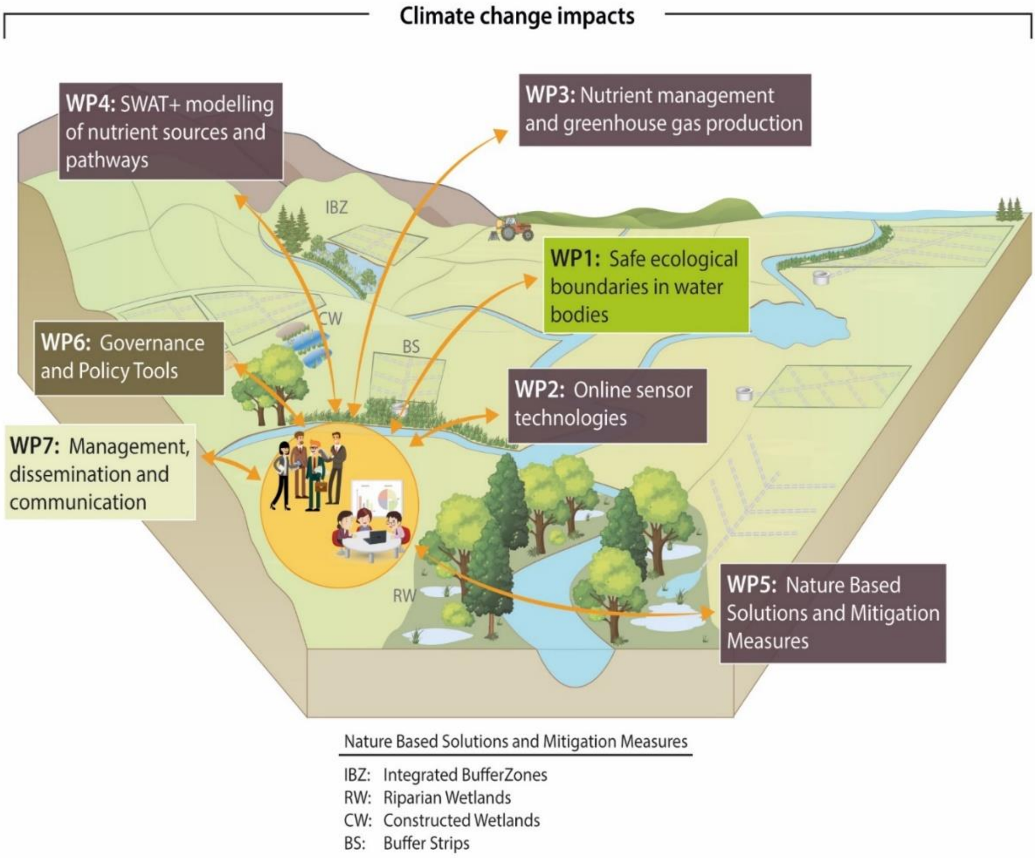
NORDBALT ECOSAFE



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Contents

Introduction

This technical note is presenting current and modelled reference values for nutrients in the NordBalt-Ecosafe partner countries expanding earlier work done in the BIOWATER project for the Nordic countries and Denmark (Skarbøvik et al. 2020). The current reference values are given for all relevant common types of lowland rivers and lakes for total phosphorus and total nitrogen. The national criteria or methods used to set the current reference values are also described in the note. The reported national reference values for river and lake types are compared with modelled reference values based on a Swedish model, and the results and implications are briefly discussed.

1 Current reference values and criteria used to set them

1.1 Common types of lowland rivers and lakes

To compare the current reference values for nutrients used in the NordBalt-Ecosafe partner countries, we have used the common typology that was developed in the early years of the Water Framework Directive (WFD) implementation to allow comparison and intercalibration of biological assessment systems for ecological status (EC, 2018). Most of the national types are linked to these common types (Lyche Solheim et al. 2019).

All the common types of lowland rivers and lakes are given in Table 1 for the Northern and Central-Baltic regions. We focus on the lowland areas, because those areas are most affected by nutrient enrichment due to more agriculture and higher population density than in upland areas.

Table 1. Common intercalibration types in the Northern and Central-Baltic regions.

a) Rivers

Region	Countries	Type code	Type description
Northern	FI, NO, SE	R-N1	lowland, small (10-100 km2), moderate alkalinity (0.2-1 meq/L), clear (colour < 30 mg Pt/L)
	FI, NO, SE	R-N2	lowland, small-medium (10-1000 km2), siliceous, low alkalnity (< 0.2 meq/L), clear (colour < 30 mg Pt/L)
	FI, NO, SE	R-N3	lowland, small-medium (10-1000 km2), siliceous, low alkalinity (< 0.2 meq/L), humic (colour > 30 mg Pt/L)
	FI, NO, SE	R-N4	lowland, medium (100-1000 km2), moderate alkalinity (0.2-1 meq/L), clear (colour < 30 mg Pt/L)
Central-Baltic	DK, LV, PL	R-C1	lowland, small (< 100 km2; 3-8 m wide), siliceous, sand, alkalinity > 0.4 meq/L
	DK, LV, PL	R-C2	lowland, small (< 100 km2; 3-8 m wide), siliceous, rock, alkalinity < 0.4 meq/L
	DK, LV, PL	R-C4	lowland, medium (100-1000 km2; 8-25 m wide), sand or gravel, mixed geology (calcareous) (alkalinity > 0.4 meq/L)
	DK, LV, PL	R-C5	lowland, large (1000-10 000 km2; > 25 m wide), mixed (calcareous) (alkalinity > 0.4 meq/L)
	DK, LV, PL	R-C6	lowland, small (< 300 km2; 3-10 m wide), gravel, calcareous, alkalinity > 2 meq/L

b) Lakes

Region	Countries	Type code	Type description
Northern	FI, NO, SE	L-N1	lowland, shallow (3-15 m mean depth), moderate alkalinity (0.2-1 meq/L), clear (colour < 30 mg Pt/L)
	FI, NO, SE	L-N2a	lowland, shallow (3-15 m mean depth), low alkalinity (<0.2meq/L), clear (colour < 30 mg Pt/L)
	FI, NO, SE	L-N2b	lowland, deep (>15 m mean depth), low alkalinity (<0.2meq/L), clear (colour < 30 mg Pt/L)
	FI, NO, SE	L-N3a	lowland, shallow (3-15 m mean depth), low alkalinity (<0.2meq/L), humic (colour >30 mg Pt/L)
	FI, NO, SE	L-N8a	lowland, shallow (3-15 m mean depth), moderate alkalinity (0.2-1 meq/L), humic (colour > 30 mg Pt/L)
Central-Baltic	DK, LV, PL	L-CB1	lowland, shallow (3-15 m mean depth), high alkalinity (> 1 meq/L), residence time 1-10 years
	DK, LV, PL	L-CB2	lowland, very shallow (<3 m mean depth), high alkalinity (> 1 meq/L), residence time 0.1-1 years
	LV	L-CB3	lowland, shallow (3-15 m mean depth), siliceous, moderate alkalinity (0.2- 1 meq/L), residence time 1-10 years

There is also another lowland type that is quite common in agricultural areas, where the catchment soils are rich in clay content. This type is called clay-rivers and clay-affected lakes, which have naturally quite turbid waters and, therefore, also naturally higher concentration of phosphorus.

We have identified clay-rivers to have > 20% clay content in the catchment soils, which corresponds to roughly having a concentration of suspended sediment > 10 mg SS L^{-1} based on a non-linear regression (Figure 1).

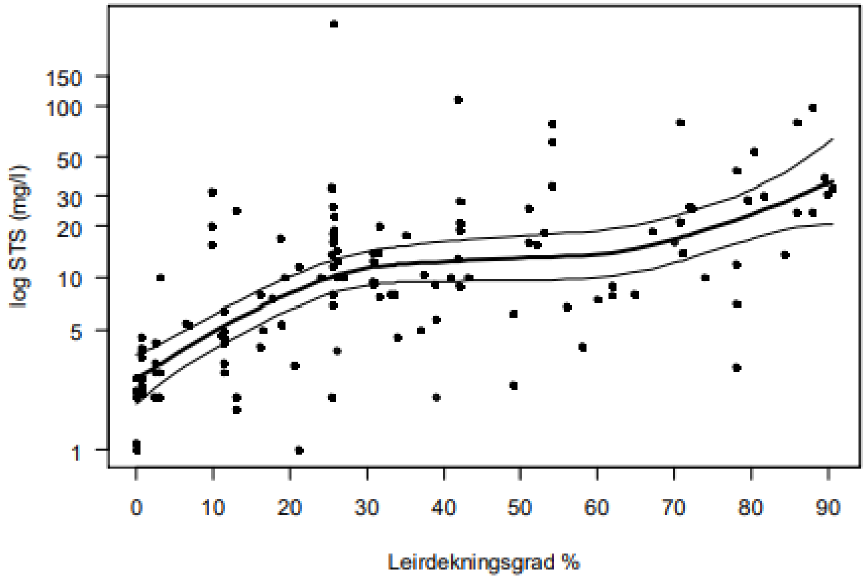

Figure 1. Relationship between measures suspended solids (STS) and % clay cover in the catchment (Leirdekningsgrad) based on lowland rivers below the marine deposit line in five different river basins in South-Eastern Norway. The first breakpoint on the curve corresponds to 20-30% clay cover at ca. 10 mg STS L-1 (Figure copied from Eriksen et al. 2015).

1.2 Current reference values for nutrients in different types of rivers and lakes

The currently used reference values are given for the different common types of rivers and lakes for total phosphorus (TotP) in Table 2, including also clay rivers (Table 2e) and for total nitrogen (TotN) in Table 3. The criteria or methods used to set them are given in section 2.3.

The reference values are relatively similar among the countries in the Nordic region, although Finland has slightly higher values than Norway, probably due to the browner waters also within each of the common types. The same pattern was found for reference values of chlorophyll n lakes during the intercalibration of phytoplankton assessment systems (Lyche Solheim et al. 2014).

In the Central-Baltic region, the reference values are much higher than in the Nordic region, except Danish lakes, which are in line with the values from the Nordic region. The values for Latvia are in line with the Danish river values, but are considerably higher than the Danish value for lakes. Poland has remarkable much higher values than Latvia for both rivers and lakes. For rivers, the Polish values are four times higher than the Danish and Latvian rivers. For lakes, the Polish values are four to ten times higher than the Danish values and two to three times higher than the Latvian values. The very high Polish reference values are based on other reference criteria than those used in the other countries. This is discussed in more detail in section 2.3 below.

Table 2 a-e. Reference values for total phosphorus concentrations for common types of rivers and lakes in Nordic and Central Baltic regions.

Nordic region

a. Total P (µg P/L), Rivers

Type code	NO	SE	FI
R-N1	9	5	11
R-N2	6	4-5	11
R-N3	9	4-27	14
R-N4	9	-	11

b. Total P (µg P/L) , Lakes

Type code	NO	SE	FI
L-N1	6	4-13	8-12
L-N2a	4	2-9	5-12
L-N2b	3	3-5	5-8
L-N3a	6	4-16	12-22
L-N8a	7	4-22	12-30

Central Baltic region

c. Total P (µg P/L), Rivers

Type code	SE (Skåne)	DK	LV	PL
R-C1	12-36	43	-	170
R-C2	7-19	-	-	-
R-C4	8-28	-	50-60	200
R-C5	9-22	-	40-45	170
R-C6	7-34	54	40-45	-

d. Total P (µg P/L), Lakes

Type code	DK	LV	PL
L-CB1	7-16	20-30	40
L-CB2	6-13	25-30	80
L-CB3		15-30	

e) Total P (µg P/L) - Clay rivers (both regions)

	FI	NO	SE	DK	LV	PL
Clay rivers	< 40	20-40	8-76	-	-	87-1870

For clay rivers, the Nordic countries have relatively similar reference values, but they are higher than in the other river types in the Nordic countries, which is to be expected due to phosphorus adsorbed to the clay-particles. For the Central-Baltic countries, the values are missing for Denmark and Latvia, while Poland also for this type has very much higher reference values and a very wide range spanning two orders of magnitude.

Table 3 a-d. Reference values for total nitrogen concentrations for common types of rivers and lakes in Nordic and Central Baltic regions

Nordic region

a. Total N (µg N/L) , Rivers

Type code	NO	SE	FI
R-N1	275	435	235
R-N2	200	139-188	235
R-N3	275	140-1057	315
R-N4	275	-	235

b. Total N (µg N/L) , Lakes

Type code	NO	SE	FI
L-N1	275	168-322	320-400
L-N2a	200	74-253	170-360
L-N2b	175	167-167	170-350
L-N3a	275	193-490	400-520
L-N8a	325	218-494	400-670

Central Baltic region

b. Total N (µg N/L) ,Rivers

Type code	DK	LV	PL
R-C1	1060	-	2000
R-C2	-	-	-
R-C4	-	1800-2000	2200
R-C5	-	1800	2000
R-C6	1480	1500	2000

d. Total N(µg N/L) ,Lakes

Type code	DK	LV	PL
L-CB1	190-530	500-800	1000
L-CB2	180-420	1000	1500
L-CB3	-	500-1000	-

1.3 Reference criteria used to set the current reference values

The criteria and methods used to set the reference values are given in Table 4 and 5 below. These are based on the official criteria agreed during the intercalibration of the assessment systems for the biological quality elements in each region.

Table 4. Reference criteria for nutrients in rivers (this should reflect the landuse applied as filters to select reference sites)

Country	NO	SE	FI	DK	LV	PL
Max % agri	5%	-	10%	10%	20% as arable land	None
Max Population density	5 p.e./km2	-	10 p.e./km2	-	None	None
Point sources	none	-	minimal	None	None	None
HYMO-changes	minimal	-	minimal	Minimal	No HYMO alterations	None
Other approach	Modelling for clay rivers	Modelling for all rivers	For clay rivers expert judgement based on monitoring data from the impacted rivers and other river types	None	None	Good biological status

Table 5. Reference criteria for nutrients in lakes

Country	NO	SE	FI	DK	LV	PL
Max % agri	5%	-	10%	None	None	None
Max Population density	5 p.e./km2	-	10 p.e./km2	None	None	None
Point sources	none	-	minimal	None	No direct inflow of untreated or treated wastewater	None
HYMO-changes	minimal	-	minimal	None	The threshold of <5% of HYMO changes of the shore line	None
Other approach		Modelling for all lakes		EU tool kit applied using regression between biological indicator and nutrients	None	Good biological status

Further specifications of reference criteria or other methods used to set the current reference values are given in the following:

Norway:

The reference criteria were used to select reference sites which were used to set the reference values. The criteria are listed in the NGIG Technical Intercalibration Report (e.g. Lyche Solheim et al. 2014). The same criteria were used for both lakes and rivers. The reference values were set as the median of the nutrients data in a population of reference lakes or reference rivers for each type. The reference values are being validated with data from the national Norwegian WFD surveillance monitoring programmes for reference lakes (ØKOFERSK) and reference rivers (REF-ELVER).

For clay rivers, the reference values for phosphorus are based on a regression model with total phosphorus as a function of % clay cover in the catchment. The criteria used to identify clay rivers are rivers with more than 10 mg/L total suspended solids and/or a turbidity of more than 5 NTU as annual median values (Direktoratsgruppen for Vanndirektivet, 2018). Lyche Solheim et al. (2008) recommended that the suspended sediment should have less than 20% organic material (loss of ignition at 550 ◦C), and that water samples should be taken over a period of three years.

The other criterion is that the clay soil coverage in the catchment upstream of the sampling site should be at or higher than 20% (Eriksen et al. 2015).

Schneider and Skarbøvik (2022) compared the PIT index for benthic algae with TP concentrations in clay rivers. They commented that concentrations of TP significantly increased with both suspended solids (SS) and catchment clay cover, and therefore both criteria could be used to quantify the "clay effect" at a specific site. However, they recommended using % catchment clay cover. Firstly due to costs (often less costly to determine the soil conditions than to monitor SS and turbidity with sufficient frequency); secondly due to the high variability and therefore uncertainty of SS concentrations; and thirdly since high SS can be caused by poor catchment management, for example less vegetation along streams and therefore high bank erosion.

Sweden:

Site specific reference values are calculated for each water body from water chemistry and physiographical parameters where water colour, clay content and lake mean depth are the most important variables. For each type, the range of the individual reference values are given. This approach was chosen in Sweden to overcome the large within-type gradients in humic bound phosphorus and the fact that the reference sites used for setting class boundaries for biological quality elements are mainly forest sites, not representative for water bodies in the agricultural landscape. To get more representative reference values for rivers in agricultural areas, a regression model was developed. For details se section 3.

Finland:

The reference criteria (Table 3) were used to set the reference values and are listed in the NGIG Technical Intercalibration Report (e.g. Lyche Solheim et al. 2014). Nutrient reference values were established based on expert judgement of monitoring data from minimally disturbed rivers of other river types and from data on disturbed rivers draining agricultural and clay-rich catchments. A national review panel evaluated the boundaries. Based on annual statistics, review panel work and tests with preliminary classification results, river type-specific High/Good status class boundaries for TP and TN were set as the 75th–90th percentiles of the nutrient concentrations among the reference or least disturbed rivers.

For rivers only H/G boundaries are reported in national guidance documents (Aroviita et al. 2019). Basically, values lower than the H/G-boundary represent nutrient reference concentrations. In this Nordbalt-Ecosafe report, for comparison, type-specific reference values were derived by multiplying the national H/G boundaries by 0.7. This factor was taken from the mean relation between reference values and H/G boundaries in Finnish lakes and is the same as for Swedish lakes and rivers.

For lakes, ranges of reference values are given since many national types with different reference values are included in each of the common types.

Denmark:

The Danish reference or background nutrient concentrations in streams are derived from the national monitoring programme (NOVANA) where a total of 19 smaller streams are monitored every 3 years. The monitoring of such streams has been ongoing since 1989 for six of the streams (Kronvang et al., 2015). These streams and catchments are judged to represent least disturbed conditions (LDC) (*sensu* Stoddard et al., 2006) for stream water quality in Denmark. The stream water quality is, however, impacted by the atmospheric deposition of NOx and NHx both from long-distance sources and nearby sources (farms) from outside these small forested or other more open nature (heathland) catchments (typically <5 km2).

The Danish reference nutrient concentrations in lakes are derived utilizing an EU developed toolkit (Phillips et al., 2018) with establishment of a categorial and/or logistic regression analysis between biological indicators and nutrient concentrations. As biological indicator chlorophyll a has been used with values of 3.85 µg/l for the national lake types 1, 2, 5, 6, 10, 12 and 14 and 7.50 µg/l for the national lake types 9, 11, 13 and 15 (Søndergaard et al., 2019).

Latvia:

The criteria used to identify reference sites for rivers in Latvia is adopted from Pardo et al. (2012):

- < 4% of urban land use in the catchment area;
- < 20% of arable land in the catchment;
- The river section is not affected by hydropower plants or other dams (natural hydrological flow regime);
- The river section is heterogeneous (no channelization/straightening, no bank stabilization, no anthropogenic barriers causing stagnant water);
- O2 > 8 mg/l;
- BOD5 < 2 mg/l;
- NH4-N < 0.09 mg/l;
- Total nitrogen < 1.8 mg/l;
- Total phosphorus < 0.06 mg/l.

Overall, 13 rivers meet the criteria of reference sites for rivers.

The criteria used to identify reference sites for lakes in Latvia is adopted from Bohmer et al. (2014):

- > 85% of natural land use in the catchment area;
- No intensive agriculture within a zone of 200 m from the lake shore;
- < 5% of urban land use within a zone of 200 m from the lake shore;
- No direct inflow of untreated or treated wastewater;
- < 5% of hydromorphological modifications of the shore line.

Overall, 18 lakes meet the criteria of reference sites for lakes.

Poland:

The current physico-chemical reference values for rivers and lakes were developed based on the ECOSTAT CIS guidance (Phillips et al. 2018) and using the Excel ToolKit. A detailed description of the methodology for selecting reference values can be found in Kolada et al, 2018. The Polish reference values given in Table 2 and 3 are not representing true reference sites, but rather represent high/good boundaries for best available sites. The methodology used to set those boundaries are given below.

The derivation of reference values for rivers was based not on the nature of the catchment area, but on the good biological status established according to the following indicators: Diatom index for river and dam reservoir classification (IO), Macrophyte Index for Rivers (MIR), Polish Multimetric Macroinvertebrate Index (MMI). Analyses were performed for all abiotic types of rivers and for the following parameters: dissolved oxygen, BOD5, OWO, conductivity, pH, phosphate phosphorus and total phosphorus, nitrate nitrogen, ammonia nitrogen and total nitrogen. The dataset counted more than 3,500 physico-chemical samples, 1,500 for macrophytes and benthic macroinvertebrates (MIR and MMI) and nearly 3,000 for phytobenthos (IO). In developing boundary values for indicators not included in the ECOSTAT CIS guidance, categorical methods were adapted, i.e. AAQ Average Adjacent Quartiles (AAQ) and AAM Average Adjacent Medians (AAM). The selection of the final boundary values also took into account the values of the previous classification and expert judgment. For example, for very large lowland rivers of type R-L2, due to the small number of biological measurements, statistical methods could not be used, and therefore the previous high/good boundaries were kept. For many river types, common (aggregated) values were proposed and as a result, 9 separate high/good boundary values were introduced for 22 river types. Only a few of these were matching the common intercalibrations types given in Table 1.

As for rivers, the basis for deriving reference values was not the nature of the catchment area, but the good biological status represented by the Phytoplankton Metric for Polish Lakes (PMPL) index. This indicator was chosen because of the strongest relationships with physical and chemical indicators and the absence of additional conditions (Ecological Status Macrophyte Index (ESMI) and Diatom Index for Lakes (IOJ) were also analyzed). Analyses were performed for 531 lakes (1000 samples), all abiotic types, and for the following parameters: total nitrogen, total phosphorus, Secchi disk visibility, specific electrolytic conductivity. For physicochemical indicators non-parametric or semi-non-parametric tests were used, as these are insensitive to the inhomogeneity of variance (Spearman rank correlation, Mann-Whitney U test). The ECOSTAT CIS guidance (Phillips et al. 2018) could not be used, due to the heterogeneous nature of the data (different data distributions, different number of lakes in the types and classes of ecological status compared). In the absence of statistical significance of the tests, categorical methods were used, i.e., the average value of the upper quartile of the upper class (AAQ Average Adjacent Quartiles) and the average value of the median of the upper class (AAM Average Adjacent Medians). When selecting the final boundary values, the values of the previous classification and expert evaluation were also taken into account.

2 Modelling of reference values

2.1 Main approach

The statistical model for site specific reference values for nutrients was developed in Sweden to address two problems with the commonly used type- specific approach. One is the large within type variation of colour in reference sites, especially pronounced in brown waters, where nutrient concentrations are strongly correlated to water colour (Huser and Fölster, 2013). The other problem is that a reference filter used to select reference sites includes a maximum fraction of agricultural land (e.g., < 10%), which will give a bias of the reference values towards the naturally most nutrient poor waters, since the nutrient rich land is chosen for agriculture. Those reference values are therefore not representative for the naturally more nutrient rich waters within the type.

To solve these issues, Sweden developed a regression model for site specific reference values of nutrients including water chemistry, minimally impacted by eutrophication, geographical data and catchment characteristics (Fölster et al, 2021). The regression models aimed to predict modelled background values of nutrients from the source apportionment calculations delivered to HELCOM (Ejhed et al, 2016). The background then represents a state without point sources, deposition, forestry or population and with non-fertilised and non-harvested ley as land use of the agricultural land. The modelling of the background nutrient concentrations for HELCOM is optimised for source apportionment of the load to the Baltic Sea and is, therefore, based on geographically distributed data. This might, however, cause large errors for the modelling outcome for single water bodies. By using the site-specific information for water chemistry the random error was reduced (Fölster et al, 2021). For impacted sites that were included in the model to represent all kinds of waterbodies, the reference value could not be validated by data. Instead, the predicted reference values were consulted with experienced managers at the water authorities, using their expert judgement.

The regression parameters for the models for $\log(TotP_{ref})$ and $\log(TotN_{ref})$ in rivers and lakes are presented in Tables 6 a-d below. For TotP, alternative models could be used, when data on some of the variables were missing (Appendix 3). For TotN, no alternative models are given, so if any data is missing, no reference value could be calculated.

Table 6. Regression parameters for the best site-specific models for log ($TotP_{ref}$) and log ($TotN_{ref}$) in rivers and lakes. The parameter values are the slope for each variable (except the intercept) and are ranked from the variables with the highest positive or negative slope on top to the lowest slope at the bottom of each table.

a. TotP in rivers

Parameters	Value
Intercept	1,393
logAbsF	0,574
log%Clay in catchment+1	0,451
logCa+Mg*	0,264
logSO4	-0,249
logAlt	-0,0629
log%Wetlands+1	-0,129
log%Water surface area	0,0425

b. TotP in lakes

Parameters	Value
Intercept	2,058
logMg	0,782
logSO4	-0,399
logMedeldjup	-0,395
logAbsF	0,335
log%Wetlands+1	-0,152

c. TotN in rivers

Parameters	Value
Intercept	5,356
logAbsF	0,390
logCa	0,217
log%Water surface area+1	-0,113
logAlt	-0,044
log Catchment area	-0,029
%Forest cover	-0,00235
NS Coordinates*	-3,23E-07
EW Coordinates*	2,93E-07

d. TotN in lakes

Parameters	Value
Intercept	3,825
logAbsF	0,344
logMedeldjup	-0,182
logCa	0,166
logAlt	-0,0670
NS Coordinates*	-1,02E-07

*NS and EW coord. in SWEREF99 (EPSG 3006) correspond to latitude and longitude respectively

2.2 Limitations of the calibration data for the model

The calibration data set consisted of monitoring stations representative for the water bodies with water chemistry including relevant variables. The data sets covered the ranges of input data as presented in Table 7. When extrapolated outside the range of the calibration data set, the results must be interpreted with care.

Table 7. Limits of the calibration data for the model

Rivers

Variable	Min	Max
AbsF	0,009	0,656
Colour (mg Pt/l)	4,5	328
% Clay in catchm.	0	14
SO4 meq/l	0,029	6,286
Ca+Mg meq/l	0,087	7,679
Altitude m	0,16	582
% Wetland	0	45
% Water surface	0	35

Lakes

Variable	Min	Max
AbsF	0,009	0,599
Colour (mg Pt/l)	4,5	300
Lake mean depth m	0,6	27
SO4 meq/l	0,008	1,637
Mg meq/l	0,018	0,931
% Wetland	0	39
Alkalinity meq/l	-0,039	3,91
Altitude m	0,5	303

The model for site specific reference values of nutrients calibrated for Sweden was applied on data from the other countries to explore the applicability of such the approach. The coordinates of the input data were limited to the area of Sweden to avoid extrapolations far outside the calibration data, except for Norway and Finland, where the actual latitude was used. For Norwegian clay-rivers, the latitude was set to a westernmost longitude in Sweden. For Finland an easternmost longitude was used. For Denmark and Poland, the coordinates were taken from southernmost Sweden for all sites.

2.3 Datasets and variables

The different countries delivered data for the model following a template. The most important variables for the river model for phosphorus are water colour (or filtered absorbance), average % clay content in the catchment and Ca+Mg (Table 6a). The water colour (in mg Pt L-1) are calculated from the filtered absorbance by multiplying the absorbance with 500. For lakes, the most important variables are Mg, SO4, mean depth and water colour (or filtered absorbance) for the phosphorus model (Table 6b). For the nitrogen model water colour (or filtered absorbance) and Ca were the most important variables for both rivers and lakes in addition to mean depth for lakes. Some of these variables were often also the most challenging ones for the countries to find data for and sometimes had to be estimated.

Finland

Data from 290 lowland river water bodies and 589 lakes were delivered from Finland with 99 of the river sites and 200 of the 484 reported lakes belonged to any of the IC types evaluated in this report. The water chemistry data are from 2010-2021. Clay content was delivered as percentage of the catchments covered by clay soils. Most areas of clay soil are arable land, but not all. Since the clay content in clay soils according to FAO soil types, is around 50%, the coverage of clay soils was multiplied by 0.5 to get average clay content in the whole catchment. The longitude was set to the easternmost latitude in the Swedish data.

Norway

Data from Norway was extracted from a Nordic data compilation aimed to develop common Nordic systems for status classification for physicochemical quality elements (Fölster et al, 2021). Data was completed from NIVA with land use data and modelled lake depth. The sites covered both reference sites and impacted sites. 17 of the 63 lowland rivers delivered and 26 of the 68 lowland lakes belonged to any of the IC-types in this report and could be included. No data on clay content in the soils was available, but the rivers were classified if they were impacted from clay soils or not. For non-clay rivers, the clay content was set to zero. For clay impacted site, a high and a low clay content was estimated by assuming the fraction of clay soils in the catchment to be either 10 % or 50 % and to set the clay content of the clay soils to 50 %. For each Norwegian clay impacted river sites, two calculations of reference values were made: one assuming 5 % clay content in the catchment and one assuming 25 % clay.

Sweden

For Sweden the site-specific regression model is the official method for reference values of nutrients, so the results here presented are the same as Table 3. The data consisted of 1060 low land rivers with 258 in any of the IC types and 777 lowland lakes with 168 in any of the IC-types. All waterbodies included different levels of disturbance.

Denmark

Denmark delivered data from 12 rivers, all from any of the IC types. Data on soil texture of the agricultural soil was used to calculate the average clay content of the catchment. Data on water colour was missing. Instead, 25 and 75 percentiles of colour in monitoring data from other sites in the same region to give two alternative classifications for each stream. Data from 20 lakes with 14 in of any of the IC types was delivered.

Latvia

Data from 13 rivers, all belonging any of the IC-types and 18 lakes with 15 in any of the IC-types included in this study was delivered from Latvia. All sites were references.

Poland

Data for modelling was delivered for 1 084 lowland rivers and 270 lowland lakes. 930 of the rivers and 263 of the lakes belonged to any odd the IC-types. Data on Mg was often missing, so for TotPref, the alternative model with alkalinity was then used. Coordinates from a southernmost site Sweden was used. Due to the large number of sites, the ranges of reference values were given as 10 and 90 percentiles.

2.4 Modelled reference values for different types of rivers and lakes

Data from the different countries were lumped together for each common type. For rivers, the sites from each type were then divided into two groups according to clay content. The boundary between low and high clay content was set to 10 % average clay content in the catchment, corresponding to 20 % coverage of clay soils. The ranges of modelled reference values are given in Table 8 for the different common types of rivers and in Table 9 for different lake types. The number of sites for each type is highly different.

For the Central Baltic region, the models for $TotP_{ref}$ including Ca, Mg and SO4 gave very high values. For example, for some Latvian reference sites, twice as high as the measured value. This is probably due to a different relationship between Tot-P, Ca, Mg and SO4 in Latvian natural waters compared to the Swedish calibration dataset, reflecting different geology. To get more realistic estimations of the reference values, the model including Alkalinity was used for lakes in the central Baltic region. For rivers an alternative model without Ca, Mg and SO4 was used that only included AbsF, %Clay content in catchment, Altitude and %Wetland in catchment. Alkalinity was tested as a candidate parameter for the alternative model, but in opposite of what was found for lakes, it was not statistically significant and not included.

Table 8. Modelled reference values for total phosphorus and total nitrogen concentrations for common types of **rivers** in Nordic and Central Baltic regions. For each river type, the modelled values were divided into two classes of clay content (low and high), using 10% clay content in the catchment as a boundary. For each type and clay class, the range is given as minimum and maximum values, followed by the number of sites for each type (and sub-type: low versus high clay-content). Values are also shown for all lowland rivers in the dataset, including those not belonging to any of the IC-types.

Region	IC-type	TotP (µg P/L)				TotN (µg N/L)			
		Low clay	N	High clay	N	Low clay	N	High clay	N
Nordic	R-N1	4-5	3	24-53	4	197-435	2	-	0
	R-N2	2-5	13	-	0	77-310	12	-	0
	R-N3	4-33	352	-	0	140-1057	261	-	0
	R-N4	9-11	2	-	0	196-262	2	-	0
	Clay IC types			24-53	4			-	0
	Clay all lowland			11-99	135			479-1245	76
Central Baltic	R-C1	2-29	313	5-55	349	243-1864	313	378-1614	349
	R-C2	2-3	2	-	0	214-294	2	-	0
	R-C4	3-34	96	9-49	123	344-1281	96	346-1269	123
	R-C5	6-28	39	12-39	69	335-1044	39	421-1082	69
	R-C6	7-15	4	12-49	5	593-823	4	455-1059	5
	Clay IC types			5-55	546			346-1614	546
	Clay all lowland			5-82	611			346-1781	611

Table 9. Modelled reference values for total phosphorus and total nitrogen concentrations for common types of **lakes** in Nordic and Central Baltic regions. For each type, the range is shown as minimum and maximum values, followed by the number of sites for each type.

Region	Type code	TotP (µg P/L)	N	TotN (µg N/L)	N
Nordic	L-N1	4-13	48	118-322	44
	L-N2a	2-12	39	74-253	39
	L-N2b	2-5	12	75-168	7
	L-N3a	4-23	220	166-725	206
	L-N8a	4-29	75	190-494	53
Central Baltic	L-CB1	5-66	217	142-459	213
	L-CB2	9-65	64	232-1023	63
	L-CB3	5-17	11	131-566	11

2.5 Comparison of modelled reference values with current reference values

The current reference values for rivers and lakes are compared with ranges of modelled reference for each common type in Table 10 and 11.

The comparison of the current reference values used in each country and the modelled reference values show some striking results that should be further discussed with stakeholders:

1. The Polish reference values are not representing true reference sites, but rather best available high/good boundary values from rivers and lakes that are classified to be in good status for the biological quality elements, for which the metrics have been successfully inter-calibrated. The current values used to represent good status sites in Poland are very much higher than in Latvia and Denmark. They are also much higher than the ranges of reference values estimated with the Swedish model, even for the rivers with high clay content. This suggests that the biological metrics used in Poland do not seem to respond to nutrients in rivers, or that the Swedish model underestimate the reference values for the Central-Baltic region. For lakes, however, the model gives ranges that are in line with the Polish reference (good status) values for the stratified lakes (L-CB1). For the unstrati -fied lakes, the Polish value is higher than the upper limit of the range predicted by the model.

2. The model predicts quite low lower limits for rivers, varying from 2-5 µg P/L for total P and 77-371 µg N/L for total N, while the higher limit of the range, varying from 5-33 µg P/L for total P and 197-1592 µg N/L for total N is more in line with the current values in the Nordic region for rivers with low clay content.

3. For the Central-Baltic region, the model predicts lower values than the current values, which are higher than the high end of the range predicted for all the common river types. This may indicate that the current values are too high and do not represent real reference values, or that the model underestimates the reference values for that region.

4. For rivers draining clay catchments, the model predicts for total P 4-55 µg P/L for both regions combined. The lower end of this range is lower than those currently used, which may indicate that the model underestimates the reference value for clay-rivers. The upper end of the range is however in line with the current values used in Finland and Norway, although is a bit lower than the upper end of the current Swedish values. Unfortunately, there are no values reported for clay-rivers by Denmark and Latvia, but their values reported for the Central-Baltic river-types could be more representative for clay-rivers than for other river types.

5. For lakes, the model predicts reference values that are in line with the current values used for all common lake types in both regions, although the lower end of the range predicted is a lot lower than those reported for the Central-Baltic lake-types.

Table 10. Comparison of current and modelled reference values for total phosphorus and total nitrogen for common types of rivers in Nordic and Central Baltic regions. Modelled reference values are given as ranges of minimum and maximum values, followed by the number of sites for each type.

Common type		Country	TotPref (µg P/l)	N	TotNref (µg N/l)	N
R-N1	Current	FI	3		235	
		NO	9		275	
		SE	5		435	
	Modelled	Low clay	4-5	2	197-197	1
		High clay	5-53	5	435-435	1

R-N2	Current	FI	11		235	
		NO	6		200	
		SE	4-5		139-188	
	Modelled	Low clay	2-5	8	77-310	8
		High clay	4-5	5	139-188	4
R-N3	Current	FI	14		315	
		NO	9		275	
		SE	4-27		140-1057	
	Modelled	Low clay	4-33	183	140-1057	180
		High clay	5-27	169	197-907	81
R-N4	Current	FI	10,5		235	
		NO	9		275	
		SE	-		-	
	Modelled	Low clay	5-30	63	371-1582	63
		High clay	11-82	57	383-1781	57
R-C1	Current	DK	43		1060	
		LV	-		-	
		PL	170		2000	
	Modelled	Low clay	2-29	313	243-1864	313
		High clay	5-55	349	378-1614	349
R-C2	Current	DK	-		-	
		LV	-		-	
		PL	-		-	
	Modelled	Low clay	2-3	2	214-294	2
		High clay	-	0	-	0
R-C4	Current	DK	-		-	
		LV	50-60		1800-2000	
		PL	200		2200	
	Modelled	Low clay	3-34	96	344-1281	96
		High clay	9-49	123	346-1269	123
R-C5	Current	DK	-		-	
		LV	40-45		1800	
		PL	170		2000	
	Modelled	Low clay	6-28	39	335-1044	39
		High clay	12-39	69	421-1082	69
R-C6	Current	DK	54		1480	
		LV	40-45		1500	
		PL	-		-	
	Modelled	Low clay	7-15	4	593-823	4
		High clay	12-49	5	455-1059	5
Clay rivers	Current	FI	<40			
		NO	20-40			
		SE	8-76			
		DK	-			
		LV	-			
		PL	87-1870			
	Modelled	High clay	4-55	725		

Table 11. Comparison of current and reported reference values for total phosphorus and total nitrogen concentrations for common types of lakes in Nordic and Central Baltic regions.

Common type		Country	TotPref (µg P/l)	N(TotP)	TotNref (µg N/l)	N (TotN)
L-N1	Current	FI	8-12		320-400	
		NO	6		275	
		SE	4-13		168-322	
	Modelled	All	4-13	48	118-322	44
L-N2a	Current	FI	5-12		170-360	
		NO	4		200	
		SE	2-9		74-253	
	Modelled	All	2-12	39	74-253	39
L-N2b	Current	FI	5-8		170-350	
		NO	3		175	
		SE	3-5		167-167	
	Modelled	All	2-5	12	75-168	7
L-N3a	Current	FI	12-22		400-520	
		NO	6		275	
		SE	4-16		193-490	
	Modelled	All	4-23	220	166-725	206
L-N8a	Current	FI	12-30		400-670	
		NO	7		325	
		SE	4-22		218-494	
		All	4-29	75	190-494	53
L-CB1	Current	DK	13		400	
		LV	20-30		500-800	
		PL	40		1000	
	Modelled	All	5-66	217	142-459	213
L-CB2	Current	DK	40		600	
		LV	25-30		1000	
		PL	80		1500	
	Modelled	All	9-65	64	232-1023	63
L-CB3	Current	DK				
		LV	15-30		500-1000	
		PL				
	Modelled	All	5-17	11	131-566	11

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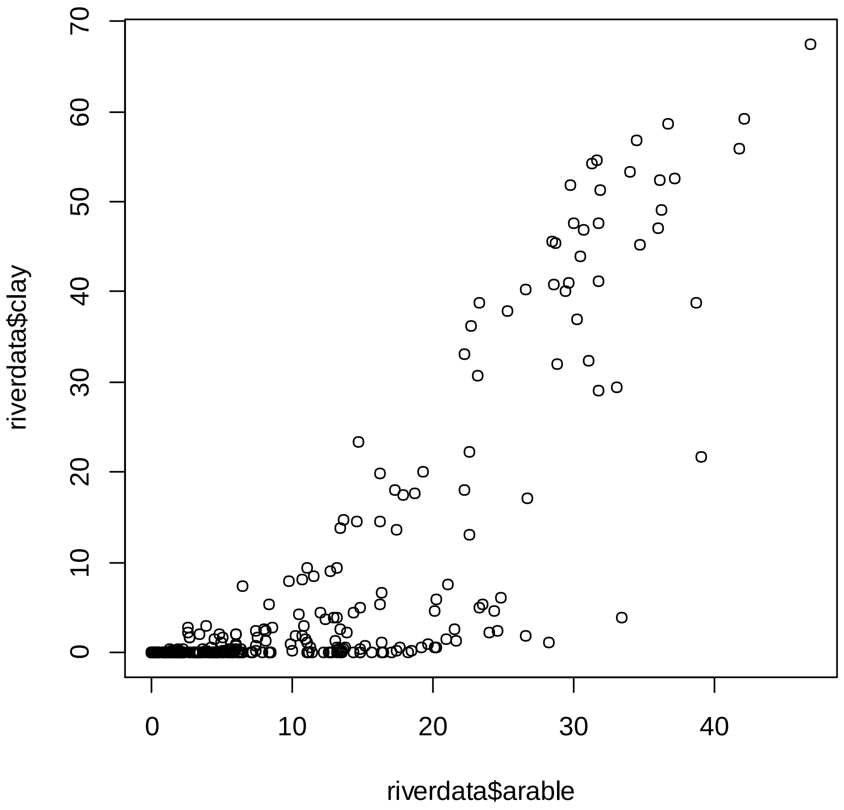
4 Appendix 1

Figure 2. Relationship between % of clay soil of the catchment and % arable land of catchment area in river data in Finland.



5 Appendix 2

Regression parameters for alternative models for logTotPref

Lakes

Model abbreviation	Intercept	logMean depth	logAbsF	logSO4	logMg	log%Wetland	logAlkainity	logAltitude	log%forest
MgS	2,0584	-0,3955	0,3351	-0,3993	0,7818	-0,1524			
Mg	1,9340	-0,3814	0,2871		0,4442				
Alk	1,7598	-0,3527	0,2422				0,2319	-0,1165	
Skog	3,0989	-0,3883	0,3867			-0,2043		-0,1839	-0,5352
Red	3,5654		0,5793			-0,1992		-0,2730	-0,7405

Rivers

Model abbreviation	Intercept	logAbsF	log%Clay in catchm.	logSO4	log(Ca+Mg)	logAltitude	log%Wetland	log%Watersurface
MgS	1,3930	0,5740	0,4514	-0,2485	0,2638	-0,0629	-0,1288	0,0425
Red*	1,4836	0,5193	0,4722			-0,0616	-0,0986	

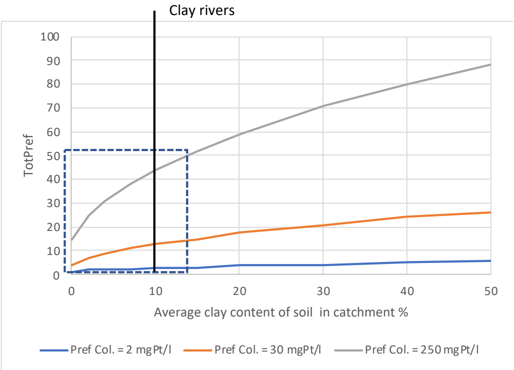
*alkalinity was tested but was not significant

6 Appendix 3

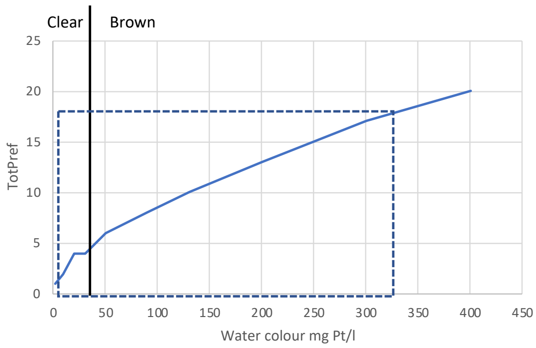
Theoretical relations between input data and modelled TotP reference values.

Rivers

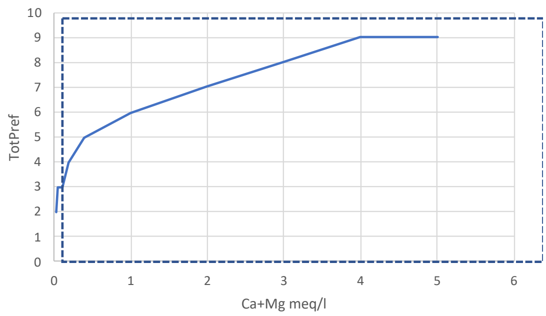
a



b



c



d

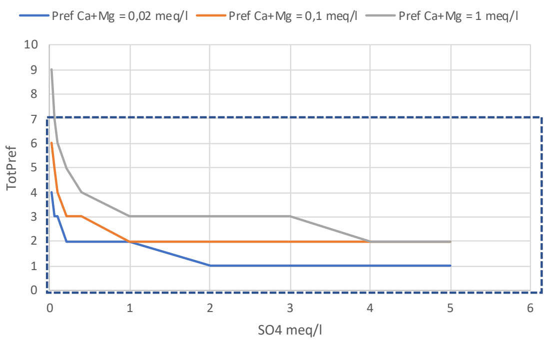
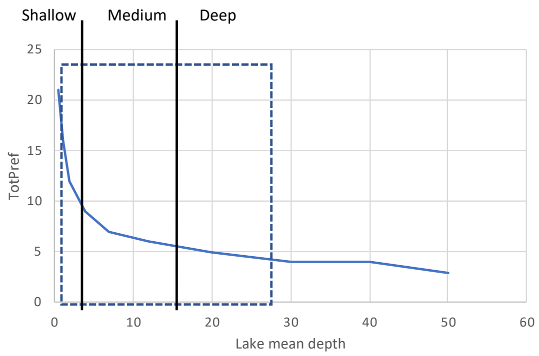


Figure A3:1. Theoretical relation between modelled TotPref and input data in rivers for avarage clay content in catchment (a), water colour (b), Ca + Mg (c) and SO4 (d). In plot d, three levels of Ca + Mg was used.

Lakes

a



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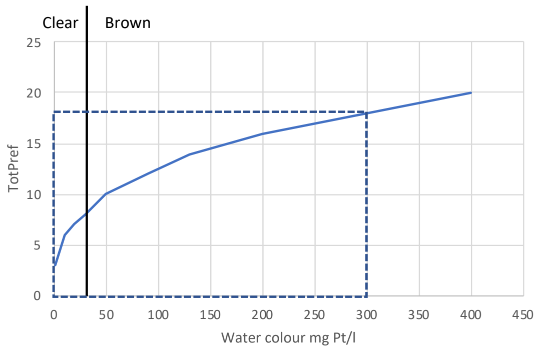
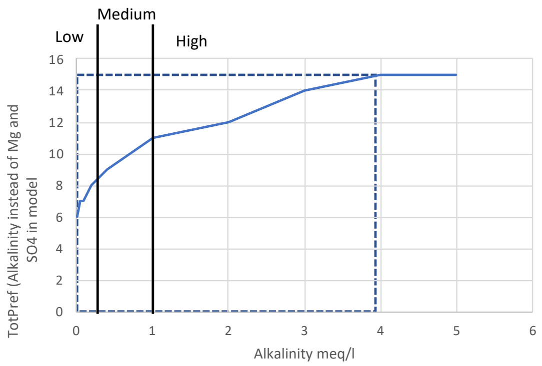


c

d



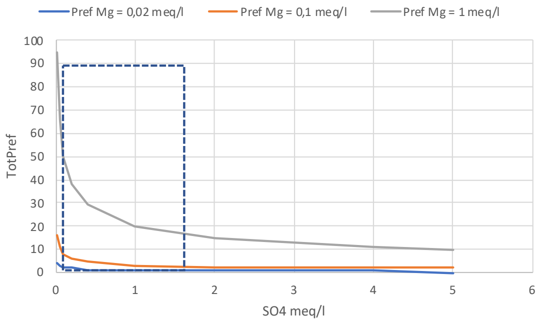


Figure A3:2. Theoretical relation between modelled TotPref and input data in lakes for lake mean depth (a), water colour (b), Ca + Mg (c) and SO4 (d). In plot d, three levels of Ca + Mg was used.

7 Appendix 4

Figure 3. Ranges of %Clay and Colour in calibration dataset for the regression model.