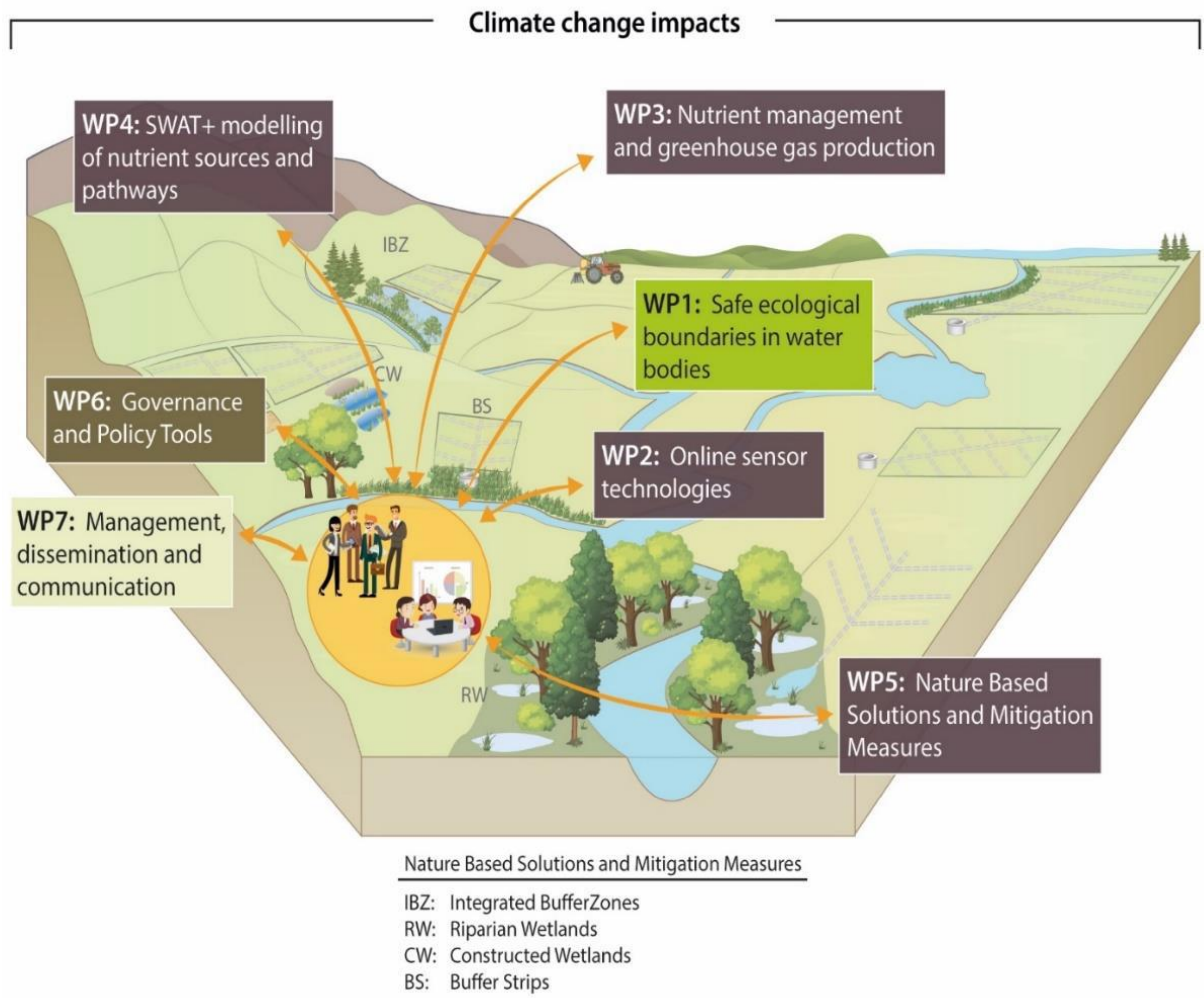

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Factsheet

Safe ecological boundaries for nutrients in Lakes and Rivers

Why do we need new boundaries for nutrients?

The WFD requires that the good/moderate (GM) boundaries for nutrients are compatible with good ecological status for sensitive biological quality elements (BQEs). The nutrient boundaires reported by the countries with their 2nd River Basin Management Plans (RBMPs) raised a concern in the EC/EEA and ECOSTAT about this compatibility for many countries (Kelly et al. 2021). The aim of this fact sheet has therefore been to identify safe ecological boundary values for phosphorus and nitrogen in different types of Nordic-Baltic rivers and lakes in line with good status for the BQEs. The focus is on water bodies in lowland areas because these are often impacted by nutrient loads from agriculture.

How do we set nutrient boundaries that safeguard good ecological status?

Data included nutrient concentrations (total phosphorus and total nitrogen) and ecological quality ratio (EQR) for nutrient sensitive biological quality elements for a large number of lowland rivers and lakes. Typology data were also provided for grouping of different water bodies to common regional types in the Nordic and Central-Baltic regions. Binomial logistic regression was used to assess relationships between normalised EQR values (nEQR) for the BQEs and nutrient concentrations in order to derive safe ecological nutrient boundaries that would allow good status for the BQEs (Phillips et al. 2023; more details are given in the Annex).

Recommendations for Safe ecological boundaries

The derived GM boundaries given in Tables 1 and 2 below are recommended target values for nutrients in line with WFD requirements. The reference values are taken from NordBalt-Ecosafe D1.1 (Fölster et al. 2023).

The boundaries derived are mostly in line with the GM boundaries reported by the Northern countries, but are considerably lower than those reported by several Central-Baltic countries, especially for rivers (Kelly et al. 2021).

Table 1. Good/moderate (GM) boundaries (and reference values) derived for total phosphorus (TP) and total nitrogen (TN) for different lowland types of rivers and lakes in **Nordic countries**: Norway, Sweden and Finland. The GM values are averages with confidence intervals (95%) given in parenthesis, and reference values (ref) are listed for comparison. WBs gives the total number of water bodies included in the analysis.

Nordic	Type code	Type name	WBs (total)	TP ref µg L^{-1}	TP GM µg L^{-1}	TN ref µg L^{-1}	TN GM µg L^{-1}	BQE used for GM boundaries
Rivers	R-N1	Mod alk clear	112 (TP) 103 (TN)	4-5	18 (12-25)	197-435	653 (416-868)	Phytobenthos
	R-N3	Low alk humic	397 (TP) 375 (TN)	4-33	29 (23-35)	140-1057		Phytobenthos
	R-N4	Mod alk humic	96 (TP) 155 (TN)	9-11	24 (10-39)	196-262		Phytobenthos
	New	Clay rivers	135	11-99	33 (45-60)	479-1245		Benthic invertebrates
Lakes	L-N1	Mod alk clear	63	4-13	14 (11-17)	188-322	537 (189-927)	Phytoplankton
	L-N2a	Low alk clear	394	2-5	14 (12-15)	75-168	428 (380-475)	Phytoplankton
	L-N3a	Low alk humic	453	4-23	19 (17-20)	166-725	511 (472-551)	Phytoplankton
	L-N8a	Mod alk humic	110 (TP) 108 (TN)	4-29	24 (20-29)	190-494	681 (588-782)	Phytoplankton

Table 2. Good/moderate (GM) boundaries (and reference values) derived for total phosphorus (TP) and total nitrogen (TN) for different lowland types of rivers and lakes in **Central-Baltic countries:** Denmark, Latvia and Poland. The GM values are averages with confidence intervals (95%) given in parenthesis, and reference values (ref) are listed for comparison. WBs gives the total number of water bodies included in the analysis.

Central-Baltic	Type code	Type name	WBs (total)	TP ref µg L^{-1}	TP GM µg L^{-1}	TN ref µg L^{-1}	TN GM µg L^{-1}	BQE used for GM boundaries
Rivers	R-CB2*	Small, siliceous	61	2-3	119 (16-362)	214-294	n.a.	Benthic Invertebrates
	R-CB5	Large, mod-high alk	164 (TP) 160 (TN)	6-28	106 (68-138)	335-1044	2299 (1588-3348)	Phytobenthos
Lakes	L-CB1	High alk clear, shallow	678 (TP) 695 (TN)	5-66	44 (39-49)	142-459	1079 (993-1173)	Phytoplankton
	L-CB2	High alk clear, very shallow	230 (TP) 229 (TN)	9-65	55 (47-63)	232-1023	1333 (1170-1501)	Phytoplankton

*R-CB2: Data from river type R-CB3 used from Poland

References:

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Kelly, M., Phillips, G., Teixeira, H., Salas, F., Varbiro, G., Lyche Solheim, A., & Poikane, S. (2021). Physico-chemical supporting elements in inland waters under the Water Framework Directive: A review of national standards to support good ecological status. JRC Technical Report 127875, EUR 31040 EN. 170 pp. https://doi.org/10.2760/470539

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Annex: Summary of methodology for analysis of safe ecological boundaries for four biological quality elements

Introduction

The setting of the good/moderate boundary values follows the approach of Phillips (2023). In this approach, the nutrient concentrations are combined with normalised ecological quality ratios (nEQR) for sensitive biological quality elements (BQEs) to establish safe ecological boundary values for nutrients in line with good ecological status for these sensitive BQEs.

This approach was used for setting safe ecological boundary values for total nitrogen (TN) and total phosphorus (TP) in different types of Nordic and Central Baltic rivers and lakes. The BQEs used in lakes included phytoplankton and macrophytes and in rivers phytobenthos and benthic invertebrates. In the following, the data sources and analysis are described in more details.

Processing of biological (nEQR) and nutrient data from the countries

1. Before the regression analysis of nEQR vs. nutrient concentrations to estimate safe ecological boundaries, all data were aggregated to one value per water body by averaging eventual data from different years. Details per country and BQE are given below.
2. Initial plots of nutrients versus nEQR were visually inspected to identify which river and lake types had sufficient data to run regression models.
3. Logistic binary regression in accordance with the methods used in Phillips (2023) were conducted for each river/lake type for all biological quality elements in the two ecoregions. In short, the method of Phillips (2023) involves modelling the likelihood of good or high status (nEQR > 0.6) as a function of log(nutrient concentration), while allowing for a more flexible and robust estimation of threshold values based on an assessment of the confusion matrix (fig. A1).
   The threshold value is here defined as the nutrient concentration where the likelihood of good or high status is over a certain limit (p).
4. A set of statistical measures were calculated based on the confusion matrix to assess the success of the models predicting correct classifications (e.g. kappa [a measure of overall classification accuracy], the false negative rate and the false positive rate).
5. From the calculated set of measures, the p-values and associated good/moderate boundary values for TP and TN were determined using the precautionary principle (i.e., measure with the highest p-values was chosen) to maximize the probability of achieving good status for the BQEs.
6. This procedure was used for each river/lake type in each of the two regions.
7. Relationships with $r^2 < 0.15$ were not used.

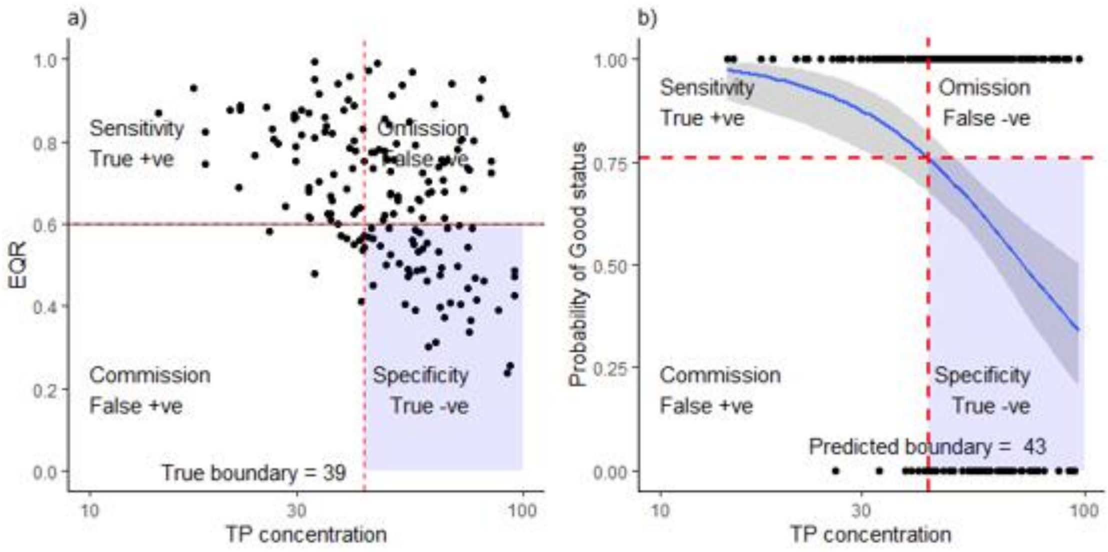

Figure A1 (inserted from Phillips et al. 2023 with permission from the author a) scatter plot illustrating an inverted wedge shaped relationship between biota (EQR) and total phosphorus (TP) concentration; b) logistic regression fit applied to these data with EQR expressed as a binary classification (threshold EQR = 0.6) . Red dotted lines represent the confusion matrix for a binary classifications of biology and TP class threshold the latter selected using a probability threshold (p=0.76) that increased the proportion of true positive classifications (Specificity = 0.9). Blue box highlights the True negatives. Data taken from artificial data set where a true relationship between EQR and TP were perturbed by an unknown environmental factor that decreased the sensitivity of the biota generating an inverted wedge-shaped data cloud. The vertical dotted lines in a) show the boundary value of the true (un-perturbed) relationship (39ugL-1) in comparison to b) the predicted boundary (43ugL-1) from logistic regression.

Data sources

Data on water body level for each of the four BQEs and water chemistry parameters (including total phosphorus and total nitrogen) were obtained from the partners involved in the NORDBALT-ECOSAFE project. Nordic data included rivers and lakes from Norway, Sweden and Finland, while data from the Central-Baltic region included rivers and lakes from Denmark, Latvia and Poland. An overview of the data is given in Table A1.

Some countries provided data on yearly averages per water body (WB), while others submitted one average value per water body for a given time period, e.g. 2012-2020. More details on the datasets can be provided on request.

Table A1. Overview of the data retrieved in template from partners. Green indicates that data from the templates are ready for use, yellow that data further treatment was needed and red that data is missing. The numbers are number of water bodies across all types in each region used for the analyses.

	Northern countries			**Central-Baltic countries**		
BQE and water category	NO	SE	FI	DK	LV	PL
Phytobenthos in rivers	N=154	N=161	N=290	n.a.	N=87	N=1645
Benthic invertebrates in rivers	N=487	N=3*	n.a.	N=83	N=0	N=1061
Phytoplankton in lakes	N=197	N=184	N=639	N=30	N=236	N=642
Macrophytes in lakes	N=90	N=81	N=121	N=44	N=154	N=501

*SE data on benthic invertebrates from R-N3 could not be used due to lack of water bodies with EQR values in moderate or worse status. No other Northern countries reported data for R-N3.