Y2 = 1.7271 * \ln(x) - 0.4071$
H / G	4.0	3.0
G / M	7.2	5.4
M / P	13.0	9.7
P / B	23.0	17.0

Lake type	6.1	6.2	6.3
As of: 23.11.2011	Polymictic Central Highland Lakes		
Table 7c	Natural and HMWB and AWB lakes		
Parameter	Chlorophyll-a Seasonal Mean (µg/l)		
Assessment-function	$Y2 = 1.7987 * \ln(x) - 1.8358$	$Y2 = 1.7987 * \ln(x) - 2.3358$	$Y2 = 1.7987 * \ln(x) - 2.8358$
H / G	6.3	8.4	11.1
G / M	11.5	14.7	19.4
M / P	19.0	26.0	34.0
P / B	34.0	45.0	59.0



Continuation of Table 7: Status-class boundaries for the parameter chlorophyll-a seasonal-mean and lake type specific assessment functions to calculate Y2, arranged by ecoregion in groups of equal reference status (Table 7d – 7e)

Lake type	11.1 and 11.1k	11.2 and 11.2k	14, 14k, 10.2 and 10.2k
As of: 30.07.2012	Polymictic Lowland Lakes and Stratified Lowland Lakes with large VQ		
Table 7d	Natural and HMWB and AWB lakes		
Parameter	Chlorophyll-a Seasonal Mean (µg/l)		
Assessment-function	$Y2 = 1.7113 * \ln(x) - 2.3776$	$Y2 = 1.7113 * \ln(x) - 2.8776$	$Y2 = 1.7113 * \ln(x) - 1.8776$
H / G	9.6	12.9	7.2
G / M	17.3	23.2	12.9
M / P	31.0	41.5	23.2
P / B	55.6	74.5	41.5

Lake type	12 and 12k	10.1 and 10.1k	13 and 13k
As of: 30.07.2012	Lowland Riverine Lakes	Stratified Lowland Lakes	
Table 7e	Natural and HMWB and AWB lakes		
Parameter	Chlorophyll-a Seasonal Mean (µg/l)		
Assessment-function	$Y2 = 1.7113 * \ln(x) - 3.3776$	$Y2 = 1.7113 * \ln(x) - 1.3776$	$Y2 = 1.7113 * \ln(x) - 0.8776$
H / G	17.3	5.4	4.0
G / M	31.0	9.6	7.2
M / P	55.6	17.3	12.9
P / B	99.8	31.0	23.2

Resulting values smaller than 0.5 are set to 0.5 and values larger than 5.5 are set to 5.5. The suffix "k" (e.g. 13k) is used to indicate artificial and heavily modified lakes.

2.1.3 METRIC "CHLOROPHYLL-A MAXIMUM"

The metric chlorophyll-a-maximum is used only if the following 2 criteria (a and b) are satisfied.

- a) Individual chlorophyll-a values are available for more than 2 months
- b) The maximum chlorophyll-a value is more than 125% of the seasonal-mean chlorophyll-a value

When (a) and (b) both apply, then the chlorophyll-a-max-value (x) is transformed using a lake type specific formula (see functions in table 8) into the assessment value of parameter (Y3). If both the criteria listed in points (a) and (b) are not satisfied, then the chlorophyll-a-max-value is not used.



Table 8 Status-class boundaries for the parameter chlorophyll-a-maximum, and lake type specific assessment functions to calculate Y3, arranged by ecoregion in groups of equal reference status (Table 8a –8e).

Lake type	1	2	3	4
As of: 10.01.2016	Pre-alpine lakes			Alpine lakes
Table 8a	Natural and HMWB and AWB lakes			
Parameter	Chlorophyll-a Maximum (µg/l)			
Assessment-function	$Y3 = 1.7509 * \ln(x) - 4.1188$	$Y3 = 1.6245 * \ln(x) - 1.7357$	$Y3 = 1.7547 * \ln(x) - 1.546$	$Y3 = 2.1137 * \ln(x) - 1.8208$
H / G	24.76	7.33	5.67	4.81
G / M	43.82	13.56	10.03	7.72
M / P	77.58	25.10	17.74	12.40
P / B	137.33	46.46	31.36	19.89

Lake type	5 and 8	7 and 9
As of: 23.11.2011	Stratified Central Highland Lakes	Stratified Central Highland Lakes
Table 8b	Natural and HMWB and AWB lakes	
Parameter	Chlorophyll-a Maximum (µg/l)	
Assessment-function	$Y3 = 1.5237 * \ln(x) - 1.5933$	$Y3 = 1.5366 * \ln(x) - 1.1267$
H / G	7.6	5.5
G / M	17.7	10.6
M / P	28.5	20.5
P / B	54.2	38.6

Lake type	6.1	6.2	6.3
As of: 23.11.2011	Polymictic Central Highland Lakes		
Table 8c	Natural and HMWB and AWB lakes		
Parameter	Chlorophyll-a Maximum (µg/l)		
Assessment-function	$Y3 = 1.495 * \ln(x) - 2.1374$	$Y3 = 1.495 * \ln(x) - 2.6374$	$Y3 = 1.495 * \ln(x) - 3.1374$
H / G	11.0	16.0	22.0
G / M	23.0	31.0	43.0
M / P	44.0	61.0	85.0
P / B	84.0	118.0	166.0



Continuation of Table 8: Status-class boundaries for the parameter chlorophyll-a-maximum, and lake type specific assessment functions to calculate Y3, arranged by ecoregion in groups of equal reference status (Table 8d – 8e)

Lake type	11.1 and 11.1k	11.2 and 11.2k	14, 14k, 10.2 and 10.2k
As of: 30.07.2012	Polymictic Lowland Lakes and Stratified Lowland Lakes with large VQ		
Table 8d	Natural and HMWB and AWB lakes		
Parameter	Chlorophyll-a Maximum (µg/l)		
Assessment-function	$Y3 = 1.7113 * \ln(x) - 3.5638$	$Y3 = 1.7113 * \ln(x) - 4.0638$	$Y3 = 1.7113 * \ln(x) - 3.0638$
H / G	19.3	25.8	14.4
G / M	34.6	46.3	25.8
M / P	62.0	83.1	46.3
P / B	111.3	149.0	83.1

Lake type	12 and 12k	10.1 and 10.1k	13 and 13k
As of: 30.07.2012	Lowland Riverine Lakes	Stratified Lowland Lakes	
Table 8e	Natural and HMWB and AWB lakes		
Parameter	Chlorophyll-a Maximum (µg/l)		
Assessment-function	$Y3 = 1.7113 * \ln(x) - 4.5638$	$Y3 = 1.7113 * \ln(x) - 2.5638$	$Y3 = 1.7113 * \ln(x) - 2.0638$
H / G	34.6	10.7	8.0
G / M	62.0	19.3	14.4
M / P	111.3	34.6	25.8
P / B	199.6	62.0	46.3

Resulting values smaller than 0.5 are set to 0.5 and values larger than 5.5 are set to 5.5. The suffix "k" (e.g. 13k) is used to indicate artificial and heavily modified lakes.

2.2 METRIC "ALGAL CLASSES"

The metric "Algal Class" is composed of two to four different individual class parameters, depending on the lake type-group (Table 9). As individual class-parameters, either the summed biovolume of one or more algal classes, or their percent contribution to the seasonal-mean total biovolume (April-October), or the late-summer mean (July-Oct) total biovolume, are used. Membership of a particular "Algal Class" is defined in a column of the harmonised taxa list for phytoplankton (Mischke & Kusber 2009), with the exception of heterotrophic taxa, which are excluded from the summed biovolume calculation.

The individual class parameters are calculated separately and finally averaged arithmetically to yield the metric "Algal Classes".



Table 9 Use of the individual class-parameters as seasonal means (Sea) or "late-summer mean" from Juli to October (JO) for different lake type-groups with biovolume or percent composition. Natural, HMWB and AWB lakes of the same lake type are assessed in the same way.

Algal Class	Ecoregion	Alpine & Pre-alpine			Central highland					Lowland					
		Lake type	1	2+3	4	5	6	7	8	9	10	13	11	12	14
	Data type	Summed biovolume (mm³/l)													
Bacillario- & Chlorophyceae											Sea	Sea			
Bacillario- & Cryptophyceae				Sea									Sea	Sea	Sea
Chloro- & Cryptophyceae		Sea	Sea			Sea									
Chloro- & Euglenophyceae		Sea													
Chlorophyceae					Sea		Sea						Sea	Sea	Sea
Cryptophyceae & Cyanobacteria		Sea	Sea	Sea									Sea	Sea	Sea
Cryptophyceae					Sea		Sea	Sea	Sea	Sea	Sea	Sea			
Cyanobacteria					Sea	JO	Sea	Sea	Sea						
Dinophyceae & Cyanobacteria										JO	JO				
	Data type	Percent contribution of the Algal Class to total biovolume (%)													
Chryso- & Dinophyceae						Sea		Sea	Sea						
Chrysophyceae					Sea		Sea			Sea	Sea				
Dinophyceae				Sea											

To obtain the metric "Algal Classes" the raw data must be processed in the following sequence:

- a) Biovolumes are summed of all taxa in a sample that belong to an individual class-parameter, excluding the heterotrophic organisms. For some individual class-parameters the biovolumes of two Algal Classes are summed (see Table 9).
- b) Depending on the lake type and taxon, as indicated in Table 9, either a seasonal mean for the months April to October (inclusive), or a late-summer mean for the months July to October (inclusive) is calculated from the daily values.
- c) For some individual class-parameters it is necessary to further calculate the percentage contribution of that class' biovolume to total biovolume, based on the period mean values.
- d) In the case of individual class-parameter "cyanobacteria" in the Alpine and Pre-alpine ecoregion (types 1, 2, 3 and 4), there is only one boundary value to describe the "bad" status. If values are below this boundary, then the assessment cannot be made using this parameter.
- e) The individual Algal Class biovolume or percentage values (x) are transformed using a lake type specific formula into parameters (Y) on a continuous scale between 0.5 and 5.5. Assignment of a lake to a particular type is made either by following the recommendation of the responsible authorities or following the criteria in Table 4. Natural, HMWB and AWB lakes of the same type-code are assessed in the same way.

Resulting values smaller than 0.5 are set to 0.5 and values larger than 5.5 are set to 5.5.

Finally, the metric "Algal Classes" is calculated by taking the arithmetic mean of two or more applicable individual class-parameters.



Table 10 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **Pre-alpine lake types 1, 2 and 3** as status of 5th January 2015.

Algal class	Chlorophyceae + Cryptophyceae	Chlorophyceae + Euglenophyceae	Cryptophyceae + Cyanobacteria
Data type for x	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)
Assessment period	Jul – Oct	Apr – Oct	Apr – Oct
Lake type	1 / 2 / 3	1 / 2 / 3	1 / 2 / 3
H / G	0.78 / 0.15 / 0.12	0.19 / - / -	0.64 / 0.17 / 0.13
G / M	1.74 / 0.22 / 0.17	0.55 / - / -	1.31 / 0.25 / 0.20
M / P	3.90 / 0.33 / 0.26	1.63 / - / -	2.68 / 0.38 / 0.30
P / B	8.7 / 0.5 / 0.40	4.9 / - / -	5.5 / 0.6 / 0.5
Transformation function type 1	$y = 0.6194 * \ln(x) + 2.6582$	$y = 0.4592 * \ln(x) + 3.25$ and if $y = 0$ set 0.1	$y = 0.6971 * \ln(x) + 2.8109$
Transformation function type 2	$y = 0.6297 * \ln(x) + 2.95$	----	$y = 0.608 * \ln(x) + 2.8333$
Transformation function type 3	$y = 0.6297 * \ln(x) + 2.85$ and all types if $y = 0$ set 0.1	----	$y = 0.608 * \ln(x) + 2.7333$ and all types if $y = 0$ set 0.1

Table 11 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **deep Alpine lake type 4** as of: 17th January 2016.

Algal class	Baccillariophyceae + Cryptophyceae	Cryptophyceae + Cyanobacteria	Dinophyceae
Data type for x	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)	%
Assessment period	Apr – Oct	Apr – Oct	Apr – Oct
H / G	0.32	0.09	7.4
G / M	0.46	0.13	5.3
M / P	0.68	0.18	3.8
P / B	1.0	0.27	2.7
Transformation function	$y = 0.6514 * \ln(x) + 2$ and if $y = 0$ set 0.1	$y = 0.6724 * \ln(x) + 2.8907$ and if $y = 0$ set 0.1	$y = -746 * \ln(x) + 2.7467$



Table 12 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **calcareous (hard-water) stratified central highland lakes of type 5** (as of: 23. November 2011).

Algal class	Chlorophyceae	Chrysophyceae	Cryptophyceae	Cyanobacteria
Data type for x	Biovolume (mm ³ /l)	%	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)
Assessment period	Apr – Oct	Apr – Oct	Apr – Oct	Apr – Oct
Boundary value		> 0.6 %		> 0.3 mm ³ /l
H / G	0.03	5.8	0.1	
G / M	0.08	2.4	0.19	0.55
M / P	0,21	1	0.36	1.5
P / B	0,56		0.69	4.1
Transformation function	$y = 1.009 \cdot \ln(x) + 5.0761$	$y = - 1.126 \cdot \ln(x) + 3.4802$	$y = 1.5399 \cdot \ln(x) + 5.0609$	$y = 0.9915 \cdot \ln(x) + 3.089$

Table 13 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **calcareous (hard-water) stratified central highland lakes of type 7** (as of: 23. 11. 2011).

Algal class	Chlorophyceae	Chrysophyceae	Cryptophyceae	Cyanobacteria
Data type for x	Biovolume (mm ³ /l)	%	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)
Assessment period	Apr – Oct	Apr – Oct	Apr – Oct	Apr – Oct
Boundary value		> 0.6 %		> 0.3 mm ³ /l
H / G	0.02	9.0	0.07	
G / M	0.05	3.7	0.14	0.33
M / P	0.13	1.5	0.26	0.91
P / B	0.34	0.6	0.50	2.5
Transformation function	$y = 1.009 \cdot \ln(x) + 5.5761$	$y = - 1.126 \cdot \ln(x) + 3.9802$	$y = 1.5399 \cdot \ln(x) + 5.5609$	$y = 0.9915 \cdot \ln(x) + 3.589$

Table 14 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **low-calcium (soft-water) stratified central highland lakes of type 8** (as of: 23. 11. 2011).

Algal class	Chrysophyceae + Dinophyceae	Cryptophyceae	Cyanobacteria
Data type for x	%	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)
Assessment period	Apr – Oct	Apr – Oct	Apr – Oct
Boundary value	< 60%		> 0.4 mm ³ /l
H / G	12.1	0.07	---
G / M	5.7	0.11	0.39
M / P	2.7	0.20	1.2
P / B	1.3	1.34	3.9
Transformation function	$y = - 1.332 \cdot \ln(x) + 4.8225$	$y = 1.8387 \cdot \ln(x) + 6.4862$	$y = 0.8686 \cdot \ln(x) + 3.3151$



Table 15 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **low-calcium (soft-water) stratified central highland lakes of type 9** (as of: 23. 11. 2011).

Algal class	Chrysophyceae + Dinophyceae	Cryptophyceae	Cyanobacteria
Data type for x	%	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)
Assessment period	Apr – Oct	Apr – Oct	Apr – Oct
Boundary value	< 60%		> 0.4 mm ³ /l
H / G	17.6	0.05	---
G / M	8.3	0.09	---
M / P	3.9	0.15	0.7
P / B	1.9	1.26	2.2
Transformation function	$y = - 1.332*\ln(x) + 5.3225$	$y = 1.8387*\ln(x) + 6.9862$	$y = 0.8686*\ln(x) + 3.8151$

Table 16 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **polymictic central highland lakes of type 6** with all VTQ sub-types (as of: 23.11.2011).

Algal class	Chrysophyceae + Dinophyceae	Cryptophyceae + Chlorophyceae	Cyanobacteria
Data type for x	%	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)
Assessment period	Apr – Oct	Apr – Oct	Apr – Oct
Boundary value	> 0.6%		> 1.0 mm ³ /l
Lake-sub-type	6.1 / 6.2 / 6.3	6.1 / 6.2 / 6.3	6.1 / 6.2 / 6.3
H / G	13.1 / 8.5 / 5.6	0.74 / 1.0 / 1.3	1.0 / 1.6 / 2.7
G / M	5.6 / 3.6 / 2.4	1.3 / 1.6 / 2.1	2.7 / 4.6 / 7.6
M / P	2.4 / 1.4 / 1.2	2.1 / 2.8 / 3.6	7.6 / 13 / 21
P / B	1.2 / 0.7 / 0.43	3.6 / 4.8 / 6.2	21 / 36 / 60
Transformation function 6.1	$y = - 1.172*\ln(x) + 5.5134$	$y = 1.8756*\ln(x) + 3.0658$	$y = 0.972*\ln(x) + 2.5246$
Transformation function 6.2	$y = - 1.172*\ln(x) + 5.0134$	$y = 1.8756*\ln(x) + 2.5658$	$y = 0.972*\ln(x) + 2.0246$
Transformation function 6.3	$y = - 1.172*\ln(x) + 4.5134$	$y = 1.8756*\ln(x) + 2.0658$	$y = 0.972*\ln(x) + 1.5246$



Table 17 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **stratified lowland lakes of type 13 and type 10** with VQ-sub-types (as of: 12.02.2013).

Algal class	Bacillariophyceae + Chlorophyceae	Chrysophyceae	Cryptophyceae	Dinophyceae + Cyanobacteria
Data type for x	Biovolume (mm ³ /l)	%	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)
Assessment period	Apr – Oct	Apr – Oct	Apr – Oct	Jul - Oct
Boundary value		> 0.4 %		
Lake-sub-type	13 / 10.1 / 10.2	13 / 10.1 / 10.2	13 / 10.1 / 10.2	13 / 10.1 / 10.2
H / G	0.32 / 0.43 / 0.57	5.9 / 4.5 / 3.4	0.13 / 0.18 / 0.25	0.34 / 0.53 / 0.83
G / M	0.57 / 0.77 / 1.03	3.4 / 2.6 / 2.0	0.25 / 0.34 / 0.47	0.83 / 1.3 / 2.0
M / P	1.03 / 1.38 / 1.86	2.0 / 1.5 / 1.2	0.47 / 0.65 / 0.89	2.0 / 3.1 / 4.8
P / B	1.86 / 2.49 / 3.35	1.2 / 0.9 / 0.67	0.89 / 1.22 / 1.68	4.8 / 7.4 / 11.5
Transformation function 13	$y = 1.7049 * \ln(x) + 3.4457$	$y = - 1.848 * \ln(x) + 4.766$	$y = 1.5768 * \ln(x) + 4.6864$	$y = 1.1387 * \ln(x) + 2.7158$
Transformation function 10.1	$y = 1.7049 * \ln(x) + 2.9457$	$y = - 1.848 * \ln(x) + 4.266$	$y = 1.5768 * \ln(x) + 4.1864$	$y = 1.1387 * \ln(x) + 2.2158$
Transformation function 10.2	$y = 1.7049 * \ln(x) + 2.4457$	$y = - 1.848 * \ln(x) + 3.766$	$y = 1.5768 * \ln(x) + 3.6864$	$y = 1.1387 * \ln(x) + 1.7158$

Table 18 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **polymictic lowland lakes of type 11 with sub-types** (as of: 12.02.2013).

Algal class	Bacillariophyceae + Cryptophyceae	Chlorophyceae	Cryptophyceae + Cyanobacteria
Data type for x	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)
Assessment period	Apr – Oct	Apr – Oct	Apr – Oct
Lake-sub-type	11.1 / 11.2	11.1 / 11.2	11.1 / 11.2
H / G	0.9 / 1.2	0.07 / 0.11	0.73 / 1.1
G / M	1.5 / 2.0	0.16 / 0.23	1.6 / 2.3
M / P	2.7 / 3.54	0.34 / 0.50	3.3 / 4.8
P / B	4.6 / 6.1	0.73 / 1.07	7.1 / 10.4
Transformation function 11.1	$y = 1.8141 * \ln(x) + 1.7224$	$y = 1.3069 * \ln(x) + 4.9137$	$y = 1.3154 * \ln(x) + 1.9229$
Transformation function 11.2	$y = 1.8141 * \ln(x) + 1.2224$	$y = 1.3069 * \ln(x) + 4.4137$	$y = 1.3154 * \ln(x) + 1.4229$



Table 19 Lake type specific boundary values for the individual class-parameters of the metric "Algal Classes" and their transformation functions for **polymictic lowland lakes of types 12 and 14** (as of: 12.02.2013).

Algal class	Bacillariophyceae + Cryptophyceae	Chlorophyceae	Cryptophyceae + Cyanobacteria
Data type for x	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)	Biovolume (mm ³ /l)
Assessment period	Apr – Oct	Apr – Oct	Apr – Oct
Lake-sub-type	12 / 14	12 / 14	12 / 14
H / G	1.5 / 0.7	0.16 / 0.05	1.6 / 0.5
G / M	2.7 / 1.2	0.34 / 0.11	3.3 / 1.1
M / P	4.6 / 2.0	0.73 / 0.23	7.1 / 2.3
P / B	8.0 / 3.5	1.60 / 0.50	15.2 / 4.85
Transformation function 12	$y = 1.8141 * \ln(x) + 0.7224$	$y = 1.3069 * \ln(x) + 3.9137$	$y = 1.3154 * \ln(x) + 0.9229$
Transformation function 14	$y = 1.8141 * \ln(x) + 2.2224$	$y = 1.3069 * \ln(x) + 5.4137$	$y = 1.3154 * \ln(x) + 2.4229$

2.3 METRIC PHYTOPLANKTON-TAXA-LAKE-INDEX

The assessment of lakes with the Phytoplankton-Lake-Index (Phytoplankton-Seen-Index = PTSI) is based on six indicator lists for different lake type groups and is carried out in two steps.

The correct indicator list for the type of lake to be assessed must be selected in advance. There are currently six lists available (Table 20) each to be used for a different set of lake types. In total they grade 447 indicator taxa, and are included here in Appendix II as Table 33. For each taxon, a taxon-specific trophic score (TAW) and weighting factor (stenoecy factor) is given for each of the six lists.

Step 1: Trophic classification (oligotrophic to hypertrophic) of lakes by means of indicator taxa. The numerical scale and its interpretation is consistent with the LAWA trophic status index for lakes (see LAWA 2014).

Table 20 Indicator lists of PTSI and the corresponding lake types following Riedmüller et al. (2013a).

Appropriate indicator list	Abbreviation	Phytoplankton lake types
List for natural lakes and HMWB & AWB of the Alpine and Pre-alpine ecoregions.	AVA	1, 2, 3 and 4
List for natural lakes and HMWB & AWB (reservoirs, gravel pits etc.) of the German Central Highland ecoregion.	MG	5, 6, 7, 8 and 9
List for natural stratified lakes of the north German Lowland ecoregion.	TLgesch	10 and 13
List for natural polymictic lakes of the north German Lowland ecoregion.	TLpoly	11, 12 and 14
List for stratified HMWB & AWB of the north German Lowland ecoregion.	TgeschAWB	10k and 13k
List for polymictic HMWB & AWB of the north German Lowland ecoregion.	TpolyAWB	11k, 12k and 14k



Step 2: Assessment by means of the PTSI. For this, the PTSI is compared to the pre-set trophic reference value for the appropriate lake type. The difference between the PTSI and the reference value is first calculated and this is subsequently transformed into an ecological quality value (EQ = ecological quality) between 0.5 and 5.5.

Details of step 1: Trophic classification based on phytoplankton indicators

The PTSI must be calculated for each sampling date. To do this, trophic scores and weighting factors (stenoecy factors) for all taxa recorded in the sample are retrieved from Table 33 in Appendix II. The biovolume of a recorded taxon is taken into account using abundance classes. Taxa biovolume values are transformed into eight different abundance classes according to values in Table 21.

The calculation of PTSI is similar to that for other common indicator-based metrics like the saprobity index (DIN 38410).

Based on a sample's recorded-taxa list:

$$PTSI = \frac{\sum \text{Abundance class}_i \times TAW_i \times \text{Stenoecy factor}_i}{\sum \text{Abundance class}_i \times \text{Stenoecy factor}_i}$$

PTSI = Phytoplankton-Taxa-Seen-Index per sample

Abundance class_i = Abundance class of the ith indicator taxon in the sample, based on the biovolume classes in Table 21.

TAW_i = Trophic score of the ith indicator taxon

Stenoecy_i = Stenoecy factor of the ith indicator taxon (SF)

To calculate a trophic classification value for a lake-year, for which the individual sampling dates should be as evenly spaced in time as possible, the arithmetic mean of the individual sample values should be taken without first calculating monthly means. To assess the trophic state for a given year using the PTSI, a minimum of 4, and in the normal case 6, sampling dates are required. The determination of trophic status from a single PTSI value, or from the annual mean of PTSIs, can be done using Table 22.

Table 21 Determination of abundance classes for PTSI from the biovolume of an indicator taxon, estimated by microscopic analysis of a sample following Nixdorf et al. (2010).

Class biovolume (mm ³ /l)	Abundance class
≤ 0.0001	1
> 0.0001-0.001	2
> 0.001-0.01	3
> 0.01-0.1	4
> 0.1-1	5
> 1-5	6
> 5-25	7
> 25	8



Table 22 Determination of the trophic status of a lake using PTSI (the range of values and trophic states are similar to those of the LAWA trophic classification (LAWA 2014)).

PTSI	Trophic class
0.5-1.5	oligotrophic
> 1.5 – 2.0	mesotrophic 1
> 2.0 – 2.5	mesotrophic 2
> 2.5 – 3.0	eutrophic 1
> 3.0 – 3.5	eutrophic 2
> 3.5 – 4.0	polytrophic 1
> 4.0 – 4.5	polytrophic 2
> 4.5	hypertrophic

Details of step 2: Assessment according to the WFD with regard to lake type specific trophic reference values

On the basis of the difference between the annual-PTSI and the reference trophic state value, the ecological quality (EQ) can be calculated as a continuous PTSI-assessment value between 0.5 and 5.5 (in accordance with the EU-WFD). The trophic reference value for each lake type is given in Table 1. The EQ-PTSI value can be calculated directly from the following formula:

$$\text{EQ-PTSI} = 0.5 + (\text{PTSI} - \text{trophic reference value}) \times 2$$

In very occasional cases, the resulting EQ-PTSI value can be smaller than 0.5 or larger than 5.5, these should be set to 0.5 and 5.5 respectively. Using Table 3 these index values can be matched to the corresponding ecological status classes of the EU-WFD. The assessment process only gives a reliable indication of the trophic status if a minimum of 4 indicator taxa per sample are present when calculating the annual mean, and if at least four sampling dates are available per year. If either one of the two criteria are unfulfilled, then the complete Phyto-See-Index is invalidated and the calculated index-value can only be taken as informative for the ecological status.



2.4 OPTIONAL DIATOM-INDEX: DI-PROF USING BENTHIC SAMPLES FROM THE PROFUNDAL ZONE OF NATURAL LOWLAND LAKES

In addition to the three obligatory metrics ("Biomass", "Algal Classes" and PTSI), the optional metric "DI-PROF" can be used to supplement the assessment of natural lowland lakes of types 10-14. The phytoplankton of oligotrophic and weakly mesotrophic lowland lakes is often dominated by diatoms (Bacillariophyceae), which in most cases cannot be determined to species level using the Utermöhl method without an additional preparation of their silicate skeletons (frustules). This can result in too few indicator taxa being identified for a valid PTSI score.

In cases when too few indicator taxa are determined using the Utermöhl method, the addition of a DI-PROF score can ensure that the complete final assessment is valid, when it otherwise would not have been. Final PSI assessment values that include a DI-PROF score are returned by the PhytoSee tool in a special field named "PSI_m_DiProf".

The DI-PROF index was developed by Schönfelder (2004; 2006). It uses the silicate skeletons (frustules) of planktonic diatom indicator taxa that have accumulated in the uppermost layer of the profundal zone sediment of a lake. Their dominance scores are determined from specially prepared diatom samples (not the Utermöhl method).

Sampling and determination of the profundal diatoms should be carried out following the instructions given in Nixdorf et al. (2010). For this, a sediment sample should be collected during the sampling time period, taken from the sediment surface (0-1 cm) at the deepest point of the lake (profundal sample).

The diatom skeletons (frustules) found in this sediment sample are then processed and prepared. The relative abundances of the planktonic diatom taxa are determined using stable diatom preparations (embedded in synthetic resin with a high refractive index) examined under a microscope with 1200x magnification and an oil immersion objective lens with aperture > 1.30. The planktonic diatom taxa should be identified using the relevant literature and coded according to the nomenclature of the DV-List of Mauch et al. (2003), with online updates as of August 2007. This ensures that the taxonomic naming of the selected indicator taxa will match with those of DI-PROF (see Table 23). Because of considerable changes to the taxonomic grouping and nomenclature between the August 2007 and September 2011 versions of the DV-List, if the newer code-system is employed, the user is responsible for the correct assignment of names.

The calculated dominance values of the planktonic taxa (DOM-W_i) are multiplied by taxon-specific trophic-optimum factors (TO-PROF_i) and weighting factors (G-PROF_i), to produce a diatom trophic index for each sample. The trophic-optimum and weighting factors are given in Table 23. The DI-PROF for a given sample is calculated with the following formula:

$$DI_PROF_k = \frac{\sum(\sqrt{DOM_W_{i,k}} \times TO_PROF_i \times G_PROF_i)}{\sum(\sqrt{DOM_W_{i,k}} \times G_PROF_i)}$$

DI_PROF_k = Trophic index for planktonic diatoms in a profundal sediment sample k

DOM_W_{i,k} = Percent contribution of the ith taxon in sample k

TO_PROF_i = Trophic optimum factor of the ith taxon

G-PROF_i = Weighting factor of the ith taxon

**Table 23** Trophic-optimum (TO-PROF_i) and weighting factors (G-PROF_i) for the Di-PROF according to Schönfelder (2006), extended to include taxa in the DV-List as of August 2007.

DV-Nr	Taxon name in the DV-List (Mauch et al. 2003; updated online as of March 2007)	Trophic-optimum (TO-PROF _i)	Weighting factor (G-PROF _i)
16151	<i>Actinocyclus normanii</i>	11.42	0.3
6050	<i>Asterionella formosa</i>	1.19	3.5
6798	<i>Aulacoseira ambigua</i>	7.75	0.9
6785	<i>Aulacoseira granulata</i>	8.62	0.7
16783	<i>Aulacoseira granulata</i> var. <i>curvata</i>	8.62	0.7
6800	<i>Aulacoseira granulata</i> var. <i>angustissima</i>	8.62	0.7
6907	<i>Aulacoseira islandica</i>	1.47	3.6
6786	<i>Aulacoseira islandica</i> ssp. <i>helvetica</i>	1.47	3.6
6788	<i>Aulacoseira subarctica</i>	0.55	2.5
16791	<i>Cyclostephanos delicatus</i>	5.64	1.7
6943	<i>Cyclostephanos dubius</i>	6.63	1.4
6177	<i>Cyclostephanos invisitatus</i>	9.94	0.5
6178	<i>Cyclotella atomus</i>	5.14	2.3
6929	<i>Cyclotella comensis</i>	-6.3	0.3
16185	<i>Cyclotella cyclopuncta</i>	0.08	1.9
6179	<i>Cyclotella distinguenda</i>	4.11	3.9
6731	<i>Cyclotella distinguenda</i> var. <i>unipunctata</i>	0.08	1.9
6733	<i>Cyclotella krammeri</i>	-7.07	0.2
6002	<i>Cyclotella meneghiniana</i>	11.1	0.4
6936	<i>Cyclotella ocellata</i>	-0.77	1.5
6735	<i>Cyclotella praetermissa</i>	1.5	3.4
6945	<i>Cyclotella pseudostelligera</i>	2.71	5.7
6204	<i>Cyclotella radiosa</i>	1.89	4.4
6928	<i>Cyclotella rossii</i>	-0.25	1.5
16190	<i>Cyclotella schumannii</i>	-10.07	0.1
16804	<i>Cyclotella tripartita</i>	-11.38	0.1
6210	<i>Diatoma tenue</i>	5.14	2.8
6075	<i>Fragilaria crotonensis</i>	2.61	5
6399	<i>Fragilaria delicatissima</i>	2.95	7.1
16575	<i>Fragilaria ulna acus</i> - Sippen	3.39	5.1
6410	<i>Fragilaria ulna angustissima</i> – Sippen	6.2	1.8
6233	<i>Fragilaria ulna</i> var. <i>acus</i>	3.39	5.1
6594	<i>Nitzschia graciliformis</i>	3.75	5.5
6795	<i>Stephanodiscus alpinus</i>	1.15	3.4
6009	<i>Stephanodiscus hantzschii</i>	6.89	1.3
6817	<i>Stephanodiscus hantzschii</i> var. <i>tenuis</i>	6.89	1.3
6226	<i>Stephanodiscus minutulus</i>	2.88	5.1
6940	<i>Stephanodiscus parvus</i>	2.88	5.1
6796	<i>Stephanodiscus neoastraea</i>	3.79	5.8
6091	<i>Tabellaria flocculosa</i>	-4.36	0.5
16764	<i>Tabellaria flocculosa</i> var. <i>ambigua</i>	-4.36	0.5
16765	<i>Tabellaria flocculosa</i> var. <i>asterionelloides</i>	-4.36	0.5
16766	<i>Tabellaria flocculosa</i> var. <i>geniculata</i>	-4.36	0.5
16767	<i>Tabellaria flocculosa</i> var. <i>intermedia</i>	-4.36	0.5
16768	<i>Tabellaria flocculosa</i> var. <i>linearis</i>	-4.36	0.5
16769	<i>Tabellaria flocculosa</i> var. <i>pelagica</i>	-4.36	0.5
16770	<i>Tabellaria flocculosa</i> var. <i>teilingii</i>	-4.36	0.5



The index requires that the percentage contribution of a planktonic taxon is calculated as a proportion only of the planktonic diatoms. Membership of the life form type "planktonic" or "benthic" is not clear for all taxa, such that this must be specified for the DI-PROF-Index. Therefore, prior to calculating the index, only the planktonic diatoms are selected from the list of taxa counted in a diatom analysis. This was achieved in consultation with the developer of the index, and with a linked list of the taxon names coded in the DV-List (as of 2007), which has been verified by Ilka Schönfelder. This linked list is integrated in an external Access-based calculation tool "Di_Prof_Berech" (Mischke, unpublished, August 2007 and later) and automatically assigns the appropriate diatom taxa as planktonic, as well as calculating the DI-PROF-index. It returns a table in the correct import format for the PhytoSee calculation tool.

The ecological status class, in accordance with the EU-WFD, can be determined using the difference between the calculated DI-PROF index for a sample and that for the reference trophic state.

It should be noted that the DI-PROF is based on own reference trophic states (see Table 24) do not distinguish between sub-types and refer to the very good / good boundary and are 0.25 LAWA index units higher (lake type 12 and sub-type 10.1) or lower (type 11.2) than the Phyto-See-Index calculated without DI-PROF (compare Table 1 with Table 24).

Table 24 Class boundaries for the assessment of north German post-glacial lakes with the plankton based metric DI-PROF following Schönfelder (2006).

Lake type	Reference trophic status	"Bewertung mit Prädikat"				
		Very good	Good	Moderate	Poor	Bad
		with a current DI-PROF in the range				
13	oligo – mesotrophic	< 1.75	1.75...2.24	2.25...2.74	2.75...3.24	>3.24
10	mesotrophic	< 2.25	2.25...2.74	2.75...3.24	3.25...3.74	> 3.74
14	strongly mesotrophic	< 2.50	2.50...2.99	3.00...3.49	3.50...3.99	> 3.99
11	strongly mesotrophic	< 2.50	2.50...2.99	3.00...3.49	3.50...3.99	> 3.99
12	eutrophic	< 3.25	3.25...3.74	3.75...4.24	4.25...4.74	> 4.74



2.5 BIODIVERSITY-METRIC ACCORDING TO LEBMANN & NIXDORF (2009) FOR THE ASSESSMENT OF ACIDIC MINING LAKES

The assessment of extremely acidic mining lakes is based on the so-called "Biodiversity Index" as well as on the biomass of phytoplankton measured as biovolumes. The method for this assessment is currently under revision.

The assessment of acidic mining lakes for the "excellent" and "good" ecological potential is carried out according to Leßmann & Nixdorf (2009), which makes use of the Shannon Index and is supported by evenness as an supplementary parameter. However, boundaries for the latter are not well defined for status classes less than "moderate".

Leßmann & Nixdorf (2009) list the following prior conditions in order to use the biodiversity metrics for assessing the ecological potential:

- Acidic lakes (pH <6)
- Application for mining lakes with pH <3 is limited
- Hydrological and chemical conditions in steady state
- Assignment of lake type in imitation of those for natural lakes but with suffix "s"; three subtypes are defined in Phyto-See-Tool version: 7s, 10.1s und 13s
- Monitoring of several years with at least four samples taken per year

2.5.1 CALCULATION OF SHANNON INDEX AND EVENNESS

In ecological reasearch the most common diversity index is the Shannon Index. It takes into account the number of species found as well as the contribution of individuals or taxa biomasses within the total sum. The Shannon Index H_s presents the mean grade of uncertainty for finding a specific species within a random sample.

Measured parameters are the total number of species or genera (taxa) and their biovolumes (not number of individuals). The Shannon Index in regard to the biodiversity index is calculated according to the following formula:

$$H_s = - \sum_{i=1}^s p_i \ln p_i \quad \text{mit } p_i = \frac{n_i}{N}$$

S: Total number of taxa

N: Total biovolume

n_i : Biovolume of taxon i

The H_s value increases with both, number of taxa and even contributions of all taxa to the total number of individuals or biovolume. In case of only one species H_s becomes zero. The maximum value is restricted by the total number of taxa, since $H_{max} = \ln S$.

The second biodiversity index evenness (E_s) is used as a auxiliary parameter.

Based on the Shannon Index evenness is calculated according to the following formula:

$$E_s = \frac{H_s}{H_{max}} = \frac{H_s}{\ln S}$$



The evenness value enables to evaluate whether the Shannon Index result is driven mainly by the total number of taxa, or by the even contribution of taxa in the total biovolume of a sample (Leßmann & Nixdorf, 2009). Evenness is the ratio of Shannon Index to Hmax, which is calculated for optimal even distribution of taxa within the total biovolume. This results in evenness always being high when taxa have no mass development plus the same frequency or share in total biovolume, even when total number of taxa is low.

2.5.2 HIGH AND GOOD ECOLOGICAL POTENTIAL BASED ON BIODIVERSITY INDEX

Based on phytoplankton species, each of the parameter values i.e. "Shannon Index" and "evenness" are transformed into assessment values for extremely acidic mining lakes by applying the status class boundaries provided in Table 25.

The second biodiversity index, evenness (Es), is calculated and the result must be provided, but is not included in the calculation of the biodiversity-metric.

Table 25 Boundaries as lowest limits (Shannon Index and evenness) between high, good and moderate potentials for the ecological assessment of phytoplankton composition.

Class Boundary	Shannon Index Hs	Evenness Es (auxiliary parameter)
high / good	1.5	0.6
good / moderate	1.0	0.4

The assessment of total biomass of phytoplankton found in acidic mining lakes should reflect the analogous boundaries defined for natural lakes of the same lake type, which results in a slight modification from the proposal found in Leßmann & Nixdorf (2009). Please note that for the assessment of acidic lakes the parameters "chlorophyll-a seasonal mean" and "chlorophyll-a maximum" are only used as supporting quantities. In this case the total biovolume of phytoplankton with the same class boundaries as the natural lake types 7, 10.1 and 13 (see Table 6) are used. The acidic mining lakes are marked with suffix "s" (e.g. 13s). The assessment results for "chlorophyll-a seasonal mean" and "chlorophyll-a maximum" are displayed in the export file of the PhytoSee tool, but they are not included for calculating the final Phyto-Index.



2.6 CALCULATION OF THE FINAL PSI (PHYTO-SEE-INDEX)

The Phyto-See-Index is based on the metrics "Biomass", "Algal Classes", "PTSI", and for natural lowland lakes the optional "DI-PROF". The ability and sensitivity of these metrics to measure ecological status differs between the various lake types. Therefore, metric weighting factors were established to adjust the indices of the single metrics in the final calculation of the PSI. These weighting factors were derived from a lake type specific regression analysis to determine the correlation between the individual metrics and trophic status (Riedmüller et al. 2013a, LAWA 2014).

The individual metrics are combined to form the final PSI value by calculating a weighted mean (with the exception of the acidic mining lakes). The lake type specific weighting factors are given in Table 26.

The calculation of the final Phyto-See-Index (PSI) is achieved in the following sequence:

- a) Multiply each metric by its lake type and metric-specific weighting factor
- b) Sum all weighted metric values
- c) Divide by the sum of all applied weighting factors
- d) Round the result to one decimal place
- e) Assign the result the appropriate WFD ecological status class according to Table 3, i.e.: PSI-Values between 0.5 and 1.5 = "Very Good", values from 1.51 to 2.5 = "Good", and so on.

In the case of the acidic mining lakes, the two metrics "Biomass" and "Biodiversity" are assessed according to the "worst-case" principle. That means that the worst of the two is taken as the final PSI, rather than a weighted mean. If the diversity is such that only a single taxon has been identified, then the assessment is invalid and cannot be used. The output of the PSI-tool will not include this lake year.

Example: For a lake of type 12, the following assessment value would be calculated:

Metric results: Biomass = 3.3; Algal Class = 3; PTSI = 4.5.

The calculation of the Phyto-See-Index (PSI) would follow as:

$$PSI = \frac{(3.3 \times 4) + (3 \times 3) + (4.5 \times 2)}{4 + 3 + 2} = 3.57 = \textit{rounded to 3.6}$$



Table 26 Weighting factors (W) for determining the German Phyto-See-Index from its individual metrics. Precise descriptions of the lake groups are given in Table 20, and of the lake types in Table 5. AVA = Alpine and Pre-alpine, MG = Central Highland, TL = Lowland, HMWB = Heavily Modified Water Body, AWB = Artificial Water Body.

Lake type	W Biomass	W Algal Class	W PTSI	W DI-PROF	Biodiversity	As of date
1	1	1	1			02.02.2015
2	4	2	3			02.02.2015
3	4	3	3			02.02.2015
4	5	3	3			02.02.2015
5	3	2	3			03.12.2011
6.1	3	1	2			03.12.2011
6.2	3	1	2			03.12.2011
6.3	3	1	2			03.12.2011
7	3	2	3			03.12.2011
8	3	2	3			03.12.2011
9	3	2	3			03.12.2011
10.1	4	3	3	1		15.01.2013
10.1k	4	3	3			15.01.2013
10.1s	x				x	"worst case"
10.2	4	3	3	1		15.01.2013
10.2k	4	3	3			15.01.2013
11.1	4	3	2	2		15.01.2013
11.1k	4	3	2			15.01.2013
11.2	4	3	2	2		15.01.2013
11.2k	4	3	2			15.01.2013
12	4	3	2	2		15.01.2013
12k	4	3	2			15.01.2013
13	4	3	3	3		15.01.2013
13k	4	3	3			15.01.2013
13s	x				x	"worst case"
14	4	3	2	1		15.01.2013
14k	4	3	2			15.01.2013

2.6.1 MINIMUM INPUT DATA REQUIREMENTS FOR RELIABLE ASSESSMENT WITH THE PSI

A shortfall in the previously described data requirements can have the result that assessment cannot be made for one of the individual component metrics, or for the final combined PSI metric. When one of the individual metrics is missing, a final PSI assessment value can still be calculated from the remaining metrics, but a warning must be included and this warning should be taken into account when management actions are planned for that waterbody (hereafter referred to as "warning label"). Warning labels are automatically included in the exported results files by the assessment tool PhytoSee (since version 4.0) in the following fields: "Gesamtbewertung verbal stufig" (*final assessment verbal class*) for invalid assessment in the final PSI, "Beprobung konform?" (*compliant sampling?*) when a sample did not conform to the method requirements, and "Warn_Chla" if there is a problem with the biomass parameter Chlorophyll-a.



If more than one of the component metrics is missing or invalid than the final PSI assessment must also be considered invalid (see condition e).

According to current knowledge, the requirements for the PSI-method are:

- a) If the number of sampling dates per year is less than four, no valid assessment is possible. No row will appear for this year in the output from the PhytoSee tool.
- b) If the number of sampling dates per year is between four and five (1-2 fewer than the required 6 samples per year between March and November), the resulting assessment value will be uncertain. This applies particularly for discriminating between Good and Moderate status. The warning label "Nur 4-5 Proben - Bewertung unsicher!" (*only 4-5 samples –assessment uncertain*) is applied.
- c) The minimum number of required indicator taxa for the PSI-method is a yearly average of four. When fewer than four have been identified, assessment via the metric PTSI is not possible. A PSI calculated from the remaining metrics is uncertain and will be labelled with the warning "Gesamtindex ohne PTSI Metrik ungültig!" (*final assessment invalid without PTSI metric*).
- d) In the case too few, or complete absence of, Chlorophyll-a measurements, a final PSI assessment value can still be calculated. In this case, the metric "Biomass" is based solely on the total biovolume of phytoplankton. Since the European intercalibration process within the Geographic Intercalibration Group for the Central Baltic Ecoregion (CB GIG) is based only on the metric "chlorophyll-a" to describe phytoplankton biomass, assessment results obtained without chlorophyll-a values are not sufficient for reports to the EU about the ecological status of lakes. The warning label "zu wenige Chla-Werte < 4 - keine Bewertung des Parameters!" (*too few chla-values < 4 – no assessment of the parameters!*) will be applied.
- e) If there are fewer than the required number of samples, and in addition missing values for the assessment parameter "Chlorophyll-a seasonal mean" in the metric "Biomass", then no PSI assessment value can be given. In this case the PhytoSee tool will return both appropriate warning labels.



3 PHYTOSEE – ASSESSMENT TOOL FOR CALCULATING THE PHYTO-SEE-INDEX

The phytoplankton based Phyto-See-Index (PSI) for assessing the ecological status of lakes (for EU-WFD purposes), requires extensive calculations to be made with raw survey data. The assessment tool PhytoSee 6.0 allows the automatic calculation of PSI following the most up to date version of the method.

Since PhytoSee 6.0, if supplementary zooplankton data are supplied, a grazing-index classification can be added to the phytoplankton based PSI assessment. The PhytoLoss module handles the import of zooplankton data, grazing-index calculation, and export of the resulting index. Instructions and guidance for the use of the PhytoLoss module, and a description of the method, are documented in Deneke et al. (2015) and are not included here.

The PhytoSee tool was first described in the form of instructions for use in Mischke (2008). Since then several changes and extensions to the method have been made until the current version 6.0 (Mischke et al. 2015). The tool PhytoSee provides automatic calculation of the PSI so that the user only needs to focus on the preparation of the input data. The required fields in the Excel-based input data templates are mostly unchanged since 2008. Using a set of hierarchically organised queries, which ensure lake type specific calculation of the assessment values for the six to eight individual metrics, PhytoSee returns the index metrics and final weighted PSI value, together with the intermediate results and underlying input data, in an export file with explanations of the contained fields.

All relevant parameters required by the tool for assessment are included in PhytoSee:

- The harmonized taxa list with identification codes (HTL ID; Mischke & Kusber 2009),
- The six different PTSI indicator-taxa lists with taxon-specific trophic-scores and weighting factors (stenoecy factors) for nearly 500 different indicator taxa (see Table 33), and
- All factors and constants required for about 170 transformation functions used when calculating indices for the individual metrics in the Phyto-See-Index. These are in the Access-table "Seen_Klassenmetrik" (*lake-class metrics*).

In principle it is possible to enter data directly into the input tables of the PhytoSee-Database and to correct the existing entries. In this way, new sampling stations can be entered into the table "Gewässername_SeeNr" (*Waterbody-name_LakeNo*). It is however advisable to first prepare the data using the pre-prepared Microsoft Excel templates, so that no mandatory fields are overlooked.

Additionally, the PhytoSee tool offers three different systems to help prepare the import data: help with the summation of biovolume estimates (chapter 3.2.3.1); translation from DV-coded taxa records (chapter 3.2.3.2); and creation of sample and taxa data from DV-coded recorded-taxa lists (chapter 3.2.3.3).



3.1 TECHNICAL REQUIREMENTS AND GENERAL USAGE ADVICE

The PhytoSee tool is not platform independent, the software Microsoft Access© (version 2000 and later) is required. The functionality of PhytoSee 6.0 has been tested with Microsoft Access© versions up to 2010 running on the operating system Windows XP. In general, all functions of Microsoft Access© are available that are described in the Microsoft Access handbook.

Warning: None PhytoSee tool version runs on 64-bit-software on 64 bit Windows. When software Access is installed in a 32-bit version, the tool is running.

The most recent version at the time of writing is **PhytoSee_6_0_PhytoLoss_1_2_Format2003_09012015.mdb**.

Please note: PhytoSee version 5.1 (dated 02.01.2014) and PhytoSee 6.0 (dated 11.12.2014) both contain a calculation error (bug) that affects the selection of the Month in the Algal Classes metric for the period "July to October" (see guidance documentation for the latest software version). These versions should no longer be used.

The current PhytoSee version and all later updated versions will herein be referred to by the abbreviation PhytoSee_XY.mdb. PhytoSee is cost-free and the source code is available on request. It can be found for download as a ZIP-file:

http://www.gewaesser-bewertung.de/index.php?article_id=163&clang=0

The PhytoSee tool is not available for individual download, rather it is available as part of a ZIP archive together with comprehensive requisite instruction and guidance documents:

"PhytoSee_vs_6.0korrrg.zip" (latest version as of writing; Online-Version 27.01.2015)

The respective guidance documents for the current version of PhytoSee:

- a) Give an overview of the assessment relevant changes and implementation improvements since the previous version of the tool, and
- b) Provide a list of all the supplementary documents (e.g. Excel file "Formatvorlage_PhytoSee" (*format-template_PhytoSee*)).

The program PhytoSee_XY.mdb is proprietary software and is not allowed to be copied or distributed commercially. It is intended to be used as a database for collected phytoplankton and accompanying data. It guarantees space efficient storage for large volumes of data and allows the creation of user-defined queries in the same place. Fundamentally, the file PhytoSee_XY.mdb is a pre-prepared MS Access-database containing pre-defined tables for the import of phytoplankton survey data, which then automatically performs all the calculations for the Phyto-See-Index.

Before use, the assessment tool PhytoSee_XY.mdb must be extracted from the ZIP-archive, together with the supplementary documents and files, into a normal folder on the computer where it will be used.

To test whether the PhytoSee tool is compatible with the installed version of MS Access, after opening the file, press the button "Bewertungsergebnisse SEEN – Messstellen" (*assessment results LAKES – sampling stations*) on the starting page. If the Access version is compatible with PhytoSee_XY.mdb, after a few seconds to minutes a table will appear with the assessment results for the included example data (duration dependent on the volume of data and speed of the machine). If this table does not appear, MS Access version 2010 should be used.

The example data include phytoplankton assessment input data for at least one survey year for each lake type, and can serve as a test dataset for validation should the algorithm be re-implemented on another platform.



To avoid confusion between the example data in the downloaded tool, it is recommended to rename the example database extracted from the ZIP-archive. This can be done with any folder/file renaming function. In the next step, the example data should be deleted in the input tables.

In the following section some general advice for the use of Microsoft Access Databases will be given. No liability is accepted for their completeness or functionality (the use of the original software help from Microsoft is advised). A basic knowledge of MS Access is required for the use of the PhytoSee_XY tool.

3.1.1 DELETION AND INPUT OF DATA IN ACCESS-TABLES

After the basic function test (see above) the included example data, in tables "Taxon_BV_Seen" (*Taxon_BV_Lakes*) and "Probendaten_Seen" (*sample-data lakes*) can be deleted. The deletion can be made in Access by opening the appropriate tables and selecting the rows to delete by clicking on the outermost left-hand edge of the table (grey frame). To select multiple rows for deletion, hold the [Shift] key at the same time as selecting rows with the cursor. All rows can be selected at once by first selecting the topmost row, then selecting the bottom row while holding down the [Shift] key. Once the correct rows are selected, use the Access command "Delete Record". An empty table with pre-defined fields will be left remaining.

Data from an Excel-file can be entered into an Access-table using the clipboard (copy/paste):

- 1.) Copy the data values to be entered (without the row names!) from a pre-formatted Excel-table into the clipboard,
- 2.) Open the Access-file, and then the appropriate table in Access with a double click, and
- 3.) Paste with the Access command "Paste Append".

For this process to work, it is required that the order of the columns, and the field attributes (i.e. Text or Numeric, see next section) are defined in the same way in the Excel- and Access-tables. To ensure that this is the case, the included Excel template file "Formatvorlage_PhytoSee.xls" (*format-template_PhytoSee.xls*) should be used to prepare the data.

In most cases, the three obligatory input tables can be imported into the PhytoSee tool in stages using the provided import function (button "Dateiimport" *import-data*), which provides guidance and user instructions (see section chapter 3.2), so that the above described "copy/paste" process can be avoided.

(In case of using one of the import assistances for importing non conform data, no import function is available and the copy/paste process is needed to insert the raw data into the prepared Access tables.)

It is not necessary so save the PhytoSee_XY.mdb file after each entry when entering data values into an Access-table, Access will auto save the file each time the cursor is moved out of a field, or after an input query is made.

In order that the size of the database (xy.mdb) does not increase unduly, due to temporarily saved but no longer needed content, it is useful from time-to-time to use the command "Compact and Repair Database" from the "Database Tools" menu.

3.1.2 DISCRIMINATING BETWEEN FIELD ATTRIBUTES

A database requires, among other things, that entries into a field (column) are pre-defined as being either "Text" (e.g. lake name), "a number" (e.g. a numerical value for a measurement such as Chlorophyll-a concentration) or a "Logical" Yes/No entry. The input data must be defined in Excel in the same format as stipulated in the included format template (see also Table 27). For example, data for Chlorophyll-a, Secchi depth and total phosphorus must be in numeric



columns when they are to be entered into the input table "Probendaten_Seen" (*sample-data lakes*). A numeric field can be defined either as a "General – No specific format" number, or as a "Number" with a fixed number of decimal places after the "." decimal delimiter. "General – No specific format" cells have no specific number format. To avoid any loss of precision when transferring data between Excel and Access, it is advisable to use "General – No specific format" fields in Excel.

As a matter of principle, special characters in numeric fields (such as < or >) cannot be read as numbers. Even a single cell formatted as TEXT, in an otherwise numeric column, will cause import problems. For the transfer of parameter values that are below the detection limit, a value that is half the detection limit is usually given in place. Special characters are not allowed in field names (column names): e.g. superscript numbers, brackets or "&" characters.

Numeric formatting (e.g. rounding to a single decimal place) cannot be transferred out of Access-tables into Excel using the export routine. This means that when the output of the PSI calculations is exported to Excel, the rounding of Index-Values is lost.

Advice for entering numbers into fields otherwise defined as text (e.g. the field "Seen Subtyp" *lake-sub-type*): The Excel-software automatically guesses and assigns the field type of newly entered data, which can be problematic. For example, if a "13" is entered as the lake type, Excel will automatically designate the type as "Number" and this must be overridden. Using the Excel command: "Format" >> "Cells" >> "Text", the current cell, and any highlighted cells, will be converted to "Text". A further error that can occur, due to the automatic field type recognition, is that the entry "11.1" for the lake type 11.1 may be recognised by Excel as a "Date", if the field is not already formatted as "Text".

3.1.3 THE PRIMARY KEY AND ITS HIERARCHICAL STRUCTURE IN THE PHYTOSEE TOOL

In a database, tables should be provided with a "Primary Key" that uniquely identifies each row (duplicate primary key values are not allowed within a table). Other tables that also contain the primary key can be linked together using the primary key (see FIGURE 1). In order that all linked tables only contain the same joint primary key (with referential integrity) it is needed to fill-in the import tables in a hierarchical principle.

In PhytoSee, the sampling location must be entered first, then the sample ID number, then the sample data, and finally the recorded phytoplankton taxa. If the sample location is missing in the field "Gewässername_SeeNr" (*Waterbody-name_LakeNo*), import of sample data will not be allowed. If the sample ID number (*LaufNr*) is missing from the field "Probendaten_Seen" (*sample-data lakes*), import of recorded phytoplankton taxa into the table "Taxon_BV_Seen" (*Taxon_BV_Lakes*) will not be allowed. To continue, the connection to the taxa list via the field "ID" is required. Finally, a numerical value must be entered in the field "Biovolumen mm³/l".

In all the above mentioned cases, an automatic error message is triggered if there is a key violation.

For Primary Key violations: "*Der Datensatz kann nicht hinzugefügt oder geändert werden, da ein Datensatz in der Tabelle "XY" in Beziehung stehen muss*" (the dataset cannot be appended or altered because a entry in another table "XY" must be related to it...)

For errors in compulsory fields: "*Sie müssen einen Wert in das Feld "XY" eingeben*" (a value must be entered in field "XY").

Primary key fields, and other fields for which an entry is defined as necessary, are compulsory fields in the PhytoSee tool.

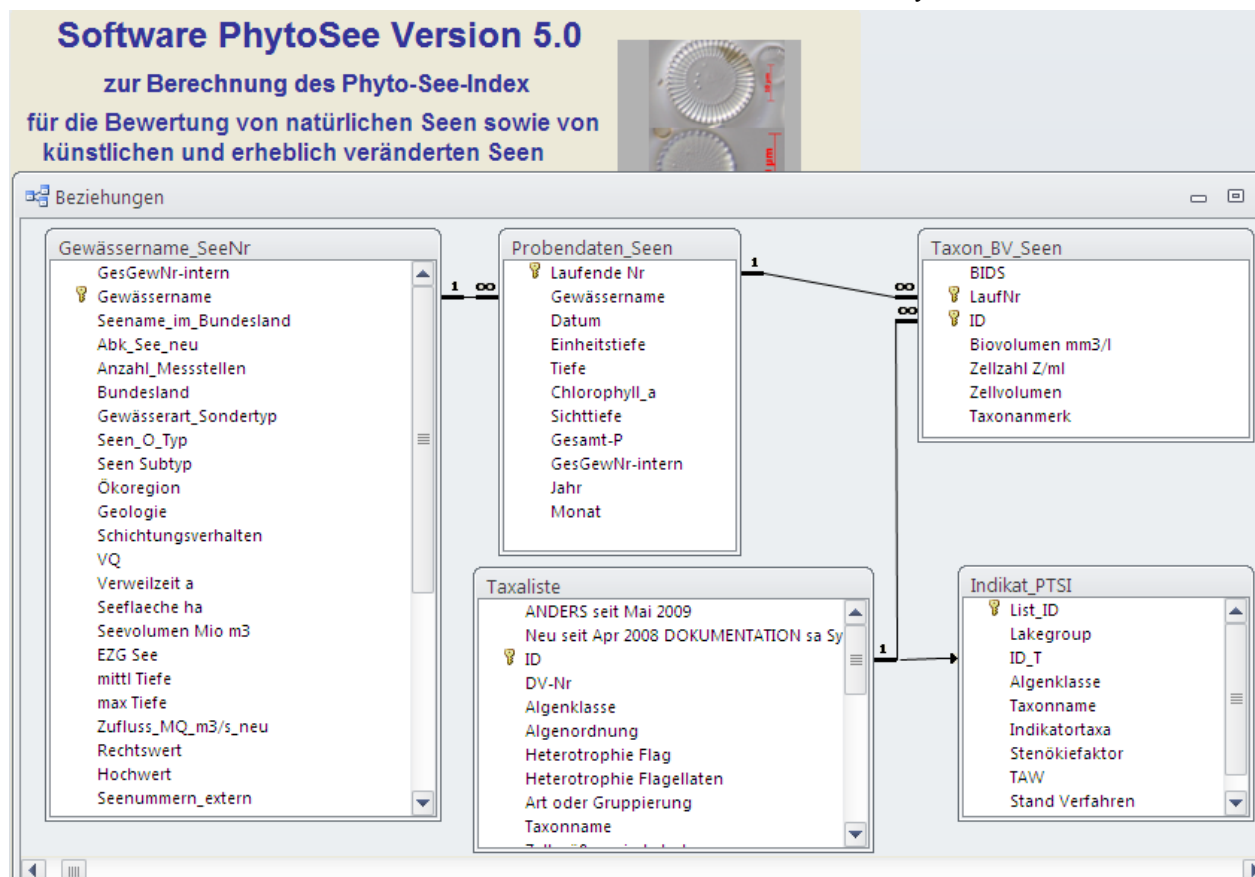


3.2 TEMPLATE FOR THE STRUCTURE OF THE SURVEY DATA TABLES

The survey data include a) the assignment of a studied lake to a particular lake type (see chapter 1.2.5), b) the chlorophyll-a concentration measured according to DIN, and c) the biovolumes of the individual recorded phytoplankton taxa, which according to Nixdorf et al. (2010) should be determined on at least six sampling visits per year.

The survey data must be organised in an Excel-based template file before importing into PhytoSee. The survey data are entered into 3 input tables. Compulsory fields are: a sample station identification code, the sample station name and the appropriate lake type for phytoplankton assessment. In addition to the sample ID number, the sample list, coupled via the sample station name and ID code, must include the date of sampling and the chlorophyll-a concentration. The recorded taxa list requires the sample ID number, the taxa identification code and the taxa biovolume. Optionally, further information to aid in the interpretation of the Phyto-See-Index can be entered in the non-compulsory fields of the template. These might include the total phosphorus concentration and the Secchi depth. Lakes with special conditions, or which belong to a special type (e.g. reservoirs), should be indicated in the field "Gewässerart_Sondertyp" (*waterbody type special*) (see chapter 1.2.6).

Figure 1: The input tables of PhytoSee_XY.mdb, shown with their linked fields, together with the harmonised taxa list and the indicator taxa list for the PTSI. This structure is also valid for PhytoSee 6.0.





Entries in the primary key fields must follow the same format for matching samples in all tables. The data types and the origin for entries in the compulsory fields of the three input tables are explained in Table 27.

Table 27 The compulsory fields for calculation of the Phyto-See-Index.

Name of the compulsory field	Explanation
Gewässername (lake station name)	Text field: Content is user defined; corresponds to sampling station name; contents of the corresponding fields in the input tables "Gewässername_SeeNr" (<i>Waterbody-name_LakeNo</i>) and "Probendaten_Seen" (<i>sample-data lakes</i>) must be identical.
Seen Subtyp (lake-sub-type)	Text field: The lake-sub-type, defined for the Phyto-See-Index, must be assigned as one of the abbreviations from Table 4 (1 st column): 1, 2+3, 4, 5, 6.1, 6.2, 6.3, 7, 8, 9, 10.1, 10.2, 11.1, 11.2, 12, 13, 14 AWB and HMWB lakes, and other special types from the North German Lowland, receive the suffix "k" behind the lake type number, e.g. 10.1k. Acidic mining lakes receive the suffix "s".
GesGewNr-intern (Internal lake station number)	Text field: Content is user defined; corresponds to the sample station ID code; contents of the corresponding fields in the input tables "Gewässername_SeeNr" (<i>Waterbody-name_LakeNo</i>) and "Probendaten_Seen" (<i>sample-data lakes</i>) must be identical.
GewässernameWB* (name lake/waterbody)	Text field: Content is user defined; corresponds to the name given to a whole lake or waterbody (which may have multiple sample stations) identified as distinct for EU-WFD purposes. If the whole waterbody is represented by the sample station given in "Gewässername", then this name can be repeated here.
GesGewNr-internWB*	Text field: Content is user defined; corresponds to an ID code for the whole lake or waterbody.
Auswahl (selection)	Yes / No-Field: Must be "Yes" to be included in the index calculation.
Laufende Nr = LaufNr (sample ID number)	Numeric field: (General – No specific format): this is a sample ID number to identify individual water samples. It is user defined and should include the waterbody name plus the data and possibly the depth of the water sample.
Datum: "Jahr"; "Monat" (Date: "Year"; "Month")	Date field: DD.MM.YYYY or similar. User defined from the date of sampling. From this the compulsory fields, Month and Year are derived.
Chlorophyll_a	Numeric field (General – No specific format): Concentration of chlorophyll-a ($\mu\text{g/l}$) measured according to DIN (Phaeophytin-a corrected) for each sample date.
ID	Numeric field (Integer): Taxon ID number according to the harmonised taxa list for Phytoplankton (HTL, see Mischke & Kusber Mai 2009).
Biovolumen mm^3/l (Biovolume)	Numeric field (General – No specific format, or with 9 decimal places): Microscopy determined biovolume of the species or taxon ($\text{mm}^3/\text{l} = \text{cm}^3/\text{m}^3$) calculated from cell count / ml and median cell volume of the taxon (see Nixdorf et al. 2010).

*Only relevant for the overall assessment for a lake which has been sampled and assessed at multiple sampling stations (an issue for table S_Wasserkörper_Bewertung).

Changes to the format template since its description in Mischke et al. (2008):

- The worksheet "Seenjahr" (*lake-year*) has been removed as it is not obligatory
- A new worksheet "DV_kodiert" for DV-coded taxa records according to Mauch et al. (2003) updated to the online-version of DV-Code from September 2011
- A new worksheet "DV_kodiert_m_Probendaten" (*DV_coded_m_sample-data*) for DV-coded taxa records with sample data for automatic creation of sample ID numbers



- The number of fields (columns) have been reduced in the table "Probendaten_Seen" (*sample-data lakes*). The preparation of survey data entails arranging the following tables according to the example given in the template file "Formatvorlage_PhytoSee_Auswertungsprogramm_02_03.xls" (*format template PhytoSee calculation program 02 03.xls*).

The following **three input tables** are to be filled-in in the Excel-file worksheets with the same names:

1. Gewässername_SeeNr (waterbody name_lake No.): Compulsory fields are "GesGewNr-intern" (*Waterbody number - internal*); "Gewässername" (*waterbody name*); "Seen Subtyp" (*lake type*)

Functions of the table: Assignment of sampling stations to lake-(sub)types, assignment of multiple sampling stations, when required, to a common waterbody and linking lakes to their hydrological and morphometric data.

2. Probendaten_Seen (sample data lakes): Compulsory fields are "Laufende Nr" (*sample ID number*); "Gewässername" (*Waterbody name*); "Datum" (*Date*); "Chlorophyll_a"; "GesGewNr-intern" (*Waterbody number - internal*); "Jahr" (*Year*); "Monat" (*Month*).

Functions of the table: Matching sample ID numbers (Laufende Nr) with sample dates (Beprobungsdatum) and trophic parameters such as chlorophyll-a, total phosphorus concentration, Secchi depth and sample depth.

3. Taxon_BV_Seen (taxon_BV_lakes): Compulsory fields are "LaufNr" (*sample ID number*); "ID"; "Biovolumen mm³/l (*biovolume mm³/l*)"

Functions of the table: Matching estimated taxon biovolumes to their appropriate taxon codes (ID) and sample ID numbers (Laufende Nr). Compact listing of all recorded taxa. Output of the simplified taxon names by linking to the taxa list in the Export-Table "Taxaliste_Roh" (taxalist raw). When there are cell counts for multiple size classes of the same taxon (Mehrfachnennung - duplicates), the input table "Aufsummierungshilfe" (summation help) should be used instead (see below).

In addition to the compulsory fields specified in Table 27 and in the format template, there are several other fields that are not obligatory for assessment. Such fields must be included as columns in the same order as in the template, even when empty.

3.2.1 HOW TO ARRANGE DATA FOR THE INPUT TABLE "GEWÄSSERNAME_SEENR"

There are five compulsory fields for this table (see Table 27): "GesGewNr-intern" (*lake station number - internal*); "Seename" (*lake station name*); "Seen.Subtyp" (*lake sub-type for phytoplankton*), "Auswahl" (*selection*) (with value TRUE) as well as the fields "GesGewNr-internWB" (*whole lake number*) and "SeenameWB" (*name of waterbody*), which allow the aggregation of multiple sampling stations from a single waterbody.

Entries in the fields "GesGewNr-intern" (*Waterbody number - internal*) und "Gewässername" (*Waterbody name*) must be identical to those in the table "Probendaten_Seen" (*sample-data lakes*) and refer to the sampling stations.

The field "Seen Subtyp" must be filled with the method-defined lake type code (see Table 4). The suffix "k" (e.g. 13k) is used to denote artificial and heavily modified lakes, and the suffix "s" (e.g. 13s) denotes acidic mining lakes. The field must be formatted as TEXT.



The input table "Gewässername_SeeNr" (Waterbody-name_LakeNo) contains a great number of optional fields regarding lake morphometry, hydrology, catchment land use and Gauss- Krüger- coordinates. These fields can be left empty or can be filled later directly in the Access tables.

Entries in the field "Bundesland" (German state) can be used to select a subset of lakes for export.

If the studied lake is a special type, e.g. reservoir, marsh lake, or quarry lake, an entry can also be made in the field "Gewässerart-SonderTyp" (unusual waterbody category or special type) for documentation.

3.2.2 HOW TO ARRANGE THE DATA FOR THE INPUT TABLE "PROBENDATEN_SEE"

The sample ID number encodes each entry in the input table "Probendaten" (*Sample-Data*) with a sample ID number "Laufende Nr" and adds the chlorophyll-a concentration, the sample depth (Eu for samples from the euphotic zone or Epi for epilimnion samples) and other optional chemical-physical variables (see the example in Table 28). Each sample ID number can only be used once (duplicates are not possible). For the compulsory field "Chlorophyll_a" there must be a minimum of four values per studied year. The corresponding sample ID number is entered again in the list of phytoplankton taxa biovolumes in the third input table "Taxon_BV_Seen" (*Taxon_BV_Lakes*).

Table 28 Input table "Probendaten" (*Sample data*) with examples.

Compulsory fields					Compulsory field			Compulsory fields		
					µg/l	m	µg/l			
General-format	Text field	Date field	Text - field		General-format			Text field	General-format	
Laufende Nr <i>sample ID number</i>	Gewässername <i>waterbody name</i>	Datum <i>date</i>	Einheits-tiefe <i>sample depth</i>	Tiefe <i>depth</i>	Chlorophyll_a	Sichttiefe <i>Secchi depth</i>	Gesamt-P <i>Total P</i>	GesGew-Nr-intern <i>Waterbody number - internal</i>	Jahr <i>year</i>	Monat <i>month</i>
460001	Beutelsee	11.04.06	Eu		44	1,2	137	BRB3463	2006	4
460002	Beutelsee	30.05.06	Eu			1,8	118	BRB3463	2006	5
460003	Beutelsee	27.06.06	Eu		14,3	2	169	BRB3463	2006	6
460004	Beutelsee	25.07.06	Eu		23,9	1,6	111	BRB3463	2006	7
460005	Beutelsee	22.08.06	Eu		27,4	1	105	BRB3463	2006	8
460006	Beutelsee	26.10.06	Eu		4,4	3	218	BRB3463	2006	10

The fields "Gewässername" (*Waterbody name*) and "GesGewNr-intern" (*Waterbody number - internal*) can be duplicated here when the same sample station has been repeatedly sampled. They must correspond exactly to those used in the table "Gewässername_SeeNr" (*Waterbody-name_LakeNo*).

Entries must be made in the fields "Datum" (*date*), "Monat" (*month*) and "Jahr" (*year*) for each sample ID number. Note: when preparing the data in Excel, it is possible to automatically fill in the fields "Monat" and "Jahr" from the "Datum" field using the built in Excel-functions. For sampling dates that lie at the very end or beginning of a month, the "Monat" field can be altered by hand to shift the sample to the neighboring month. This can be beneficial when there is an unfavourable distribution of sample dates, such that e.g. there are two samples for one month but none for the neighbouring month.



Entry of chlorophyll-a concentrations is required for each sample date. However, even without a chlorophyll-a entry, the PhytoSee tool will calculate a biomass-index on the basis of the total phytoplankton biovolume alone and give an appropriate warning.

The use of a primary key prevents the same sampling dates being imported more than once. Importation of already existing entries with the same sample ID numbers (*Laufenden Nummer*) will be blocked and an error message given stating that a key violation would occur for a portion of the data and so the import cannot be carried out.

A key violation such as the above can indicate either that the same key (sample ID number "*Laufenden Nummer*") has been used for different samples, or that a partial import of the same sample has been previously made (e.g. of the chlorophyll-a concentration before the phytoplankton count data were available). In both cases the cause must be verified, and different sample ID numbers ("*Laufende Nr*") for the sample dates must be supplied by the user. Delete the data of the partial import before importing the complete data. Note that the same "*Laufende Nr*" must be used to identify the same samples in the table "*Taxon_BV_Seen*" (*Taxon_BV_Lakes*).

3.2.3 HOW TO ARRANGE DATA FOR THE INPUT TABLE "*TAXON_BV_SEEN*"

If the method description for sampling and analysis is followed, for each sample date there will be a quantitative list of recorded taxa biovolumes (in mm³/l) for at least 15–20 phytoplankton taxa. Each entry in this list has two different code numbers (short codes): first the Taxa-Code (ID) and second the sample ID number (LaufNr) which identifies the sample in the table "*Probendaten_Seen*" (*sample data lakes*).

Assignment of Taxa-Codes:

All listed taxa are to be given, by the user, a specific Taxa-Code (ID) following the guidance in the **Harmonised Taxa List** (HTL of Mischke & Kusber 2009). The Taxa-Code (ID) lists all taxon names when using identification keys which are provided for the user by a special abbreviation (s. column "*Identifikationswerk*" in HTL) Doing so, each taxon is assigned to a consistent commonly accepted taxon name. A lot of additional information is given alongside this, such as the author and year of the first description of the taxon, its position in the taxonomic system (Class, Order, Family) and its presence on the indicator taxa lists of the assessment system (see Table 33).

Table 29 Input table "*Taxon_BV_Seen*" (*Taxon_BV_Lakes*) with field names and explanations (rows 1-2). The compulsory fields are highlighted and example data are given in the 3rd – 6th rows.

BIDS	LaufNr <i>Sample no.</i>	ID	Biovolumen mm³/l	Zellzahl Z/ml <i>Cell count</i> <i>cells/ml</i>	Zellvolumen <i>Cell volume</i>	Taxonanmerk <i>Taxon comments</i>
empty	As in table " <i>Probendaten_Seen</i> "	Taxon_ID from the harmonised taxa list (HTL)	Formatted as "General" or Numeric with 9 decimal places	Data must be formatted as "General"	Data must be formatted as "General"	Deviations from the taxon names in the HTL entered here
	Compulsory fields					
	460001	55	0.628639371	889.16459	707	
	460001	222	0.476245864	284.32588	1675	
	460002	228	0.93119055	173.18031	5377	



Optional fields include "Taxonanmerk" (*taxonomy comments*), "Zellzahl (Zellen/ml)" (*cell count cells/ml*) and the specific "Zellvolumen" (*cell volume*). The column "BIDS" should remain empty and will be automatically filled by the PhytoSee tool during the import process.

If the recorded taxa list is coded using the DV-Code system from the "Taxaliste der Gewässerorganismen Deutschlands" of Mauch et al. (2003), which is widely used in German states, and if the latest version of the Excel taxa-list has been used (from September 2001), then the PhytoSee tool (version 5.0 and later) offers a conversion table to automatically transfer the DV-coded records to the HTL coding system (see below, Import help "DV_Coded").

If a different coding system, or taxonomy/identification key, was used than that provided in the HTL, the cell-counter/taxonomist is responsible for the correct assignment of species names, author and year of the first description. Help is available via the list of synonymous names (Kusber 2009). If a taxon is confidently identified but cannot be found in the HTL, then it should first be searched for in the synonym list, in case the taxonomy has been revised or updated and therefore the taxon is known under a different name in the HTL.

The following rules should be followed when assigning a Taxon-ID and the determined species name is not in the HTL:

If a taxon cannot be found in the synonym list (Kusber 2009), the ID of the next highest taxonomic rank should be assigned; i.e., an unlisted species should be given the Taxon-ID of the Genus level, an unlisted Genus should be given the Taxon-ID of the corresponding next higher taxonomic rank, the "family" or "order", and so on. In this situation, the originally identified taxon name should be entered into the field "Taxonanmerk" (*taxon comments*).

In the comment field for taxon names "Taxonanmerk" (*taxon comments*), comments should be made about unsure species identifications and the names of new species. For example, *Aulacoseira* cf. *granulata* is always given the Taxon-ID of the Genus level, but in the "Taxonanmerkung" field "*Aulacoseira* cf. *granulata*" is noted. Although entries in the "Taxonanmerk" field are ignored during calculation of the Phyto-See-Index, they are included in the export file in the worksheet "Rohdaten" (*raw data*). Entries in the "Taxonanmerk" field may be evaluated in future projects to further develop the PSI or to expand the HTL.

Assignment of recorded taxa to a sample ID number (*Laufende Nummer*):

All quantified taxa taken on the same date from the same sampling station with the same waterbody identification number (*Gewässer-Identifikationsnummer*) must be given the same sample ID number (*Laufende Nummer*, *LaufNr*). This step must be carried out by the user themselves. Because at least 6 samples are required per year, there must therefore be at least 6 sample ID numbers (*Laufende Nummern*) assigned. This can be done either by using the already existing identification number used in the laboratory or a new unique number is created. In German Federal States in which the station ID number and date of sampling are combined to create an ID for the sample, a unique numerical sample ID number (*Laufende Nummer*) must be created for each sample, using a calculation method determined by the user. In the input table "Taxon_BV_Seen" (*taxon_BV_lakes*) values of the sample ID number are duplicated for each taxon recorded on the same date and station. In contrast, duplicate entries of the same Taxon ID number for the same sample are not allowed. Therefore, importation of a second instance of an identically coded taxon will be refused by the PhytoSee tool. The taxa record list must in this case be pre-prepared with the help of the summation assistance (see below).

Once the fields "Taxon-ID", "LaufNr" (*sample ID*) and "Biovolumen mm3/l" have been filled for all taxa, the compulsory fields in the input table "Taxon_BV_Seen" (*Taxon_BV_Lakes*) are complete.



3.2.3.1 IMPORT-ASSISTANCE "SUMMATION-ASSISTANCE"

If the microscopic analysis is carried out according to Nixdorf et al. (2010), taxa that vary greatly in size will have been counted in size-classes. This means that there will be multiple entries with the same Taxon-ID for the same Sample-ID "Laufende Nummer" in the taxa records list. The taxon biovolume values must be summed for the index calculation by the PhytoSee tool. For this, the summation-assistance in the PhytoSee tool can be used.

Table 30 Input table "Aufsummierungshilfe" (*summation assistance*) for taxa counted in size-classes. Field names and descriptions are given in rows 1-2, two example entries in rows 3-4, and the method of data aggregation used when the table "Taxon_BV_Seen" (*Taxon_BV_Lakes*) is linked is given in the final row.

Laufende Nr <i>sample ID number</i>	T_ID	Biovolumen <i>mm³/l</i>	Zellzahl <i>Z/ml</i> <i>cell count</i> <i>cells/ml</i>	Zellvol μm^3 bzw Trichombreite <i>cell volume μm^3 or</i> <i>Trichome width</i>	Messeinheit nicht Zelle <i>units of non-</i> <i>cells but</i> <i>colonies</i>	BID	Taxon- anmerkung <i>Taxonomy</i> <i>notes</i>
<i>As in table</i> <i>"Proben-</i> <i>daten_ Seen"</i> <i>sample data</i> <i>lakes</i>	<i>Taxon_ID</i> <i>Number</i> <i>from the</i> <i>Taxa list</i> <i>HTL</i>	<i>Formatted as</i> <i>"General" or</i> <i>Number with</i> <i>9 decimal</i> <i>places</i>	<i>Formatted</i> <i>as</i> <i>"General"</i>	<i>Formatted as</i> <i>"General"</i>	<i>empty</i>	<i>empty</i>	<i>Deviations</i> <i>from the</i> <i>taxon names</i> <i>in the HTL</i>
Compulsary fields							
460006	55	0.199595					<30 μm
460006	55	0.555199					>30 μm
Group	Group	Sum	Sum	Mean			First value

The summation-assistance (*Aufsummierungshilfe*) is an input table that can be used in place of the input table "Taxon_BV_Seen" (*Taxon_BV_Lakes*). It is not necessary to separately enter here only those records with duplicate entries, rather the entire data packet (entire recorded taxa list with all Taxa-ID and biovolumes coded with sample ID numbers) can be imported this way. The correct configuration of the survey data is detailed in the template input table "Aufsummierungshilfe" and is as shown in Table 30. The compulsory fields are the same as those for the "Taxon_BV_Seen" table: "Laufende Nr" (*sample ID number*), Taxon-ID = "ID" and "Biovolumen(n) mm³/l".

- The data are entered into the filed area of the Excel template file for the input table "Aufsummierungshilfe".
- The data-region is then copied (without headings) to the clip-board, and entered into the open Access table "Rohdaten_Taxon_BV_mit_Groessenklassen" (*raw-data_taxon_BV_with_size-classes*) using the "Append Data" function.
- Change to the "Design" view of the **QUERY** "Aufsummierung_Rohdaten_Groessenklassen" and execute the query by clicking the [! Run] button.

Two questions will then appear in a window and should both be answered with "Yes":

"Sie beabsichtigen, eine Anfügeabfrage auszuführen, die Daten in Ihrer Tabelle ändern wird." (*agree to carry out a query that will alter the table*)

"Sie beabsichtigen X-Zeilen anzufügen?" (*agree to add X-rows to the table*)

After this, the summed taxa biovolumes and all further required fields will be automatically added to the input table "Taxon_BV_Seen" (*Taxon_BV_Lakes*). In this step, not only the biovolumes, but also the other fields will be grouped, summed, the first entry used, or the mean taken, as indicated in the final row of Table 30.



Justification for the preclusion of duplicate listing of taxa: Assessment by the metric PTSI using indicator taxa converts the taxa biovolumes into 8 "abundance classes" (see Table 21). Partial biovolumes from the same taxon (e.g. when counted in size-classes) might each be assigned a different abundance class, and the mean of these would not produce the same abundance class as would the summed total biovolume for that indicator taxon.

3.2.3.2 IMPORT-ASSISTANCE "DV-KODIERT"

The import-assistance "DV-kodiert" (*DV-coded*) should be used once the tables "Gewässername_SeeNr" (*Waterbody-name_LakeNo*) and "Probendaten" (*Sample data*) (with sample ID No and and chlorophyll-a values) have already been completed and imported, and only the table "Taxon_BV_Seen" (*Taxon_BV_Lakes*) remains to be prepared and imported. (If the table "Probendaten_Seen" (*Sample data_Lakes*) has not been created then the import-assistance "DV_kodiert_mit_Probendaten" (*DV_coded_with_Sample-Data*) is used).

- a) The data are entered into the field-area of the template file (see Excel sheet table) for the input table "DV-kodiert" (*DV_coded*).
- b) The data-region is then copied, without headings, to the clipboard, and entered into the open Access table "Rohdaten_DV_kodiert" (*Raw-data_DV_coded*) using the Access-function "Append Data".
- c) Change to the "Design" view of the **QUERY** "Anfügeanfrage_bei_Rohdaten_DV_kodiert" and execute the query by clicking the [! Run] button.

Two questions will then appear in a program window and should both be answered with "Yes":

"Sie beabsichtigen, eine Anfügeabfrage auszuführen, die Daten in Ihrer Tabelle ändern wird." (*agree to carry out a query that will alter the table*)

"Sie beabsichtigen X-Zeilen anzufügen?" (*agree to add X-columns to the table*)

The result of this is that the DV-coded taxa are automatically given a Taxon-ID from the harmonized taxa list and entered into the Access table "Taxon_BV_Seen" (*Taxon_BV_Lakes*). The translation is made according to the table "Translate_von_DV_Nr_nach_HTL" (*Translate_from_DV_No_to_HTL*).

Note: The entry of duplicated taxa (due to size-classes, etc.) is not possible, and will generate a key violation error message. If this occurs biovolumes from the same sample belonging to the same taxon must be summed in advance by the user.

3.2.3.3 IMPORT-ASSISTANCE "DV KODIERT MIT PROBENDATEN"

The import-assistance "DV-kodiert_m_Probendaten" (*DV-coded with Sample data*) can be used when you want to simultaneously create the tables "Probendaten_Seen" (*Sample-data_Lakes*) and "Taxon_BV_Seen" (*Taxon_BV_Lakes*) from DV-coded data. To do this, the compulsory fields concerning lake details must already be filled-out in the input table "Gewässername_SeeNr" (*Waterbody-name_LakeNo*) otherwise the resulting query will return zero rows.

- a) The data are manually entered into the field area of the template file (Excel table) for the input table "DV-kodiert_m_Probendaten" (*DV_coded_with_Sample-data*).



- b) The data-region is then copied, without headings, to the clipboard, and entered into the open Access table "Rohdaten_DV_kodiert_mit_Probedaten" (*Raw-data_DV_coded_with_Sample-data*) using the Access-function "Append Data".
- c) Change to the "Design" view of the **QUERY** "Anfueg_Probedaten_aus_TabRohdaten_DV_code_mit_Probedaten" and execute the query by clicking the [! Run] button.
- a) Finally carry out the **QUERY** "Anfueg_TAXA_bei_Rohdaten_DV_kodiert_mit_Probedaten" by double clicking the query name.

In steps c and d two questions will appear in the program window which must be answer "Yes"

1. "Sie beabsichtigen, eine Anfügeabfrage auszuführen, die Daten in Ihrer Tabelle ändern wird." (*agree to carry out a query that will alter the table*)
2. "Sie beabsichtigen X-Zeilen anzufügen?" (*agree to add X-columns to the table*)

With the query "Anfueg_Probedaten_aus_TabRohdaten_DV_code_mit_Probedaten" (*Append sample data from table raw-data DV coded with sample-data*), sample ID numbers will be taken either from the field "ProbenNr_org_Zahl" or the field "Laufende Nr". If there are missing entries, or a key violation due to a "ProbenNr_org_Zahl" being the same as an existing sample ID number, a new "Laufende Nr" will be automatically generated. This is created by adding 1 to the largest existing sample ID number (*Laufenden Nummer*) in the table "Probedaten_Seen" (*Sample-data_Lakes*). Therefore there must already be at least one sample with a "Laufenden Nr" in the table (see example table "Probedaten_Seen_leer" (*Sample-data_Lakes_empty*)).

In addition to the sample ID number, this query also fills in the other compulsory fields in Access-table "Probedaten_Seen".

With the subsequent query "Anfueg_TAXA_bei_Rohdaten_DV_kodiert_mit_Probedaten" (*Append TAXA from raw-data DV-coded with sample-data*), the DV coded taxa are automatically given a Taxon-ID from the harmonised taxa list (HTL) and entered into the table "Taxon_BV_Seen" (*Taxon_BV_Lakes*). The translation is made according to the table "Translate_von_DV_Nr_nach_HTL" (*Translate from DV No to HTL*). The sample ID number is taken from the field "Laufende Nr" of the previously filled Access-table "Probedaten_Seen" and matched to the recorded taxa.

Note: It is not possible to append duplicate taxa entries from the same sample (e.g. due to size classes), and this will provoke a key violation error. In this situation the biovolumes from the same taxon and sample must be summed in advance by the user.



3.3 IMPORTING TABLES INTO PHYTOSEE WHICH HAVE BEEN PRE-PREPARED IN EXCEL

The PhytoSee tool has an import function for Phytoplankton-Data on its starting page with a button labelled "Import Excel-Daten" (*Import Excel Files*) (see FIGURE 2, Middle). Correctly listed taxa records (with biovolumes summed per taxon and sample, and ID coded according to the HTL) can be imported to the input tables of the Access database using the import-button-function. This functionality is not available for the three import assistance systems described in the previous three sub-chapters.

The import function ensures that the above described hierarchical coupling of the input tables is maintained during importation. On pressing the "Import Excel-Daten" button, the three pre-prepared input Excel template files "Formatvorlage.xls" (each a separate worksheet in Excel) are loaded, one after the other, by the Access-Program "PhytoSee_XY-mdb", checked for inadmissible duplicate entries, and imported.

Figure 2: The first page of "PhytoSee_6_0_PhytoLoss_1_2_XY.mdb"* showing the Import and Export buttons; middle for phytoplankton and on the right for Metazooplankton. The integrated Access objects can be found/opened using the navigation area to the left, and are arranged in the groups: "Eingangstabellen" (*input tables*), "Anfüge-Hilfen" (import assistance), "Bewertungsrelevanten Tabellen fuer den Phyto-See-Index" (relevant tables for assessment with the Phyto-See-Index), and "Nicht zugewiesenen Objekte" (*other objects*). Objects belonging to the PhytoLoss-Module are in groups with the prefix "PL_".

*In this image, the view options in the left-hand navigation area of Microsoft Access (2010) were selected as: benutzerdefinierten Gruppen / alle anzeigen / (Anzeigen als Liste) / sortiert nach Name (*user defined groups / show all / (show as list) / sort by name*).



3.3.1 IMPORTING WATERBODY DATA

To import waterbody data, press the button "Import Excel-Daten" on the first page of "PhytoSee_XY.mdb". The following window(s) will appear:

Window: "1st Step: Import Waterbodies – Do you wish to import waterbody data?" - Answer with "Ja" (*Yes*) and select/enter the path to the Excel-file with the pre-prepared input tables (*Formatvorlage_Seen_XY.xls*) in the newly opened window, then press the button "Öffnen" (*open*). A window should appear with the message "Gewässerimport abgeschlossen – Import erneut aufrufen für weitere Daten" (*Waterbody import concluded – To import more data start the process again*).

3.3.2 IMPORTING SAMPLE DATA

To import sample data, press the button "Import Excel-Daten" on the first page of "PhytoSee_XY.mdb". The following window(s) will appear:

Window: "1st Step: Import Waterbodies – Do you wish to import waterbody data?" (*Wollen Sie Gewässerdaten importieren?*) – Answer with "Nein" (*No*).

Window: "2nd Step: Import Samples – Do you wish to import sample data?" (*Wollen Sie Probenimportieren?*) – Answer here with "Ja" (*Yes*) and select/enter the path to the Excel-file with the pre-prepared input tables (*Formatvorlage_Seen_XY.xls*) in the newly opened window, then press the button "Öffnen" (*open*). A window should appear with the message "Probenimport abgeschlossen – Import erneut aufrufen für weitere Daten" (*Sample data import concluded – To import more data start the process again*).

3.3.3 IMPORT TAXA RECORDS

To import taxa records, press the button "Import Excel-Daten" on the first page of "PhytoSee_XY.mdb". The following window(s) will appear:

Window: "1st Step: Import Waterbodies – Do you wish to import waterbody data?" (*Wollen Sie Gewässerdaten importieren?*) – Answer with "Nein" (*No*).

Window: "2nd Step: Import Samples – Do you wish to import sample data?" (*Wollen Sie Probenimportieren?*) – Answer with "Nein" (*No*).

Window: "3rd Step: Import taxa records (Probenimport – Taxadaten importieren). Answer here with "Ja" (*Yes*) and select/enter the path to the Excel-file with the pre-prepared input tables (*Formatvorlage_Seen_XY.xls*) in the newly opened window, then press the button "Öffnen" (*open*). A window should appear with the message "Taxaimport abgeschlossen – Import erneut aufrufen für weitere Daten" (*Taxa record import concluded – To import more data start the process again*).

For all three import steps, error warnings will be given if inadmissible duplicate entries are present (i.e. triggering key violation errors), either because the data were already in the database or because the Sample-ID numbers, or Taxa-ID numbers for an existing sample, have already been used. Advice for resolving errors will also be given (FIGURE 3).

The import assistance searches for identically named worksheets and column names, such that the order of the columns is not important, but their names and formats must not be changed from those in the templates.



As an alternative to using the import assistance, chapter 3.1.1 describes how pre-prepared input tables can be imported. Input data are copied from the data regions of pre-prepared Excel tables and entered into the corresponding identically named Access table using the "Paste Append" function, as described in chapter 3.1.1 and in the data format templates.

Figure 3: Warning/Error messages given by the PhytoSee tool if data to be imported already exist in the database. This prevents the entering of duplicate records.



When entering data manually, it is very important to pay attention to the column order in the prepared Excel table, which must be identical to the Access table. If the column order is incorrect in the Access file, this can be easily rearranged to match the template: columns can be dragged and dropped while in the Access "table view". [Note: The column order in table "Gewässername_SeeNr" (*Waterbody-name_LakeNo*) is different in PhytoSee 6.0 Version 26.01.2015 to that in the data format template. This will be corrected in the next update.]

3.3.4 DELETION OF PARTIALLY IMPORTED DATA PACKETS

Partially imported data packets must be removed prior to using the summation assistance. Therefore, all entries (rows) of a sample in the Access input table "Taxon_BV_Seen" (*Taxon_BV_Lakes*) should be deleted.

If there are data in the input table "Taxon_BV_Seen", which, due to a partial data import need to be summed together with further biovolume entries from the same data packet (identifiable from the field "LaufNr" (*sample ID number*)), these must be completely deleted before any new importation is made using the summation assistance.

To delete them, all rows from the relevant packet (identified by the LaufNr) can be marked with the cursor in the Access-Table and deleted using the Access command "Bearbeiten; Datensatz löschen" (*Delete Record*).



3.3.5 INCLUDING THE EXTERNALLY CALCULATED DI-PROF-INDEX IN THE PHYTO-SEE-INDEX

To enter externally calculated DI-PROF-Index values into PhytoSee, the input table "DI-PROF" in the format template "Formatvorlage_PhytoSee_XY.xls" can be used. Once the compulsory fields in the Excel template have been filled, each See-Nummer (*lake-number*) and year of each row of the DiProf-Note (classification number by DiProf index) will be filled and manually entered into the Access table "Bewertung_di_Prof" (*assessment_di_Prof*) using the "Paste Append" function. The Access table "Bewertung_di_Prof" is found (since PhytoSee Version 6.0) in the navigation group "Bewertungsrelevante Tabellen fuer den Phyto-See-Index" (*assessment relevant tables for the Phyto-See-Index*).

Once the DiProf-Note has been successfully entered, the DI-PROF index will be automatically integrated into the final Phyto-See-Index assessment value for lowland lakes – using the appropriate type specific weighting factors. This can be checked by viewing the Access query "S_Gesamtbewertung_1" (*S-Final-Assessment_1*) by clicking the button "Bewertungsergebnisse Seen – Messstellen" (*assessment results lakes – sampling stations*) (see chapter 4.4.1).

Automated calculation of the optional assessment metric DI-PROF, according to Schönfelder (in Mischke et al. 2008) cannot be carried out with the PhytoSee tool. Instead, this can be achieved using the tool "DiProfBerech.mdb", which is available on request. Because the taxonomic coding of the diatoms is done according to the DV-Liste 2007, and this has since undergone extensive revision, the correct assignment of DI-PROF indicator taxa names cannot be automated and must be carried out by a diatom specialist.

3.4 CALCULATION OF THE PHYTO-SEE-INDEX AND OUTPUT OF THE ASSESSMENT RESULTS

3.4.1 CHECKING THE COMPLETENESS OF THE ASSESSMENT RESULTS WITHIN THE PHYTOSEE TOOL

To calculate the Phyto-See-Index and all associated metrics, the button "Bewertungsergebnisse Seen – Messstellen" (*assessment results lakes – sample stations*) must be pressed on the starting page of PhytoSee_xy.mdb, and the subsequent question, "Sollen alle Zwischenergebnisse neu durchgerechnet werden?" (*should all intermediate results be recalculated?*), answered with "Ja" (*Yes*). The answer "Nein" (*No*) only makes sense if there has been no change to the data, i.e. no further data have been imported since the previous calculation.

A blue window will appear with the message "Berechnung läuft!" (*calculation in progress*) – and, depending on the amount of data and speed of the machine, it can take from a few seconds to several minutes for the Access Query table "S_Gesamtbewertung_1" (*S_final-assessment_1*) to appear. For each individual combination of sampling station and surveyed year, a row of assessment results is produced, together where applicable with the required supplementary information and warnings messages (see chapter 2.6.1). The table "S_Gesamtbewertung_1" also provides a check, prior to exporting the results, that the complete number of survey years and sample stations are present.



If one or more survey years are missing from table "S_Gesamtbewertung_1", the following entries should be checked:

- 1) Do the values in the fields "Gewässername" (*Waterbody name*) and "GesGewNr-intern" (*Waterbody number - internal*) in the input tables "Gewässername_SeeNr" (*Waterbody-name_LakeNo*) and "Probendaten_Seen" (*sample-data lakes*) match identically?
- 2) Are there any missing entries in the field "GesGewNr-intern" (*Waterbody number - internal*) of the input table "Probendaten_Seen" (*sample-data lakes*) – or missing entries for any survey date in any other compulsory field?
- 3) Check that all entries in the field "Seen Subtyp" (*lake sub-type*) in the input-table "Gewässername_SeeNr" (*Waterbody-name_LakeNo*) correspond to one of the abbreviations in Table 4 on page 9.
- 4) For the missing stations/years, are there fewer than the required minimum of 4 samples during the period March to November? If this is the case then the Phyto-See-Index will not be calculated for those years, and no results row returned.

Where all compulsory fields are correctly filled, all survey years will appear in the results table "S_Gesamtbewertung_1".

Please note: The contents of the field "Seen Subtyp" (*lake sub-type*) in the results table "S_Gesamtbewertung_1" is automatically given the prefix "PP" to indicate the bio-component phytoplankton. For example, for the lake type 10.1, the type number "PP 10.1" will be given.

The entire contents of the Access table "S_Gesamtbewertung_1" can be selected at once by clicking in the upper left most grey field. The contents can then be copied to the clipboard and pasted into Excel.

3.4.2 EXPORT OF THE ASSESSMENT RESULTS

The usual way to export the assessment results, together with column heading names, is by exporting to an Excel file by clicking the button "Export Bewertungsergebnisse" (*Export Assessment Results*) on the starting page of PhytoSee. The window "Auswahl der Datensätze nach Bundesland" (*select data according to German state*) will open, with the default "alle" (*all*) preselected. This selection can be overwritten by the user with the first letters of a German state name. After clicking "OK", the corresponding data for export are selected and the window "Speichern unter" (*save as*) will appear with an automatically generated suggested file name of the form:

"PhytoSee-Export_5.0_15-08-2013_12-41Uhr.xls"

The export file will be saved once a location to save the file has been selected. The saving process can take from a few seconds to several minutes because the entire calculation has to be remade. The window "Berechnung läuft" (*calculation in progress*) will appear with a progress indicator. A window with the message "Daten wurden unter – x Datei-Pfad – abgespeichert" (*file has been saved under the path xxx*) will appear to confirm that the export process is complete.

The PhytoSee export file contains multiple worksheets and a large amount of information. An overview of the exported results is shown in Table 31. The worksheet "Info" contains the PhytoSee tool version number and lists all field names from the table "Gesamtbewertung" (*final assessment*) with explanations.

Additionally, all intermediate results of the individual metric calculations are included on additional worksheets in the export file (see Table 31).

**Table 31** Generated Excel-Worksheets in the PhytoSee tool export file.

Worksheet name	New?	Description
Gesamtbewertung (<i>final assessment</i>)	Enhanced since PhytoSee 5.0	Phyto-See-Index for each sampling station and more*
S_Wasserkörper_Bewertung (<i>S_waterbody_assessment</i>)	since PhytoSee 4.0	Phyto-See-Index for the "waterbody": when appropriate, the mean of Phyto-See-Indices from multiple stations at a single lake or lake-basin*
S_BW_BV_AlgK	since PhytoSee 2.0	Assessment of total biovolume, mean vegetation period chl _a , max chl _a as well as individual results from the Algal Class assessment
S_Klassen_Saison_Kreuztabelle (<i>S_Classes_Season_Crosstable</i>) (in PhytoSee 5.0 still called "S_Bew_Klassen_alle")	different in PhytoSee 5.1	Summed biovolumes and percentage composition of the Algal Classes during assessment relevant time periods, and total biovolume.
S_PTSI_Tag (<i>S_PTSI_Day</i>)	since PhytoSee 2.0	Phytoplankton-Taxa-Seen-Index (PTSI) calculated per day. Note: for the PTSI, samples from the winter period are not excluded.
S_PTSI_Taxa_Roh (<i>S_PTSI_Taxa_Raw</i>)	since PhytoSee 2.0	Lists of all used indicator taxa for each plankton sample, with TAW and Stecocy factors, their taxon biovolumes and transformation into one of 8 abundance classes (see Table 21). (for each station and date)
Taxa_Rohliste (<i>Taxa_raw-list</i>)	since PhytoSee 2.0 + Chl _a	Returns the entered recorded-taxa-lists with ID coding according to the harmonised taxa list (see Mischke & Kusber Mai 2009). Includes sample number, lake name, chlorophyll-a concentration and date. Size classes for each taxon and date are summed.
DV_Taxa_Uebersetzung_Import (<i>DV_taxa_translation_import</i>)	new	Documents originally entered DV_Nr taxon names and their conversion to taxa names and IDs from the internal harmonised taxa list (HTL)
Zoo_morpho_GILDEN_Phyto_export (<i>Zoo_morpho-gild_phyto_export</i>)	new	Returns the entered recorded taxa lists for phytoplankton, grouped according to edibility guilds for zooplankton for the use in the "PhytoLoss" module.
Saure_Seen (<i>acidic lakes</i>)	new	Phyto-See-Index for each sampling station (biomass and diversity based)

*Explanations of the columns of this table can be found in the "Info" worksheet of the export file.

In this way, the user can for example extract the PhytoSee calculated percentage contribution of the individual Algal Class biovolumes to the seasonal mean total biovolume (Ges_BV2) from the worksheet "S_Klassen_Saison_Kreuztabelle". It is also often of interest to the user to know which of the recorded taxa have been used as indicator taxa for the Phytoplankton-Taxa-Seen-Index (PTSI), and which abundance classes, trophic anchor values (*Trophieankerwert* TAW), and weighting factors they have been assigned (in export worksheet "S_PTSI_Taxa_Roh").

The tool should be exited by clicking the button "Programm beenden" (*close program*).

Changes to the export files in the latest version of PhytoSee include:

- New fields in the assessment output are "Version-Programm" (*program version*), "Hochwert", "Rechtswert" (*Northing and Easting*), "Seename_im_Bundesland" (*lake name in its German state*), "Beschreibung des Phytoplankton Seesubtyps" (*description of the phytoplankton lake type*) as well as five new parameters for the Algal Classes metric.
- Changes since version 4.0 of PhytoSee 4.0: Separate assessment of individual sampling stations (worksheet "S_Gesamtbewertung") and subsequent assessment of whole waterbodies (as appropriate) by calculating the mean of multiple sampling stations (worksheet "S_Wasserkörper_Bewertung")
- Output of the assessment for acidic mining lakes (worksheet "Saure_Seen_PSI")
- Documentation of the assignment of taxa names from the PhytoSee tool's harmonised taxa list to taxa imported with DV-Coded taxa names (DV_Taxa_Uebersetzung_Import)
- Output of the edibility guilds of phytoplankton for the calculation of a zooplankton grazing-effect index.



4 LITERATURE RELEVANT TO THE DESCRIPTION OF THE PHYTO-SEE-INDEX

4.1 NATIONALLY APPLICABLE STANDARDS, REGULATIONS AND DECISIONS OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

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- DIN EN 15204 (2006-12): Wasserbeschaffenheit - Anleitung für die Zählung von Phytoplankton mittels der Umkehrmikroskopie (Utermöhl-Technik); Deutsche Fassung EN 15204: 2006
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6 ANNEXES TO HANDBOOK PHYTO-SEE-INDEX

6.1 ANNEX I: MODIFICATION OF CODING LIST

Please note that an update for German coding list will be available at the end of the year 2017.

Table 32 List of modifications of the coding list for phytoplankton species (HTL) since version May 2009.

Taxonname	Taxon ID HTL	DV-Nr	Modifications since May 2009	Indicator Taxon in PTSI
<i>Cyclotella pseudocomensis</i>	3000	16867	New species	X
<i>Oscillatoria tenuis</i>	3001	8004	New species; until 2011 confused with <i>Leptolyngbya tenuis</i> (ID 427)	X
<i>Cyclotella balatonis</i>	3002	36300	New species a part of former <i>Cyclotella radiosa</i> (p.p. <i>C. comta</i>)	X
<i>Discostella</i>	3003	26287	New genus	X
<i>Discostella stelligera</i>	266	26897	New species and including <i>Discostella stelligeroides</i>	X
<i>Cyclotella costei</i>	254	26891	Synonym: <i>Cyclotella cyclopuncta</i>	X
<i>Surirella ovata</i>	1310	6016	Taxon deleted: findings sort to Taxon ID 734	
<i>Aulacoseira pusilla</i>	1867	26882	Eintrag korrigiert fuer "Mindestbestimmungsniveau"	
<i>Mychonastes jurisii</i>	275	17310	Synonym <i>Pseudodictyosphaerium</i> (Simpson & Van Valkenburg, 1978)	
<i>Neocystis/Mychonastes</i> (Syn <i>Pseudodictyosphaerium</i>)/ <i>Chori cystis</i>	883		Taxon group deleted - (Simpson & Van Valkenburg, 1978)	
<i>Kephyrion circumvallatum</i>	1610	7430	Taxon deleted - Synonym of <i>Pseudokephyrion circumvallatum</i> (ID 1865)	
<i>Leptolyngbya tenuis</i>	427	8176	Correction: Synonym <i>Phormidium tenue</i>	X
<i>Woloszynskia ordinata</i>	1744	8278	Taxon deleted – synonym to <i>Gymnodinium ordinatum</i> (ID 1764)	X
<i>Gymnodinium ordinatum</i>	1764	17506	Correction: Synonym <i>Woloszynskia ordinata</i>	



6.2 ANNEX II: LIST OF INDICATOR TAXA

Please note that an update for German coding list with currently accepted indicator names will be available at end of the year 2017.

Table 33 List of indicator taxa in the PTSI with their trophic scores (TAW) and stenoecy factors (SF) according lake type groups (Table 20). AVA = Alpine (A) and Prealpine (VA) ecoregion, MG = central highlands, TL = North German lowlands, Tgesch = stratified lakes in the lowlands, Tpoly = polymictic lakes in the lowlands, AWB = artificial water bodies (in this case lake type group includes also HMWB (= heavily modified waterbodies). Taxa ordered by algae classes (AC).

		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
BAC	10	<i>Acanthoceras</i>					2,10	1	3,13	1	3,94	2		
BAC	1	<i>Acanthoceras zachariasii</i>					2,10	1	3,13	1	3,94	2		
BAC	8	<i>Actinocyclus</i>									4,95	3		
BAC	7	<i>Actinocyclus normanii</i>									4,95	3	4,17	1
BAC	12	<i>Amphora ovalis</i>	0,98	2					0,35	1				
BAC	73	<i>Asterionella</i>									2,18	1		
BAC	72	<i>Asterionella formosa</i>									2,18	1		
BAC	75	<i>Aulacoseira ambigua</i>	3,68	3	2,41	1	2,81	1	2,57	1	5,68	2	4,97	1
BAC	1277	<i>Aulacoseira distans</i>			1,67	1								
BAC	78	<i>Aulacoseira granulata</i>	3,22	1	4,20	2	3,97	1			4,35	1	4,21	1
BAC	77	<i>Aulacoseira granulata</i> Morphotyp <i>curvata</i>	3,22	1	4,20	2	3,97	1			4,35	1	4,21	1
BAC	79	<i>Aulacoseira granulata</i> var. <i>angustissima</i>	3,22	1	4,20	2	3,97	1			4,35	1	4,21	1
BAC	81	<i>Aulacoseira islandica</i>							3,47	2				
BAC	81	<i>Aulacoseira islandica</i> ssp. <i>islandica</i>	1,42	2			2,55	2						
BAC	82	<i>Aulacoseira italica</i>			1,41	1			2,87	2				
BAC	913	<i>Aulacoseira italica</i> var. <i>tenuissima</i>			1,41	1								
BAC	1045	<i>Aulacoseira muzzanensis</i>											5,50	4
BAC	84	<i>Aulacoseira subarctica</i>	1,39	3	2,27	1								
BAC	177	<i>Cocconeis placentula</i>							0,28	4			1,89	1
BAC	1260	<i>Cyclostephanos delicatus</i>			5,46	2							4,66	3
BAC	247	<i>Cyclostephanos dubius</i>	2,33	1	2,95	1	3,59	2			4,77	2	3,94	2
BAC	248	<i>Cyclostephanos invisitatus</i>	2,51	2	2,91	1	3,55	1	4,63	1	5,46	1	4,30	1
BAC	250	<i>Cyclotella atomus</i>											4,69	1
BAC	3002	<i>Cyclotella balatonis</i>			2,22	1	2,76	2			1,45	1	2,57	1
BAC	251	<i>Cyclotella bodanica</i>	0,90	2					0,31	1				
BAC	252	<i>Cyclotella comensis</i>	0,80	3	1,33	2	0,65	2	0,32	3	1,01	2	1,70	2
BAC	254	<i>Cyclotella costei</i>	0,95	2	1,43	1			0,30	1				
BAC	255	<i>Cyclotella delicatula</i>	0,95	2									1,33	1



		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
BAC	256	<i>Cyclotella distinguenda</i>	1,74	1										
BAC	257	<i>Cyclotella distinguenda</i> var. <i>unipunctata</i>							0,30	4				
BAC	870	<i>Cyclotella krammeri</i>							0,29	1				
BAC	870	<i>Cyclotella kuetzingiana</i>					0,68	2						
BAC	260	<i>Cyclotella meneghiniana</i>	1,35	1	4,33	2	2,44	2	3,57	2	4,45	1	3,80	1
BAC	261	<i>Cyclotella ocellata</i>	1,95	1	2,10	2	1,60	2	0,82	1	0,93	2	1,54	1
BAC	3000	<i>Cyclotella pseudocomensis</i>	1,11	2										
BAC	264	<i>Cyclotella radiosa</i>			2,22	1	2,76	2			1,45	1	2,57	1
BAC	872	<i>Cyclotella tripartita</i>					0,66	2	0,37	2				
BAC	269	<i>Cymatopleura solea</i>	0,85	3										
BAC	1016	<i>Diatoma mesodon</i>			0,49	4								
BAC	283	<i>Diatoma tenuis</i>					3,11	1			2,91	1	3,12	1
BAC	284	<i>Diatoma vulgaris</i>	0,91	2	1,90	1								
BAC	258	<i>Discostella glomerata</i>	0,86	2										
BAC	262	<i>Discostella pseudostelligera</i>			2,35	1	2,91	1	3,89	1				
BAC	266	<i>Discostella stelligera</i>			1,05	1							1,71	3
BAC	336	<i>Fragilaria capucina</i>	1,40	2			1,91	1	1,52	1	1,25	2	1,79	1
BAC	337	<i>Fragilaria capucina</i> radians - Sippen	1,40	2			1,91	1	1,52	1	1,25	2	1,79	1
BAC	338	<i>Fragilaria capucina</i> var. <i>gracilis</i>							1,52	1				
BAC	339	<i>Fragilaria capucina</i> var. <i>rumpens</i>							1,52	1				
BAC	1169	<i>Fragilaria capucina</i> var. <i>vaucheriae</i>	1,40	2			1,91	1	1,52	1	1,25	2	1,79	1
BAC	341	<i>Fragilaria construens</i>					1,79	1	2,98	1	2,74	1	3,15	1
BAC	1884	<i>Fragilaria construens</i> f. <i>binodis</i>					1,91	1			2,74	1	3,15	1
BAC	1170	<i>Fragilaria construens</i> f. <i>venter</i>					1,79	1			2,74	1	3,15	1
BAC	342	<i>Fragilaria crotonensis</i>			2,32	1	1,84	1	1,79	1	1,98	1	1,72	1
BAC	343	<i>Fragilaria cyclosum</i>	1,16	3										
BAC	350	<i>Fragilaria danica</i>	1,04	3										
BAC	338	<i>Fragilaria gracilis</i>					1,91	1			1,25	2	1,79	1
BAC	339	<i>Fragilaria rumpens</i>											1,79	1
BAC	1246	<i>Fragilaria tenera</i>			1,13	1			0,52	2			1,45	1
BAC	348	<i>Fragilaria ulna</i>									2,70	1		
BAC	349	<i>Fragilaria ulna</i> angustissima - Sippen					3,63	1			4,05	1	3,85	1
BAC	352	<i>Fragilaria ulna</i> var. <i>ulna</i>	1,34	1							2,70	1		
BAC	369	<i>Gomphonema</i>											1,73	1



		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
CHL	46	<i>Ankistrodesmus spiralis</i>	3,40	2										
CHL	1801	<i>Ankistrodesmus stipitatus</i>	3,40	2										
CHL	52	<i>Ankyra</i>					3,71	2	2,50	1				
CHL	48	<i>Ankyra ancora</i>					3,71	2	2,50	1				
CHL	49	<i>Ankyra judayi</i>	2,74	2			3,71	2	2,50	1	1,89	1	2,88	1
CHL	50	<i>Ankyra lanceolata</i>	2,12	1			3,71	2	2,50	1	1,83	3		
CHL	94	<i>Botryococcus braunii</i>	0,83	2	1,76	1	0,71	1	0,80	1				
CHL	100	<i>Carteria</i>	3,06	2			2,05	1	0,97	1	4,40	2	1,62	1
CHL	1010	<i>Carteria globulosa</i>	3,06	2			2,05	1	0,97	1	4,40	2	1,62	1
CHL	1802	<i>Carteria klebsi</i>							0,97	1				
CHL	1802	<i>Carteria klebsii</i>	3,06	2									1,62	1
CHL	1011	<i>Carteria multifilis</i>	3,06	2			2,05	1	0,97	1	4,40	2	1,62	1
CHL	99	<i>Carteria pseudomultifilis</i>	3,06	2			2,05	1	0,97	1	4,40	2	1,62	1
CHL	1006	<i>Characium</i>	3,92	3										
CHL	109	<i>Chlamydocapsa planctonica</i>	2,62	1										
CHL	122	<i>Chlorella</i>	3,86	2			2,39	1	3,54	1	4,81	1		
CHL	120	<i>Chlorella ellipsoidea</i>	3,86	2			2,39	1	3,54	1	4,81	1		
CHL	1530	<i>Chlorella minutissima</i>	3,86	2					3,54	1				
CHL	121	<i>Chlorella pyrenoidosa</i>	3,86	2			2,39	1	3,54	1	4,81	1		
CHL	123	<i>Chlorella vulgaris</i>	3,86	2			2,39	1	3,54	1	4,81	1		
CHL	126	<i>Chlorogonium</i>							0,99	1				
CHL	1531	<i>Chlorogonium elongatum</i>							0,99	1				
CHL	1805	<i>Chlorogonium fusiforme</i>							0,99	1				
CHL	126	<i>Chlorogonium intermedium</i>							0,99	1				
CHL	126	<i>Chlorogonium tetragamum</i>							0,99	1				
CHL	749	<i>Chlorotetraedron incus</i>					4,93	3	5,51	3				
CHL	179	<i>Coelastrum astroideum</i>	3,30	1	3,26	2	2,86	2	3,86	2	3,55	1	4,62	1
CHL	181	<i>Coelastrum microporum</i>	2,36	2									4,98	1
CHL	182	<i>Coelastrum polychordum</i>	2,80	1										
CHL	183	<i>Coelastrum pseudomicroporum</i>	3,18	2									5,38	3
CHL	184	<i>Coelastrum reticulatum</i>	2,65	1	3,22	1	1,89	3						
CHL	194	<i>Coenocystis planctonica</i>							0,29	3				
CHL	213	<i>Crucigenia</i>									2,05	1		
CHL	210	<i>Crucigenia fenestrata</i>									2,05	1		
CHL	212	<i>Crucigenia quadrata</i>	3,12	4							2,05	1		
CHL	214	<i>Crucigenia tetrapedia</i>					4,87	1			2,05	1		



		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
CHL	215	<i>Crucigeniella apiculata</i>									4,73	4	5,40	2
CHL	216	<i>Crucigeniella pulchra</i>			0,86	2								
CHL	217	<i>Crucigeniella rectangularis</i>					1,99	1	1,03	1				
CHL	288	<i>Dictyosphaerium ehrenbergianum</i>					4,01	2	4,55	2				
CHL	289	<i>Dictyosphaerium pulchellum</i>					2,27	1	3,60	1	2,25	1	3,05	1
CHL	291	<i>Dictyosphaerium tetrachotomum</i>					0,95	1	1,51	1				
CHL	320	<i>Eudorina elegans</i>	3,09	2							4,59	2	4,03	2
CHL	1584	<i>Fotterella tetrachlorelloides</i>							1,73	2				
CHL	366	<i>Golenkinia radiata</i>			2,57	2	4,23	1	4,73	1				
CHL	405	<i>Kirchneriella contorta</i>			3,31	1								
CHL	408	<i>Kirchneriella lunaris</i>			1,71	2								
CHL	420	<i>Lagerheimia ciliata</i>	3,42	1	3,62	1	3,83	1	4,30	1			4,82	2
CHL	422	<i>Lagerheimia genevensis</i>			2,67	1	3,15	1	3,95	1				
CHL	425	<i>Lagerheimia subsalsa</i>	3,24	1	5,39	1								
CHL	450	<i>Micractinium pusillum</i>	3,80	2	4,73	1	3,29	1	3,98	1				
CHL	464	<i>Monoraphidium arcuatum</i>			4,59	1			4,04	1			4,85	1
CHL	468	<i>Monoraphidium contortum</i>							3,05	1				
CHL	469	<i>Monoraphidium griffithii</i>	3,20	1							5,34	1	4,87	1
CHL	471	<i>Monoraphidium komarkovae</i>			2,71	1	2,33	1	3,67	1	5,09	3	4,56	1
CHL	472	<i>Monoraphidium minutum</i>	3,97	2			3,90	2			2,82	2		
CHL	474	<i>Monoraphidium tortile</i>			3,12	1								
CHL	489	<i>Nephrochlamys subsolitaria</i>	6,50	2										
CHL	490	<i>Nephrocytium agardhianum</i>	1,89	2										
CHL	513	<i>Oocystis borgei</i>									5,01	1	5,43	4
CHL	514	<i>Oocystis lacustris</i>									2,70	1	3,22	1
CHL	515	<i>Oocystis marssonii</i>					2,22	2	3,27	2				
CHL	527	<i>Pandorina morum</i>	1,77	1	2,47	1					4,55	2	2,65	1
CHL	534	<i>Pediastrum boryanum</i>			5,01	1								
CHL	1848	<i>Pediastrum boryanum</i> var. <i>brevicorne</i>			5,01	1								
CHL	928	<i>Pediastrum boryanum</i> var. <i>longicorne</i>			5,01	1								
CHL	535	<i>Pediastrum duplex</i>	3,27	2	3,96	1			4,92	1				
CHL	536	<i>Pediastrum duplex</i> var. <i>gracillimum</i>	3,27	2	3,96	1								
CHL	539	<i>Pediastrum simplex</i>	2,83	2	3,68	2			3,70	2	4,91	1		



		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
CHL	764	<i>Tetrastrum staurogeniaeforme</i>							5,43	2	3,17	1		
CHL	765	<i>Tetrastrum triangulare</i>	1,53	1			4,07	1			4,20	1		
CHL	775	<i>Treubaria triappendiculata</i>			3,57	1								
CHL	814	<i>Volvox</i>	2,92	3					4,52	4				
CHL	812	<i>Volvox aureus</i>	2,92	3					4,52	4				
CHL	813	<i>Volvox globator</i>	2,92	3					4,52	4				
CHL	815	<i>Willea irregularis</i>	1,44	2					0,40	2				
CHL	817	<i>Willea wilhelmii</i>					1,03	3	0,43	3				
CHR	93	<i>Bitrichia</i>			0,92	3								
CHR	90	<i>Bitrichia chodatii</i>	0,96	3	0,92	3	0,70	3	0,78	3				
CHR	1009	<i>Bitrichia danubiensis</i>			0,92	3								
CHR	91	<i>Bitrichia longispina</i>			0,92	3								
CHR	92	<i>Bitrichia ochridana</i>			0,92	3								
CHR	1519	<i>Bitrichia ollula</i>			0,92	3								
CHR	1520	<i>Bitrichia phaseolus</i>			0,92	3								
CHR	131	<i>Chromulina</i>							0,46	1			1,48	1
CHR	129	<i>Chromulina crassa</i>							0,46	1			1,48	1
CHR	130	<i>Chromulina minima</i>							0,46	1			1,48	1
CHR	1532	<i>Chromulina rosanoffi</i>							0,46	1			1,48	1
CHR	142	<i>Chrysamoeba</i>					0,92	2	1,48	2				
CHR	151	<i>Chrysolykos planctonicus</i>	1,37	1	0,93	2			0,30	3				
CHR	152	<i>Chrysolykos skujae</i>	0,88	2										
CHR	306	<i>Dinobryon</i>									1,45	1		
CHR	296	<i>Dinobryon bavaricum</i>	2,01	1	1,56	1	1,65	1	1,23	3	1,04	1	1,40	4
CHR	297	<i>Dinobryon crenulatum</i>			0,84	2	0,80	1	1,05	1				
CHR	298	<i>Dinobryon cylindricum</i>			1,11	1	0,90	1	1,35	1	0,98	1	2,17	1
CHR	299	<i>Dinobryon divergens</i>	1,24	1	0,89	2	1,08	1	0,89	1	1,69	1	1,42	1
CHR	300	<i>Dinobryon divergens</i> var. <i>schauinslandii</i>	1,24	1			1,08	1			1,69	1		
CHR	302	<i>Dinobryon sertularia</i>	1,71	1	0,82	1	1,15	2	1,67	2				
CHR	1569	<i>Dinobryon sertularia</i> var. <i>protuberans</i>	1,71	1	0,82	1								
CHR	303	<i>Dinobryon sociale</i>	1,51	1	1,04	1	1,70	1			1,75	1	1,94	3
CHR	304	<i>Dinobryon sociale</i> var. <i>americana</i>	1,51	1	1,63	1	1,70	1	1,40	2	1,75	1	1,94	3
CHR	305	<i>Dinobryon sociale</i> var. <i>stipitatum</i>	1,51	1	1,04	1	1,70	1	1,10	2	1,75	1	1,94	3
CHR	307	<i>Dinobryon suecicum</i>			0,78	1								
CHR	1579	<i>Epipyxis tubulosa</i>							0,50	4				
CHR	1611	<i>Kephyrion littorale</i>											1,46	4
CHR	400	<i>Kephyrion rubri-claustri</i>							0,38	1				



		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
CHR	402	<i>Kephyrion tubiforme</i>							0,28	2				
CHR	438	<i>Mallomonas akrokomos</i>	3,21	2					3,23	1				
CHR	439	<i>Mallomonas caudata</i>	2,45	2	1,75	1	2,60	1						
CHR	512	<i>Ochromonas</i>					1,74	1						
CHR	508	<i>Ochromonas globosa</i>					1,74	1						
CHR	509	<i>Ochromonas nana</i>					1,74	1						
CHR	510	<i>Ochromonas ornata</i>					1,74	1						
CHR	511	<i>Ochromonas sphaerella</i>					1,74	1						
CHR	599	<i>Pseudokephyrion entzii</i>			1,23	1					1,50	1	1,73	1
CHR	1786	<i>Pseudokephyrion hyalinum</i>			0,69	4								
CHR	889	<i>Pseudokephyrion pseudospirale</i>							0,28	4				
CHR	601	<i>Pseudopedinella erkensis</i>	1,01	1					0,67	1			1,51	1
CHR	1718	<i>Spiniferomonas cornuta</i>			1,16	1								
CHR	850	<i>Stichogloea doederleinii</i>			0,72	4	0,66	2	0,39	2				
CHR	740	<i>Synura</i>	3,39	3			3,20	3	4,16	3	2,08	1		
CHR	1311	<i>Synura sphagnicola</i>	3,39	3			3,20	3	4,16	3	2,08	1		
CHR	741	<i>Synura uvella</i>	3,39	3			3,20	3	4,16	3				
CHR	811	<i>Uroglena</i>	1,65	1	0,94	1	1,30	1	1,21	1			1,58	4
CHR	810	<i>Uroglena americana</i>	1,65	1	0,94	1	1,30	1	1,21	1			1,58	4
CHR	811	<i>Uroglena americana / volvox</i>							1,21	1				
CON	158	<i>Closterium aciculare</i>	2,24	2	2,25	1	2,02	1	3,16	1	3,72	1	3,60	1
CON	159	<i>Closterium acutum</i>	3,00	2	2,13	1	4,40	1			1,41	1	2,50	1
CON	160	<i>Closterium acutum var. linea</i>	3,00	2							6,04	2		
CON	161	<i>Closterium acutum var. variabile</i>	3,00	2					2,69	1	1,95	1		
CON	168	<i>Closterium limneticum</i>	3,37	1	4,87	1			5,71	1	3,99	2	5,13	1
CON	172	<i>Closterium pronum</i>									5,23	1	4,26	1
CON	198	<i>Cosmarium bioculatum</i>					0,65	1	0,48	1				
CON	199	<i>Cosmarium depressum</i>	1,48	2										
CON	200	<i>Cosmarium depressum var. planctonicum</i>	1,48	2										
CON	477	<i>Mougeotia</i>	2,89	1	1,29	1	2,96	2	4,07	2	2,78	1	1,97	4
CON	478	<i>Mougeotia thylespora</i>	2,89	1	1,29	1	2,96	2	4,07	2	2,78	1	1,97	4
CON	479	<i>Mougeotia viridis</i>	2,89	1	1,29	1	2,96	2	4,07	2	2,78	1	1,97	4
CON	712	<i>Staurastrum</i>							3,76	1				
CON	705	<i>Staurastrum chaetoceras</i>							3,76	1				
CON	706	<i>Staurastrum cingulum</i>			5,62	1			3,76	1				



		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
CON	712	<i>Staurastrum cingulum / gracile</i>							3,76	1				
CON	712	<i>Staurastrum cingulum var. obesum</i>							3,76	1				
CON	708	<i>Staurastrum gracile</i>					3,34	1	3,76	1	5,68	4		
CON	709	<i>Staurastrum gracile var. nanum</i>					3,34	1	3,76	1	5,68	4		
CON	1720	<i>Staurastrum longipes</i>							3,76	1				
CON	710	<i>Staurastrum paradoxum</i>							3,76	1	4,99	2	4,38	2
CON	711	<i>Staurastrum pingue</i>	1,54	3	2,60	1	1,34	2	3,76	1				
CON	1791	<i>Staurastrum planctonicum var. bulbosum</i>							3,76	1				
CON	713	<i>Staurastrum tetracerum</i>	3,62	1			1,03	2	3,76	1	1,86	1		
CRY	236	<i>Cryptomonas 30-35µm</i>									3,36	1		
CRY	237	<i>Cryptomonas 35-40µm</i>	1,80	1							3,36	1		
CRY	238	<i>Cryptomonas 40-45µm</i>	1,80	1							3,36	1		
CRY	239	<i>Cryptomonas 45-50µm</i>	1,80	1							3,36	1		
CRY	240	<i>Cryptomonas 50-55µm</i>	1,80	1							3,36	1		
CRY	241	<i>Cryptomonas 55-60µm</i>	1,80	1							3,36	1		
CRY	220	<i>Cryptomonas curvata</i>	1,80	1							3,36	1		
CRY	221	<i>Cryptomonas erosa</i>					1,81	1						
CRY	222	<i>Cryptomonas erosa/ ovata/phaseolus</i>					1,81	1	2,95	1				
CRY	225	<i>Cryptomonas ovata</i>					1,81	1						
CRY	226	<i>Cryptomonas phaseolus</i>					1,81	1						
CRY	227	<i>Cryptomonas reflexa</i>			2,53	1								
CYA	17	<i>Anabaena circinalis</i>			2,44	1	3,25	2	3,79	2	5,20	2		
CYA	18	<i>Anabaena compacta</i>									6,11	2	5,10	4
CYA	19	<i>Anabaena crassa</i>			4,46	2					3,00	4		
CYA	21	<i>Anabaena flos-aquae</i>	1,46	1	3,08	1								
CYA	941	<i>Anabaena flos-aquae/ A. perturbata</i>	1,46	1										
CYA	24	<i>Anabaena lemmermannii</i>					1,50	1	2,38	1				
CYA	25	<i>Anabaena macrospora</i>			2,82	1								
CYA	26	<i>Anabaena planctonica</i>	3,34	2										
CYA	28	<i>Anabaena sigmoidea</i>			5,54	2							4,78	4
CYA	29	<i>Anabaena solitaria</i>	1,46	1	3,08	1								
CYA	32	<i>Anabaena spiroides</i>	1,21	1							4,50	1	4,93	3
CYA	1268	<i>Anabaena viguieri</i>									6,12	3		
CYA	38	<i>Anabaenopsis</i>					4,72	1	5,27	1	6,12	2	5,26	2



		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
CYA	35	<i>Anabaenopsis arnoldii</i>					4,72	1	5,27	1	6,12	2	5,26	2
CYA	36	<i>Anabaenopsis cunningtonii</i>							5,27	1			5,26	2
CYA	37	<i>Anabaenopsis elenkinii</i>					4,72	1	5,27	1	6,12	2	5,26	2
CYA	58	<i>Aphanizomenon</i>	2,98	1							3,88	1	4,40	1
CYA	54	<i>Aphanizomenon flos-aquae</i>	2,98	2	3,17	1					3,88	1		
CYA	55	<i>Aphanizomenon gracile</i>	2,98	2	2,64	1	3,38	1	3,83	1	3,88	1		
CYA	56	<i>Aphanizomenon issatschenkoi</i>			2,78	3	4,17	2	4,60	2	3,88	1		
CYA	64	<i>Aphanocapsa</i>									1,34	1		
CYA	59	<i>Aphanocapsa delicatissima</i>	1,57	1							1,34	1		
CYA	60	<i>Aphanocapsa elachista</i>	2,27	1							1,34	1		
CYA	861	<i>Aphanocapsa grevillei</i>									1,34	1		
CYA	61	<i>Aphanocapsa holsatica</i>									1,34	1		
CYA	62	<i>Aphanocapsa incerta</i>									1,34	1		
CYA	63	<i>Aphanocapsa reinboldii</i>									1,34	1		
CYA	66	<i>Aphanothece clathrata</i>	1,57	1			1,10	2	1,45	2	0,92	1	2,01	1
CYA	134	<i>Chroococcus limneticus</i>	1,26	2	1,20	2	0,82	1	1,01	1	1,59	1	4,58	1
CYA	135	<i>Chroococcus minutus</i>	1,29	2			1,00	1	0,36	3				
CYA	137	<i>Chroococcus turgidus</i>	0,83	2										
CYA	187	<i>Coelosphaerium kuetzingianum</i>					1,12	1	1,64	1				
CYA	246	<i>Cyanodictyon</i>					1,28	2	1,91	2				
CYA	244	<i>Cyanodictyon imperfectum</i>					1,28	2	1,91	2				
CYA	245	<i>Cyanodictyon planctonicum</i>					1,28	2	1,91	2				
CYA	1287	<i>Cyanodictyon reticulatum</i>					1,28	2	1,91	2				
CYA	267	<i>Cylindrospermopsis raciborskii</i>					4,80	2	5,58	2	4,97	1	4,32	1
CYA	365	<i>Gloeotrichia echinulata</i>					1,86	1	3,02	1				
CYA	375	<i>Gomphosphaeria</i>			1,49	1					3,26	1		
CYA	370	<i>Gomphosphaeria aponina</i>			1,49	1					3,26	1		
CYA	975	<i>Gomphosphaeria natans</i>			1,49	1					3,26	1		
CYA	427	<i>Leptolyngbya tenuis</i>	1,30	2										
CYA	431	<i>Limnothrix planctonica</i>					4,20	3	4,83	3	5,40	4	5,00	4
CYA	432	<i>Limnothrix redekei</i>	4,88	2			4,04	1	4,57	3	4,68	2	5,62	4
CYA	448	<i>Merismopedia</i>	2,68	1			1,56	1	2,80	1	5,13	1		
CYA	1629	<i>Merismopedia duplex</i>	2,68	1					2,80	1				



		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
CYA	821	<i>Woronichinia naegeliana</i>	1,68	2			2,66	2	4,19	2	5,16	2	4,54	1
DIN	102	<i>Ceratium cornutum</i>	0,81	3			0,68	3	0,60	3				
DIN	103	<i>Ceratium furcoides</i>					3,67	2	4,24	2	3,08	3	3,37	3
DIN	104	<i>Ceratium hirundinella</i>									1,92	1	1,69	1
DIN	390	<i>Gymnodinium</i>									2,22	1		
DIN	383	<i>Gymnodinium acuminatum</i>									2,22	1		
DIN	386	<i>Gymnodinium cnecoides</i>			0,81	4					2,22	1		
DIN	1604	<i>Gymnodinium discoidale</i>			0,81	4								
DIN	387	<i>Gymnodinium fuscum</i>									2,22	1		
DIN	877	<i>Gymnodinium lacustre</i>			0,81	4					2,22	1		
DIN	389	<i>Gymnodinium lantzschii</i>	1,02	1							2,22	1		
DIN	385	<i>Gymnodinium uberrimum</i>	0,99	1	1,02	1	1,97	1	0,57	1	2,22	1	1,84	1
DIN	886	<i>Peridiniopsis</i>									4,89	4		
DIN	957	<i>Peridiniopsis berlinense</i>									4,89	4		
DIN	545	<i>Peridiniopsis cunningtonii</i>									4,89	4		
DIN	845	<i>Peridiniopsis penardiforme</i>									4,89	4		
DIN	546	<i>Peridiniopsis polonicum</i>									4,89	4		
DIN	547	<i>Peridinium aciculiferum</i>	2,77	1	2,20	1					4,10	2		
DIN	548	<i>Peridinium bipes</i>	2,39	2									1,50	4
DIN	549	<i>Peridinium cinctum</i>			2,18	2	1,21	1			4,15	1		
DIN	558	<i>Peridinium umbo-natum-Komplex</i>	1,15	1									1,64	1
DIN	560	<i>Peridinium willei</i>	1,08	2	1,08	1	1,18	2	1,43	2	0,94	2		
DIN	1744	<i>Woloszynskia ordinata</i>			0,84	1								
EUG	326	<i>Euglena</i>	3,74	1	3,79	2	4,11	1	3,20	1	4,93	1		
EUG	322	<i>Euglena acus</i>	3,74	1	3,79	2			3,20	1				
EUG	323	<i>Euglena ehrenbergii</i>	3,74	1	3,79	2	4,11	1	3,20	1	4,93	1		
EUG	1580	<i>Euglena gasterosteus</i>	3,74	1										
EUG	324	<i>Euglena gracilis</i>	3,74	1	3,79	2			3,20	1				
EUG	1581	<i>Euglena granulata</i>	3,74	1	3,79	2			3,20	1				
EUG	1261	<i>Euglena hemichromata</i>	3,74	1	3,79	2			3,20	1				
EUG	326	<i>Euglena limnophila</i>							3,20	1				
EUG	1823	<i>Euglena mutabilis</i>	3,74	1	3,79	2			3,20	1				
EUG	998	<i>Euglena oxyuris</i>	3,74	1	3,79	2	4,11	1	3,20	1	4,93	1		
EUG	325	<i>Euglena pisciformis</i>	3,74	1	3,79	2			3,20	1				
EUG	1824	<i>Euglena proxima</i>	3,74	1	3,79	2			3,20	1				
EUG	1825	<i>Euglena spirogyra</i>	3,74	1	3,79	2			3,20	1				
EUG	973	<i>Euglena tripteris</i>	3,74	1	3,79	2	4,11	1	3,20	1	4,93	1		



		lake group	AVA		MG		TL_gesch		Tgesch AWB		TL_poly		Tpoly AWB	
AC	HTL-ID	Taxon HTL	TAW 1	SF 1	TAW 2	SF 2	TAW 3	SF 3	TAW 4	SF 4	TAW 5	SF 5	TAW 6	SF 6
EUG	327	<i>Euglena variabilis</i>	3,74	1	3,79	2	4,11	1	3,20	1	4,93	1		
EUG	328	<i>Euglena viridis</i>	3,74	1	3,79	2	4,11	1	3,20	1	4,93	1		
EUG	569	<i>Phacus</i>	4,15	1										
EUG	986	<i>Phacus acuminatus</i>	4,15	1										
EUG	566	<i>Phacus longicauda</i>	4,15	1										
EUG	1777	<i>Phacus orbicularis</i>	4,15	1										
EUG	1674	<i>Phacus platyaulax</i>	4,15	1										
EUG	567	<i>Phacus pleuronectes</i>	4,15	1										
EUG	1297	<i>Phacus pseudonordstedtii</i>	4,15	1										
EUG	1849	<i>Phacus pusillus</i>	4,15	1										
EUG	568	<i>Phacus pyrum</i>	4,15	1			5,00	1	5,77	1	6,04	2	4,08	2
EUG	1850	<i>Phacus suecicus</i>	4,15	1										
EUG	1675	<i>Phacus tortus</i>	4,15	1										
EUG	1049	<i>Phacus triqueter</i>	4,15	1										
EUG	771	<i>Trachelomonas volvocina</i>	2,53	2										
HAP	144	<i>Chrysochromulina</i>					1,91	1	0,63	1	2,54	1	1,53	1
HAP	143	<i>Chrysochromulina parva</i>					1,91	1	0,63	1	2,54	1	1,53	1
PRA	684	<i>Scourfieldia cordiformis</i>											1,66	1
PRA	758	<i>Tetraselmis cordiformis</i>	1,20	2										
ULV	313	<i>Elakatothrix</i>									1,54	1	2,30	1
ULV	311	<i>Elakatothrix gelatinosa</i>					1,23	1	1,94	1	1,54	1	2,30	1
ULV	312	<i>Elakatothrix genevensis</i>									1,54	1	2,30	1
ULV	1574	<i>Elakatothrix spirochroma</i>											2,30	1
ULV	1218	<i>Elakatothrix viridis</i>			5,09	1							2,30	1
ULV	1592	<i>Gloeotila pelagica</i> f. <i>spiralis</i>			0,80	4								
ULV	413	<i>Koliella longiseta</i>					3,47	2	3,92	2	2,87	2	3,19	2
ULV	578	<i>Planctonema lauterbornii</i>	1,00	2										
ULV	1725	<i>Stichococcus pelagicus</i>			0,80	4								
XAN	377	<i>Goniochloris mutica</i>			5,70	2							5,16	3
XAN	852	<i>Trachydiscus sexangularis</i>							0,39	3				
XAN	852	<i>Trachydiscus sexangulatus</i>					0,65	2						
XAN	778	<i>Tribonema</i>					1,30	1	2,27	1	2,66	2	3,30	2
XAN	999	<i>Tribonema aequale</i>					1,30	1	2,27	1	2,66	2	3,30	2
XAN	776	<i>Tribonema elegans</i>							2,27	1			3,30	2
XAN	1314	<i>Tribonema minus</i>					1,30	1	2,27	1	2,66	2	3,30	2
XAN	777	<i>Tribonema monochloron</i>							2,27	1			3,30	2
XAN	779	<i>Tribonema vulgare</i>					1,30	1	2,27	1	2,66	2	3,30	2



6.3 ANNEX III: HISTORY OF METHOD DEVELOPMENT

In lakes that have not been strongly influenced by human activity, the biomass and composition of pelagic algae, known as phytoplankton, are limited and determined by the availability of nutrients. Excessive anthropogenic input of nutrients (phosphorus and nitrogen), leads to the eutrophication of inland waters, during which their trophic status transitions from oligotrophic to eutrophic. The total biovolume of phytoplankton increases and there are extensive changes to its taxonomic composition (e.g. shifts to cyanobacterial blooms). In accordance with the European Water Framework Directive (EU-WRRL 2000, EU 2008), this sensitivity of phytoplankton to environmental pressures of eutrophication should be used to assess the ecological status of lakes across Europe.

In Germany, to implement the EU-WRRL, a consistent method, the Phyto-See-Index (PSI) has been used since 2008 for the assessment of lakes using phytoplankton. The Phyto-See-Index is fully documented in Mischke & Nixdorf (2008) and is based on the findings of preparatory work by Nixdorf et al. (i.a. 2006). The English version of this method description was used for the European intercalibration process for ecological assessment methods (Mischke et al. 2008). Since then, the EU intercalibration process has been completed and approved, which means among other things that a member states' ecological assessment methods must be comparably strong as those in other states within the same ecoregion (Phillips et al. 2014; Wolfram et al. 2014). The European Commission has published the agreed classification systems of the member states as the result of the intercalibration process, here the Phyto-See-Index, in the Official Journal of the European Union (Europäische Kommission 2008, 2013).

Since then, the Phyto-See-Index has been further developed in seven projects¹, managed and supported by the German Working Group of the Federal States on Water Issues (LAWA; <http://www.lawa.de/>):

- Methods proposal for the German central highland lakes, HMWB & AWB (LAWA O 3.06; Hoehn et al. 2009)
- Fine-tuning of the Phyto-See-Index (LAWA O 9.08; Mischke et al. 2009)
- Adaptation of the Phyto-See-Index (LAWA O 9.09; Mischke et al. 2010)
- Implementation tests and method adaptation for HMWB & AWB & German central highland lakes (LAWA O 7.08; Riedmüller & Hoehn 2011)
- Ecological assessment of natural lakes and HMWB & AWB using phytoplankton (LAWA O 4.10; Riedmüller et al. 2013a)
- Extension of the assessment possibilities for lakes pursuant to the EU-WRRL for the biological component phytoplankton (LAWA O 8.12; Riedmüller et al. 2015)
- Evaluation of lake trophic state, good ecological potential and physico-chemical supporting quality components (LAWA O 7.16; Riedmüller et al., in prep.)

¹These reports can be found at the following address: <http://www.laenderfinanzierungsprogramm.de/> under the titles “Vorhaben” and “Vorhaben des Ausschusses Oberflächengewässer und Küstengewässer (AO)”



The present method description includes all changes that have been agreed by the LAWA-expert group for lakes, up to December 2016, and includes changes to the following areas:

1) A considerable expansion was made to the methods for lakes in the German central highlands as well as for artificial and heavily modified lakes (AWB und HMWB), groups which include reservoirs and flooded quarry/gravel pits. Following an initial method proposal (Hoehn et al. 2009) the boundary values and lake typology were heavily revised in response to the results of an implementation test by the German states (Riedmüller & Hoehn 2011, Riedmüller et al. 2013b).

2 a) The boundary values for the component "Biomass" were calibrated against the boundary values for the trophic levels of the new LAWA trophic-index (LAWA 2014; Riedmüller et al. 2013a).

2 b) As for the LAWA trophic-index, all seasonal averages used in the PSI are now calculated as the simple mean of measured samples, omitting the previously used additional step of first calculating monthly means. This also applies to the PTSI-annual value.

3) For the lowland lakes, all assessment procedures that were based on the component "Algal Classes" were comprehensively revised. This was done after testing using a dataset that has been greatly expanded since 2006.

5) For the special case of strongly acidic mining lakes, a biodiversity index (Leßmann & Nixdorf 2009) was adopted as a new component of the Phyto-See-Index.

6) In the newly developed PhytoLoss-method, automated indices for the strength of grazing effects are calculated, using zooplankton data collected at the same time as the phytoplankton data. This allows further interpretation of the Phyto-See-Index with respect to the food web, and informs the options that can be given for management planning.

7) A handbook was developed for the quality assurance of the research methods "Phytoplankton zur Bestimmung des Phyto-See-Index" (Chapter 8; Mischke 2015).

8) For the lakes in the Alps and Pre-Alps it was decided to separate the former combined lake type 2-3 into two independent types with own reference conditions (LAWA O 7.16).

An documentation of the equivalence of the revised Phyto-See-Index to the results of European Intercalibration was prepared (LAWA Project O 2.15; Riedmüller et al. 2016).

The present method description do not list all changes with regard to the previous Phyto-See-Index (Mischke et al. 2008) in detail (for full details see the above named LAWA reports).

Prior to the EU Water Framework Directive coming into force, and before the introduction of the Phyto-See-Index for the ecological assessment of lakes, German natural lakes (LAWA 1999), reservoirs (LAWA 2001) and mining lakes (LAWA 2003) were classified following LAWA guidelines into eight categories, from oligo- to hypertrophic, according to their trophic pressure. The LAWA trophic-index was based on a classification formula using the parameters chlorophyll-a, Secchi-depth and total phosphorus (growing season mean and spring value), which were identified in the 1982 worldwide OECD-study (OECD 1982) as the most appropriate indicators of trophic state. The trophic classification is realized for specific lake groups, to take into account their different genesis and productivity.

To bring together the previous three LAWA-Guidelines (1999, 2001, 2003), a revised classification of lakes, into types with similar trophic characteristics, was made by Riedmüller et al. (2013a). This was done using a large



calibration dataset from over 2000 lakes, with 3000 annual time-series containing the required parameters sampled with sufficient frequency ($> 2x$ per year). The revised trophic-index according LAWA (2014) classifies six newly defined lake-groups for each of natural-, artificial-, and heavily modified- lakes, plus an additional single group for stratified small lakes.

Harmonisation of the sampling methods and parameters used for monitoring by the WFD-conforming PhytoSee-method (Nixdorf et al. 2010), was an additional aim during revision of the LAWA-trophic-index. Consequently, the previously used summer mean for trophic parameters was superseded by the seasonal mean (vegetation period mean; LAWA 2014), as defined and used in the here described Phyto-See-Index.

The parameters Secchi-depth and total phosphorus are used in both the EU-WFD (as physico-chemical supporting quality elements) and in the German surface waters regulations "*Oberflächengewässerverordnung*" (OGewV 2016), i.e. orientation values are defined for every lake type for the class boundary Good-Moderate (LAWA 2015: RAKON Arbeitspapier II; Riedmüller et al. 2013a).

The Phyto-See-Index operates in trophic classes from oligotrophic to polytrophic (see Table 2), however it differs from the trophic-classification of the LAWA-trophic-index in the following ways: in addition to biomass, it also scores the taxonomic composition of the phytoplankton and the magnitude of algal blooms (as required by the EU-WFD). Additionally, the Phyto-See-Index is based only on biological parameters, i.e. it does not use phosphorus concentration and Secchi-depth, and compares the current ecological status to a predetermined reference status, which is Europe-wide harmonised for ecoregions (Poikäne et al. 2010, 2014; Järvinen et al. 2013).

The method PhytoLoss is described in a brief guide in [part B](#) of German Handbook document, as well as in a comprehensive method description in an appendix to the final report LAWA O 8.12 (Deneke et al. 2015). The module PhytoLoss (Version 1.2, 2.0, 2.1) calculates indices for the grazing-pressure of zooplankton, and as a component of the PhytoSee 6.0 assessment tool (and future updates), it allows an expanded interpretation of the assessment results.

Further required components of the Phyto-See-Index are:

- I) German lake sampling standard (Nixdorf et al. 2008, 2010),
- II) Profile documents describing German lake types and in the cover letter instructions for assigning lake types (Riedmüller et al. 2013b),
- III) German taxa list for phytoplankton (HTL; Mischke & Kusber Mai 2009) and
- IV) Assessment tool PhytoSee for the calculation of the Phyto-See-Index (Chapter 4).