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Physico-chemical supporting elements in inland waters under the Water Framework Directive: A review of national standards to support good ecological status

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Contents

Abstract

The task group on supporting physico-chemical elements have reviewed information reported by Member States to WISE (Water Information System for Europe) on the standards for general physico-chemical quality elements including nutrients used under the European Water Framework Directive (WFD). A wide range of supporting physico-chemical elements are used by Member States. This report focusses on those that are ecologically most relevant for inland waters and which are used by enough Member States to make realistic comparisons. These are:

Rivers: BOD (Biochemical Oxygen Demand), dissolved oxygen, pH, total phosphorus (TP), soluble reactive phosphorus (SRP), total nitrogen (TN), nitrate-N, ammonium-N and salinity (conductivity and chloride);

Lakes: Transparency (Secchi depth), dissolved oxygen, pH, TP, TN.

A separate report will document the situation for transitional and coastal waters.

Systematic variation between both types and countries is apparent for several of these, although comparisons are complicated by differences in the ways that data have been reported.

Some of the standards appear unlikely to support good status for sensitive biological quality elements, based on type-specific comparisons with biological data in the EEA database (https://www.eea.europa.eu/data-and-maps/data/waterbase-biology). Further considerations and dialogue are needed with the countries using those standards.

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1. Introduction

1.1 Objectives

If countries are to achieve good ecological status for all water bodies, then it is necessary to set thresholds for pressures that are consistent with this ambition. ECOSTAT (the Water Framework Directive Common Implementation Strategy working group on ecological status) recognized that nutrients were a key pressure across all water body types, noting that there was considerable variation in threshold concentrations between countries for comparable types. The outcome of this work was the JRC Science for Policy report "Best practice in setting nutrient concentrations to support good ecological status" (Phillips et al., 2019) and a statistical toolkit to help countries review and revise their nutrient thresholds.

However, nutrients are not the only supporting physico-chemical quality elements (hereafter "supporting elements") likely to impede achievement of good ecological status and ECOSTAT's work programme was therefore extended to other water quality variables. The key questions addressed in this report is to what extent standards reported by countries are likely to support good ecological status and whether or not there is potential for ECOSTAT members to work together to produce ecologically-meaningful standards in cases where existing standards are inadequate. This, in turn, will generate further discussion on the use and relevance of supporting elements in the classification of ecological status, as well as on the use of these standards as a basis for deriving management targets to improve water quality and ecological status. As for the work on nutrients, the purpose here is not to impose a uniform approach on countries but, rather, to support them in the difficult task of achieving good ecological status across Europe's many and diverse water bodies. If nutrients or other physico-chemical quality elements are inhibiting the achievement of good status, then setting appropriate thresholds will contribute to the long-term sustainability of Europe's water resources. On the other hand, if a supporting element standard is not compatible with good status, then mitigation measures will be insufficient to restore the ecosystem back to good ecological status.

Standards for many supporting elements are reported to WISE (Water Information System for Europe); however, this report focusses only on those that are widely used and where there is good evidence of direct or indirect relationships with BQEs (Biological Quality Element) and ecosystem services. We have assumed that all national standards reported to WISE are used as part of formal assessments of ecological status but the manner in which each is used is beyond the scope of this report. Where there is a direct relationship with a BQE, then it may be possible to adapt approaches advocated in the statistical toolkit (Phillips et al. (2018) to review or revise existing standards. In some cases (e.g. oxygen conditions), there may be a combination of direct and indirect relationships, depending on the BQE and may also increase in significance as global warming raises water temperatures (Jane et al., 2021). These and other supporting elements (e.g. transparency) may complement information on nutrients and thereby contribute to the decision-making process. It is also important to note that Member States apply different combination rules to supporting elements (e.g. average, worst case or more complex scoring systems). The combination rule is very important, and will need further attention when making detailed comparisons of overall ecological status between Member States, as similar threshold values may give different classification results depending on the combination rule applied.

It is also possible that standards currently in force around Europe are not tailored to the needs of the WFD but, rather, are historic standards set to fulfil requirements of earlier directives. In particular, we note that many countries use a standard of 6 mg L^{-1} dissolved oxygen, which is a value specified in the Freshwater Fish Directive (78/659/EEC) for salmonid waters. This was designed to "support fish life" and, as such, may be appropriate for WFD purposes. However, it is not clear whether this assumption has been widely tested during the WFD era. A similar situation occurs for nitrates in freshwaters, where many countries use values derived from the Nitrates Directive (91/676/EEC): surface water and groundwater are polluted with concentration more than 50 mg/l of NO_3. In such cases there is a need to revisit these standards with the particular requirements of the WFD in mind to ensure that they are also compatible with good ecological status.

1.2 Approach

The source data for this work were provided by European Environment agency (EEA) based on data reported by EU Member States and Norway to WISE (WISE-WFD-database) and were those used to produce a summary report (ETC ICM, 2019), which was presented to ECOSTAT in spring 2019. Following this, ECOSTAT representatives were invited to check the entries for their country and the revised data, incorporating these revisions, is the basis for the present report. As this work was started before the UK left the EU, their data has also been included.

The data consisted of lists of physico-chemical supporting elements with the values representing the good/moderate class boundary used for different national types for each water category, together with information on the units and summary metrics used. The data provided had been edited to harmonise the different formats used during reporting. However, further editing was necessary to convert text to numbers and enable a consistent approach to standardization of units, quality element names (see ETC/ICM, 2019) and national type codes.

1.2.1 Harmonisation of data

Standards are reported using a variety of units and to enable meaningful comparisons of standards we have harmonized to standard units wherever possible. This was carried out in two stages: initially a lookup table was used to make an initial conversion. For example, where a Member State reported units of mg P / L we converted this to µg P / L using a factor of 1000. The results of these conversions were checked for each different physico-chemical quality element using box plots arranged by country and this revealed further clear errors in the original reporting. Where these errors were obvious further corrections were made. However, it was not always possible to make appropriate corrections and where this is the case, data were initially omitted but noted and the Member State concerned was given an opportunity to amend its data. Some results were reported as ranges; interpretation of these is discussed below.

This editing was carried out using R to provide an audit trail and avoid modifying the original source data. Full details of the initial generic editing are available in an R notebook (JoinDataV4.Rmd) and further corrections in specific R scripts dealing with each supporting element/Water Category.

1.2.2 Linking freshwater data to broad types

The data had already been matched to intercalibration type codes, but for freshwaters records were additionally matched to broad types of rivers and lakes (Lyche Solheim et al., 2019) using a lookup table. This was done because the broad types could be linked to a larger number of national types (>75%) than the intercalibration types. Although the broad typology generalises and simplifies many characteristics of lakes and rivers, and details of national classifications, it is the best means available for obtaining an EU-wide overview of the consistency in standards between Member states. As not all national type codes are unique to water categories it was necessary to select records that applied to lakes or rivers separately prior to linking with the broad type, using fields that identified whether the supporting element value applied to each of these water categories.

In some cases, national type codes could not be matched to those in the broad type lookup tables as the code was missing. In most cases these were due to the record being marked as applying to both river and lake categories which we assume was an error. In addition, many national type codes that could not be allocated to a broad type are shown in the plots in chapter 3 as "LW-00" or "RW-00" depending on whether they represent lakes or rivers. The original data are summarised in Table 1.1, with the new data after Member State checking summarised in Table 1.2. Most of these unassigned types probably relate to national types that hold very few water bodies and altogether constitute < 25% of all water bodies (Lyche Solheim et.al., 2019).

*Table 1.1. Number of national freshwater types that could not be matched to a broad type (e.g. a standard marked as applying to lakes, but having a river type code) and number of national freshwater types not assigned to a broad type (i.e. national type code did not link to any existing broad type) at the start of the project. * mainly very small lakes which are not recognized as separate water bodies, and which are treated as part of a larger river water body.*

Country	Lakes		Rivers	
	Not matched	Not assigned	Not matched	Not assigned
Austria	9	6	4	28
Belgium		4		14
Bulgaria	35	4	16	4
Croatia		1		
Czechia		7		
Estonia	7	2	5	
Finland		8		11
France		3		1
Germany			5	2
Hungary		1		
Latvia		1		
The Netherlands		13		
Malta	1		1	
Norway*	33			
Portugal			1	1
Romania	66	3	18	7
Slovenia		1		2
Sweden				
Slovakia	1			
Spain	6	26	11	104

Table 1.2. *Number of national freshwater types that could be assigned or not to a broad type following checking by Member States.*

	Lakes			Rivers		
Country	not assigned (LW-00)	assigned	"All" type used	not assigned (RW-00)	assigned	"All" type used
Austria	6	7	no	39	27	yes
Belgium	3	3	no	9	28	yes
Bulgaria	3	8	no	5	12	yes
Croatia		6	yes	5	23	yes
Cyprus			yes			yes
Czechia	8	8	no		35	no
Estonia	3	6	no		7	no
Finland	8	5	no	9	8	no
France	20	10	no	5	1	yes
Germany	8	6	no	9	21	no
Greece						yes
Hungary	4	4	no		10	no
Ireland			yes			yes
Italy	5	16	no			yes
Latvia	1	8	no		6	no
Lithuania		3	no		5	no
Luxembourg					6	yes
Netherlands	4	5	no	3	12	no
Norway	4	62	no	2	74	no
Poland	1	6	no	5	15	no
Portugal	2	2	yes	6	7	yes
Romania	10	5	no	33	52	no
Slovenia		2	no	2	72	no
Slovakia					22	no
Spain	30		no	47		no
Sweden		12	no	1	11	no

UK	5	9	yes	8	yes

1.2.3 Values applied to "All" water types

Many standards were not linked to a specific national type, instead the entry for type was recorded as "All". These records were assumed to apply to all national types for that River Basin District (RBD). An "ALL" grouping category has been included, which can be used to assess which countries reported this approach and how the range of values compared to those for the identified broad types.

1.2.4 Summarising data for presentation

The original data extracted from WISE had type specific good/moderate boundary values for each RBD, so for some countries the same type specific boundary was replicated several times. To avoid giving additional weight to these values only a single national type specific boundary value was used when plotting and summarising values (we refer to these as "discrete records" in section 3). Additionally, boundary values were not always consistent within each national type; some countries reported different values for the same broad type for different RBDs. As the number of national types also varied between countries, we present graphs showing the range of values within a broad type, with separate dots for each national type that correspond to that broad type. Red and blue dots are used when a standard was reported as a range with upper and lower thresholds rather than a single value.

We have then calculated the median, 75^{th} and 90^{th} percentiles for all standards that measure the central tendency (mean, median, see 2.2) included in the comparison and plotted these values as horizontal dotted lines on the graphs to give a quick visual insight into how individual national standards compare to an EU-wide consensus (in some cases sample size results in percentiles having the same numeric value and thus not all lines are shown in some figures). Where standards were reported as a range and we were not able to split these into clear lower and upper standards (see 2.3.2) we include both reported values if each measured the central tendency. We would expect national standards that measure the central tendency of the supporting element to cluster around the median whilst those based on higher percentiles should lie closer to the 75^{th} and 90^{th} percentile lines. Graphs show these results aggregated by both Member State and Broad Type (although percentiles are only included where more than two Member States have contributed standards to the same Broad Type) but these need to be interpreted with care. Although national standards falling above the median value for a type may be less likely to protect good ecological status for sensitive BQEs than standards falling below the median value for the type, the opposite can also happen because each broad type encompasses a wide range of national water body types and national decision-making processes use standards in different ways (see 1.1). We recommend readers focus on the big picture: a Member State that has national standards that are consistently more lenient than those of near-neighbours or those sharing similar water body types should regard this report as an opportunity to ask questions to ensure that its standards are sufficiently protective.

1.2.5 Linking the standards to sensitive biological quality elements

The relationship between summary statistics for the reported standards (median, 75^{th} and 90^{th} percentiles) and concentrations reported for the relevant supporting elements at monitoring sites where the biota is reported to be in good or better status is shown in boxplots. These are based on national records of both physico-chemical parameters (e.g. ortho-phosphate concentration in rivers) and biological quality element (BQE) data (e.g. normalised Ecological Quality Ratios (nEQR) and status class for phytobenthos in rivers) submitted annually to EEA and stored in the WISE-State-of-Environment database. The results are either based on all data for parameters where the data are insufficient to split by type (e.g. oxygen and pH) or are shown separately for aggregated broad types (e.g. lowland, calcareous, medium-large rivers) according to Lyche Solheim et al. 2019 (see also Tables 1.3 and 1.4 below) for parameters with sufficient data (e.g. nutrients). For all physico-chemical parameters except pH we used EQRs that were sensitive to eutrophication or general degradation (EQR_E and EQR_G). For pH we compared the upper standards with these EQRs, but the lower ones with EQRs sensitive to acidification (invertebrates only).

There will be variations in the way that samples are collected and analysed between countries, but status assessments for the BQEs have been harmonised via the WFD intercalibration exercise. If the summary statistics of the reported standards are appreciably above the concentrations given by the "box" for high and good status for the relevant BQE then this suggests that national standards for that supporting element are generally too relaxed and may not be protecting good status. Once again, we should stress that there may be good reasons why any individual standard deviates from this global picture, but this comparison should enable ECOSTAT to decide where its attention should be focussed over the coming years.

Table 1.3. *Translation of broad types of lakes to aggregated broad types according to Lyche Solheim et al. 2019, supplementary material table S5 and S6).*

Broad Type code	Broad Type Name	Aggregated broad type code	Aggregated Broad Type Name
L-01	Very large lakes, shallow or deep and stratified (all Europe)	LA-01	Very large lakes, stratified
L-04	Lowland, calcareous/mixed, very shallow/unstratified	LA-02	Lowland, calcareous, very shallow, unstratified
L-03	Lowland, calcareous/mixed, stratified	LA-03	Lowland-mid-altitude, calcareous (incl. humic), shallow, stratified
L-06	Lowland organic (humic) and		
L-08	Mid-altitude, calcareous/mixed		
L-10	Mid-altitude, organic (humic) and		
L-05	Lowland organic (humic) and siliceous	LA-04	Lowland-mid-altitude, humic (& siliceous)
L-09	Mid-altitude, organic (humic) and siliceous		
L-02	Lowland, siliceous	LA-05	Lowland, siliceous
L-07	Mid-altitude, siliceous	LA-06	Mid-altitude, siliceous
L-11	Highland, siliceous (all Europe), incl.		

L-12	Highland, calcareous/mixed (all Europe), incl. organic (humic)	LA-07	Highland
L-13	Mediterranean, small-large, siliceous	LA-08	Mediterranean, small-large, siliceous and calcareous
L-14	Mediterranean, small-large,		

Table 1.4. Translation of broad types of rivers to aggregated broad types according to Lyche Solheim et al. 2019, supplementary material table S5 and S6).

Broad Type code	Broad Type Name	Aggregated Broad Type code	Aggregated Broad Type Name
R-01	Very large rivers	RA-01	Very large rivers
R-04	Lowland, calcareous or mixed, medium-large	RA-02	Lowland, calcareous or mixed, medium-large
R-07	Lowland, organic and calcareous/mixed		
R-05	Lowland, calcareous or mixed, very small-small	RA-03	Lowland, calcareous or mixed, very small-small
R-02	Lowland, siliceous, medium-large	RA-04	Lowland, siliceous incl organic, medium-large
R-06b	Lowland, organic and siliceous, medium-large		
R-03	Lowland, siliceous, very small-small	RA-05	Lowland, siliceous incl organic, very small-small
R-06a	Lowland, organic and siliceous, very small-small		
R-10	Mid-altitude, calcareous or mixed, medium-large	RA-06	Mid-altitude, calcareous, incl. organic, medium-large
R-13	Mid-altitude, organic and calcareous/mixed		
R-11	Mid-altitude, calcareous or mixed, very small-small	RA-07	Mid-altitude, calcareous or mixed, very small-small
R-08	Mid-altitude, siliceous, medium-large	RA-08	Mid-altitude, siliceous incl organic, medium-large
R-12b	Mid-altitude, organic and siliceous, medium-large		
R-09	Mid-altitude, siliceous, very small-small	RA-09	Mid-altitude, siliceous incl organic, very small-small
R-12a	Mid-altitude, organic and siliceous, very small-small		
R-14	Highland (all Europe), siliceous, incl. organic (humic)	RA-10	Highland and glacial
R-15	Highland (all Europe), calcareous/mixed		

R-16	Glacial rivers (all Europe)		
R-17	Mediterranean, lowland, medium-large, perennial	RA-11	Mediterranean perennial
R-18	Mediterranean, mid-altitude, medium-large, perennial		
R-19	Mediterranean, very small-small, perennial	RA-12	Mediterranean temporary and very small
R-20	Mediterranean, temporary/intermittent streams		

For rivers, we have focussed on phytobenthos and benthic macroinvertebrates, the BQEs for which the most data are available, whilst for lakes we have used phytoplankton and, in a few instances, macrophytes. Readers should be aware that not all BQEs are sensitive to all supporting elements and that, in some cases, we have been unable to use the BQE that is most sensitive to a particular supporting element. In particular, there are no data on fish in the WISE-SoE-database, so none of the supporting elements could be linked to fish, although that would have been relevant for supporting elements such as dissolved oxygen or BOD.

We have also included an analysis of variance to indicate the strength of the differences (country and broad type) between supporting element good/moderate boundary concentrations. This is a type III analysis of variance, recommended for unbalanced designs (Fox et al., 2020) with "country" and "broad type" included as treatments. It was implemented using the "car" library within R. To assess the relative importance of country and type effects we calculate the partial omega squared value which is a bias corrected estimate of the proportion of variance explained by each variable, using the "sjstats" library in R. Bias correction, which adjusts for the difference between the sample and population estimate of this variance, is important as sample size is relatively small and thus the effect size can be overestimated. However, when the variance explained is low it can result in negative values. Following the advice of (Okada 2017) we report these negative values in the analysis of variance summary tables, but translate this to zero in the text. These analyses should be treated as broad indications of the extent to which variation amongst national standards is determined by factors other than the pressure in question. Overview of reported physico-chemical quality elements and metrics.

2 Overview of reported physico-chemical quality elements and metrics

2.1 Which physico-chemical quality elements are used?

The supporting elements used by the different countries for the different water categories are given in Table 2.1 and *ETC-ICM (2019)* based on data reported by countries to WISE with the 2nd River Basin Management Plans (RBMPs).

The principle used to select the most commonly-used supporting elements for further analyses in this report are those that are used by at least seven countries and which are also ecologically relevant. Based on these principles the supporting elements included in this report are: Rivers: BOD, O_2, pH, TP, PO_4-P, TN, NO_3-N, NH_4-N; chloride, conductivity; Lakes: Transparency, O_2, pH, TP, TN;

2.2 Metrics used for most commonly used quality elements

The most commonly used means of aggregating data are annual averages (AA-EQS), annual maximum concentration (MAC-EQS) or various high or low percentiles (Table 2.2). A full list of summary metrics reported is shown in Table 2.3.

Table 2.1. General physico-chemical quality elements reported to WISE, summarised by number of countries per water category (ETC-ICM 2019). Quality elements selected for further analysis are highlighted in blue. Data includes all EU Member States and Norway, except EL and LT, as their data were not available in WISE at the time the data were compiled in 2019.

Code	Quality element name	Rivers	Lakes	Parameter specifications
QE3-1-1-1	Secchi disk depth	3	15	
QE3-1-2-1	Water temperature (Celsius)	12	6	
QE3-1-3-1	Oxygen saturation (%)	10	9	
QE3-1-3-2	Dissolved oxygen (mg/l)	15	10	
QE3-1-3-3	Other determinands for oxygenation conditions	16	3	BOD, COD, TOC etc.
QE3-1-4-1	Practical salinity units	1	2	
QE3-1-4-2	Other determinand for salinity	8	2	Conductivity, chloride
QE3-1-5-1	Acid neutralising capacity	7	4	
QE3-1-5-2	pH	21	15	
QE3-1-5-3	Other determinands for acidification status	5	3	Alkalinity, inorganic aluminium concentration
QE3-1-6-1-1	Nitrate	18	8	
QE3-1-6-1-2	Nitrite	10	3	
QE3-1-6-1-3	Non-ionised ammonia	4	1	
QE3-1-6-1-4	Ammonium	18	10	
QE3-1-6-1-5	Total nitrogen	14	13	
QE3-1-6-4	Total inorganic nitrogen	1	1	
QE3-1-6-2-1	Orthophosphate	16	5	
QE3-1-6-2-2	Total phosphorus	21	22	
QE3-1-6-3	Silicate	1	0	
QE3-1-6-4	Other determinands for nutrient status			Kjeldahl N, SRP, N/P, TOC, BOD, suspended solids, TRIX, UMeco et

Table 2.2: Overview of parameters and metrics used. Numbers refer to the number of countries reporting standards that use a particular parameter/metric combination. Metrics have been split into those that measure the central tendency (e.g. mean, median) and those measuring a more extreme statistic (e.g. percentiles, maximum and minimum).

Supporting element	Central Tendency		Percentile	Other
	annual	seasonal		
Lakes				
Dissolved oxygen	3	3	3	1
% oxygen saturation	3	1	1	1
Secchi disk depth	13	2	1	
pH	9	2	2	2
TN	7	4	2	
TP	19	5	2	
Rivers				
Dissolved oxygen	9		7	1
% oxygen saturation	3	1	8	
pH	8	1	15	2
BOD5	13		7	1
Ammonium N	15		7	1
Nitrate as N	13		8	
TN	10	2	2	
Orthophosphate	13		6	
TP	19	2	5	
Chloride	6	1	2	
Conductivity	6		3	

Table 2.3: *List of reported metrics (as shown in legends to subsequent figures in section 3).*

Reported metric	Assumed explanation	Metric measures	
		central tendency	an extreme
AA-EQS	Annual average	yes	
Maximum	Maximum value		yes
Minimum	Minimum value		yes
GS Mean	Growth season mean	yes	
Median	Median value	yes	
95th percentile	95th percentile value		yes
Individual values	Individual values value		
MAC-EQS	Maximum acceptable concentration		yes
Perc80/m x	not known		
winter	winter summary metric (not known)		
90th percentile	90th percentile value		yes
5th percentile	5th percentile value		yes
summer	summer summary metric (not known)		
98th percentile	98th percentile value		yes
seasonal average	seasonal average value	yes	
10th percentile	10th percentile value		yes
10&90thper	10 & 90th percentile values (for a range)		yes
MinA-EQS	not known		
MinA-MaxA (per year)	not known		
Summer max	Summer max value		yes
Winter max	Winter max value		yes
Min/Jahr - Max/Jahr	Minimum and maximum January values (for a range)		yes

2.3 Challenges encountered whilst collating and comparing data

We recognize that countries are free to adopt their own approaches to implement the WFD and, as a result, this exercise has worked with the data that are supplied. Consistency in data collection within a country allows historical comparisons which may reveal trends in water quality and ecological status. However, this creates some challenges when attempting to compare national approaches.

Two principal challenges were encountered whilst compiling this report. The first is where different parameters, depth strata (in lakes) and statistical summary metrics were applied to the same supporting element and the second is ambiguity in data reporting of ranges of values for a standard. Most cases of the latter should have been picked up through our consultations with national experts; however, we encourage everyone to ensure that any further changes that are needed are made directly onto the WISE database in order to improve these outputs in the future.

2.3.1 Different parameters, depth strata and statistical summary metrics

A good example of differences in parameters is the use of either concentration of dissolved oxygen or percent saturation. The two values are, in theory, interchangeable (if the temperature was recorded at the time that the measurement was made); however, this is rarely possible with the high-level aggregations of data used in this exercise. Both approaches are valid means of assessing the oxygenation conditions of water bodies but national standards can only be compared with others that use the same parameter.

A similar issue was encountered in the use of ammonium-N and unionized ammonia. Although most countries use ammonium-N, toxicity is exerted through the action of unionized ammonia on cells and the equilibrium between ammonium and ammonia depends upon pH. In practice, too few countries measure unionized ammonia for this to be the basis of EU-wide comparisons.

We have not, at this stage, differentiated between standards set using samples collected from the top or bottom (lake hypolimnion) of the water column and those set using samples that integrate the entire water column. This will need to be considered when making detailed comparisons of standards for individual variables.

Finally, a range of statistical summary metrics are used, including annual averages, seasonal averages, upper and lower percentiles (Table 2.2). There will be, in many cases, good reasons behind these choices, which may be reflected in the decision-making process. However, there are also, we suspect, national conventions that predate the WFD and which may benefit from being revisited.

2.3.2 Ambiguity with data reporting as ranges of values:

Many countries report ranges, which can mean different things:

- If reported for "All" types, the range can be for many national types (often spanning several broad types). There may, indeed, be no reason to expect variation between types for some supporting elements;
- If reported for one national type, the range can be site (or waterbody)-specific limit values;
- Some supporting elements can have 'two-tailed' effects where either both low and high values can impede good ecological status (e.g. pH) or where a low value may directly

influence ecological status whilst a high value indicates secondary effects (dissolved oxygen and, in some cases, pH). We have attempted to split records for those supporting elements where lower and upper thresholds were provided into upper and lower standards to allow for more meaningful comparisons. However, this was not always possible due to the original reporting format, and sometimes we have had to make assumptions about whether a reported standard was a lower or upper threshold.

3 Boundary values for supporting elements within and between common types

This chapter presents a comparison of results for those quality elements (QEs) that are most commonly used in inland waters (chapter 2.1). We summarise the results for each, with further details given in the appendices. Where there were sufficient data, we also present analysis of variance tables to partition the variability of the reported standards between countries and water body broad types. Additionally, we compare the reported standards with observed concentrations using box plots showing the range of mean concentrations from water bodies categorised as Good or better and Moderate of worse for different relevant BQEs, overlain by horizontal dotted lines indicating percentiles summarising the range of the reported standards. The box plots provide a provisional indication of whether the standards will support good ecological status for the relevant BQEs and can be used as a basis for selecting standards that may need further investigation.

3.1 Oxygen

Dissolved oxygen (DO) in waters are reported as either percentage saturation or as a concentration, which complicates the comparison of standards as it is not possible to convert between the two parameters without also having the temperature at the time of measurement. We thus compare standards for each parameter separately. Dissolved oxygen has “two tailed” effects, with low values indicating potential threats to fish and invertebrates, while high values indicate excess oxygen production from plant or algal growth. For this supporting element, where possible, we therefore compare upper and lower standards separately, and interpret good status to be at risk for values below the lower value and above the upper value, e.g. 80-120% oxygen saturation.

3.1.1 Oxygen (lakes)

For lakes, similar numbers of countries report DO using concentration (6) and percentage (6).

Oxygen concentrations in lakes are influenced by many natural factors and, as a result, comparisons are difficult. The wide variability in national standards is as likely to represent differences in approaches to collecting data as it is to how standards are set.

3.1.1.1 Dissolved oxygen concentration (lakes)

There were 75 records of dissolved oxygen standards from 6 countries (Figure 3.1). Many countries use the annual mean (“AA-EQS”) as a summary metric. 5 countries (BE, BG, CY, PT, RO, UK) use a single value for each national type and 1 country (PT) present standards as a range.

The data could be linked to 7 broad types (Figure 3.2 & Table 3.2). 1 of these only (LW-00) had type specific values from more than 2 countries and thus not allowing the range of standards in broad types to be compared. 3 countries (CY, PT, UK) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 4 mg/L (BE) to 11 mg/L (PT) with an interquartile range of 6 to 7 (Figure 3.2).

A one-way analysis of variance was used to test the significance of country as there were too few types to test the effect of type (Table 3.1). The importance of the country effect can be judged from the Omega squared values which represent the proportion of variance explained by country (71.1%).

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of dissolved oxygen based on classifications for phytoplankton and macrophytes (Figure 3.3) using data taken from the EEA-WISE-SoE-database.

More information in Annex A1.1.

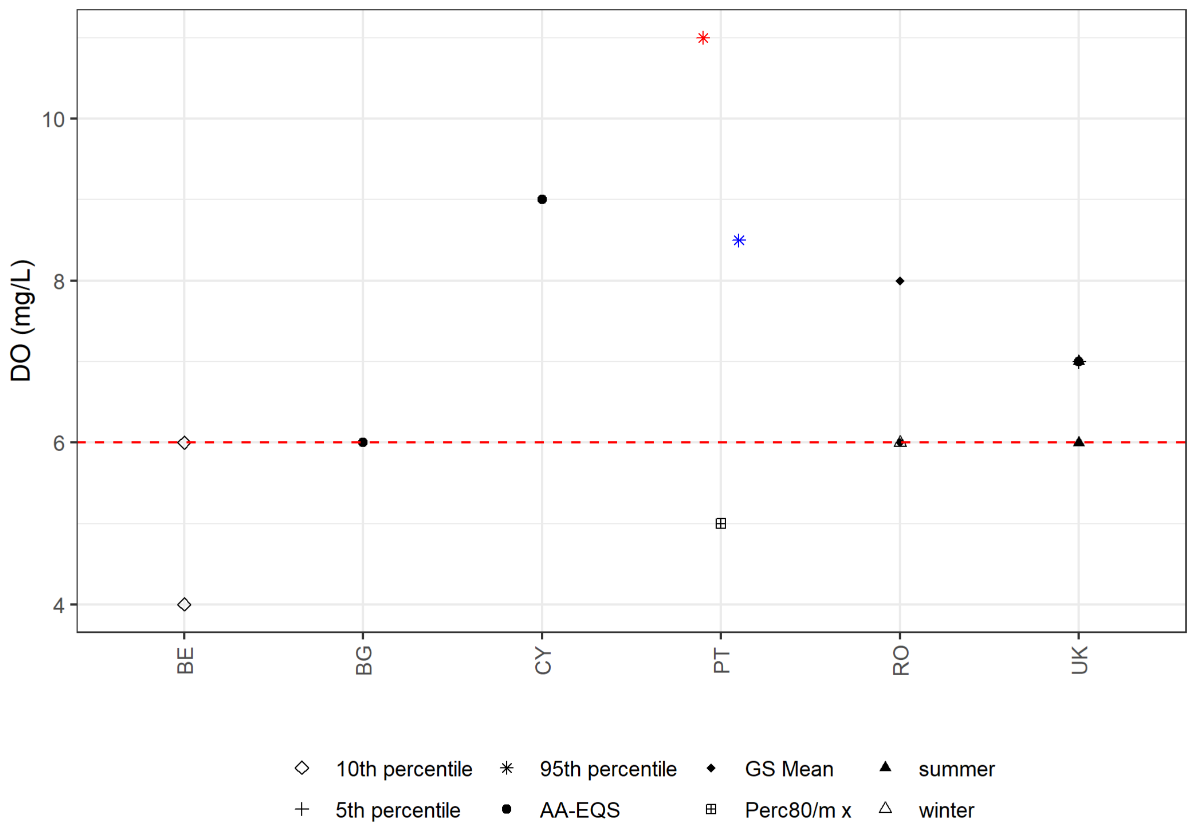

Figure 3.1: Dissolved oxygen standards by country (single value black, minimum blue, maximum red); dotted lines show interquartile range of mean or median values, (10th percentile=red, 25th percentile=orange, 50th percentile = blue (overlain by 25th as values are the same).

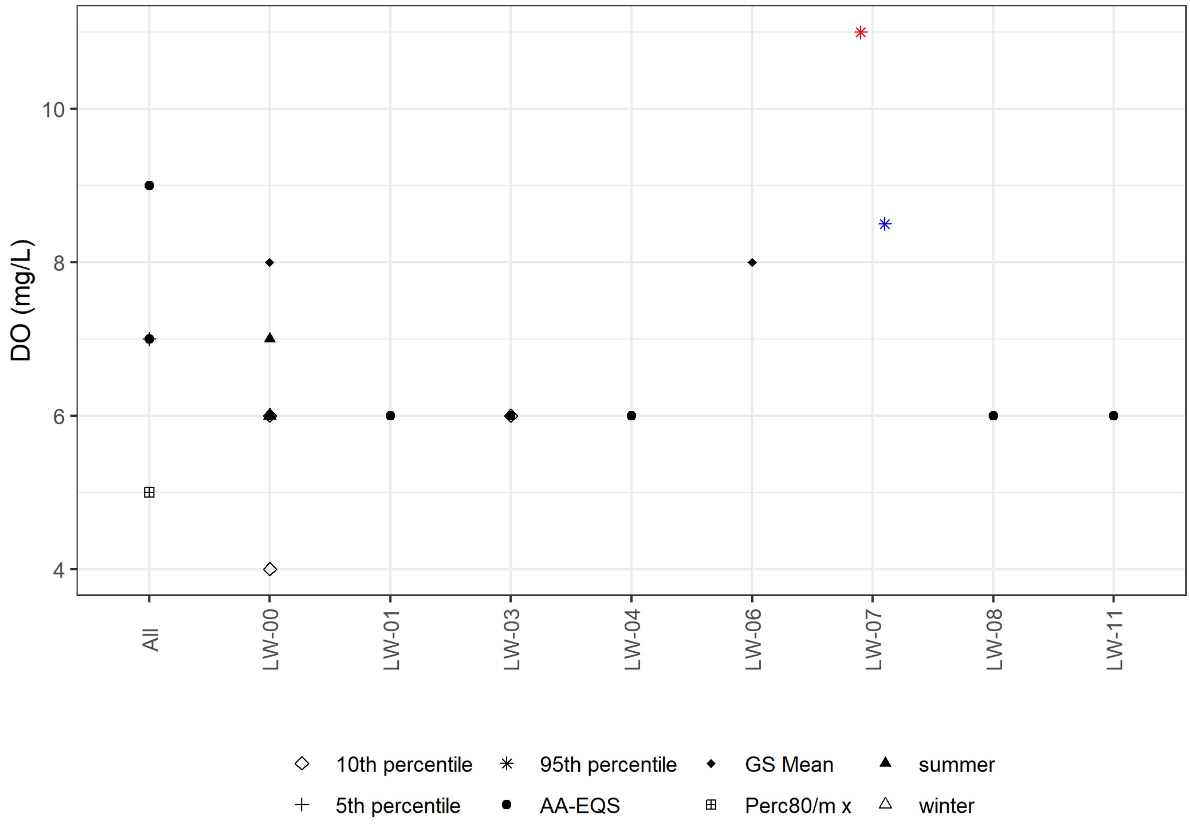

Figure 3.2: Dissolved oxygen standards by broad type (single value black, minimum blue, maximum red).

Table 3.1: Analysis of variance for factorial model relating country and broad type to Member State boundary values for dissolved oxygen (Including main and partial effect sizes and Omega squared – see 1.2.5).

	Omega sq,	Sum sq	Df	F value	Prob.
Intercept		3.2	1	258.15	0.00000
Country	0.71	0.3	3	9.18	0.01164
Residuals		0.1	6		

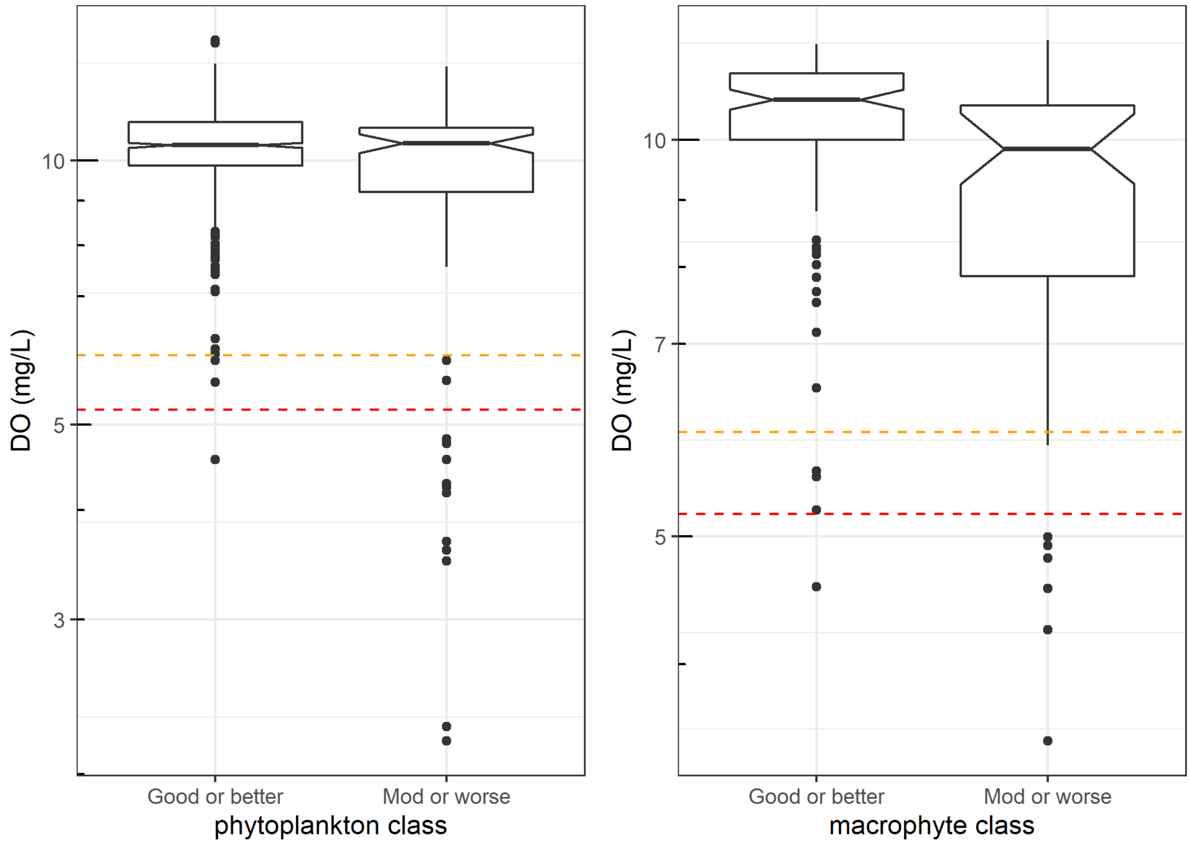

Figure 3.3: Lake Dissolved oxygen standards (dotted lines) overlain on box plots showing the range of Dissolved oxygen concentration for sites classified by phytoplankton and macrophytes. (10th percentile=red, 25th percentile=orange, median=blue overlain by 25th as values are the same*) Significance of difference between groups, (phytoplankton) Wilcoxon p=0.112 (macrophytes) Wilcoxon p= <0.001*

Table 3.2: Overview of common broad types for which standards are available, showing the number of countries/national types/distinct standards for Dissolved oxygen concentration.

Code	Broad type	Country	Type	Standard
All	All	3	1	3
LW-00	Not assigned	4	15	4
LW-01	Very large lakes shallow or deep and stratified (all Europe)	1	1	1
LW-03	Lowland stratified calcareous or mixed	2	2	1
LW-04	Lowland calcareous or mixed very shallow or unstratified	2	4	1
LW-04	Not assigned	2	4	1
LW-06	Lowland organic (humic) and calcareous or mixed	1	2	1
LW-07	Mid-altitude siliceous	1	1	1
LW-08	Mid-altitude calcareous or mixed	1	2	1
LW-11	Highland Siliceous (all Europe) incl. organic (humic)	1	2	1

3.1.1.2 Percent oxygen saturation (lakes)

There were 57 records of percent oxygen saturation standards from 6 countries (Figure 3.4). Many countries use the annual mean ("AA-EQS") as a summary metric, but minimum, maximum and higher/lower percentile were also frequently used. 3 countries (AT, IT, SI) use a single value for each national type while 3 countries (IE, NL, PT) present standards as a range.

Of these none specify that the ranges represent sub-types or RBD specific boundaries and it is assumed that the range represents upper and lower boundary values, as % oxygen saturation is a QE that might be expected to have a two tailed effect.

The standards ranged from 30% (AT) to 140% (PT), with an interquartile range of 40% to 90% (Figure 3.5). Given the bimodal distribution of the boundaries the data were split into upper and lower values, with values > 100% being placed in the upper group. The lower threshold values ranged from 30% to 80% with a median value of 60% while the upper boundaries ranged from 120% to 140% with a median value of 120%.

The data could be linked to 10 broad types (Figure 3.5 & Table 3.3), 2 countries (IE, PT) apply the same standard to all national types found in one or more of their river basin districts. Only 3 of these groups (LW-00, LW-04, LW-08) had types from more than 2 countries restricting comparisons between types.

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.3). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country and type (lower boundary values country 23.2% and type 0%; upper boundary values country -36.4% and type 0%). In both cases, data did not satisfy all assumptions of normality so these results need to be interpreted with care.

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of % oxygen saturation based on classifications for phytoplankton and macrophytes (Figure 3.6) using data taken from the EEA-WISE-SoE-database. For both phytoplankton and macrophytes EQRs sensitive to eutrophication and general degradation were used. The percentiles shown relate to the upper groups as phytoplankton and macrophytes are related to eutrophication.

More information in Annex A1.1.

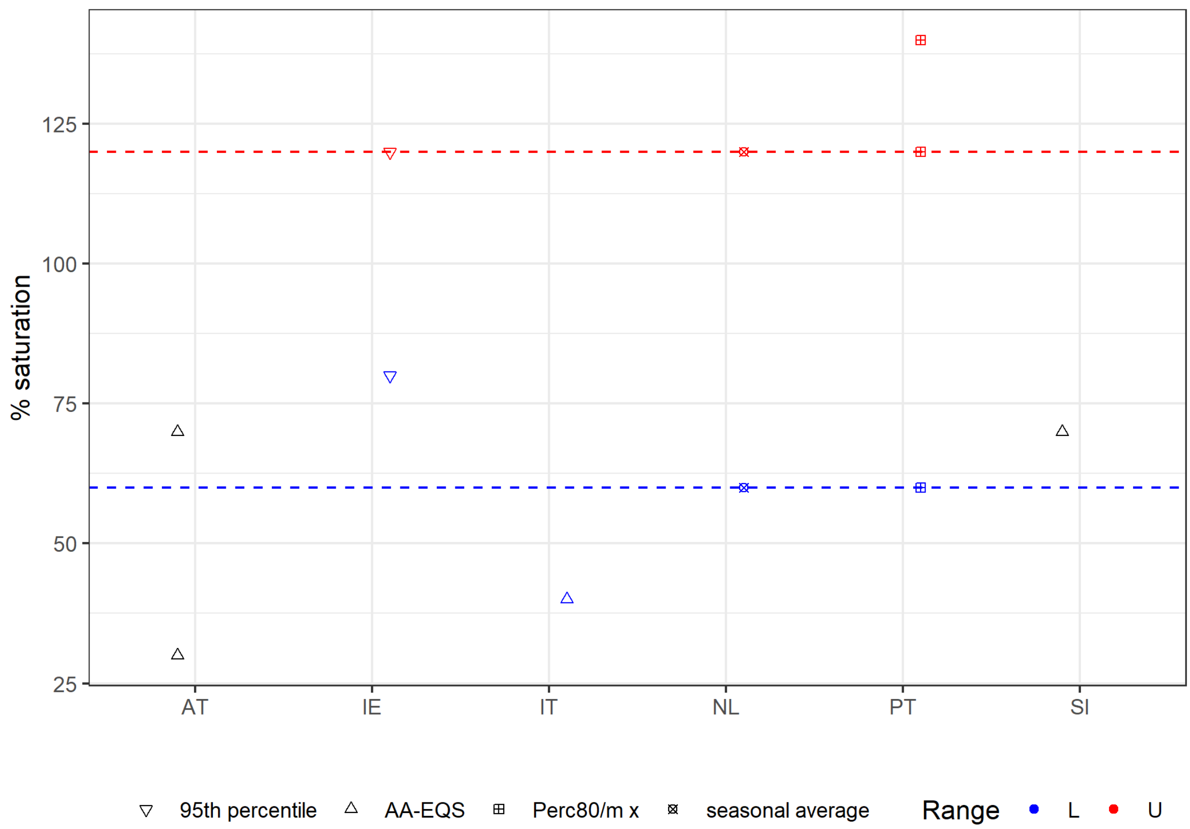

Figure 3.4: % oxygen saturation standards by country (single value black, minimum blue, maximum red); dotted lines show median values for the upper (red) and lower (blue) groups.

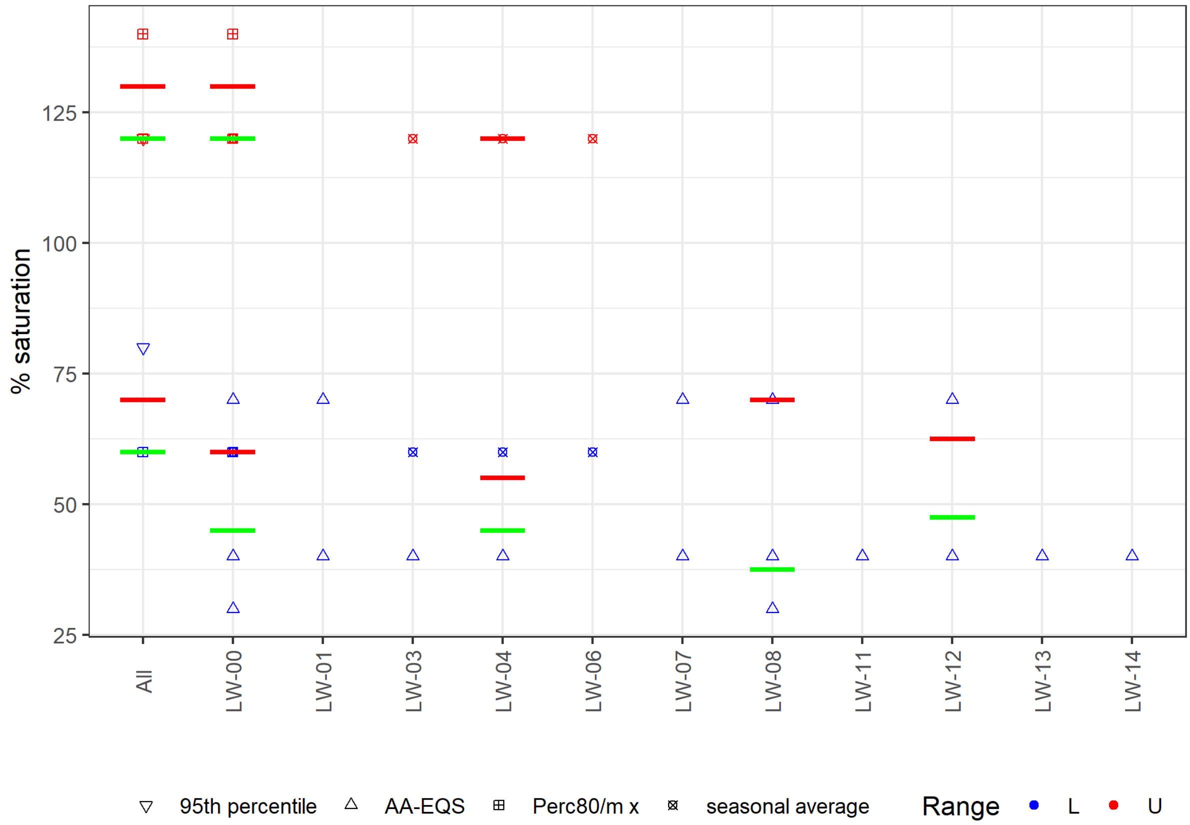

Figure 3.5: % oxygen saturation standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while LW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark the 25th (green) and 75th (red) percentiles for each group of standards).

Table 3.3: Analysis of variance for factorial model relating country and broad type to Member State boundary values for lower and upper groups of log % oxygen saturation boundaries (Including main and partial effect sizes and Omega squared – see 1.2.5.)

Lower Boundaries

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			11.4	1	133.35	0.000
Country	0.23	0.17	0.9	5	2.09	0.150
CodeBT	-0.38	-0.50	0.2	11	0.11	0.995
Residuals			0.9	10		

Upper Boundaries

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			22.90	1	1929.1	0.001
Country	-0.36	-0.17	0.0	2	0.33	0.750
CodeBT	-1.09	-0.80	0.0	4	0.00	1.000
Residuals			0.0	2		

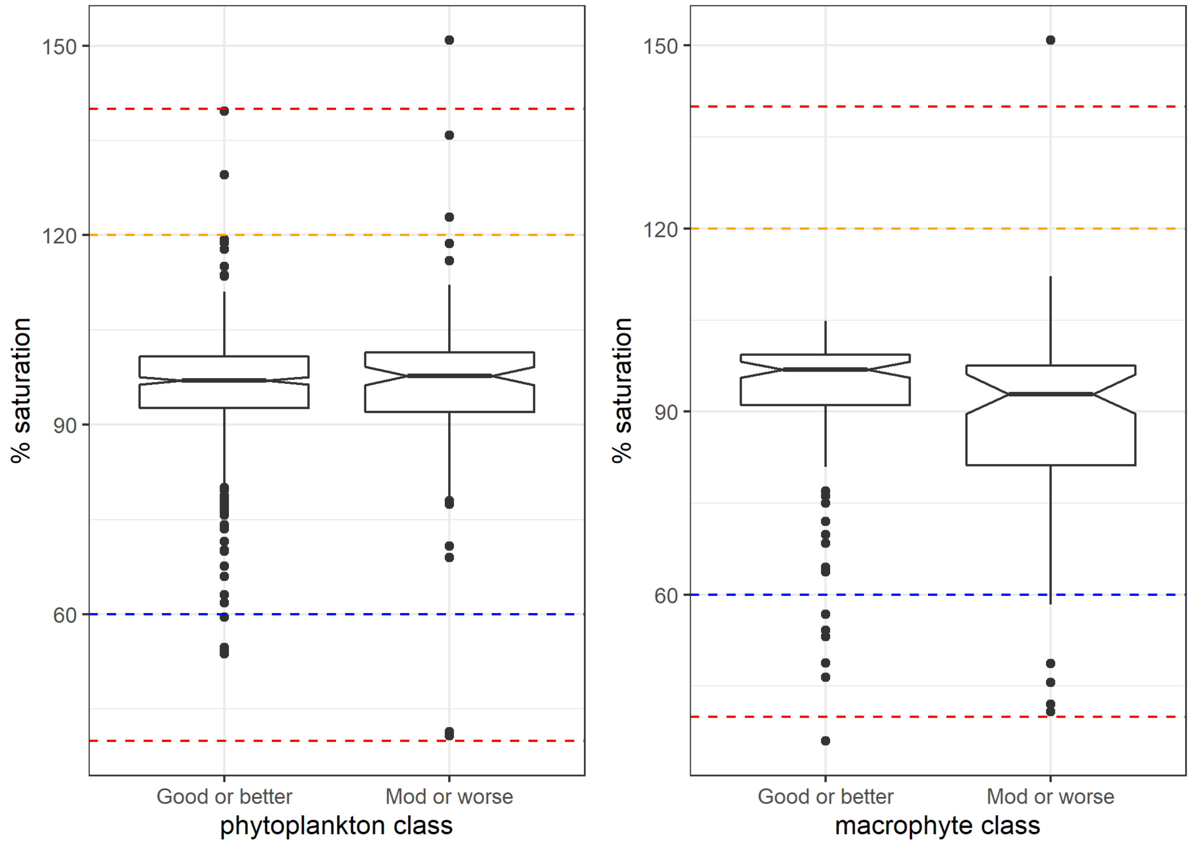

Figure 3.6: Upper and lower boundaries for lake % oxygen saturation standards (dotted lines) overlain on box plots showing the range of % oxygen saturation concentration for sites classified by phytoplankton and macrophytes. (For the upper boundaries lines show are the 90th percentile=red and median=blue and for the lower boundaries they are the 10th percentile=red, and median=blue). Phytoplankton and macrophytes used EQRs sensitive to eutrophication and general degradation with the percentiles of the upper boundaries. Significance of difference between groups, (phytoplankton) Wilcoxon p= 0.469 (macrophytes) Wilcoxon p= 0.005 (Percentiles were calculated from all summary metrics as majority of values were based on extreme percentiles) (n.b. 75th/25th percentiles are hidden as they are the same as the median).

Table 3.4: Overview of common broad types for which standards are available, showing the number of countries/national types/distinct standards for % oxygen saturation.

Code	Broad type	Country	Type	Standard
All	All	2	1	2
LW-00	Not assigned	4	17	5
LW-01	Very large lakes shallow or deep and stratified (all Europe)	2	2	2
LW-03	Lowland stratified calcareous or mixed	2	2	2
LW-04	Lowland calcareous or mixed very shallow or unstratified	3	5	3
LW-04	Not assigned	3	5	3
LW-06	Lowland organic (humic) and calcareous or mixed	1	1	1
LW-07	Mid-altitude siliceous	2	2	2
LW-08	Mid-altitude calcareous or mixed	3	5	3
LW-11	Highland Siliceous (all Europe) incl. organic (humic)	1	2	1
LW-12	Highland calcareous or mixed (all Europe) incl. organic (humic)	2	5	3
LW-13	Mediterranean small-large siliceous	1	2	1
LW-14	Mediterranean small-large calcareous or mixed	1	4	1

3.1.2 Oxygen (rivers)

For rivers there are more countries reporting DO using concentration (15) than percentage (11)

3.1.2.1 Dissolved oxygen concentration (rivers)

There were 341 records of dissolved oxygen standards from 15 countries (Figure 3.7). Many countries use the annual mean ("AA-EQS") as a summary metric. 15 countries (BE, BG, CY, DE, ES, FR, GR, HU, LT, LU, LV, PL, PT, RO, SK) use a single value for each national type and 1 country (BG) present standards as a range.

The data could be linked to 14 broad types (Figure 3.8 & Table 3.6). 8 of these (RW-00, RW-01, RW-04, RW-05, RW-08, RW-09, RW-10, RW-11) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 5 countries (BG, CY, FR, GR, PT) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 3 mg/L (PT) to 9.1 mg/L (PL) with an interquartile range of 6 to 7.5 (Figure 3.8).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.5). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (46.9%) and type (7.9%)

To link the reported standards with relevant BQEs, their interquartile ranges are marked as horizontal lines on box plots showing the distribution of Dissolved oxygen based on classifications for phytobenthos and macro-invertebrates (Figure 3.9) using data taken from the EEA-WISE-SoE.

More information in Annex A1.2.1.

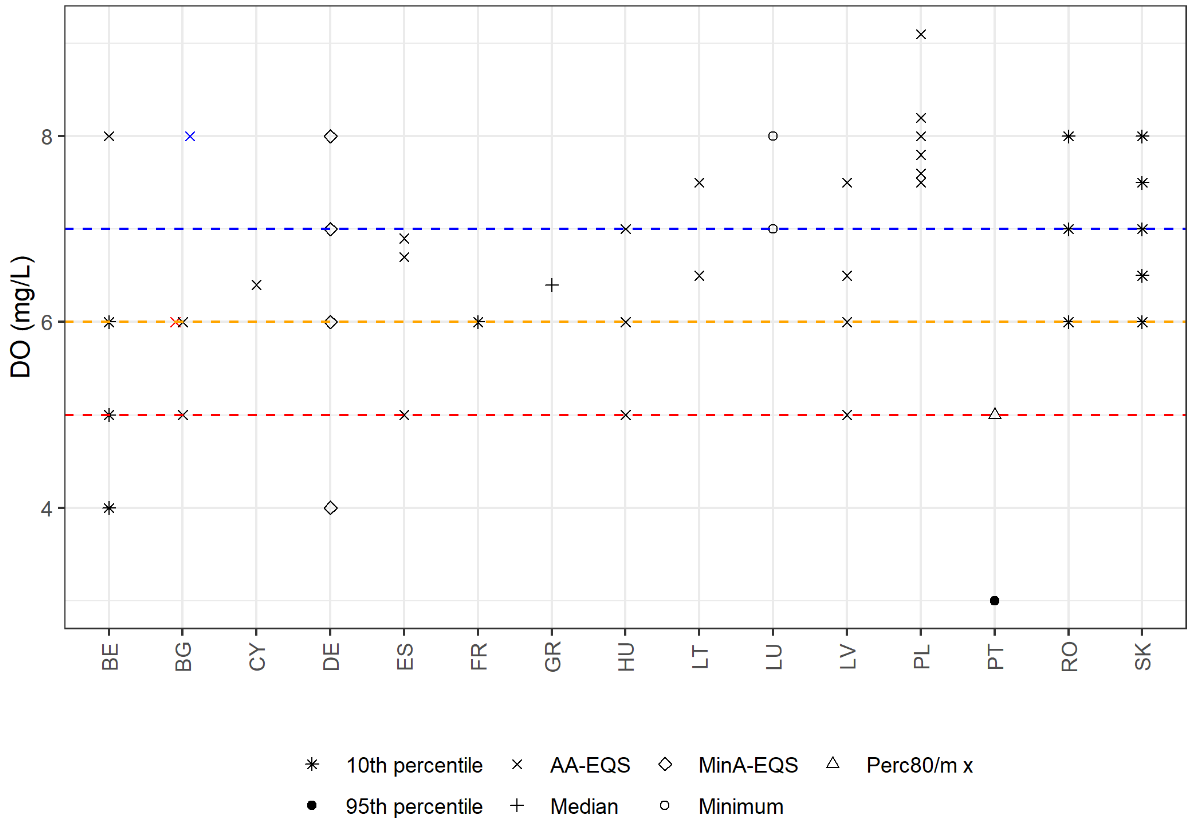

Figure 3.7: Comparison of river Dissolved oxygen standards by country. (single value black, minimum blue, maximum red symbols, dotted lines show interquartile range of mean or median values (10th percentile=red, 25th percentile=orange, 50th percentile = blue.)

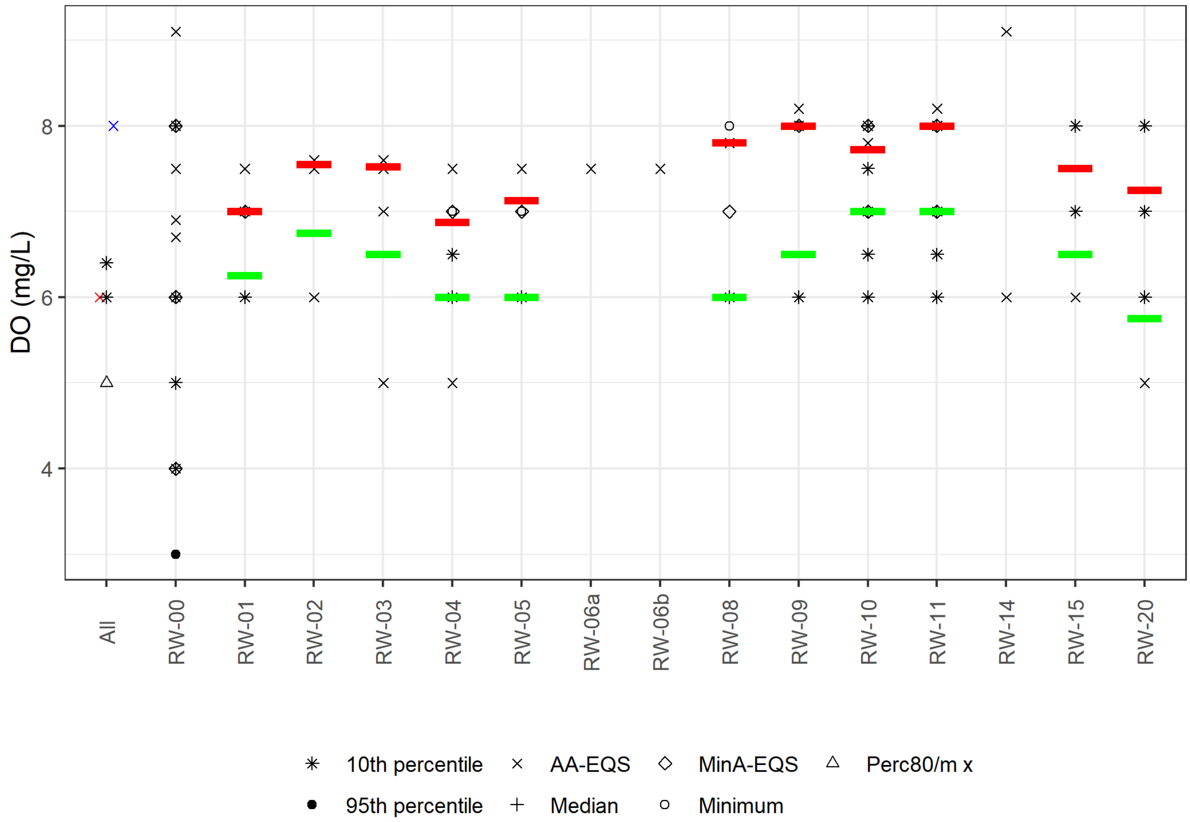

Figure 3.8: Dissolved oxygen standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while RW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark the 25th (green) and 75th (red) percentiles.

Table 3.5: Analysis of variance for factorial model relating country and broad type to Member State boundary values for Dissolved oxygen (Including main and partial effect sizes and Omega squared – see 1.2.5).

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			116.2	1	416.4	0.0000
Country	0.47	0.51	19.3	9	7.68	0.0000
CodeBT	0.08	0.15	4.5	6	2.69	0.0265
Residuals			11.7	42		

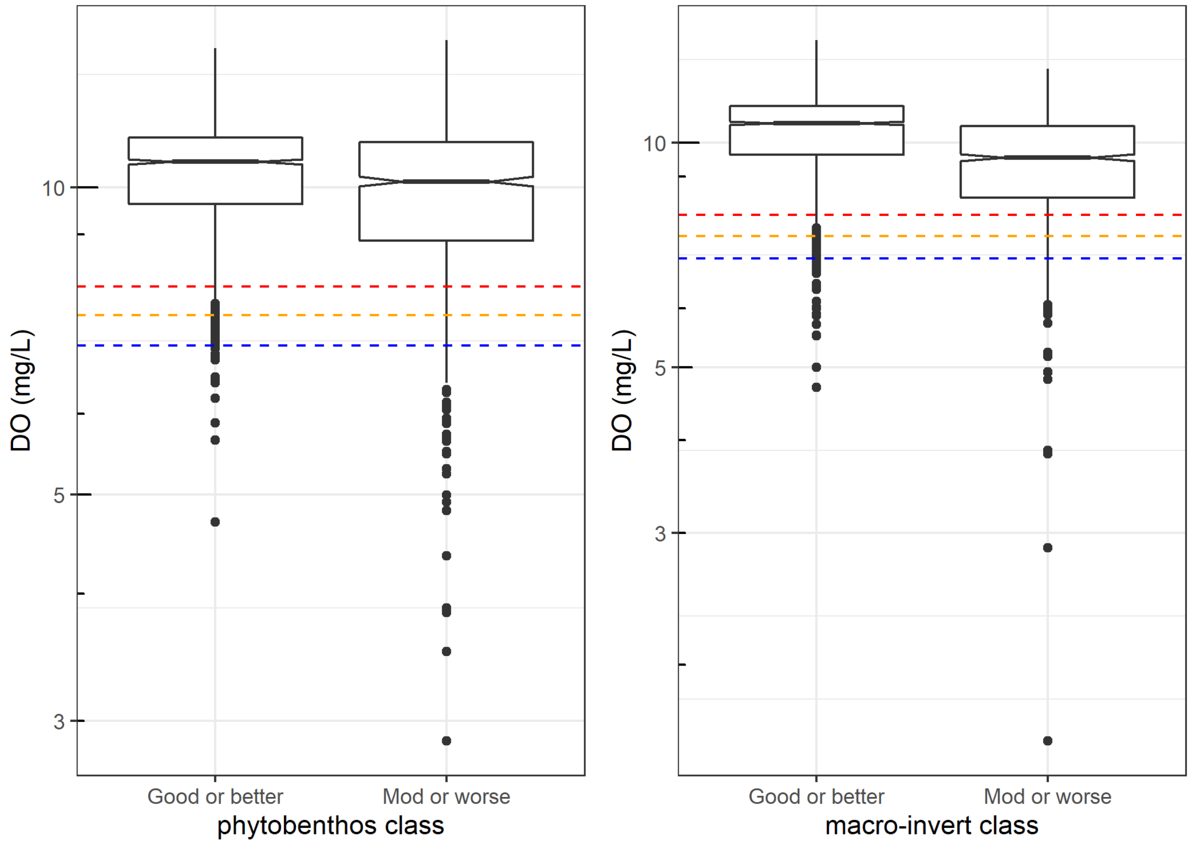

Figure 3.9: River Dissolved oxygen standards (dotted lines) overlain on box plots showing the range of Dissolved oxygen concentration for sites classified by phytobenthos and macro-invertebrates. (90th percentile=red, 75th percentile=orange, median=blue). Significance of difference between groups, (phytobenthos) Wilcoxon p=<0.001 (invertebrates) Wilcoxon p= <0.001.

Table 3.6: Overview of common broad types for which standards are available, showing the number of countries/national types/distinct standards for dissolved oxygen.

Code	Broad type	Country	Type	Standard
All	All	5	1	4
RW-00	Not assigned	8	60	9
RW-01	Very large rivers	6	16	3
RW-02	Lowland siliceous medium-large	2	3	3
RW-03	Lowland siliceous very small-small	2	5	4
RW-04	Lowland calcareous or mixed medium-large	8	43	5
RW-05	Lowland calcareous or mixed very small-small	7	13	3
RW-06a	Lowland organic and siliceous very small-small	1	1	1
RW-06b	Lowland organic and siliceous medium-large	1	1	1
RW-08	Mid-altitude siliceous medium-large	5	7	4
RW-09	Mid-altitude siliceous very small-small	5	9	3
RW-10	Mid-altitude calcareous or mixed medium-large	6	28	6
RW-11	Mid-altitude calcareous or mixed very small-small	6	25	5
RW-14	Highland (all Europe) siliceous incl. organic (humic)	2	3	2
RW-15	Highland (all Europe) calcareous or mixed	2	3	3
RW-20	Mediterranean temporary or intermittent streams	2	10	4

3.1.2.2 Percent oxygen saturation (rivers)

There were 159 records of percent oxygen saturation standards from 11 countries (Figure 3.10). Many countries use the annual mean ("AA-EQS") as a summary metric, but minimum, maximum and higher/lower percentile were also frequently used. 7 countries (CZ, EE, FR, HU, IT, PT, UK) use a single value for each national type while 5 countries (AT, ES, IE, NL, PT) present standards as a range.

Of these none specify that the ranges represent sub-types or RBD specific boundaries and it is assumed that the range represents upper and lower boundary values, as percent oxygen saturation is a QE that might be expected to have a two tailed effect.

The standards ranged from 50% (EE, NL) to 140% (PT), with an interquartile range of 70% to 120% (Figure 3.11). Given the bimodal distribution of the boundaries the data were split into two groups of upper and lower values, with values > 100% being placed in the upper group. The lower threshold values ranged from 50% to 100% with a median value of 70% while the upper boundaries ranged from 110% to 140% with a median value of 120%.

The data could be linked to 7 broad types (Figure 3.11 & Table 3.7), 6 countries (AT, FR, IE, IT, PT, UK) apply the same standard to all national types found in one or more of their river basin districts. Only 4 of these groups (RW-00, RW-01, RW-04, RW-05) had types from more than 2 countries, preventing comparisons between types.

A two-way analysis of variance was used to test the significance of country and type for lower boundaries but only a one way test for the upper boundaries as there were too few types to test the effect of type (Table 3.7). The importance of the country effect can be judged from the Omega squared values which represent the proportion of variance explained by country (lower boundary values country -5.7% and type -24.5%; upper boundary values, country effect 9.7%).

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of % oxygen saturation based on classifications for phytobenthos and macro-invertebrates (Figure 3.12) using data taken from the EEA-WISE-SOE-DATABASE. For both phytobenthos and macro-invertebrates EQRs sensitive to eutrophication and general degradation were used. The percentiles shown only relate to the lower % oxygen saturation boundary groups as there were too few upper standards to justify inclusion.

More information in Annex A1.2.2

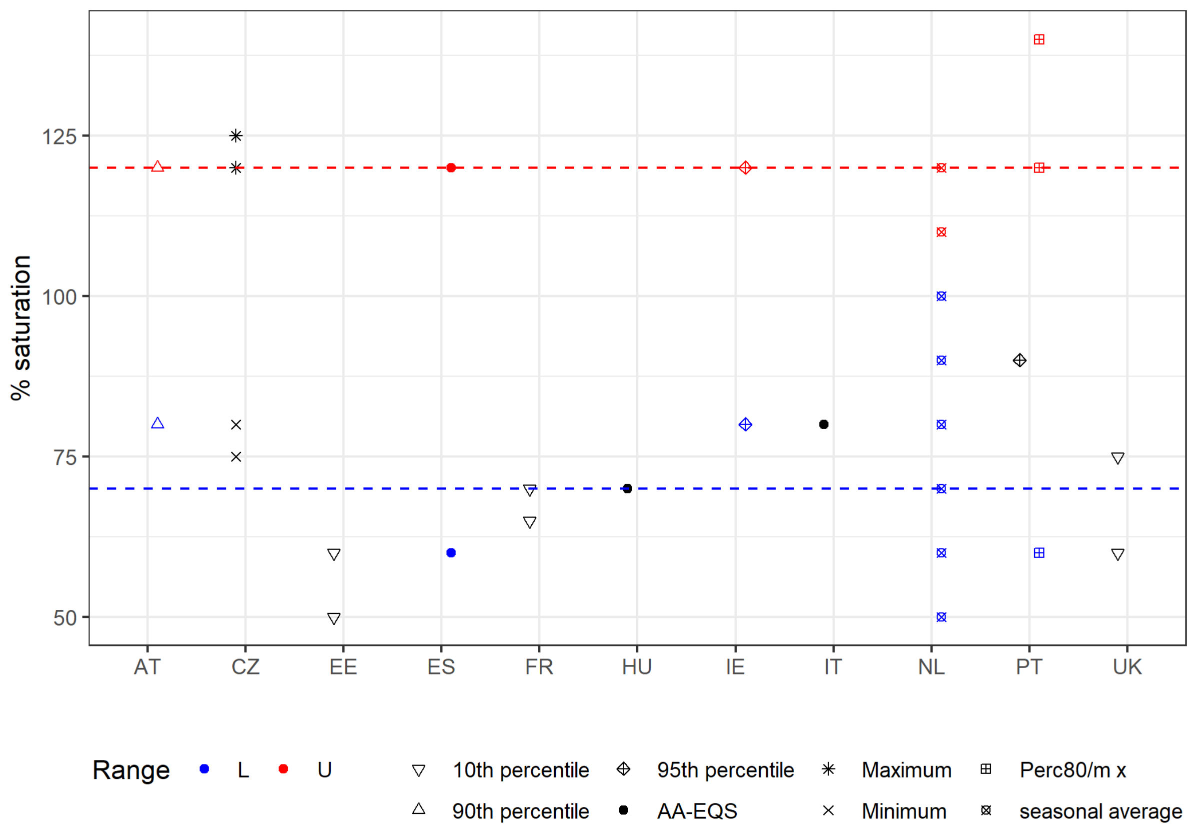

Figure 3.10: *Comparison of river % oxygen saturation standards by country. (single value black, minimum blue, maximum red symbols, dotted lines show median values for the upper (red) and lower (blue) groups).*

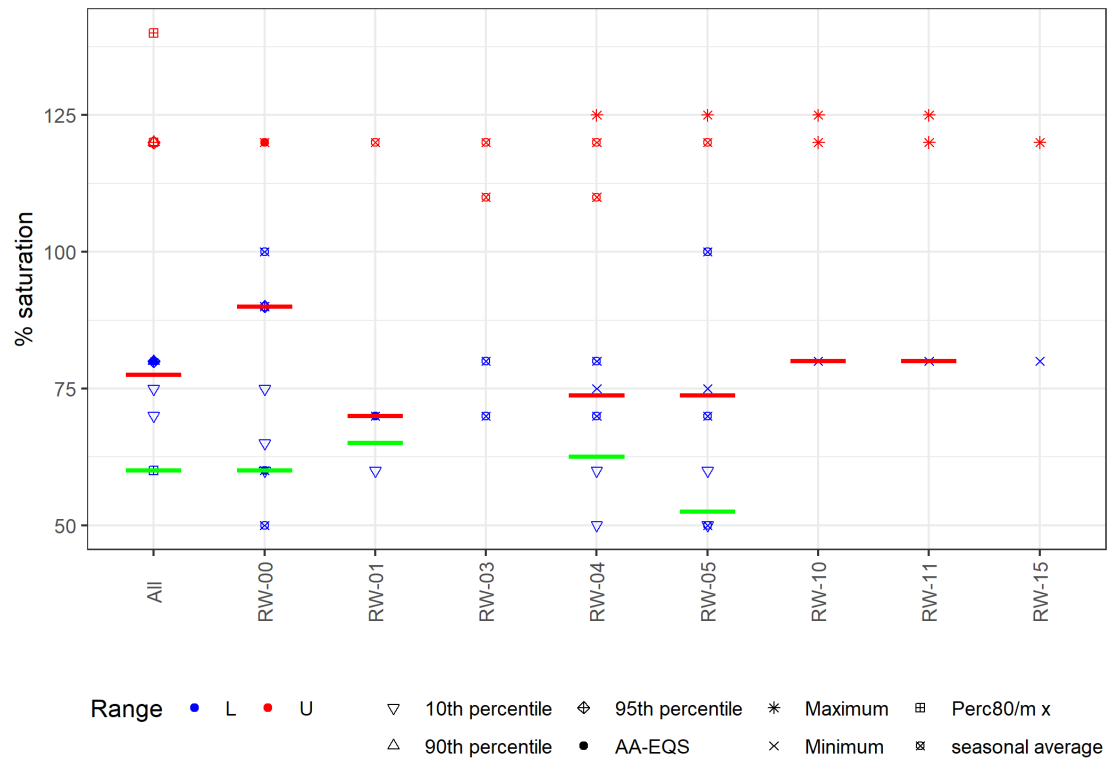

Figure 3.11: *River percent oxygen saturation standards by broad type (single value black, minimum blue, maximum red, Horizontal lines mark the 25th (green) and 75th (red) percentiles for the lower (blue dots) group of standards, (there were too few upper standards to justify inclusion of similar percentiles for this group).*

Table 3.7: *Analysis of variance for factorial model relating country and broad type to Member State boundary values for lower and upper groups of log % oxygen saturation boundaries (Including main and partial effect and Omega squared – see 1.2.5).*

Lower Boundaries	Omega sq,	Sum sq	Df	F value	Prob.
Intercept		19.20	1	453.64	0.00
Country	-0.06	0.35	10	0.83	0.6
CodeBT	-0.25	0.04	8	0.11	1.0
Residuals		0.80	19		

Upper Boundaries	Omega sq,	Sum sq	Df	F value	Prob.
Intercept		22.92	1	11439.13	0.00
Country	0.1	0.00	5	1.45	0.26
Residuals		0.03	15		

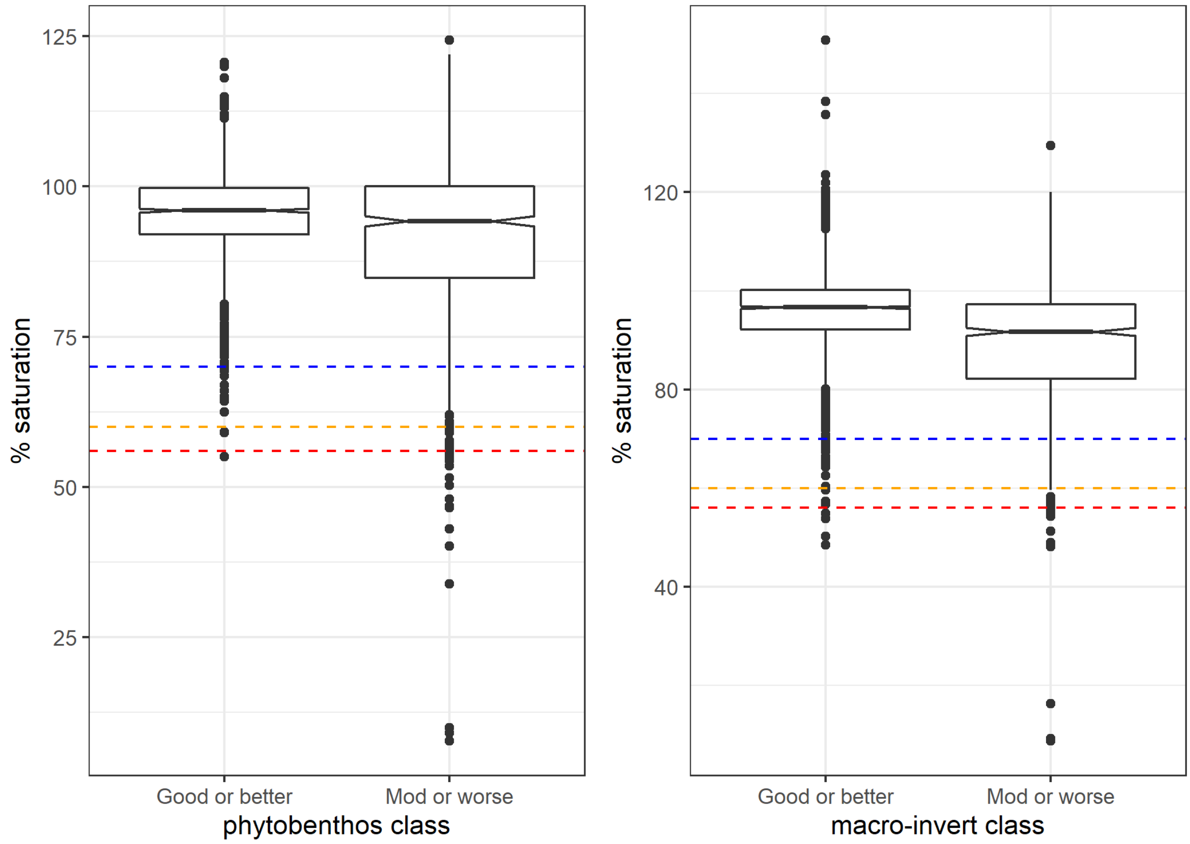

Figure 3.12: Lower boundaries for river % oxygen saturation standards (dotted lines) overlain on box plots showing the range of % oxygen saturation concentration for sites classified by phytobenthos and macroinvertebrates. (10th percentile=red, 25th percentile=orange, median=blue). Phytobenthos and macrophytes used EQRs sensitive to eutrophication and general degradation. Significance of difference between groups: phytobenthos - Wilcoxon p= <0.001; macroinvertebrates: Wilcoxon p= <0.001 (Percentiles were calculated from all summary metrics as majority of values were based on extreme percentiles)

Table 3.8: Overview of common broad types for which standards are available, showing the number of countries/national types/distinct standards for % oxygen saturation.

Code	Broad type	Country	Type	Standard

All	All	6	3	4
RW-00	Not assigned	5	31	5
RW-01	Very large rivers	3	3	2
RW-03	Lowland siliceous very small-small	1	3	2
RW-04	Lowland calcareous or mixed medium-large	3	13	6
RW-05	Lowland calcareous or mixed very small-small	3	7	5
RW-10	Mid-altitude calcareous or mixed medium-large	1	5	3
RW-11	Mid-altitude calcareous or mixed very small-small	1	6	3
RW-15	Highland (all Europe) calcareous or mixed	1	4	2

3.1.3 Dissolved oxygen: synthesis

For both lakes and rivers there are several clear differences in parameters used, with countries using either or both of concentration and percent saturation and using both upper and lower thresholds. For lakes, in particular, comparison is further complicated because it is not clear whether the epilimnion, hypolimnion or the entire water column is being assessed. Some countries that use percent saturation have separate standards specifying upper and lower thresholds. Where concentration or percent saturation depend upon spot measurements, the time of the measurement may also influence whether upper or lower thresholds are more informative, as upper thresholds will be relevant only when primary production is high. Whilst the lower threshold is of more direct interest to regulators, as this will influence the survival of fish and invertebrates, the upper threshold also reflects the impact of the pressure on primary production and may serve as a warning that direct impacts arising from low oxygen saturation are likely.

Dissolved oxygen is unlikely to directly influence algal or plant communities, but may reflect water body status determined by them. EEA data on measured oxygen concentrations in water bodies classified by different BQEs show no differences in the range of mean oxygen for phytoplankton in lakes (Figs. 3.3 and 3.6), while for lake macrophytes (Figs. 3.3 and 3.6), and river phytobenthos (Figs 3.9 and 3.12) the oxygen concentrations are lower in water bodies at worse than good status. In contrast invertebrates may be directly influenced by low dissolved oxygen and water bodies classified using this BQE showed the biggest differences (Figs 3.9 and 3.12). It was only possible to split the reported standards into upper and lower thresholds for percentage oxygen saturation. It is possible that this high-level analysis overlooks nuances that make such thresholds valuable within individual countries, but in general upper standard values tended to be at higher values than the reported data, suggesting that they represent fairly extreme conditions.

Lower standards for dissolved oxygen are likely to be set to protect fish. For both lakes and rivers, several countries continue to use the 6 mg/L threshold set by the Freshwater Fish Directive. A comparison with dissolved oxygen concentrations in water bodies classified by macroinvertebrate status (Figs 3.9 & 3.12) suggests that these thresholds are generally too lenient to protect good status. Interpretation of these results should also bear in mind that fish are likely to be more sensitive to low oxygen than invertebrates but it was not possible to show this BQE in a box plot. We also note that humic lakes may have naturally low DO concentrations (sometimes even anoxic) in the hypolimnion during stratification, even at reference conditions. This emphasises the need for local knowledge to inform how standards are set and used. A further concern is that changing thermal regimes (Kraemer et al., 2021) will affect the solubility of oxygen (Jane et al., 2021), meaning that trends in "saturation" may not reflect the actual availability of oxygen to organisms.

Development of more protective standards will also need to consider how samples are collected and, in lakes, whether the epi- or hypolimnion, or whole water column is considered) as well as appropriate summary metrics.

3.2 Transparency

3.2.1 Secchi depth (lakes)

Data for Secchi disk depth provided 222 records from 16 countries (Figure 3.13). Many countries use the annual mean ("AA-EQS") as a summary metric. 13 countries (AT, BG, CZ, EE, ES, HR, IT, LT, LV, NL, PL, PT, SI) use a single value for each national type and 7 countries (AT, BG, DE, FR, HR, IT, NO) present standards as a range.

The data could be linked to 13 broad types (Figure 3.14 & Table 3.10). 9 of these (LW-00, LW-01, LW-02, LW-03, LW-04, LW-07, LW-08, LW-11, LW-14) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 1 country (HR) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 0.5 m (PL) to 10.6 m (NA) with an interquartile range of 1.5 to 3.3 (Figure 3.14).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.9). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (38.49%) and type (3.9%)

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of Secchi disk depth based on classifications for phytobenthos and macrophytes (Figure 3.15) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A2.1

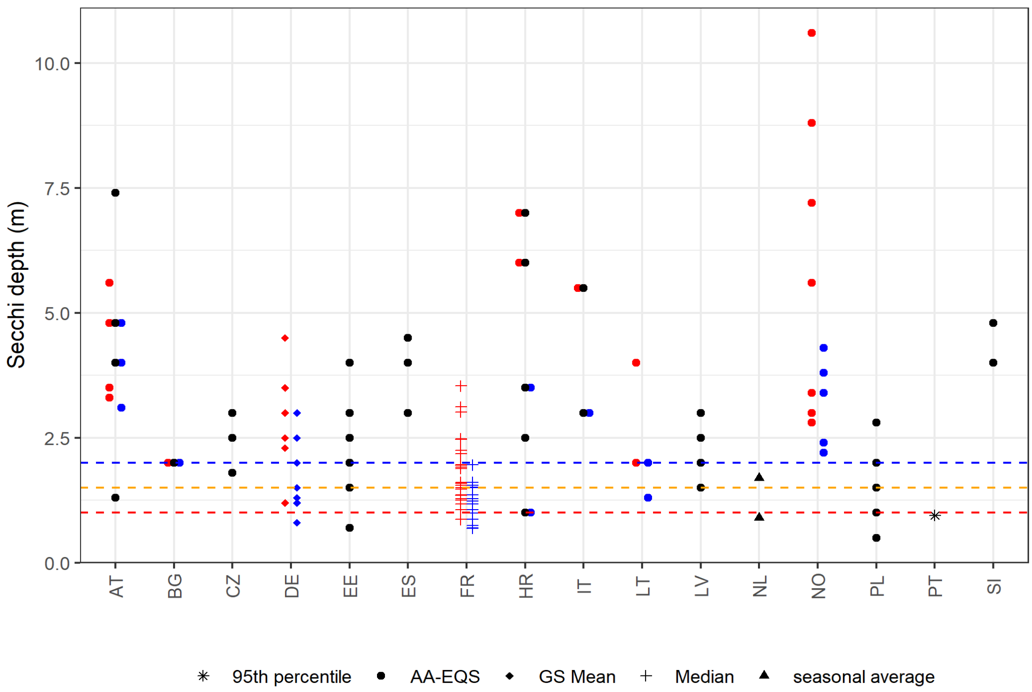

Figure 3.13: *Secchi disk depth standards by country (single value black, minimum blue, maximum red). Dotted lines show interquartile range of mean or median values, (10th percentile=red, 25th percentile=orange, 50th percentile = blue.)*

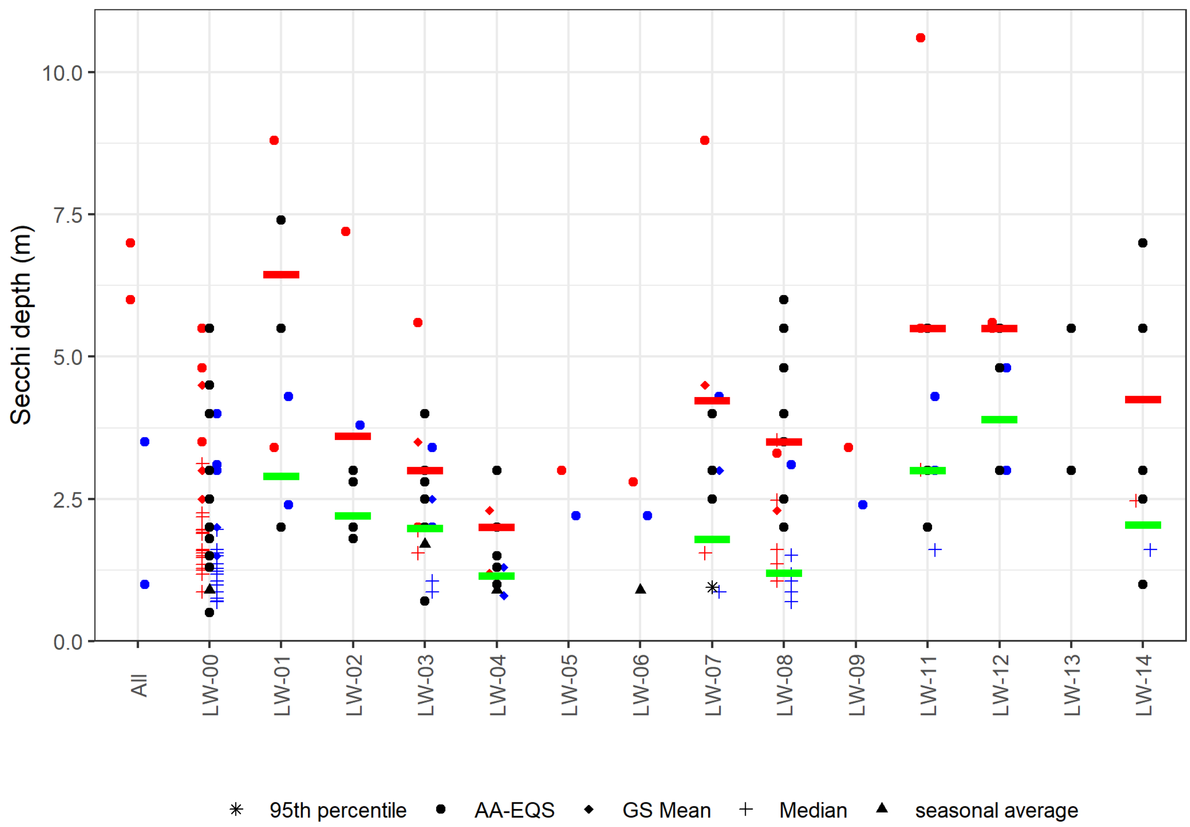

Figure 3.14: Secchi disk depth standards by broad type (single value black, minimum blue, maximum red), Horizontal lines mark the 25th (green) and 75th (red) percentiles. "All" are standards that are not

type-specific, but reported for all types in a RBD, while LW-00 are type-specific standards for national types that do not match any of the broad types.

Table 3.9: Analysis of variance for factorial model relating country and broad type to Member State boundary values for log Secchi disk depth (Including main and partial effect sizes and Omega squared – see 1.2.5) Secchi disk depth

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			5.7	1	31.02	0.0000
Country	0.38	0.40	14.4	14	5.55	0.0000
CodeBT	0.04	0.06	2.5	7	1.92	0.07874
Residuals			13.7	74		

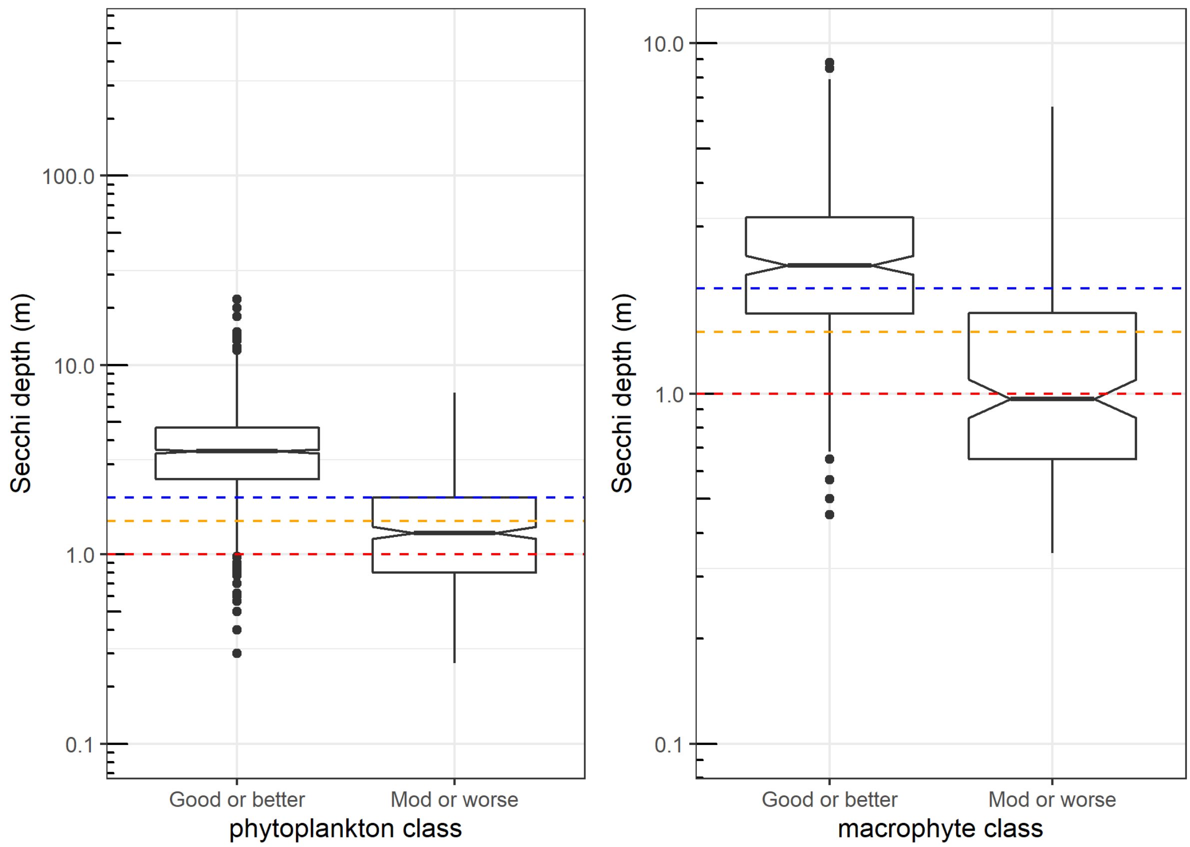

Figure 3.15: Lake Secchi disk depth standards (dotted lines) overlain on box plots showing the range of Secchi disk depth concentration for sites classified by phytoplankton and macrophytes. (10th

percentile=red, 25th percentile=orange, median=blue). Significance of difference between groups, (phytoplankton) Wilcoxon p=<0.001 (macrophytes) Wilcoxon p= <0.001

Table 3.10: *Overview of common broad types for which standards are available, showing the number of countries/national types/distinct standards for Secchi depth in lakes*.

Code	Broad type	Country	Type	Standard
All	All	1	1	2
LW-00	Not assigned	11	65	26
LW-01	Very large lakes shallow or deep and stratified (all Europe)	4	6	5
LW-02	Lowland siliceous	4	7	5
LW-03	Lowland stratified calcareous or mixed	10	21	10
LW-04	Lowland calcareous or mixed very shallow or unstratified	9	13	8
LW-05	Lowland organic (humic) and siliceous	1	1	1
LW-06	Lowland organic (humic) and calcareous or mixed	2	4	2
LW-07	Mid-altitude siliceous	7	14	6
LW-08	Mid-altitude calcareous or mixed	8	16	14
LW-09	Mid-altitude organic (humic) and Siliceous	1	2	1
LW-11	Highland Siliceous (all Europe) incl. organic (humic)	5	8	5
LW-12	Highland calcareous or mixed (all Europe) incl. organic (humic)	2	5	3
LW-13	Mediterranean small-large siliceous	1	2	2
LW-14	Mediterranean small-large calcareous or mixed	3	9	6

3.2.2 Secchi depth: synthesis

Secchi depth is a straightforward measurement that offers useful supplementary information to BQEs and other supporting elements. Light limitation is the most important driver of macrophyte status and thus Secchi depth provides important information on the way that two key BQEs interact in the presence of elevated nutrients. Interpretation of results is, however, likely to be complicated by the way it is combined with BQEs and other supporting elements in order to make a final assessment.

EEA data showed strong relationships between Secchi depth associated with different status classes for both phytoplankton and macrophytes (Fig. 3.15). For phytoplankton, the median boundary is below the 25th percentile for sites in good or better status but roughly in line with the 75th percentile for those not in good status. This suggests that current standards are broadly consistent with good status. The same is true for macrophytes: the median boundary is greater than both the 25th percentile for "good and better" and the 75th percentile for "less than good". These simplistic comparisons however take no account of complicating factors such as humic substances and inorganic turbidity (clay particles from the catchment or resuspended sediment in very shallow lakes. However, there are strong differences between countries (Table 3.9) and those with particularly lenient thresholds (≤ 1 m) should be encouraged to check these against national data on relationships with sensitive BQEs to validate whether these are sufficiently protective. It is also important be recognise that some shallow lakes are naturally highly turbid (e.g. due to suspension of particulates by wind/wave action) and, as a result, Secchi depth may not be a suitable indicator of ecological status.

3.3 pH

3.3.1 pH (lakes)

Data for pH provided 177 records from 14 countries (Figure 3.16). Many countries use the annual mean ("AA-EQS") as a summary metric, but minimum, maximum and higher/lower percentile were also frequently used. For pH 4 countries (CZ, HU, NO, RO) use a single value for each national type while 12 countries (AT, BE, BG, EE, ES, HU, IE, NL, NO, PL, PT, SI) present standards as a range.

Of these only AT and NO specify that the ranges represent sub-types or RBD specific boundaries and it is assumed that in other cases the range represents upper and lower boundary values, as pH is a QE that might be expected to have a two tailed effect.

The standards ranged from 3 (EE) to 10.5 (ES), with an interquartile range of 6.5 to 8.7 (Figure 3.17). Given the bimodal distribution of the boundaries the data were split into two groups of upper and lower values, with values > 7.0 being placed in the upper group. The lower threshold values ranged from 3 to 7 with a median value of 6 while the upper boundaries ranged from 7.3 to 10.5 with a median value of 8.5.

The data could be linked to 11 broad types (Figure 3.17 & Table 3.11), only 3 countries (CY, IE, PT) apply the same standard to all national types found in one or more of their river basin districts. 7 of these groups (LW-00, LW-01, LW-02, LW-03, LW-04, LW-06, LW-08) had types from more than 2 countries enabling comparisons between types to be made.

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.11). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (lower boundary values: 0%; upper boundary values: 5.1%) and type (lower boundary values: 20.1%; upper boundary values: 0%).

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of pH based on classifications for phytoplankton and macrophytes (Figure 3.18) using data taken from the EEA-WISE-SOE-DATABASE. For phytoplankton EQRs sensitive to acidification were used, for macrophytes EQRs sensitive to eutrophication and general degradation were used, with the percentiles shown relating to the lower and upper pH boundary groups respectively.

More information in Annex A3.1

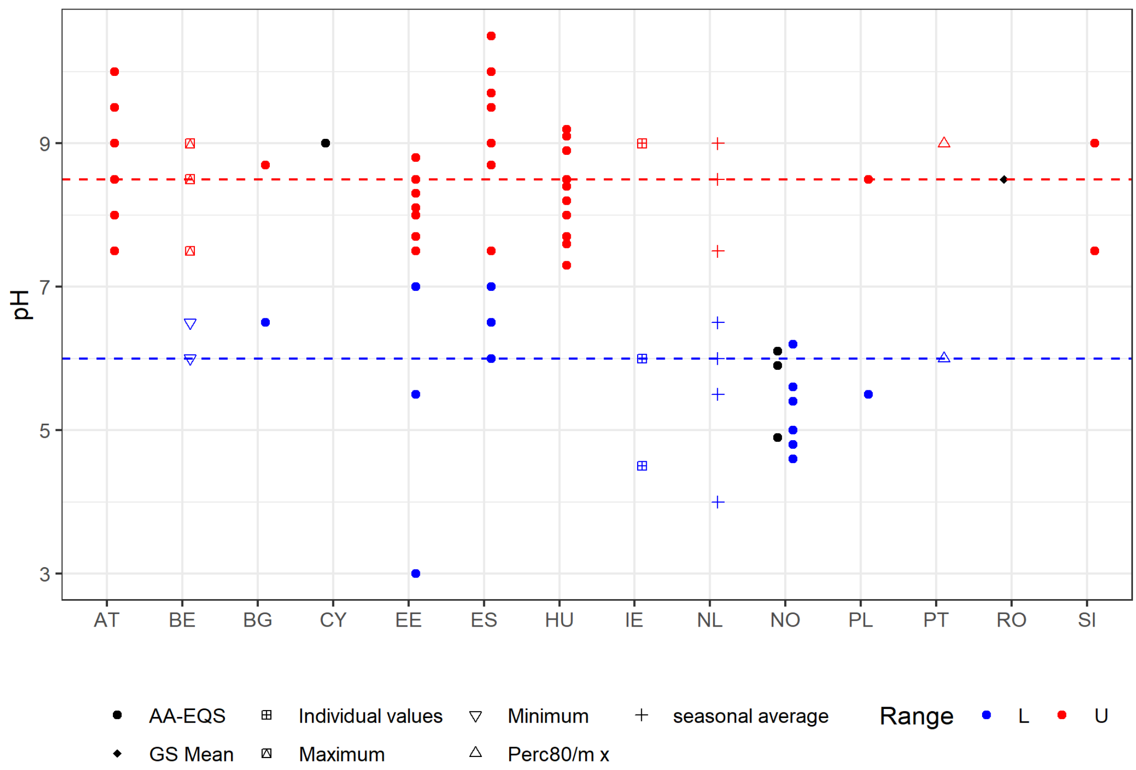

Figure 3.16: *Comparison of lake pH standards by country. (single value black, minimum blue, maximum red symbols, dotted lines show median values for the upper (red) and lower (blue) groups.*

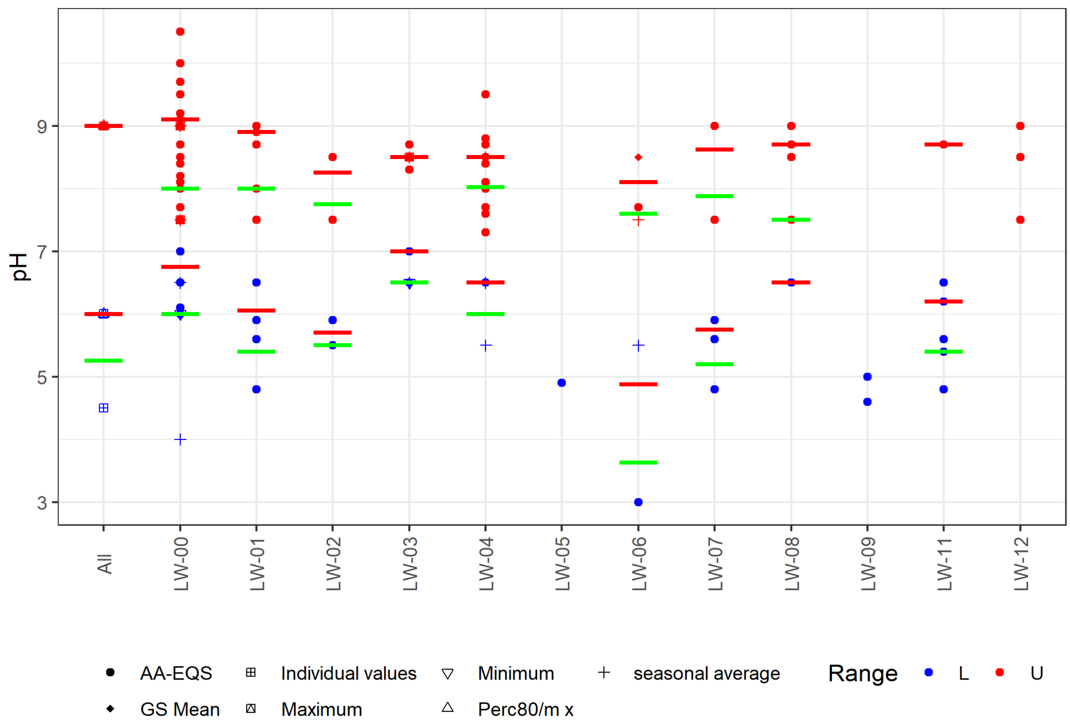

Figure 3.17: *Lake pH standards by broad type (single value black, minimum blue, maximum red, Horizontal lines mark the 25th (green) and 75th (red) percentiles for the lower (blue dots) and higher (red dots) groups of standards respectively.)*

Table 3.11: *Analysis of variance for factorial model relating country and broad type to Member State boundary values for lower and upper groups of pH boundaries (Including main and partial effect sizes, Omega squared – see 1.2.5).*

Lower Boundaries

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			61.7	1	100.04	0.000
Country	-0.11	-0.14	1.3	6	0.34	0.908
CodeBT	0.20	0.18	8.2	6	2.22	0.084
Residuals			12.3	20		

Upper Boundaries

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			756.3	1	1459.02	0.000
Country	0.05	0.05	6.5	9	1.4	0.210
CodeBT	-0.04	-0.05	1.4	6	0.47	0.831
Residuals			28.5	55		

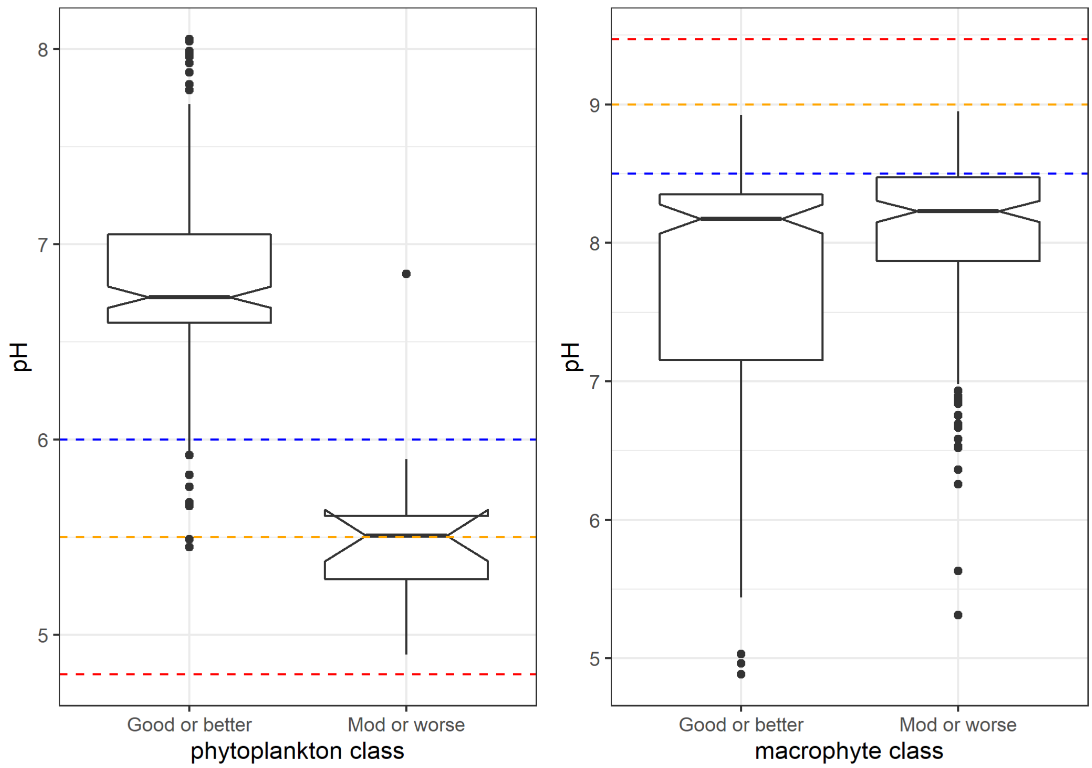

Figure 3.18: Upper and lower boundaries for lake pH standards (dotted lines) overlain on box plots showing the range of pH concentration for sites classified by phytoplankton and macrophytes. (For the upper boundaries lines show are the 90th percentile=red, 75th percentile=orange, median=blue and for the lower boundaries they are the 10th percentile=red, 25th percentile=orange, median=blue). Phytoplankton and macrophytes used EQRs sensitive to acidification or eutrophication and general degradation respectively. Significance of difference between groups, (phytoplankton) Wilcoxon p= <0.001 (macrophytes) Wilcoxon p= 0.001 (Percentiles were calculated from all summary metrics as many of values were based on extreme percentiles).

Table 3.12: Overview of common broad types for which standards are available, showing the number of countries/national types/distinct standards for H in lakes.

Code	Broad type	Country	Type	Standard
All	All	3	1	3
LW-00	Not assigned	9	62	11
LW-01	Very large lakes shallow or deep and stratified (all Europe)	4	5	5
LW-02	Lowland siliceous	3	4	2
LW-03	Lowland stratified calcareous or mixed	4	7	2
LW-04	Lowland calcareous or mixed very shallow or unstratified	6	12	8
LW-05	Lowland organic (humic) and siliceous	1	1	1
LW-06	Lowland organic (humic) and calcareous or mixed	3	4	3
LW-07	Mid-altitude siliceous	2	11	3
LW-08	Mid-altitude calcareous or mixed	3	6	2
LW-09	Mid-altitude organic (humic) and Siliceous	1	2	1
LW-11	Highland Siliceous (all Europe) incl. organic (humic)	2	5	3
LW-12	Highland calcareous or mixed (all Europe) incl. organic (humic)	1	2	1

3.3.2 pH (rivers)

There were 573 records of pH standards from 20 countries (Figure 3.19). Many countries use the annual mean ("AA-EQS") as a summary metric, but minimum, maximum and higher/lower percentile were also frequently used. 10 countries (BE, CZ, DE, FI, HR, HU, NO, PT, RO, UK) use a single value for each national type while 16 countries (AT, BE, BG, EE, ES, FR, HR, HU, IE, LU, NL, NO, PT, SE, SK, UK) present standards as a range.

Of these only NO and SE specify that the ranges represent sub-types or RBD specific boundaries and it is assumed that in other cases the range represents upper and lower boundary values, as pH might be expected to have a two tailed effect.

The standards ranged from 3.9 (SE) to 9 (HR, CZ, EE, HU, BE), with an interquartile range of 6 to 8.5 (Figure 3.20). Given the bimodal distribution of the boundaries the data were split into two groups of upper and lower values, with values > 7.0 being placed in the upper group. The lower threshold values ranged from 3.86 to 7 with a median value of 6 while the upper boundaries ranged from 8 to 9 with a median value of 8.5.

The data could be linked to 20 broad types (Figure 3.20 & Table 3.13); only 7 countries (AT, BG, FR, HR, IE, PT, UK) apply the same standard to all national types found in one or more of their river basin districts. 11 of these groups (RW-00, RW-01, RW-02, RW-03, RW-04, RW-05, RW-08, RW-09, RW-10, RW-11, RW-15) had types from more than 2 countries enabling comparisons between types to be made.

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.13). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (lower boundary values: 44.5%; upper boundary values: 45.4%) and type (lower boundary values: 0% and upper boundary values: 0%) and type (-0.5%). In both cases, data did not satisfy all assumptions of normality so these results need to be interpreted with care.

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of pH based on classifications for phytobenthos and macroinvertebrates (Figure 3.21) using data taken from the EEA-WISE-SOE-DATABASE. For phytobenthos EQRs sensitive to eutrophication and general degradation were used, for macroinvertebrates EQRs sensitive to acidification were used, with the percentiles shown relating to the upper and lower pH boundary groups respectively.

More information in Annex A3.2.

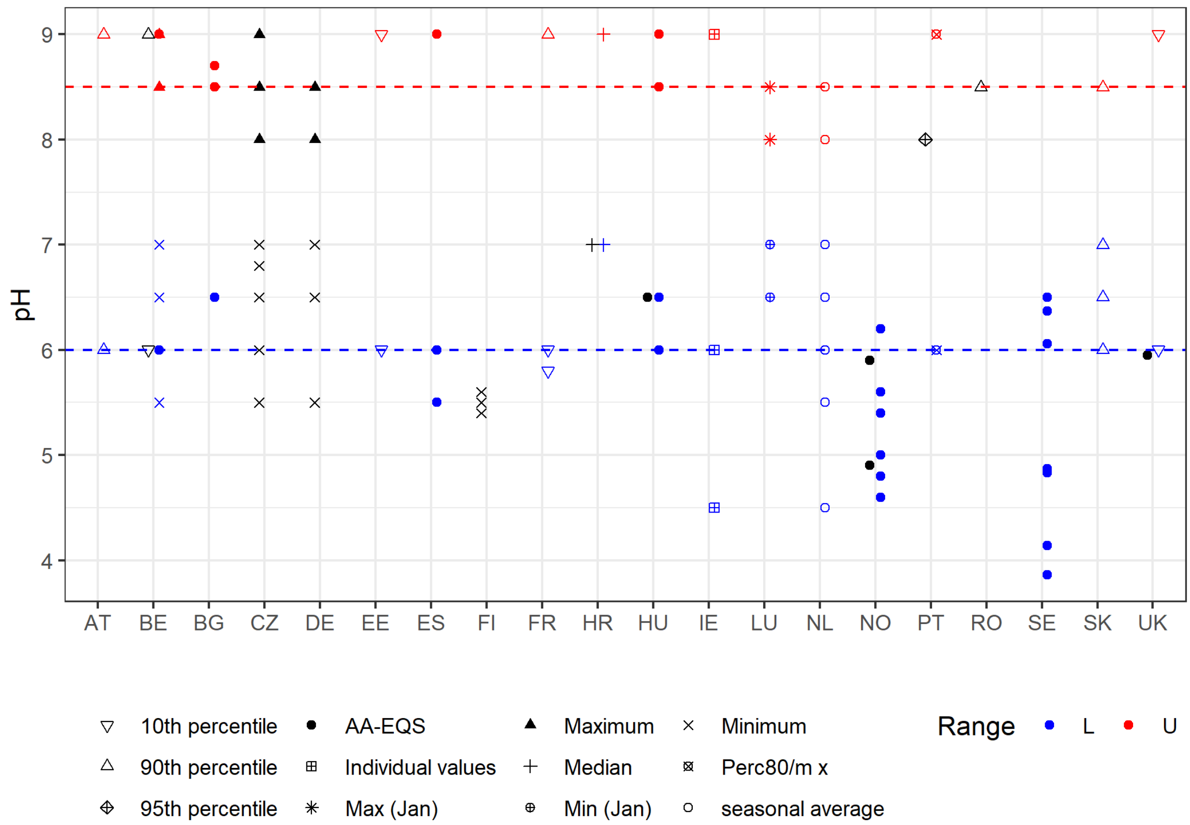

Figure 3.19: Comparison of river pH standards by country (single value black, minimum blue, maximum red). Dotted lines show median values for the upper (red) and lower (blue) groups.

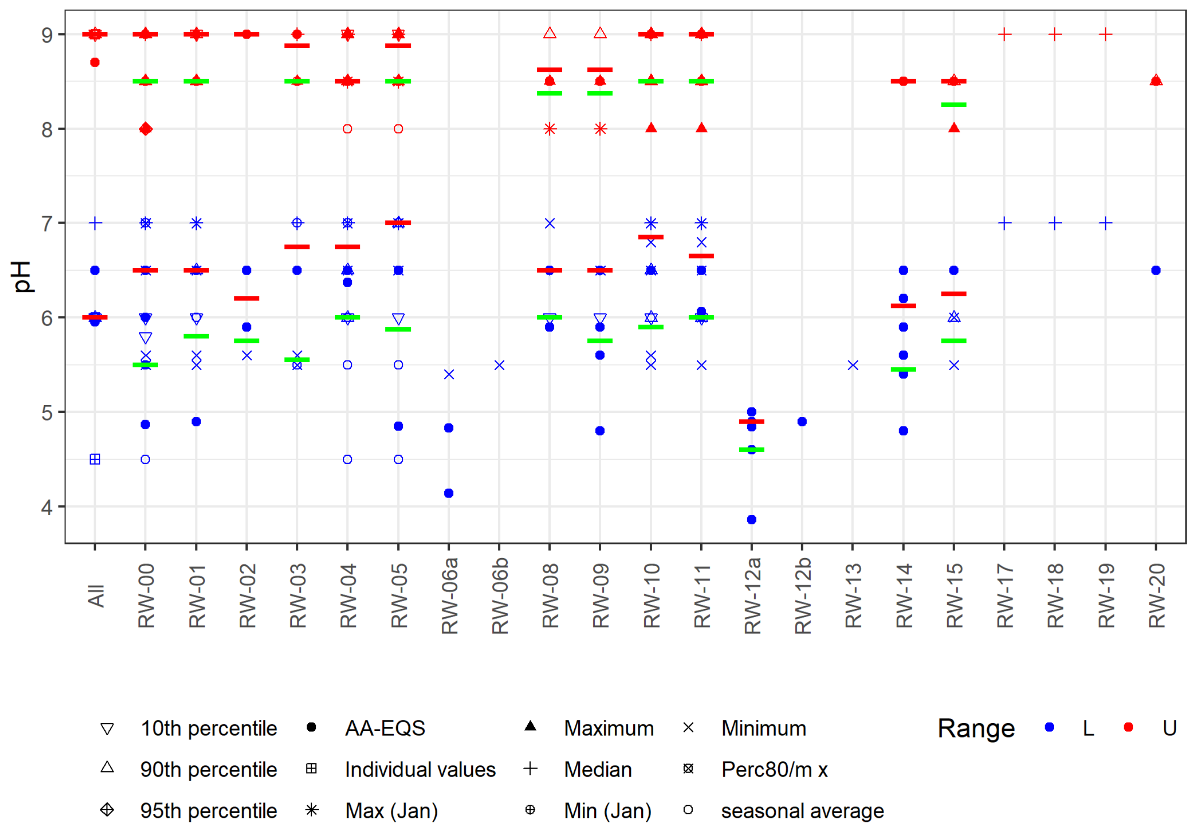

Figure 3.20: River pH standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while RW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark the 25th (green) and 75th (red) percentiles for the lower (blue symbols) and upper (red symbols) group of standards respectively.)

Table 3.13: Analysis of variance for factorial model relating country and broad type to Member State boundary values for lower and upper groups of pH boundaries (Including main and partial effect sizes, Omega squared – see 1.2.5).

Lower Boundaries

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			203.5	1	977.02	0.000
Country	0.44	0.44	17.2	12	6.89	0.000
CodeBT	-0.01	-0.02	1.5	9	0.81	0.607
Residuals			14.2	68		

Upper Boundaries

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.

Intercept			398.0	1	7507.59	0.000
Country	0.45	0.44	3.5	10	6.57	0.000
CodeBT	-0.04	-0.08	0.2	9	0.43	0.911
Residuals			2.8	52		

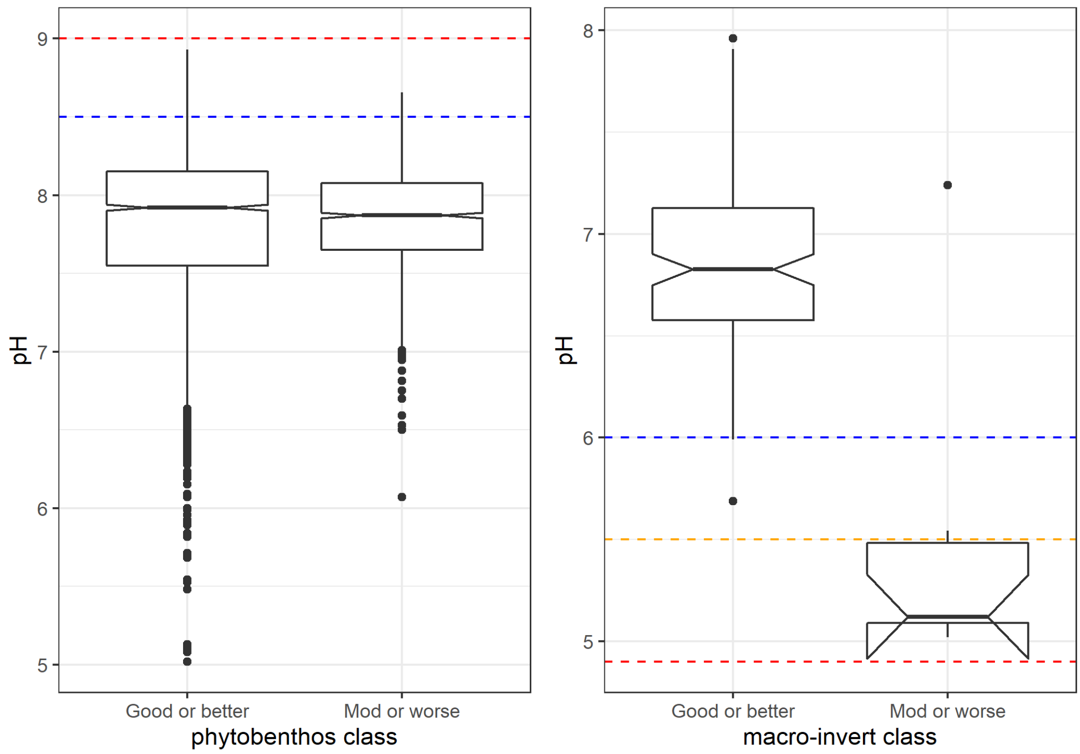

Figure 3.21: *Upper and lower boundaries for river pH standards (dotted lines) overlain on box plots showing the range of pH for sites classified by phytobenthos and invertebrates. (For the upper boundaries lines show are the 90th percentile=red, 75th percentile=orange (overlain by 90th percentile line), median=blue and for the lower boundaries they are the 10th percentile=red, 25th percentile=orange, median=blue). Phytobenthos and macrophytes used EQRs sensitive to eutrophication and general degradation with the percentiles of the upper boundaries. Significance of difference between groups, (phytoplankton) Wilcoxon p= 0.068 (macrophytes) Wilcoxon p= <0.001 (Percentiles were calculated from all summary metrics as majority of values were based on extreme percentiles).*

Table 3.14: Overview of common broad types for which standards are available, showing the number of countries/national types/distinct standards for pH in rivers.

Code	Broad type	Country	Type	Standard
All	All	7	3	5
RW-00	Not assigned	11	66	11
RW-01	Very large rivers	10	23	8
RW-02	Lowland siliceous medium-large	3	3	3
RW-03	Lowland siliceous very small-small	5	8	4
RW-04	Lowland calcareous or mixed medium-large	11	53	8
RW-05	Lowland calcareous or mixed very small-small	10	21	8
RW-06a	Lowland organic and siliceous very small-small	2	2	2
RW-06b	Lowland organic and siliceous medium-large	1	1	1
RW-08	Mid-altitude siliceous medium-large	5	13	6
RW-09	Mid-altitude siliceous very small-small	5	11	6
RW-10	Mid-altitude calcareous or mixed medium-large	8	36	9
RW-11	Mid-altitude calcareous or mixed very small-small	8	33	9
RW-12a	Mid-altitude organic and siliceous very small-small	2	9	3
RW-12b	Mid-altitude organic and siliceous medium-large	1	2	1
RW-13	Mid-altitude organic and calcareous or mixed	1	1	1
RW-14	Highland (all Europe) siliceous incl. organic (humic)	2	13	4
RW-15	Highland (all Europe) calcareous or mixed	3	7	4
RW-17	Mediterranean lowland medium-large perennial	1	3	1
RW-18	Mediterranean mid-altitude medium-large perennial	1	1	1
RW-19	Mediterranean very small-small perennial	1	4	1
RW-20	Mediterranean temporary or intermittent streams	2	10	2

3.3.3 pH: synthesis

pH is another physico-chemical supporting element for which several countries present both lower and upper standards. The former will protect against acidification whilst the latter may also be an additional indicator of eutrophication (where removal of inorganic carbon leads to an increase in pH due to a shift in the equilibrium of the carbonate-bicarbonate buffer system). In both cases, we should expect a strong type-specific effect, with the standards likely to be most relevant in soft water lake and stream types. Acid neutralizing capacity is also used to indicate acidification in such circumstances, but the number of countries reporting this PCSE was too low to permit comparisons.

Relatively few EEA data, however, are available for metrics that are sensitive to acidification and there is no particular reason to expect most metrics for lake phytoplankton and macrophytes or river phytobenthos to be sensitive to this pressure (acid-sensitive metrics for river phytobenthos are available in a few countries but were not intercalibrated). For lakes we include results from a single country (SE) who have an acid sensitive phytoplankton metric. For this metric, the median lower boundary falls between the "good and better" and "less than good" distributions (Fig. 3.18) suggesting it is broadly consistent with good status. For rivers there are, however, sufficient data for acid-sensitive invertebrate metrics to permit a more meaningful comparison between standards: again the median value and the 25th percentile falls between the "good and better" and "less than good" distributions (Fig. 3.21), suggesting adequate boundaries. However, as fewer countries contributed data for acid-sensitive metrics, these interpretations need to be treated with caution.

By contrast, upper pH standards should align with eutrophication-sensitive metrics: Fig. 3.18, however, suggests that these may be too lenient although there is considerable overlap between the "good and better" and "less than good" distributions. The relevance of these upper pH standards, particularly for well-buffered waters, and the extent to which they are based on empirical evidence rather than expert judgement still needs to be assessed.

3.4 BOD

3.4.1 BOD (rivers)

There were 429 records of BOD standards from 15 countries (Figure 3.22). Many countries use the annual mean ("AA-EQS") as a summary metric. 18 countries (AT, BE, BG, CY, CZ, DE, FR, HR, HU, IE, LT, LU, LV, PL, PT, RO, SI, SK) use a single value for each national type and none presents standards as a range.

The data could be linked to 19 broad types (Figure 3.23 & Table 3.16). 12 of these (RW-00, RW-01, RW-02, RW-03, RW-04, RW-05, RW-08, RW-09, RW-10, RW-11, RW-14, RW-15) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 4 countries (CY, FR, IE, PT) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 1.5 mg/L (CZ) to 8 mg/L (BE), with an interquartile range of 2.9 to 5 (Figure 3.23).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.15). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (52.6%) and type (9.3%)

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of BOD5 based on classifications for phytobenthos and macroinvertebrates (Figure 3.24) using data for EQR metrics responding to general degradation and eutrophication taken from the EEA SoE database (Waterbase).

More information in Annex A4.1

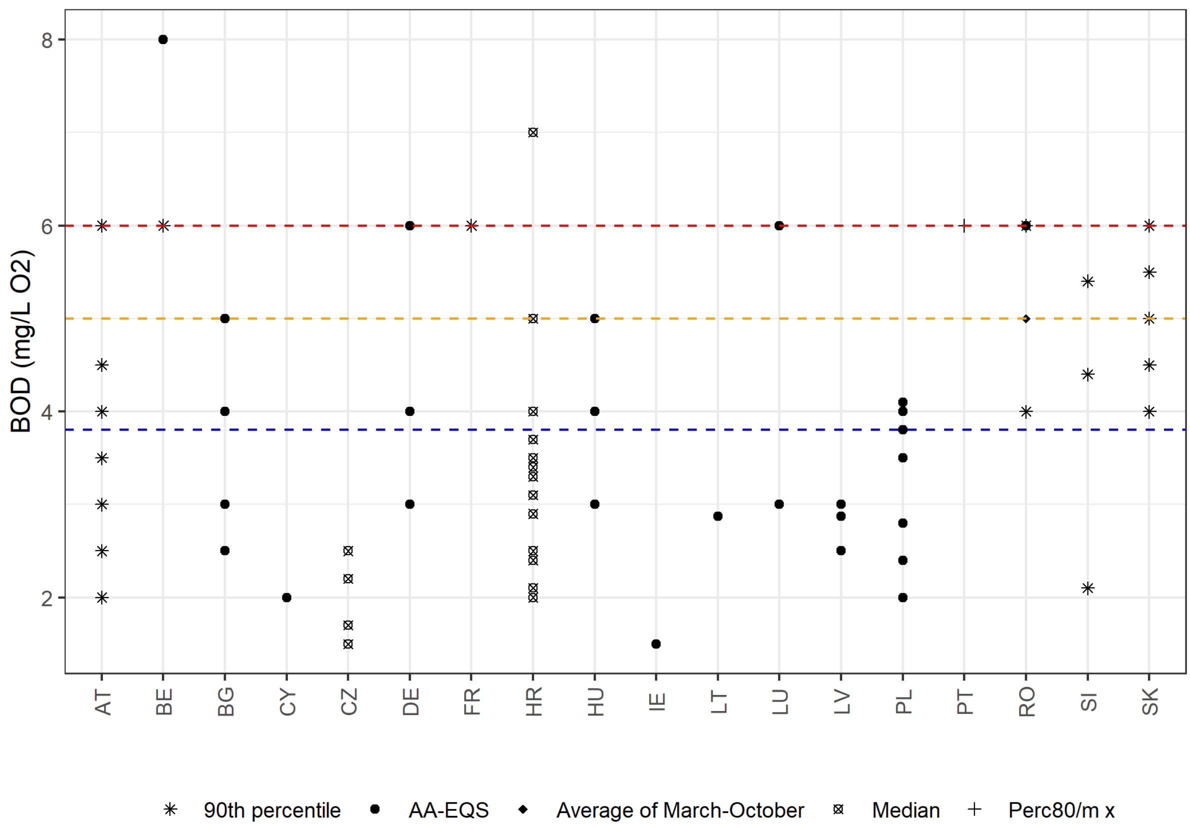

Figure 3.22: Comparison of BOD5 standards by country (single value black, minimum blue, maximum red). Dotted lines show interquartile range of mean or median values, (90th percentile=red, 75th percentile=orange, 50th percentile = blue)

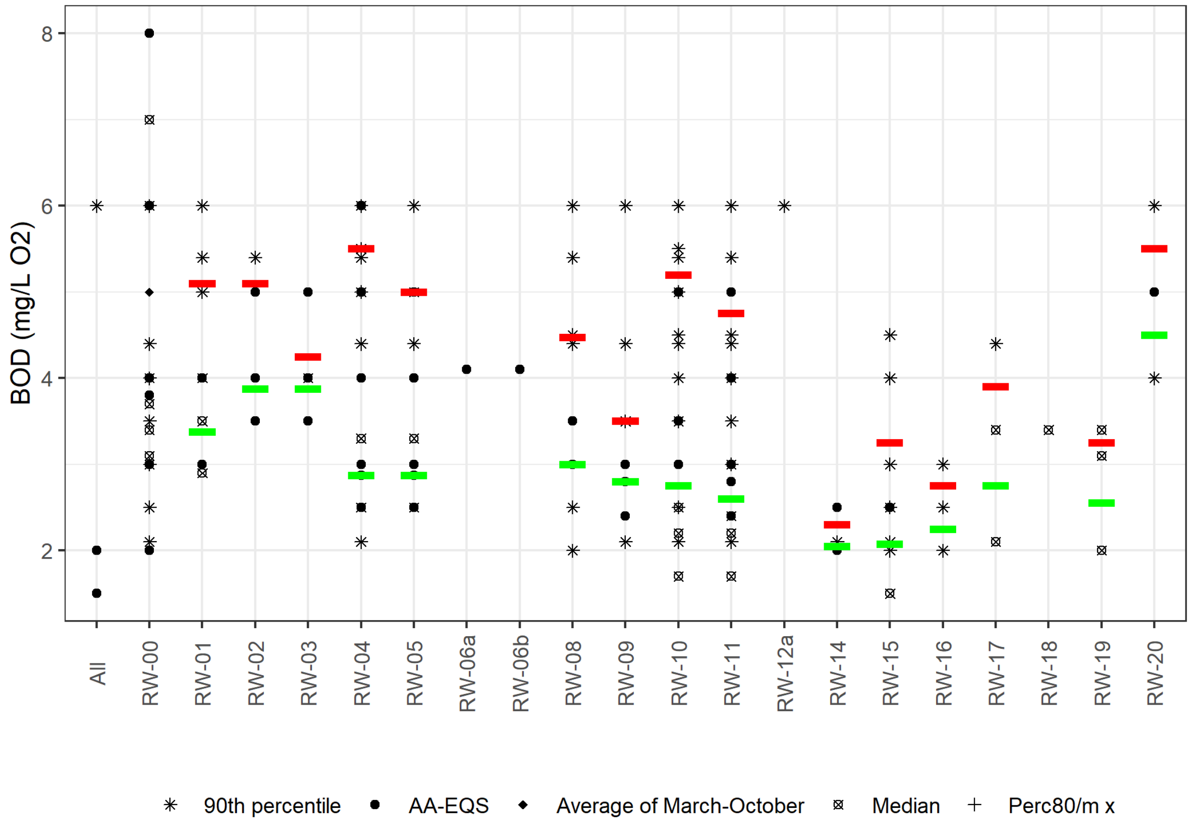

Figure 3.23: River BOD5 standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while RW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark the 25th (green) and 75th (red) percentiles).

Table 3.15: Analysis of variance for factorial model relating country and broad type to Member State boundary values for BOD5 (Including main and partial effect sizes, Omega squared – see 1.2.5).

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			81.0	1	120.82	0.00000
Country	0.53	0.58	121.60	13	13.95	0.00000
CodeBT	0.09	0.20	26.7	10	3.97	0.00014
Residuals			65.7	98		

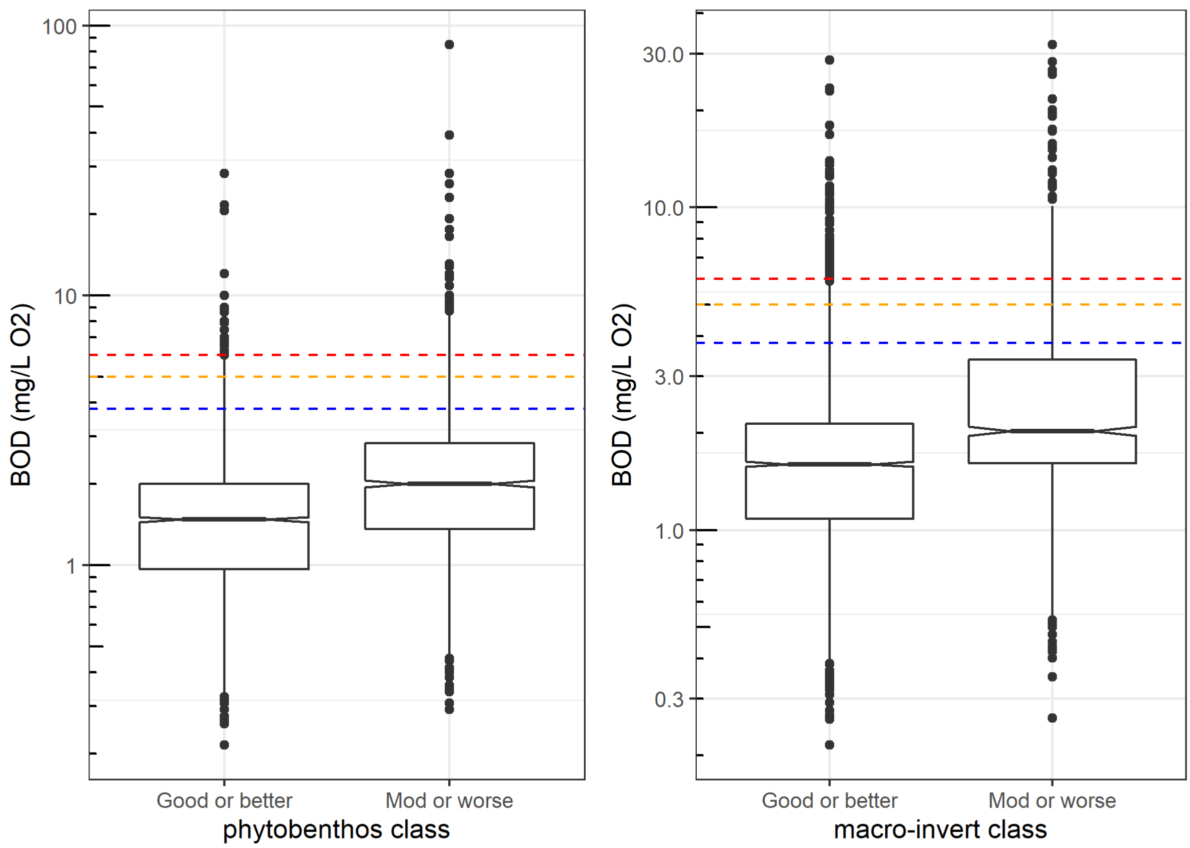

Figure 3.24: River BOD5 standards (dotted lines) overlain on box plots showing the range of BOD5 concentration for sites classified by phytobenthos and macro-invertebrates. (90th percentile=red, 75th percentile=orange, median=blue) Significance of difference between groups, (phytobenthos) Wilcoxon p=<0.001 (invertebrates) Wilcoxon p= <0.001.

Table 3.16: Overview of common broad types showing the number of countries/national types/distinct standards for BOD5 in rivers.

Code	Broad type	Country	Type	Standard
All	All	4	1	3
RW-00	Not assigned	8	48	15
RW-01	Very large rivers	8	19	7
RW-02	Lowland siliceous medium-large	3	4	4
RW-03	Lowland siliceous very small-small	3	6	3
RW-04	Lowland calcareous or mixed medium-large	12	61	11
RW-05	Lowland calcareous or mixed very small-small	10	24	8
RW-06a	Lowland organic and siliceous very small-small	1	1	1
RW-06b	Lowland organic and siliceous medium-large	1	1	1
RW-08	Mid-altitude siliceous medium-large	7	18	8
RW-09	Mid-altitude siliceous very small-small	7	15	7
RW-10	Mid-altitude calcareous or mixed medium-large	10	61	13
RW-11	Mid-altitude calcareous or mixed very small-small	10	59	13
RW-12a	Mid-altitude organic and siliceous very small-small	1	1	1
RW-14	Highland (all Europe) siliceous incl. organic (humic)	3	4	3
RW-15	Highland (all Europe) calcareous or mixed	5	14	7
RW-16	Glacial rivers (all Europe)	1	3	3
RW-17	Mediterranean lowland medium-large perennial	2	4	3
RW-18	Mediterranean mid-altitude medium-large perennial	1	1	1
RW-19	Mediterranean very small-small perennial	1	4	3
RW-20	Mediterranean temporary or intermittent streams	2	10	3

3.4.2 BOD: synthesis

5-day BOD is widely used as a measure of the scale of organic pollution impacts in rivers, mostly as annual averages. A broad trend was apparent with lowland rivers generally having higher thresholds than mid-altitude rivers which, in turn, had higher thresholds than highland and Mediterranean rivers (Fig. 3.23). Despite this, Member State still had a greater influence on threshold values than type (Table 3.15).

Both phytobenthos and macroinvertebrates respond to BOD5, although the effect in the latter was stronger than that in the former (Fig. 3.24). However, the median position of national standards in relation to these data (above the distributions of even the worse than good sites) suggests that they many may be too lenient.

3.5 Ammonium-N

3.5.1 Ammonium-N (rivers)

There were 457 records of BOD standards from 21 countries (Figure 3.25). Many countries use the annual mean ("AA-EQS") as a summary metric. 21 countries (BE, BG, CY, CZ, DE, EE, ES, FR, GR, HR, HU, IT, LT, LU, LV, NO, PL, PT, RO, SK, UK) use a single value for each national type and 1 country (PT) present standards as a range.

The data could be linked to 19 broad types (Figure 3.26 & Table 3.18). 12 of these (RW-00, RW-01, RW-02, RW-03, RW-04, RW-05, RW-08, RW-09, RW-10, RW-11, RW-14, RW-15) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 5 countries (CY, FR, GR, IT, PT) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 0.05 mg N/L (HR) to 1.4 mg N/L (RO) with an interquartile range of 0.1 to 0.47 mg N/L (Figure 3.26).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.17). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (81.2%) and type (4%)

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of Ammonium N based on classifications for phytobenthos and macroinvertebrates (Figure 3.27) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A5.1.

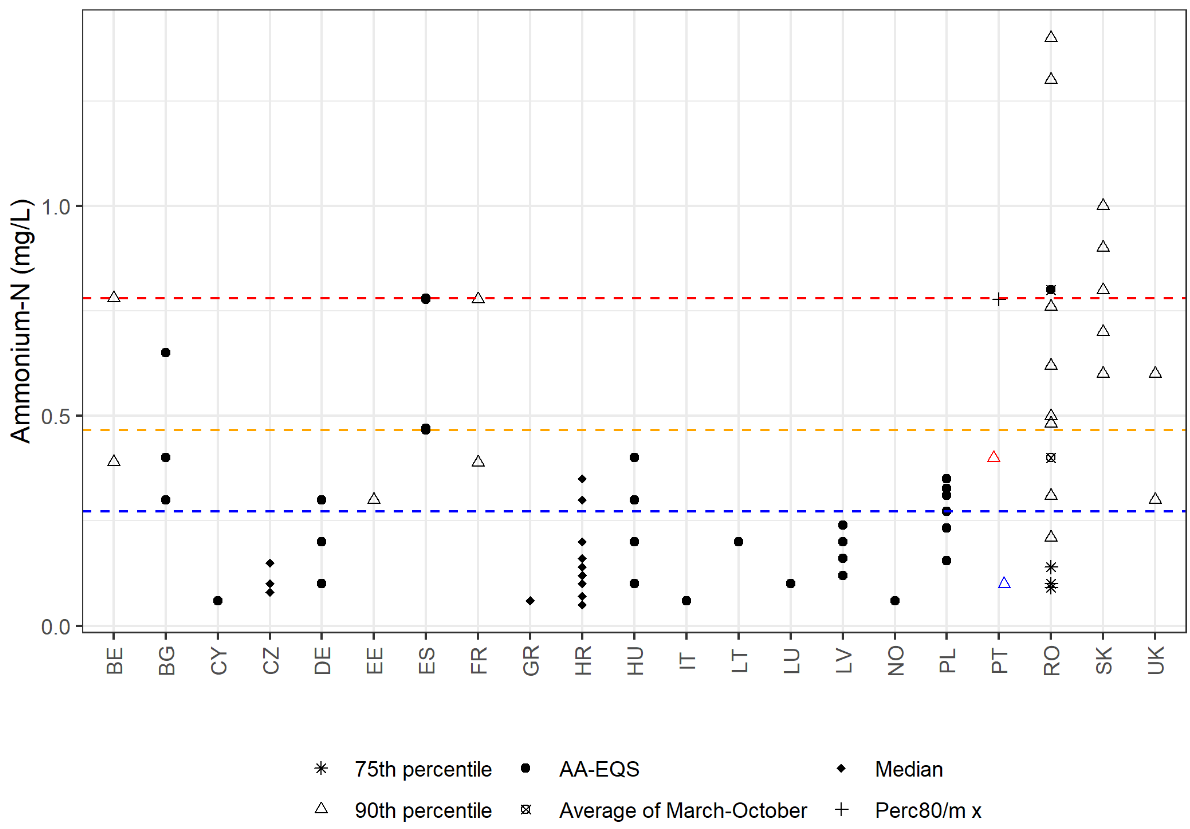

Figure 3.25: Ammonium-N standards by country (single value black, minimum blue, maximum red symbols, dotted lines show interquartile range of mean or median values, (90th percentile=red, 75th percentile=orange, 50th percentile = blue).

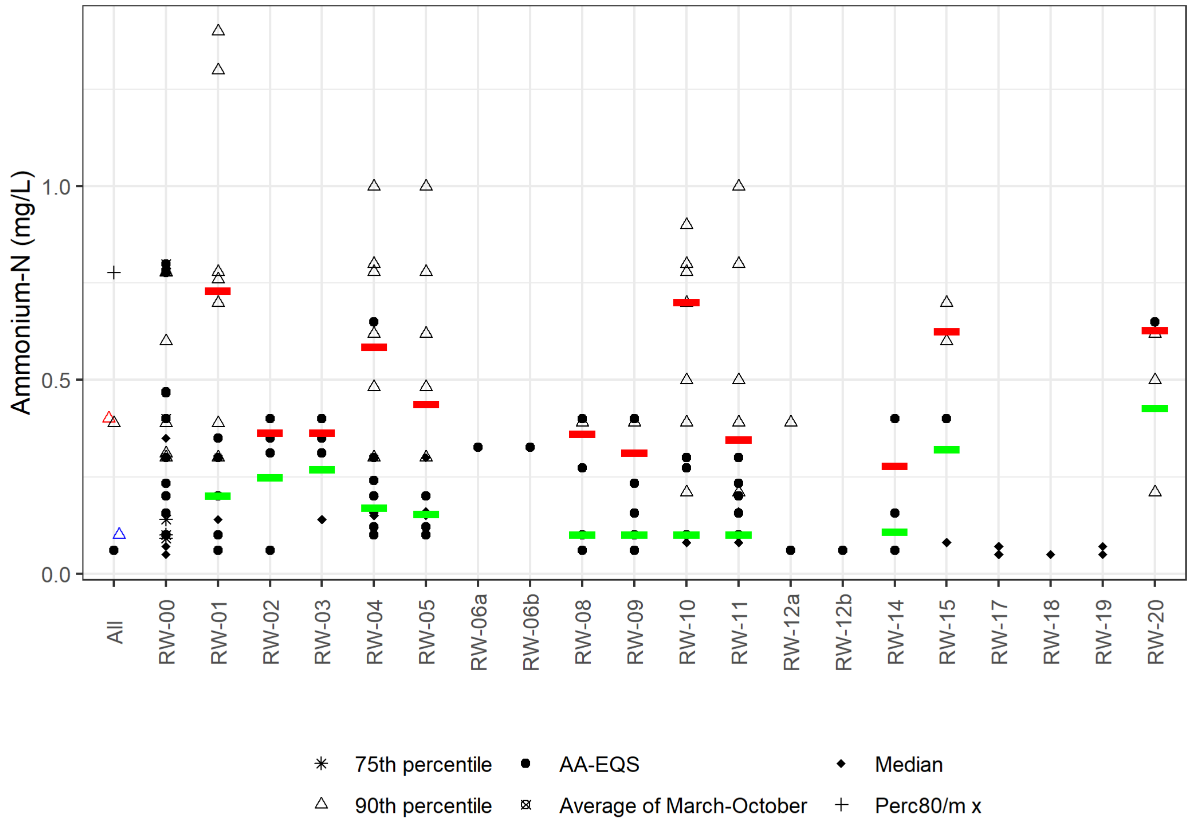

Figure 3.26: Ammonium-N standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while RW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark the 25th (green) and 75th (red) percentiles.

Table 3.17: Analysis of variance for factorial model relating country and broad type to Member State boundary values for log Ammonium-N (Including main and partial effect sizes, Omega squared – see 1.2.5.)

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			0.5	1	5.3	0.02402
Country	0.81	0.85	53.7	14	41.33	0.00000
CodeBT	0.04	0.21	3.5	10	3.75	0.00038
Residuals			7.28	78		

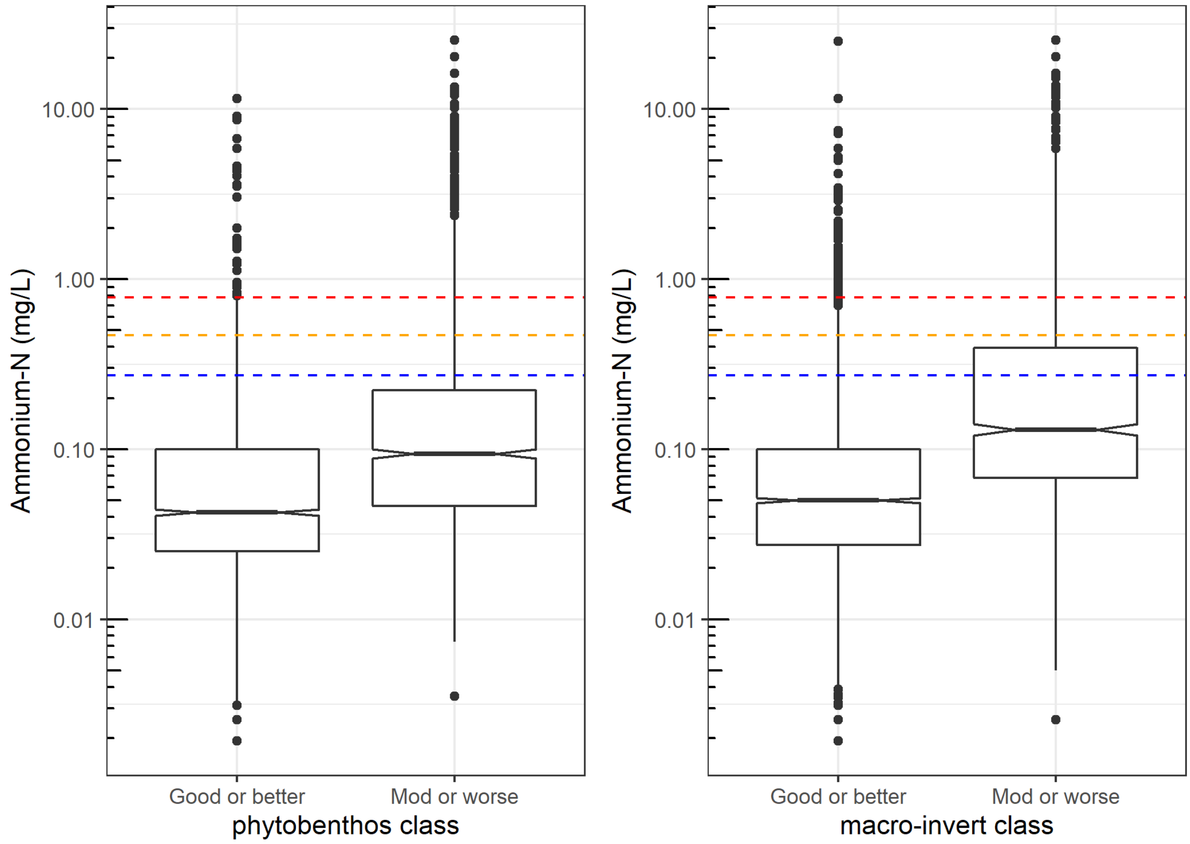

Figure 3.27: River Ammonium-N standards (dotted lines) overlain on box plots showing the range of Ammonium N concentration for sites classified by phytobenthos and macro-invertebrates. (90th percentile=red, 75th percentile=orange, median=blue). Significance of difference between groups, (phytobenthos) Wilcoxon p=<0.001 (invertebrates) Wilcoxon p= <0.001.

Table 3.18: Overview of common broad types showing the number of countries/national types/distinct standards for Ammonium-N in rivers.

Code	Broad type	Country	Type	Standard
All	All	5	1	4
RW-00	Not assigned	9	75	19
RW-01	Very large rivers	10	21	12
RW-02	Lowland siliceous medium-large	3	4	4
RW-03	Lowland siliceous very small-small	3	6	4
RW-04	Lowland calcareous or mixed medium-large	11	53	13
RW-05	Lowland calcareous or mixed very small-small	10	19	10
RW-06a	Lowland organic and siliceous very small-small	1	1	1
RW-06b	Lowland organic and siliceous medium-large	1	1	1
RW-08	Mid-altitude siliceous medium-large	6	10	5
RW-09	Mid-altitude siliceous very small-small	6	11	6
RW-10	Mid-altitude calcareous or mixed medium-large	7	35	9
RW-11	Mid-altitude calcareous or mixed very small-small	8	36	11
RW-12a	Mid-altitude organic and siliceous very small-small	2	3	2
RW-12b	Mid-altitude organic and siliceous medium-large	1	1	1
RW-14	Highland (all Europe) siliceous incl. organic (humic)	3	4	3
RW-15	Highland (all Europe) calcareous or mixed	3	7	4
RW-17	Mediterranean lowland medium-large perennial	1	3	2
RW-18	Mediterranean mid-altitude medium-large perennial	1	1	1
RW-19	Mediterranean very small-small perennial	1	4	2
RW-20	Mediterranean temporary or intermittent streams	2	10	4

3.5.2 Ammonium-N: synthesis

Ammonium-N is another widely used supporting element in rivers. It is not, itself, toxic but toxicity is exerted through the action of unionized ammonia on cells and the equilibrium between ammonium and ammonia depends upon pH (more ammonia at high pH). However, too few countries measure unionized ammonia for this to be the basis of EU-wide comparisons. Ammonium-N can also, directly or indirectly (via nitrification), be a source of nitrogen with the potential to stimulate plant and algal growth.

Although type accounted for only a small amount of variation in ammonium-N standards relative to country (Table 3.17), lowland rivers tended to have higher ammonium standards than mid altitude and highland rivers.

There was a significant difference in ammonium-N concentrations between sites with river phytobenthos and invertebrates at "good or better" status compared with "moderate or worse" (Figure 3.27). The effect was more pronounced for invertebrates. However, in both cases, the median standards were relatively lenient compared with the data distributions which, for both phytobenthos and invertebrates, suggested thresholds of less than 0.1 mg/L.

3.6 Nitrogen

As well as the information included in previous sections, this section also presents a comparison with results presented in earlier reports in order to show any changes in nutrient standards that have occurred during this period.

3.6.1 Nitrate

There were 484 records of nitrate standards (2009 dataset) from 18 countries which can be compared with the values reported in a 2014 survey (Phillips and Pitt 2015) (Figure 3.28). The majority of countries use the annual mean ("AA-EQS") as a summary metric. 18 countries (AT, BE, BG, CY, CZ, ES, FR, GR, HR, IT, LT, LU, LV, PL, PT, RO, SI, SK) use a single value for each national type and 2 countries (BG, PT) present standards as a range.

The data could be linked to 18 broad types (Figure 3.29 & Table 3.19). 12 of these (RW-00, RW-01, RW-04, RW-05, RW-08, RW-09, RW-10, RW-11, RW-14, RW-15, RW-17, RW-20) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 6 countries (BG, CY, FR, GR, IT, PT) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 0.05 mg N/L (BG) to 11.29 mg N/L (FR) with an interquartile range of 1.3 to 5.1 mg N/L (Figure 3.29).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.19). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (69.6%) and type (8.1%).

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of Nitrate as N based on classifications for phytobenthos (Figure 3.30) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A6.1.

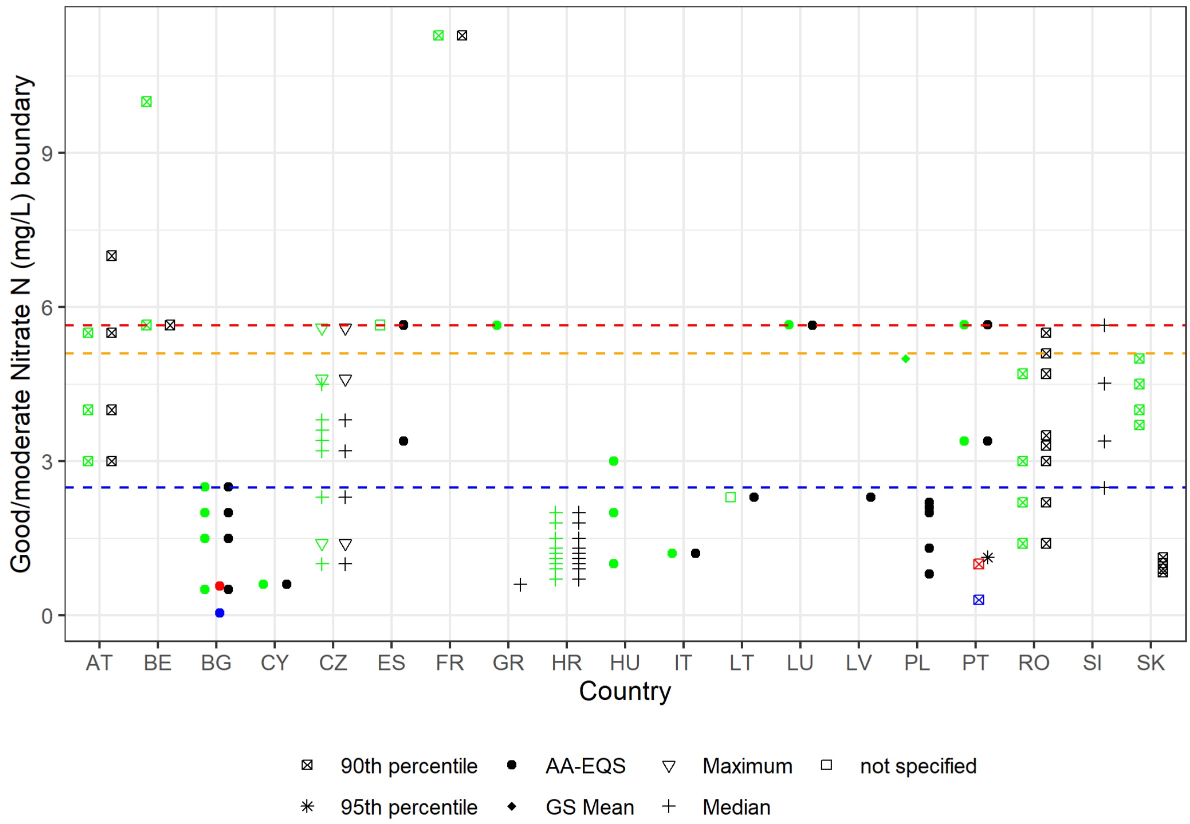

Figure 3.28: Comparison of river Nitrate as N standards by country. Green symbols represent values reported in 2014, others colours those reported in 2019 (single value black, minimum blue, maximum red symbols; dotted lines show interquartile range of mean or median values (90th percentile=red, 75th percentile=orange, 50th percentile = blue)

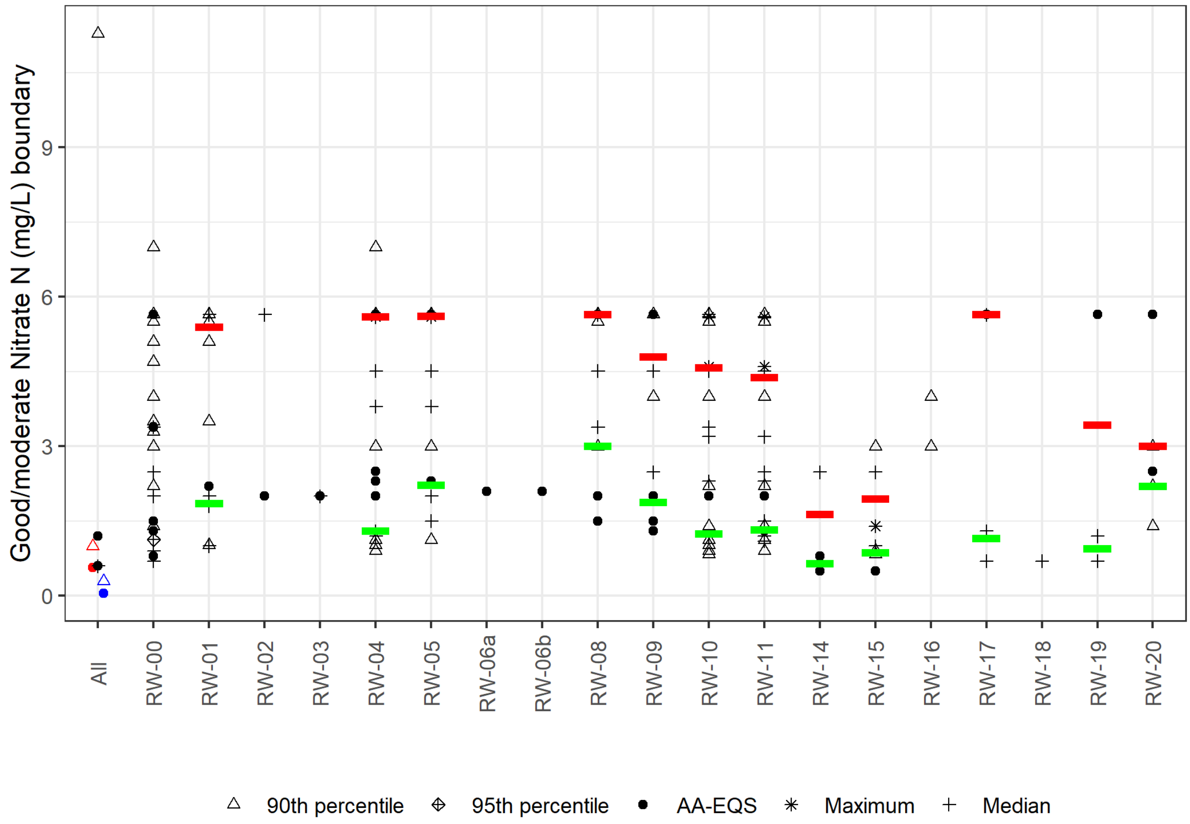

Figure 3.29: *Nitrate as N standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while RW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark 25th (green) and 75th (red) percentile.*

Table 3.19: *Analysis of variance for factorial model relating country and broad type to Member State boundary values for Nitrate as N (Including main and partial effect sizes, Omega squared – see 1.2.5).*

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			139.6	1	190.40	0
Country	0.70	0.76	262.3	12	29.81	0
CodeBT	0.08	0.27	36.9	10	5.033	0
Residuals			64.5	88		

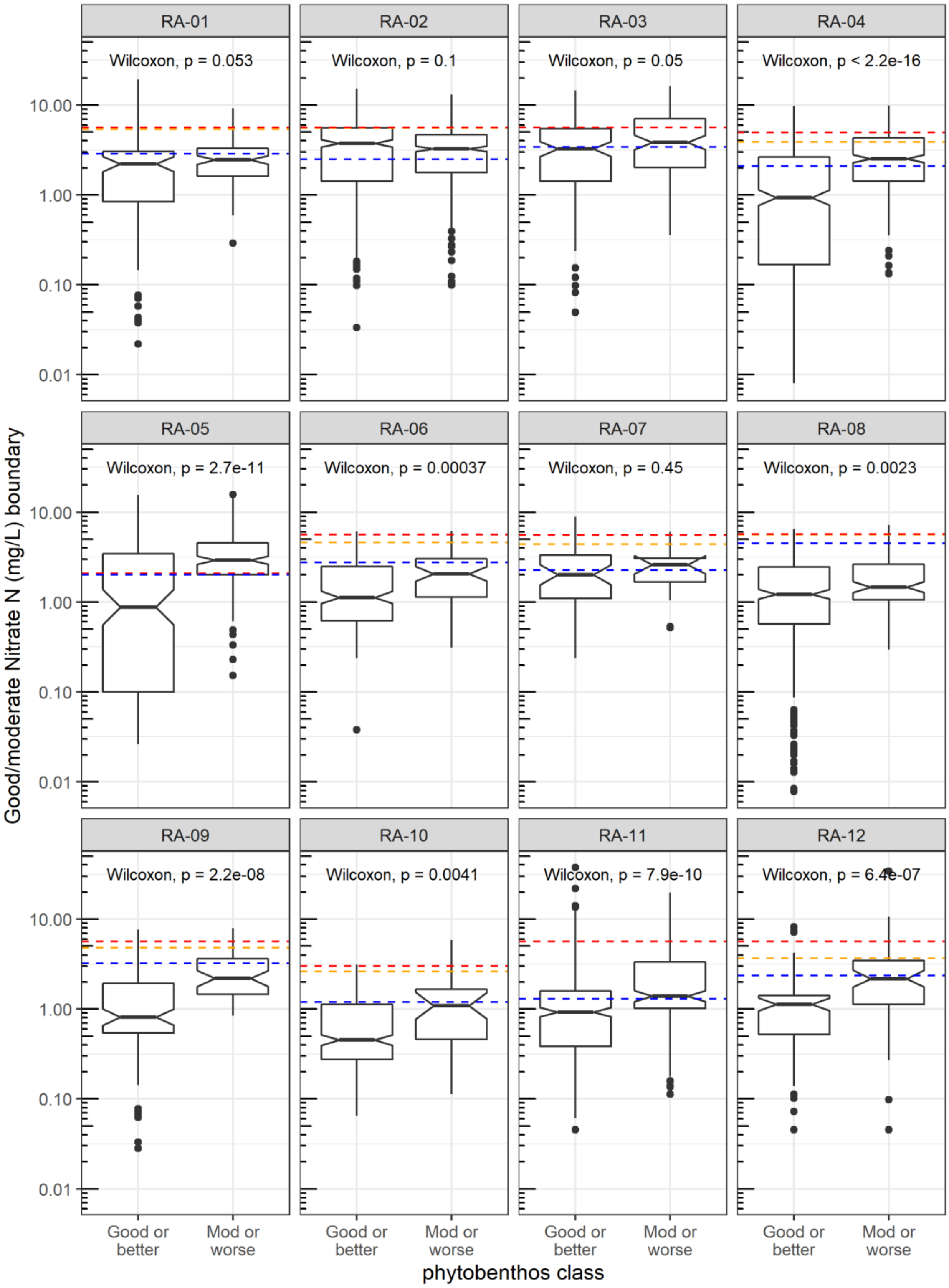

Figure 3.30 (previous page): River Nitrate (as N) standards (dotted lines) overlain on box plots showing the range of Nitrate as N concentration for sites classified by phytobenthos and macro-invertebrates as good status or better (left-hand box) or moderate status and worse (right hand box). (90th percentile=red, 75th percentile=orange, median=blue, grouped by aggregated river type (see Methods section 1.2.5, Table 1.2 for translation between the broad types shown in 3.29 and the aggregated broad types shown here). Wilcoxon test statistic shows significance of type specific differences in distribution of observed data.

Table 3.20: *Overview of common broad types and their associated aggregated types showing the number of countries/national types/distinct standards for Nitrate as N in rivers.*

Code	Broad type	Associated aggregated type code	Country	Type	Standard
All	All	All	6	1	5
RW-00	Not assigned	RA-00	9	86	22
RW-01	Very large rivers	RA-01	6	13	10
RW-02	Lowland siliceous medium-large	RA-04	2	3	2
RW-03	Lowland siliceous very small-small	RA-05	2	4	1
RW-04	Lowland calcareous or mixed medium-large	RA-02	11	51	15
RW-05	Lowland calcareous or mixed very small-small	RA-03	9	17	10
RW-06a	Lowland organic and siliceous very small-small	RA-05	1	1	1
RW-06b	Lowland organic and siliceous medium-large	RA-04	1	1	1
RW-08	Mid-altitude siliceous medium-large	RA-08	6	17	8
RW-09	Mid-altitude siliceous very small-small	RA-09	6	13	8
RW-10	Mid-altitude calcareous or mixed medium-large	RA-06	8	56	15
RW-11	Mid-altitude calcareous or mixed very small-small	RA-07	8	50	18
RW-14	Highland (all Europe) siliceous incl. organic (humic)	RA-10	3	4	3
RW-15	Highland (all Europe) calcareous or mixed	RA-10	5	14	7
RW-16	Glacial rivers (all Europe)	RA-10	1	3	2
RW-17	Mediterranean lowland medium-large perennial	RA-11	3	7	4
RW-18	Mediterranean mid-altitude medium-large perennial	RA-11	1	1	1
RW-19	Mediterranean very small-small perennial	RA-12	2	6	3

RW-20	Mediterranean temporary or intermittent streams	RA-10	3	9	5

3.6.2 Total N

3.6.2.1 Total N (lakes)

There were 335 records of Total N (TN) standards from 12 countries (2019 dataset) which can be compared with the values reported in a 2014 survey (Phillips and Pitt 2015) (Figure 3.31). Most countries use the annual mean ("AA-EQS") as a summary metric. 12 countries (BE, BG, EE, FI, HU, LT, LV, NL, NO, PL, PT, RO) use a single value for each national type and none presents standards as a range.

The data could be linked to 9 broad types (Figure 3.32 & Table 3.24). 7 of these (LW-00, LW-01, LW-02, LW-03, LW-04, LW-05, LW-06) had type specific values from more than 2 countries allowing the range of standards in these types to be compared.

The standards ranged from 0.2 mg N/L (NO) to 5 mg N/L (RO) with an interquartile range of 0.7 to 1.5 mg N/L (Figure 3.32).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.24). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (40.9%) and type (9.1%).

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of TN based on classifications for phytoplankton (Figure 3.33) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A6.2.

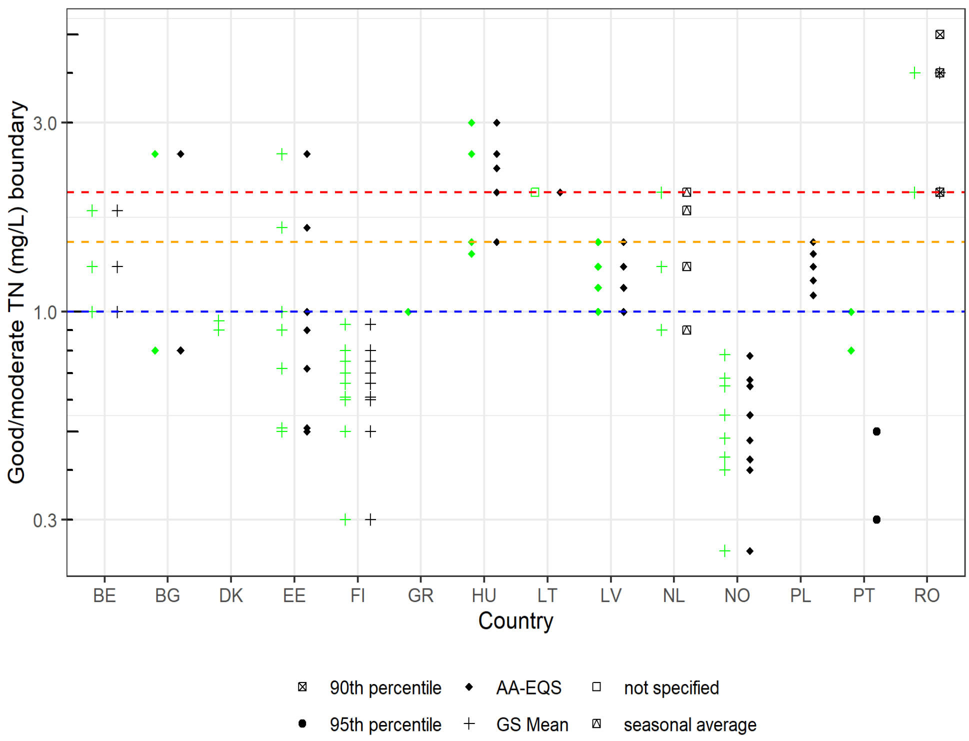

Figure 3.31 *Comparison of lake TN standards by country. Green symbols represent values reported in 2014, others colours those reported in 2019 (single value black, minimum blue, maximum red symbols; dotted lines show interquartile range of mean or median values, (90th percentile=red, 75th percentile=orange, 50th percentile = blue).*

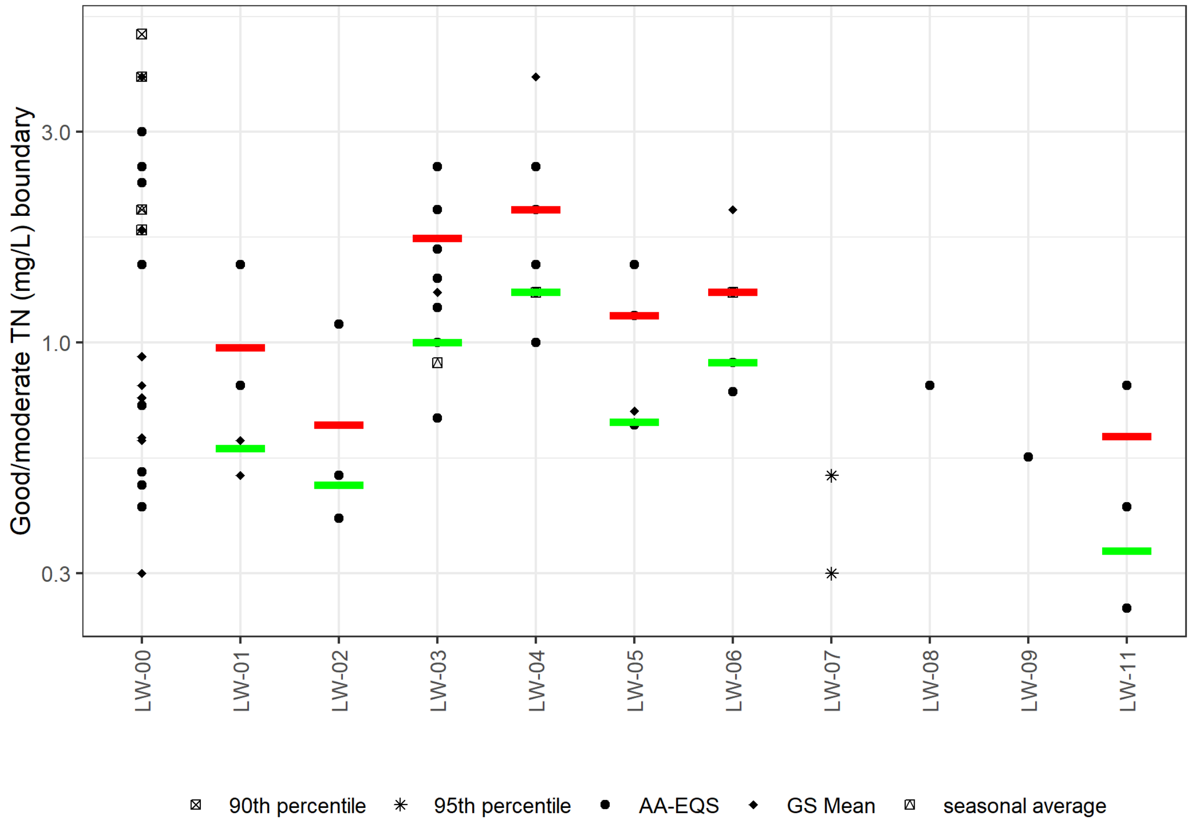

Figure 3.32: TN standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while RW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark 25th (green) and 75th (red) percentiles.

Table 3.21: Analysis of variance for factorial model relating country and broad type to Member State boundary values for log TN (Including main and partial effect sizes, Omega squared – see 1.2.5.)

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			0.1	1	0.582	0.453
Country	0.41	0.45	8.5	10	4.191	0.002
CodeBT	0.09	0.15	2.5	5	2.414	0.067
Residuals			4.7	23		

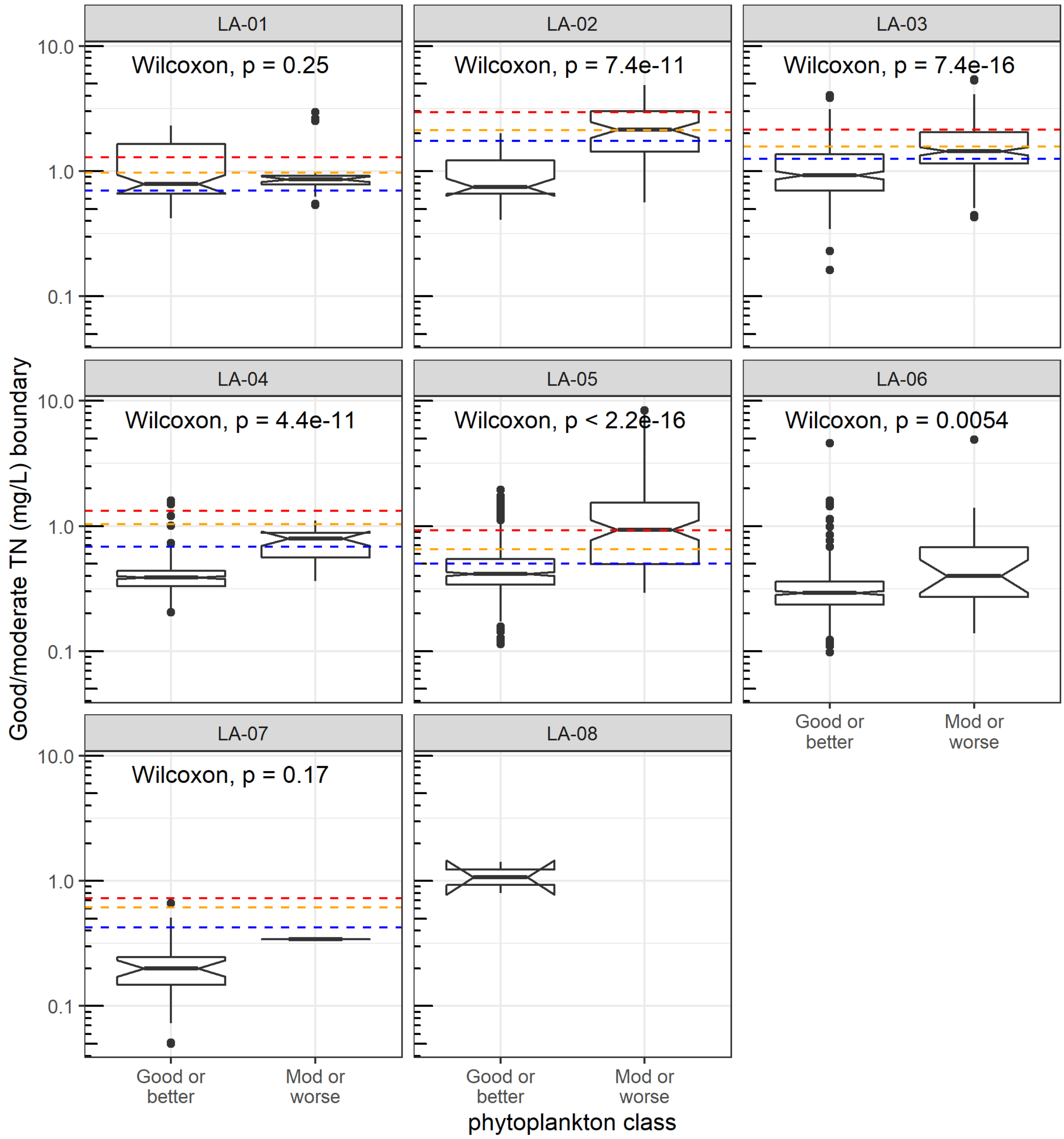

Figure 3.33: *Lake TN standards (dotted lines) overlain on box plots showing the range of TN concentration for sites classified by phytoplankton and macrophytes. (90th percentile=red, 75th percentile=orange, median=blue), including standards based on percentiles, AA-EQS, GS Mean and seasonal mean, grouped by aggregated lake type (see Methods section 1.2.5, Table 1.2 for translation between the broad types shown in 3.32 and the aggregated broad types shown here). Wilcocon test statistic shows significance of type specific differences in distribution of observed data.*

Table 3.22: *Overview of common broad types and their associated aggregated types showing the number of Member State/national types/distinct standards for TN.*

Broad type code	Broad type	Associated aggregated type code	Country	Type	Standard
All	All	All			
LW-00	Not assigned	LA-00	10	32	18
LW-01	Very large lakes shallow or deep and stratified (all Europe)	LA-01	3	4	4
LW-02	Lowland siliceous	LA-05	4	5	3
LW-03	Lowland stratified calcareous or mixed	LA-03	8	15	9
LW-04	Lowland calcareous or mixed very shallow or unstratified	LA-02	8	16	6
LW-05	Lowland organic (humic) and siliceous	LA-04	3	6	5
LW-06	Lowland organic (humic) and calcareous or mixed	LA-03	5	7	4
LW-07	Mid-altitude siliceous	LA-06	1	2	2
LW-08	Mid-altitude calcareous or mixed	LA-03	1	2	1
LW-09	Mid-altitude organic (humic) and Siliceous	LA-04	1	1	1
LW-11	Highland Siliceous (all Europe) incl. organic (humic)	LA-07	2	4	3

3.6.2.2 Total N (rivers)

There were 410 records of TN standards for rivers from 13 countries in the 2019 dataset which can be compared with the values reported in a 2014 survey (Phillips and Pitt 2015) (Figure 3.31). The majority of countries use the annual mean ("AA-EQS") as a summary metric. 13 countries (BE, BG, EE, FI, HR, HU, LT, LV, NL, NO, PL, RO, SK) use a single value for each national type and 1 country (BG) presents standards as a range.

The data could be linked to 20 broad types (Figure 3.32 & Table 3.23). 13 of these (RW-00, RW-01, RW-02, RW-03, RW-04, RW-05, RW-06a, RW-06b, RW-08, RW-09, RW-10, RW-11, RW-14) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 1 country (BG) applies the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 0.2 mg N/L (BG) to 35 mg N/L (RO) with an interquartile range of 0.9 to 3.5 mg N/L (Figure 3.32).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.23). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (74.1%) and type (4.7%). However, this result should be interpreted with caution because data do not fulfil all requirements of normality.

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of TN based on classifications for phytobenthos (Figure 3.33) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A6.2.2.

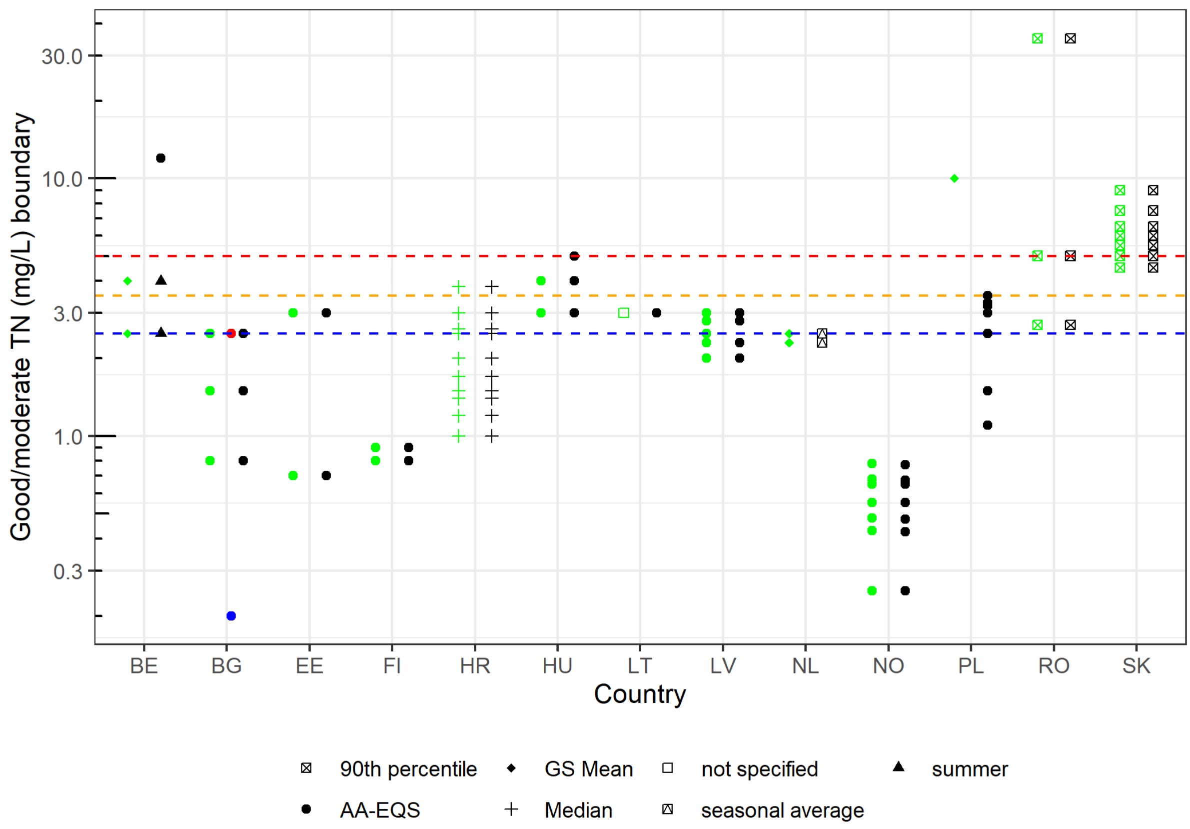

Figure 3.34: Comparison of river TN standards by country. Green symbols represent values reported in 2014, others colours those reported in 2019 (single value black, minimum blue, maximum red symbols; dotted lines show interquartile range of mean or median values, (90th percentile=red, 75th percentile=orange, 50th percentile = blue).

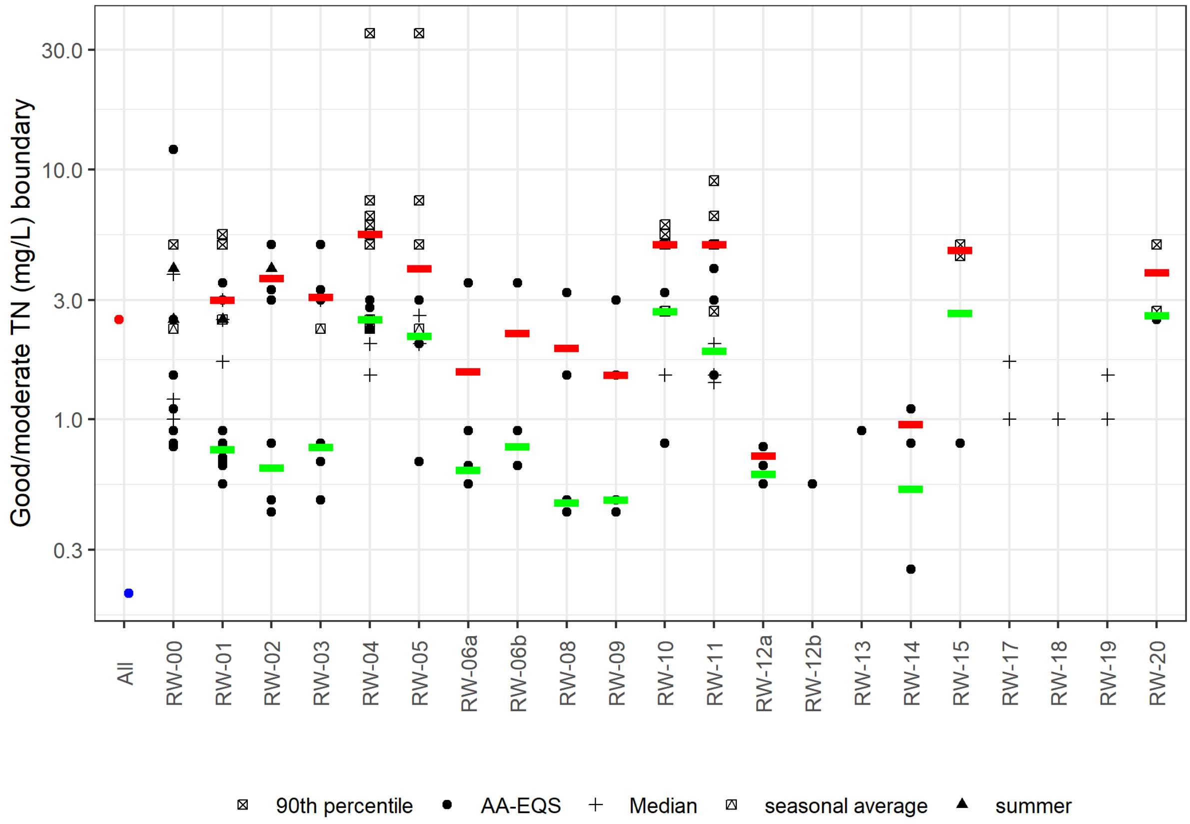

Figure 3.35: *TN standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while RW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark 25th (green) and 75th (red) percentiles.*

Table 3.23: *Analysis of variance for factorial model relating country and broad type to Member State boundary values for log TN (Including main and partial effect sizes, Omega squared – see 1.2.5).*

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			2.4	1	17.800	0.000
Country	0.74	0.78	48.2	12	29.830	0.000
CodeBT	0.05	0.18	4.4	11	2.978	0.002
Residuals			10.1	75		

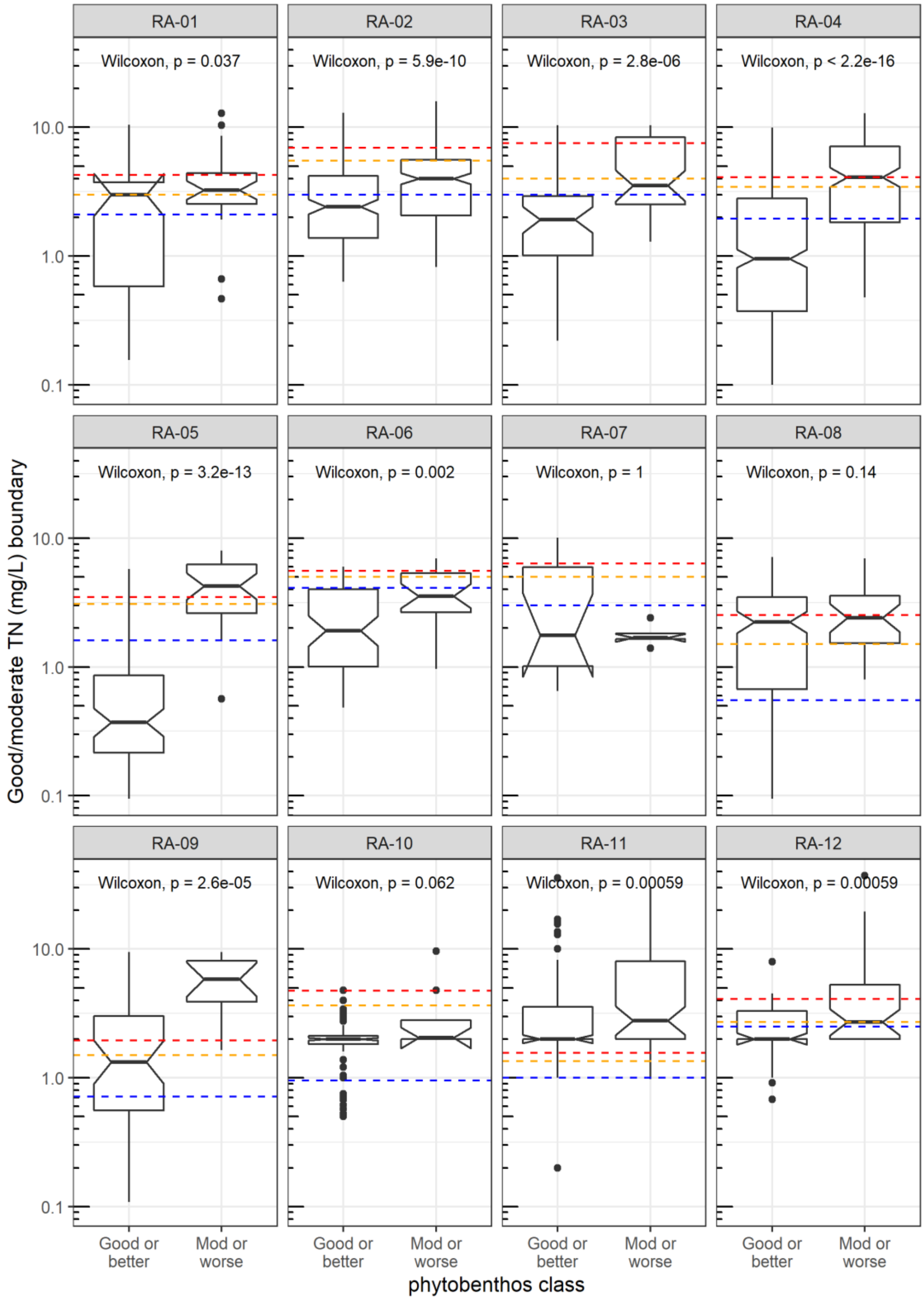

Figure 3.36 (previous page): *River TN standards (dotted lines) overlain on box plots showing the range of TN concentration for sites classified by phytobenthos and macro-invertebrates. (90th percentile=red, 75th percentile=orange, median=blue), including standards based on AA-EQS, Median, Seasonal average, summer (??) percentile, grouped by aggregated river type (see Methods section 1.2.5, Table 1.2 for translation between the broad types shown in 3.35 and the aggregated broad types shown here). Wilcocon test statistic shows significance of type specific differences in distribution of observed data.*

Table 3.24: Overview of common broad types and their associated aggregated types showing the number of countries/national types/distinct standards for r TN in rivers.

Code	Broad type	Associated type code	Country	Type	Standards
All	All	All	1	1	1
RW-00	Not assigned	RA-00	8	26	13
RW-01	Very large rivers	RA-01	10	25	13
RW-02	Lowland siliceous medium-large	RA-04	5	7	7
RW-03	Lowland siliceous very small-small	RA-05	6	14	7
RW-04	Lowland calcareous or mixed medium-large	RA-02	8	46	12
RW-05	Lowland calcareous or mixed very small-small	RA-03	8	18	8
RW-06a	Lowland organic and siliceous very small-small	RA-05	3	7	4
RW-06b	Lowland organic and siliceous medium-large	RA-04	3	3	3
RW-08	Mid-altitude siliceous medium-large	RA-08	3	9	4
RW-09	Mid-altitude siliceous very small-small	RA-09	3	13	4
RW-10	Mid-altitude calcareous or mixed medium-large	RA-06	6	21	7
RW-11	Mid-altitude calcareous or mixed very small-small	RA-07	5	18	9
RW-12a	Mid-altitude organic and siliceous very small-small	RA-09	1	13	3
RW-12b	Mid-altitude organic and siliceous medium-large	RA-08	1	2	1
RW-13	Mid-altitude organic and calcareous or mixed	RA-06	1	1	1
RW-14	Highland (all Europe) siliceous incl. organic (humic)	RA-10	3	10	3
RW-15	Highland (all Europe) calcareous or mixed	RA-10	2	3	3
RW-17	Mediterranean lowland medium-large perennial	RA-11	1	3	2
RW-18	Mediterranean mid-altitude medium-large perennial	RA-11	1	1	1

RW-19	Mediterranean very small-small perennial	RA-12	1	4	2
RW-20	Mediterranean temporary or intermittent streams	RA-12	2	10	3

3.6.3 Synthesis: nitrogen

Whilst total nitrogen (TN) is the preferred variable for assessing nitrogen in lakes, there is less consensus on appropriate variables for assessing nitrogen in rivers. 10 countries use TN whilst three use nitrate-N and nine have standards for both TN and nitrate-N.

For lakes, type effects standards (Fig. 3.32), with lowland calcareous lakes generally having the highest thresholds, followed by lowland siliceous humic lakes whilst siliceous clear lakes generally had the lowest thresholds. There was, however, a strong country effect overriding the significance of the effect of type (Table 3.24). Standards showed better agreement with the EEA data than was the case for many other supporting elements although median values for standards for a few types appear to be too lenient. This is particularly apparent for LA-04 (lowland-mid-altitude, humic and siliceous) but possibly also relevant for LA-02 (lowland, calcareous, very shallow and LA-07 (highland lakes) (Fig. 3.33).

Type also has an effect on TN and nitrate-N in rivers (Figs 3.32 & 3.29) though less obviously than was the case for lakes. Once again, calcareous rivers tend to have higher standards than those draining catchments with silicious bedrocks. Type seems to determine the extent to which higher nitrogen is associated with lower status (Fig. 3.35): strong effects are seen in RA-03, RA-04, RA-05 (lowland) and RA-09 (mid-altitude) for TN, for example, but not in the RA-01 (large rivers), RA-07 & RA-08 (mid-altitude types), amongst others. For nitrate-N, Types RA-04, RA-05 and RA-12 (Mediterranean) indicate strong effects whilst RA-01, RA-02, RA-07 and RA-08 do not (Fig. 3.30). These results highlight the need for caution when interpreting the role of nitrogen and we suspect that interactions with phosphorus are the most likely reason for these differences. As for lakes, N standards are mostly in line with the evidence from the EEA data though there are exceptions (RA-05 for TN; RA-09, RA-10 for nitrate-N).

Most lake total nitrogen boundary values have remained unchanged since the 2014 report although one value from BE was higher (5 mg N/L) than the value reported in 2014 (4 mg N/L). One country (PT) reported lower values, while two (BE, RO) reported higher values.

The range of river nitrogen standards reported in this survey was similar to that reported in 2014, with high maximum values of 11.3 mg N/L for nitrate nitrogen and 35 mg N/L for total nitrogen. For nitrate most countries reported the same boundary values as in 2014, 3 countries (GR, PL, SK) reported lower boundary values while 2 (AT, RO) included additional higher values. There were very few changes for total nitrogen, with only PL reporting lower boundary values while BE and HU reported additional higher boundary values.

3.7 Phosphorus

3.7.1 Orthophosphate (rivers)

There were 404 records from 18 countries in the 2019 dataset which can be compared with the values reported in a 2014 survey (Phillips and Pitt 2015) (Figure 3.37). The majority of countries use the annual mean ("AA-EQS") as a summary metric. 18 countries (AT, BE, BG, CY, CZ, DE, ES, FR, GR, HR, HU, IE, LT, LU, LV, PL, RO, SK) use a single value for each national type and 1 country (BG) present standards as a range.

The data could be linked to 18 broad types (Figure 3.38 & Table 3.26). 10 of these (RW-00, RW-01, RW-03, RW-04, RW-05, RW-08, RW-09, RW-10, RW-11, RW-15) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 5 countries (BG, CY, FR, GR, IE) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 10 µg P/L (BG) to 500 µg P/L (FR) with an interquartile range of 60 to 160 µg P/L(Figure 3.38).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.25). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (51.5%) and type (9%). However, this result should be interpreted with caution because data do not fulfil all requirements of normality.

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of Orthophosphate based on classifications for phytobenthos (Figure 3.39) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A6.3.

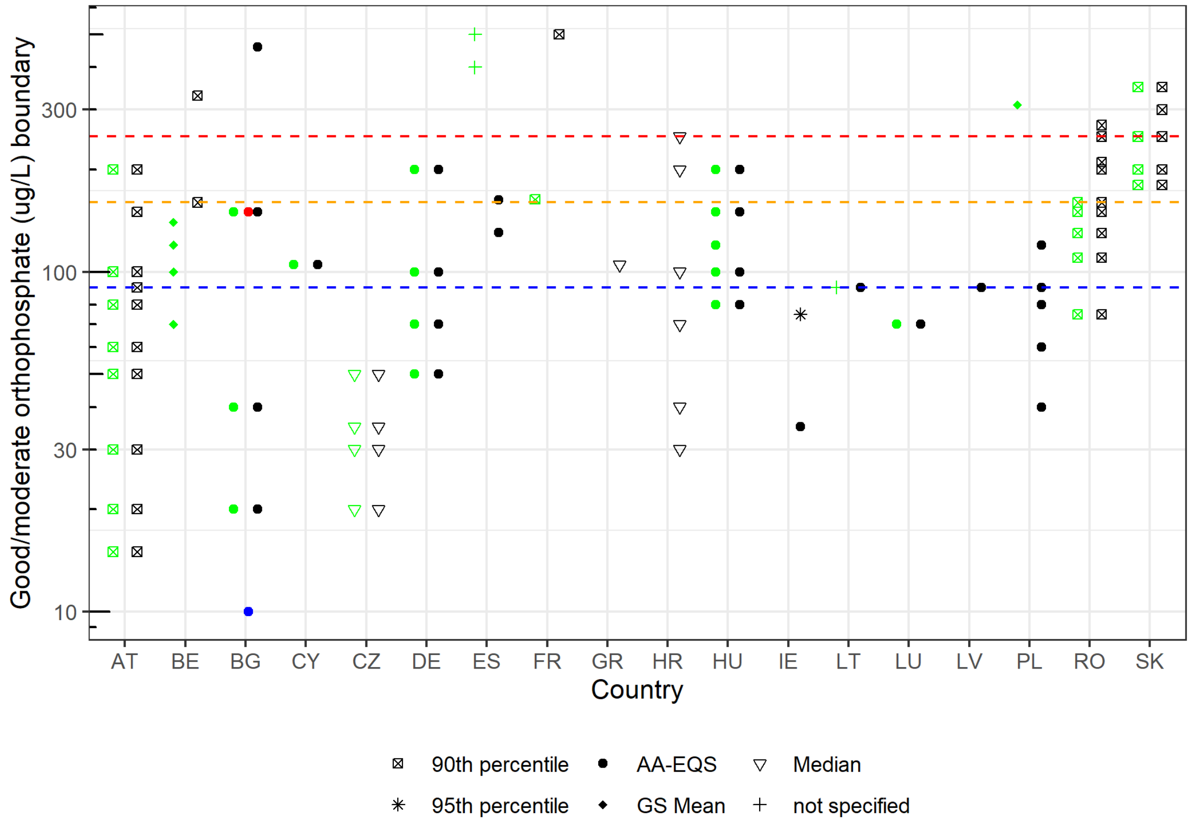

Figure 3.37: *Comparison of river Orthophosphate standards by country. Green symbols represent values reported in 2014, others colours those reported in 2019 (single value black, minimum blue, maximum red symbols. Dotted lines show interquartile range of mean or median values, (90th percentile=red, 75th percentile=orange, 50th percentile = blue).*

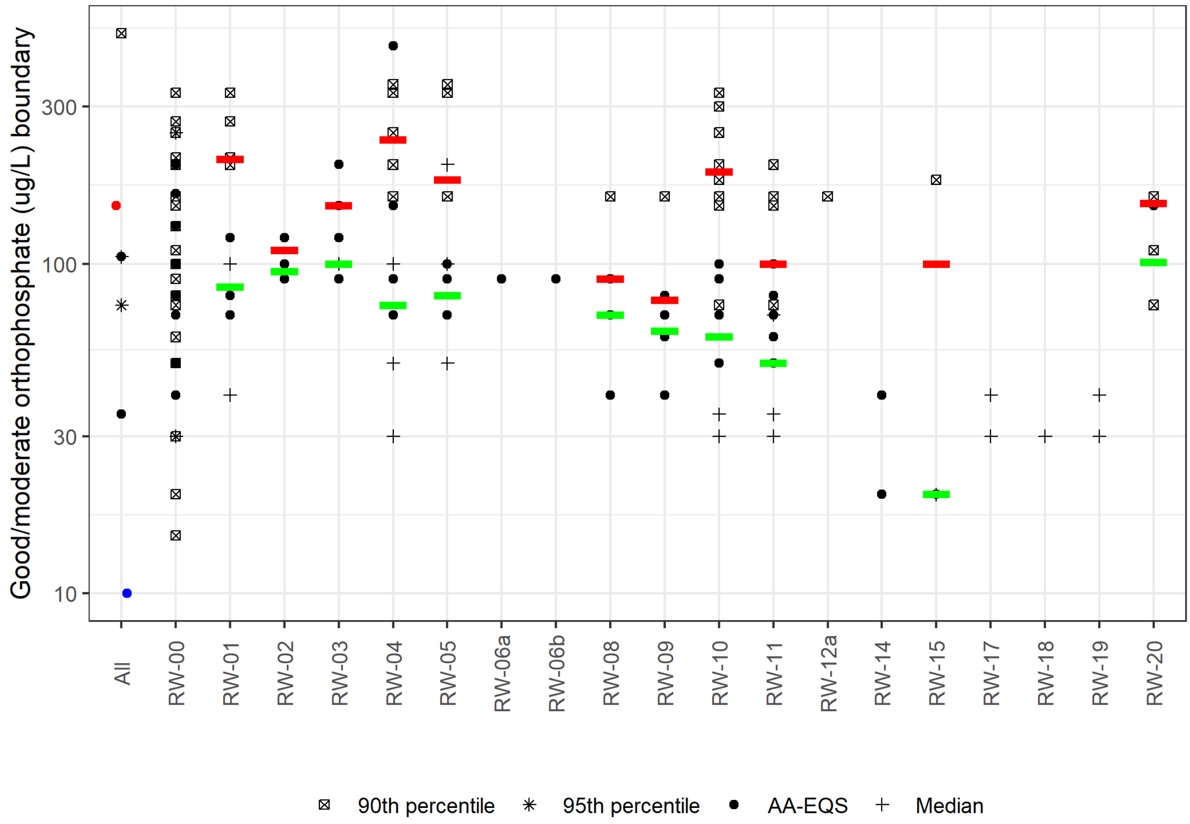

Figure 3.38: *Orthophosphate standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while RW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark 25th (green) and 75th (red) percentiles, (including standards based on percentiles, AA-EQS and Median).*

Table 3.25: *Analysis of variance for factorial model relating country and broad type to Member State boundary values for Orthophosphate (Including main and partial effect sizes, Omega squared – see 1.2.5).*

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			335188.9	1	96.789	0.000
Country	0.52	0.57	408722.2	11	10.729	0.000
CodeBT	0.09	0.19	92623.6	8	3.343	0.003
Residuals			214710.7	62		

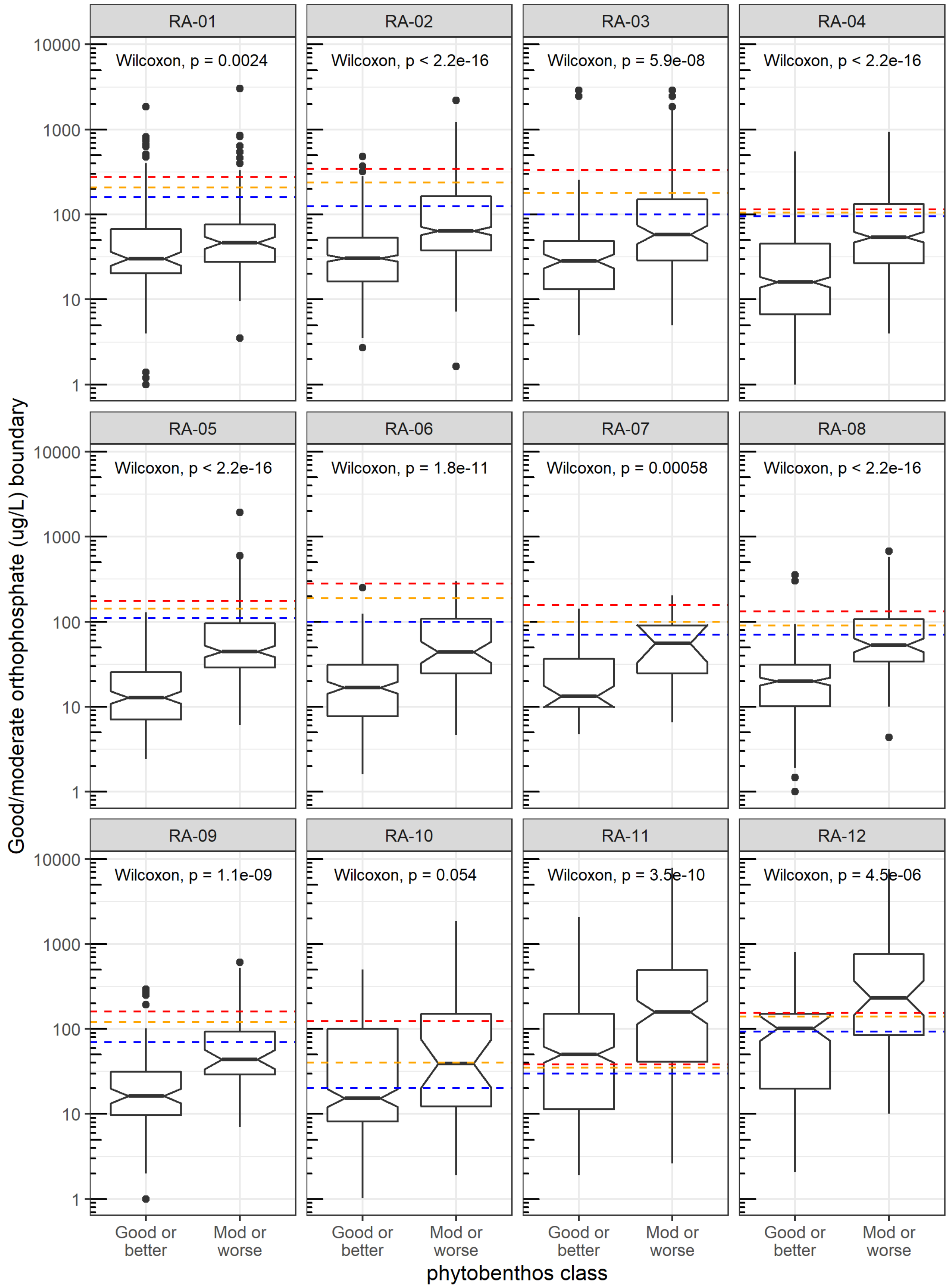

Figure 3.39: *River Orthophosphate standards (dotted lines) overlain on box plots showing the range of Orthophosphate concentration for sites classified by phytobenthos. (90th percentile=red, 75th percentile=orange, median=blue), including standards based on percentile, AA-EQS and Median, grouped by aggregated river type (see Methods section 1.2.5, Table 1.2 for translation between the*

broad types shown in 3.38 and the aggregated broad types shown here). Wilcocon test statistic shows significance of type specific differences in distribution of observed data.

Table 3.26: Overview of common broad types and their associated aggregated types showing the number of countries/national types/distinct standards for Orthophosphate in rivers.

Code	Broad type	Associated aggregated type code	Country	Type	Standard
All	All	All	5	1	5
RW-00	Not assigned	RA-00	8	99	22
RW-01	Very large rivers	RA-01	7	16	9
RW-02	Lowland siliceous medium-large	RA-04	2	3	3
RW-03	Lowland siliceous very small-small	RA-05	3	6	5
RW-04	Lowland calcareous or mixed medium-large	RA-02	10	37	12
RW-05	Lowland calcareous or mixed very small-small	RA-03	9	15	8
RW-06a	Lowland organic and siliceous very small-small	RA-05	1	1	1
RW-06b	Lowland organic and siliceous medium-large	RA-04	1	1	1
RW-08	Mid-altitude siliceous medium-large	RA-08	5	7	4
RW-09	Mid-altitude siliceous very small-small	RA-09	5	9	5
RW-10	Mid-altitude calcareous or mixed medium-large	RA-06	8	33	14
RW-11	Mid-altitude calcareous or mixed very small-small	RA-07	8	33	11
RW-12a	Mid-altitude organic and siliceous very small-small	RA-09	1	1	1
RW-14	Highland (all Europe) siliceous incl. organic (humic)	RA-10	2	3	2
RW-15	Highland (all Europe) calcareous or mixed	RA-10	3	7	2
RW-17	Mediterranean lowland medium-large perennial	RA-11	1	3	2
RW-18	Mediterranean mid-altitude medium-large perennial	RA-11	1	1	1

RW-19	Mediterranean very small-small perennial	RA-12	1	4	2
RW-20	Mediterranean temporary or intermittent streams	RA-12	2	7	4

3.7.2 Total P

3.7.2.1 Total P (lakes)

There were 866 records from 24 countries in the 2019 dataset which can be compared with the values reported in a 2014 survey (Phillips and Pitt 2015) (Figure 3.40). The majority of countries use the annual mean ("AA-EQS") as a summary metric. 20 countries (AT, BE, BG, CY, CZ, EE, ES, FI, HR, HU, IE, LT, LV, NL, NO, PL, PT, RO, SI, UK) use a single value for each national type and 7 countries (AT, DE, FR, HR, IT, SE, UK) present standards as a range.

The data could be linked to 14 broad types (Figure 3.41 & Table 3.28). 12 of these (LW-00, LW-01, LW-02, LW-03, LW-04, LW-05, LW-06, LW-07, LW-08, LW-11, LW-12, LW-14) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 5 countries (CY, HR, IE, PT, UK) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 3 µg P/L (SE) to 400 µg P/L (HU) with an interquartile range of 15 to 45 µg P/L (Figure 3.41).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.27). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (46.6%) and type (16.5%).

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of TP based on classifications for phytoplankton (Figure 3.42) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A6.4.

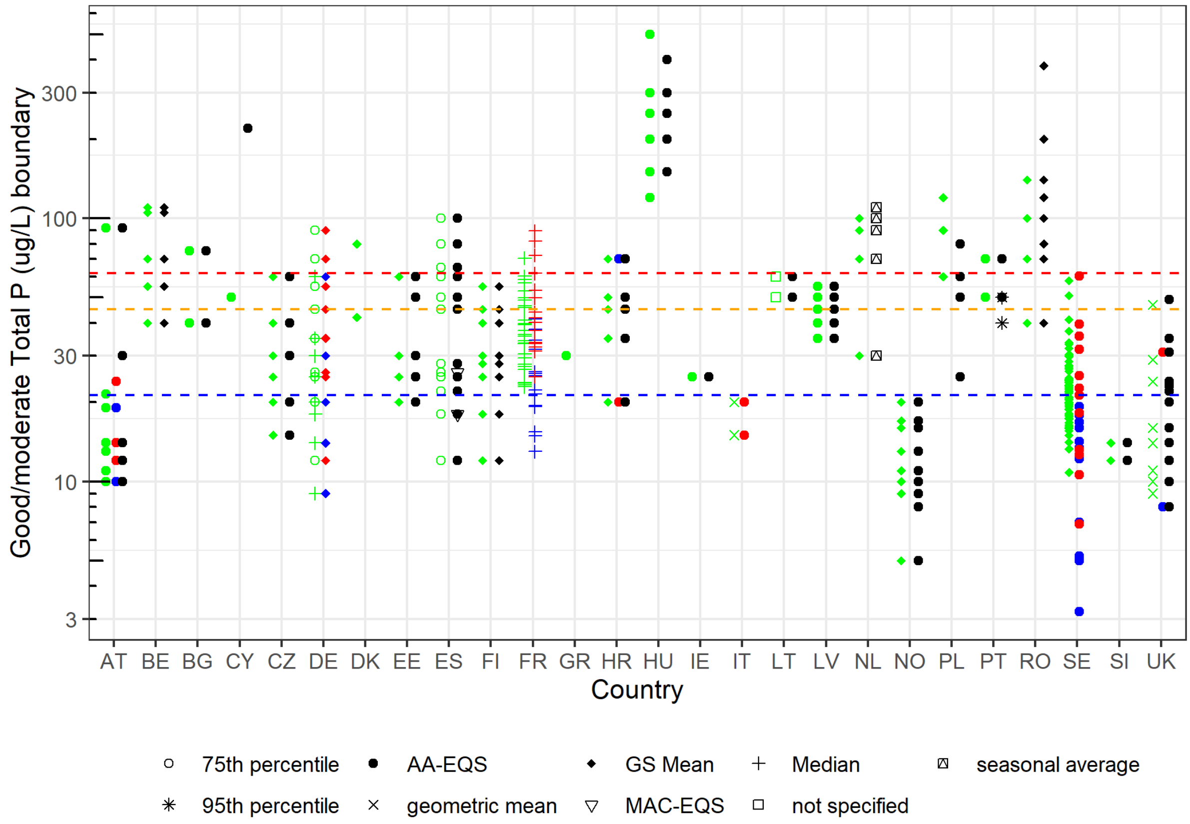

Figure 3.40: Comparison of lake TP standards by country. Green symbols represent values reported in 2014, others colours those reported in 2019 (single value black, minimum blue, maximum red symbols. Dotted lines show interquartile range of mean or median values, (90th percentile=red, 75th percentile=orange, 50th percentile = blue).

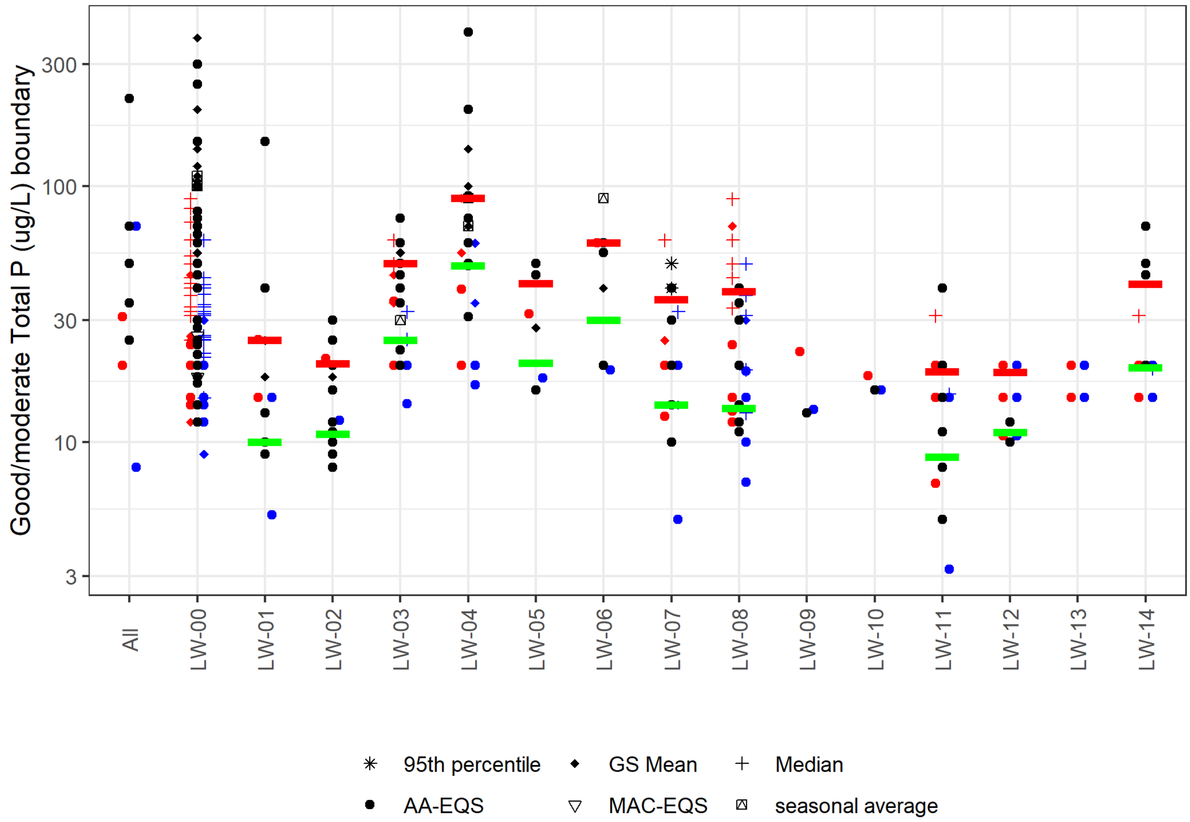

Figure 3.41: TP standards by broad type (single value black, minimum blue, maximum red). "All" are standards that are not type-specific, but reported for all types in a RBD, while LW-00 are type-specific standards for national types that do not match any of the broad types. Horizontal lines mark 25th (green) and 75th (red) percentiles, (including standards based on AA-EQS, Median, GS Mean, seasonal average and percentile).

Table 3.27: Analysis of variance for factorial model relating country and broad type to Member State boundary values for log TP (Including main and partial effect sizes and mega squared – see 1.2.5.)

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			33.5	1	212.806	0
Country	0.47	0.56	36.0	20	11.433	0
CodeBT	0.17	0.31	13.2	10	8.401	0
Residuals			21.1	134		

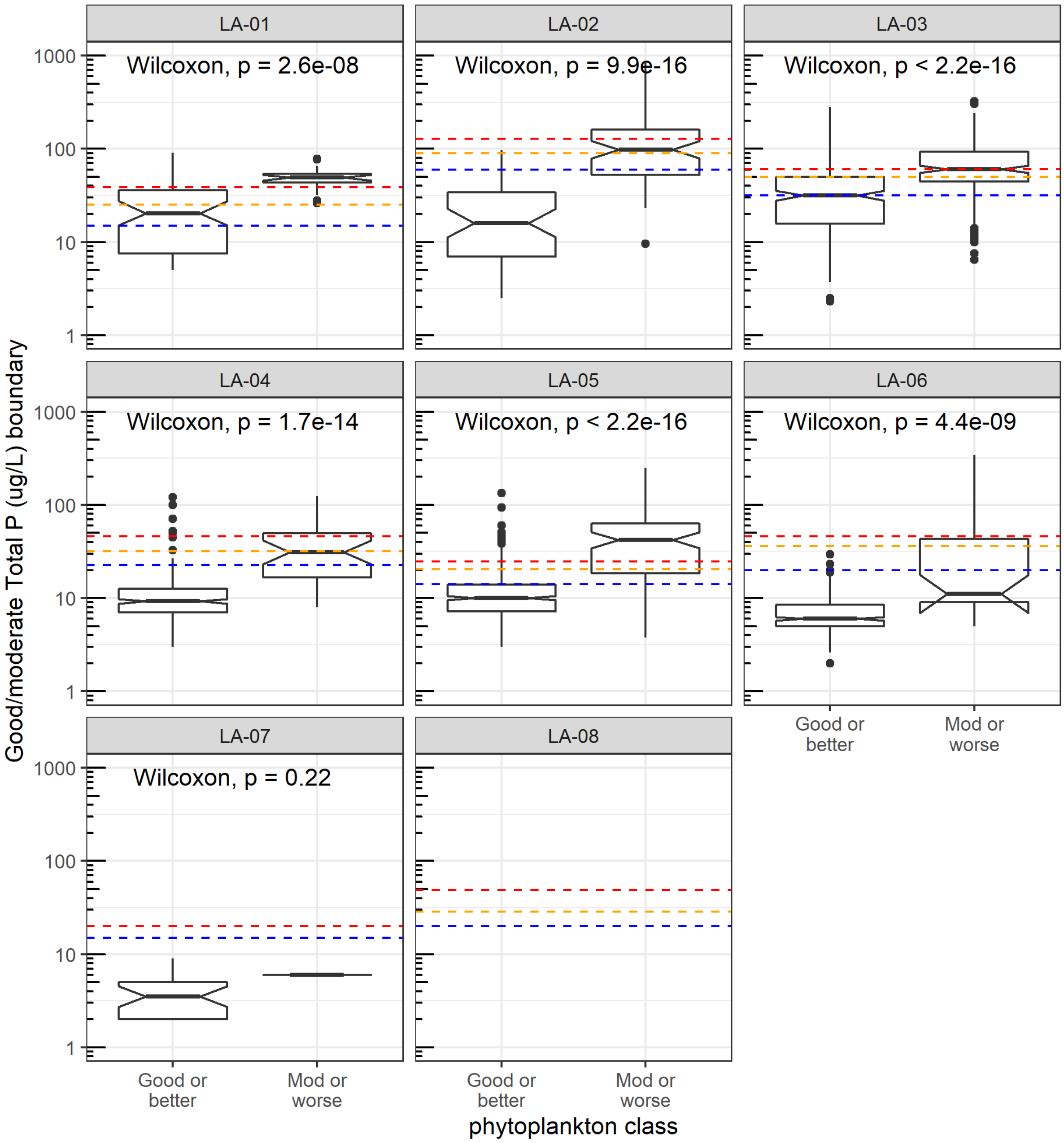

Figure 3.42: *Lake TP standards (dotted lines) overlain on box plots showing the range of TP concentration for sites classified by phytoplankton and macrophytes. (90th percentile=red, 75th percentile=orange, median=blue), including standards based on AA-EQS, Median, GS Mean, seasonal average and percentiles, grouped by aggregated lake type (see Methods section 1.2.5, Table 1.2 for translation between the broad types shown in 3.41 and the aggregated broad types shown here). Wilcoxon test statistic shows significance of type specific differences in distribution of observed data.*

Table 3.28: *Overview of common broad types and their associated aggregated types showing the number of countries/national types/distinct standards for TP in lakes.*

Code	Broad type	Associated aggregated type code	Country	Type	Standard
All	All	All	5	1	6
LW-00	Not assigned	LA-00	18	109	48
LW-01	Very large lakes shallow or deep and stratified (all Europe)	LA-01	7	13	9
LW-02	Lowland siliceous	LA-05	7	15	11
LW-03	Lowland stratified calcareous or mixed	LA-03	12	23	14
LW-04	Lowland calcareous or mixed very shallow or unstratified	LA-02	14	24	15
LW-05	Lowland organic (humic) and siliceous	LA-04	4	9	5
LW-06	Lowland organic (humic) and calcareous or mixed	LA-03	6	7	6
LW-07	Mid-altitude siliceous	LA-06	8	19	8
LW-08	Mid-altitude calcareous or mixed	LA-03	10	24	16
LW-09	Mid-altitude organic (humic) and Siliceous	LA-04	2	4	2
LW-10	Mid-altitude organic (humic) and calcareous or mixed	LA-03	2	3	1
LW-11	Highland Siliceous (all Europe) incl. organic (humic)	LA-07	6	18	8
LW-12	Highland calcareous or mixed (all Europe) incl. organic (humic)	LA-07	3	6	5
LW-13	Mediterranean small-large siliceous	LA-08	1	2	2
LW-14	Mediterranean small-large calcareous or mixed	LA-08	3	9	6

3.7.2.2 Total P (rivers)

There were 615 records from 23 countries in the 2019 dataset which can be compared with the values reported in a 2014 survey (Phillips and Pitt 2015) (Figure 3.43). The majority of countries use the annual mean ("AA-EQS") as a summary metric. 22 countries (BE, BG, CY, CZ, DE, EE, FI, FR, GR, HR, HU, IT, LT, LU, LV, NL, NO, PL, PT, RO, SI, SK) use a single value for each national type and 2 countries (BG, SE) present standards as a range, although they do not provide a reason.

The data could be linked to 20 broad types (Figure 3.44 & Table 3.30). 17 of these (RW-00, RW-01, RW-02, RW-03, RW-04, RW-05, RW-06a, RW-06b, RW-08, RW-09, RW-10, RW-11, RW-12a, RW-14, RW-15, RW-17, RW-20) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 6 countries (BG, CY, FR, GR, IT, PT) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 6 µg P/L (SE) to 1000 µg P/L (BE) with an interquartile range of 44 to 200 µg P/L (Figure 3.44).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.29). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (68.5%) and type (4.8%). However, this result should be interpreted with caution because data do not fulfil all requirements of normality.

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of TP based on classifications for phytobenthos (Figure 3.45) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A6.4.

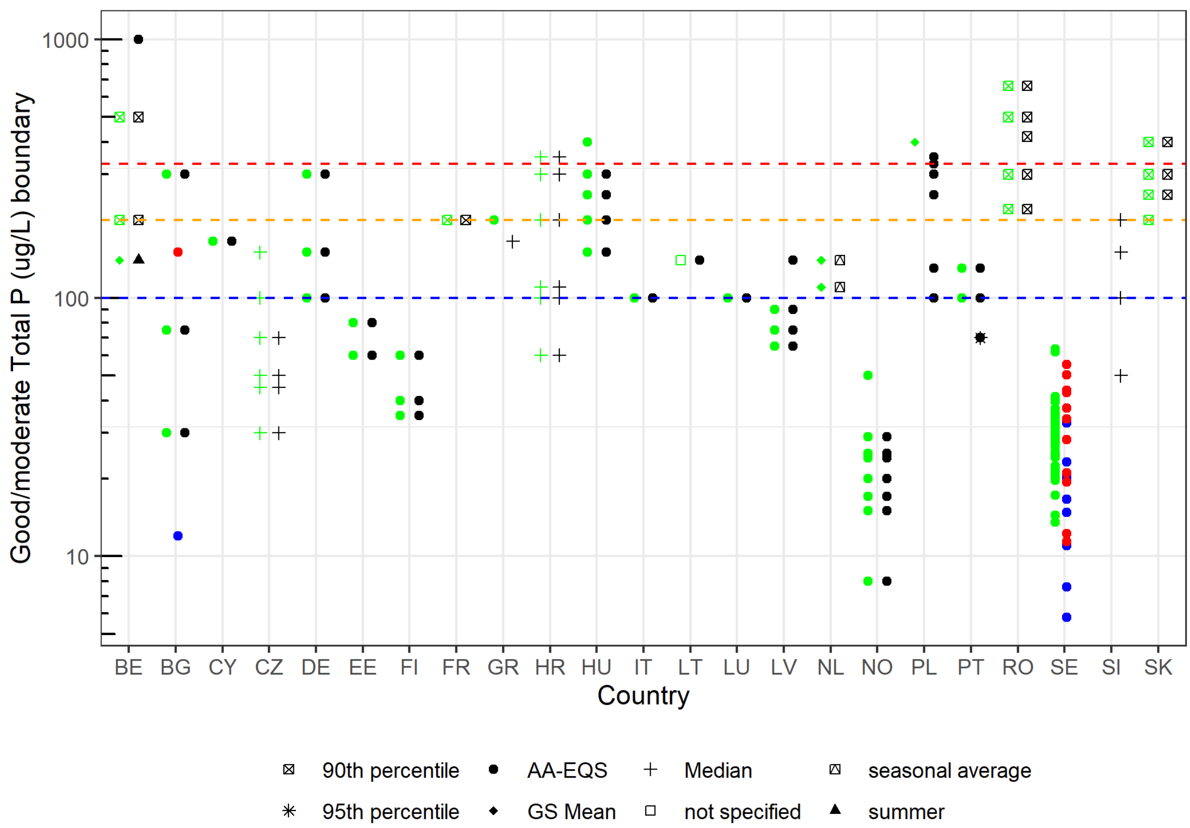

Figure 3.43: Comparison of river TP standards by country. Green symbols represent values reported in 2014, others colours those reported in 2019 (single value black, minimum blue, maximum red symbols. Dotted lines show interquartile range of mean or median values, (90th percentile=red, 75th percentile=orange, 50th percentile = blue).

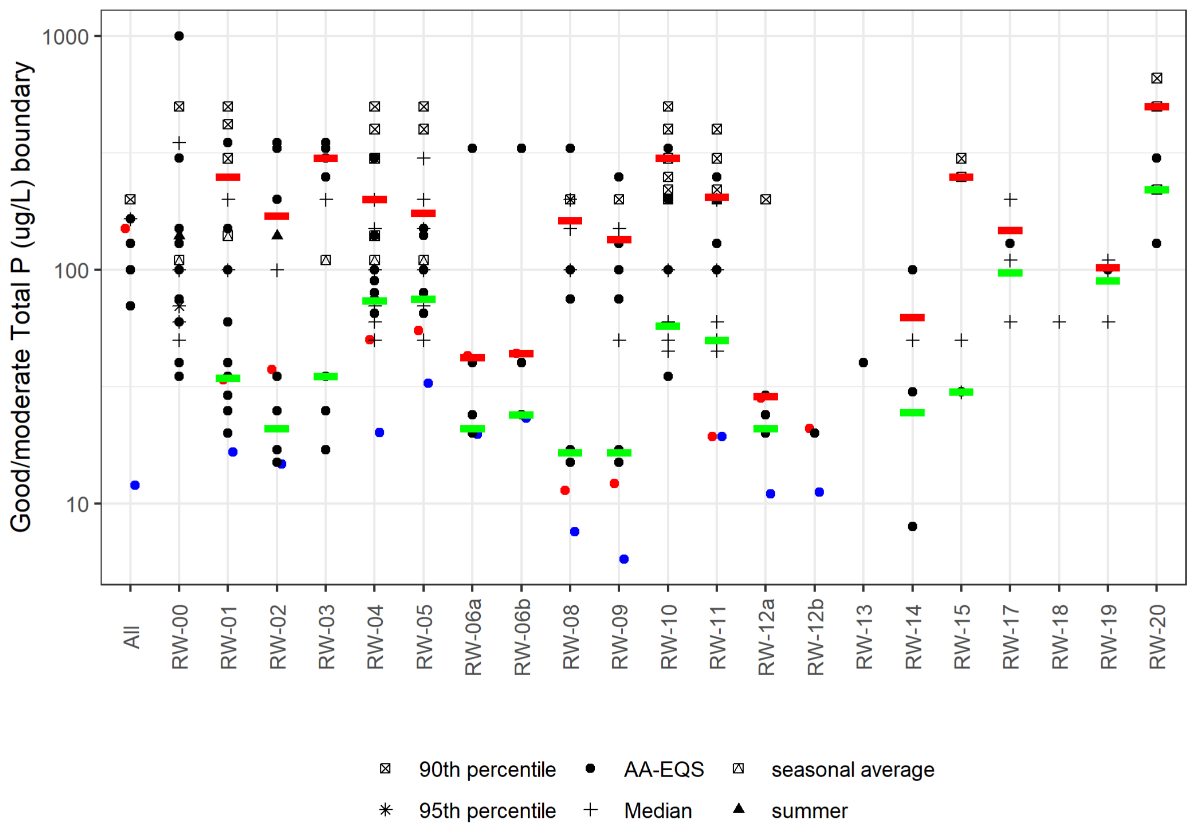

Figure 3.44: *TP standards by broad type (single value black, minimum blue, maximum red). Horizontal lines mark 25th (green) and 75th (red) percentiles, (including standards based on percentiles, AA-EQS, Median, seasonal average, summer (??).*

Table 3.29: *Analysis of variance for factorial model relating country and broad type to Member State boundary values for TP (Including main and partial effect sizes, Omega squared – see 1.2.5).*

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			759270.1	1	166.658	0
Country	0.68	0.72	2101520.3	18	25.627	0
CodeBT	0.05	0.15	210484.8	15	3.080	0
Residuals			633263.7	139		

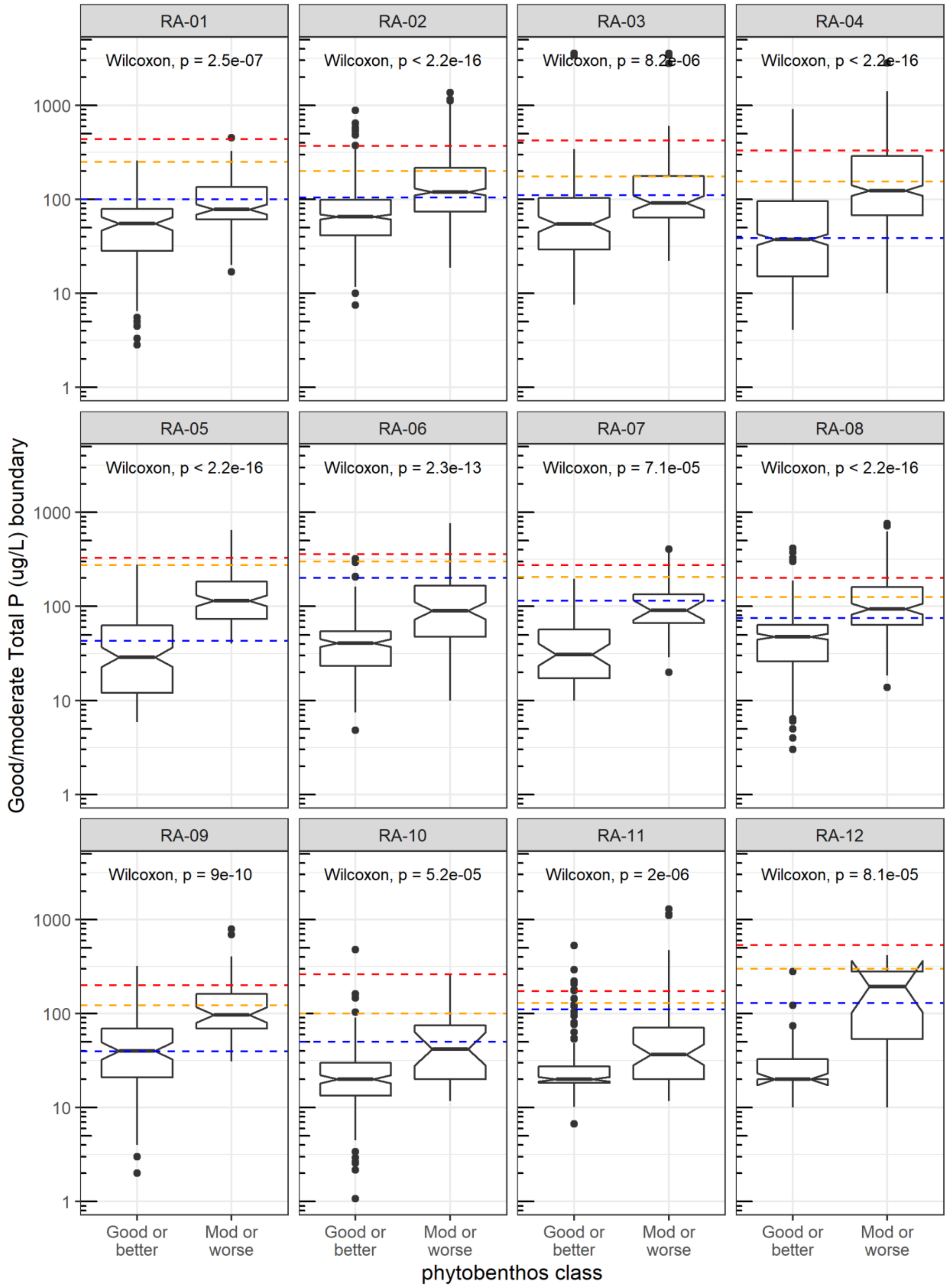

Figure 3.45 (previous page): River TP standards (dotted lines) overlain on box plots showing the range of TP concentration for sites classified by phytobenthos and macro-invertebrates. (90th percentile=red, 75th percentile=orange, median=blue), including standards based on AA-EQS, Median, seasonal average, summer (??), *percentiles, grouped by aggregated river type (see Methods section 1.2.5, Table 1.2 for translation between the broad types shown in 3.44 and the*

aggregated broad types shown here). Wilcocon test statistic shows significance of type specific differences in distribution of observed data.

Table 3.30: Overview of common broad types and their associated aggregated types for which standards are available, showing the number of countries/national types/distinct standards for TP.

Code	Broad type	Associated aggregated type code	Country	Type	Standard
All	All	All	6	1	6
RW-00	Not assigned	RA-00	10	43	15
RW-01	Very large rivers	RA-01	13	28	15
RW-02	Lowland siliceous medium-large	RA-04	7	10	10
RW-03	Lowland siliceous very small-small	RA-05	6	14	9
RW-04	Lowland calcareous or mixed medium-large	RA-02	14	68	16
RW-05	Lowland calcareous or mixed very small-small	RA-03	13	29	13
RW-06a	Lowland organic and siliceous very small-small	RA-05	4	7	5
RW-06b	Lowland organic and siliceous medium-large	RA-04	4	4	4
RW-08	Mid-altitude siliceous medium-large	RA-08	8	22	8
RW-09	Mid-altitude siliceous very small-small	RA-09	8	24	10
RW-10	Mid-altitude calcareous or mixed medium-large	RA-06	10	55	12
RW-11	Mid-altitude calcareous or mixed very small-small	RA-07	10	54	11
RW-12a	Mid-altitude organic and siliceous very small-small	RA-09	3	15	5
RW-12b	Mid-altitude organic and siliceous medium-large	RA-08	2	3	2
RW-13	Mid-altitude organic and calcareous or mixed	RA-06	1	1	1
RW-14	Highland (all Europe) siliceous incl. organic (humic)	RA-10	4	11	4

RW-15	Highland (all Europe) calcareous or mixed	RA-10	4	8	4
RW-17	Mediterranean lowland medium-large perennial	RA-11	3	7	4
RW-18	Mediterranean mid-altitude medium-large perennial	RA-11	1	1	1
RW-19	Mediterranean very small-small perennial	RA-12	2	6	3
RW-20	Mediterranean temporary or intermittent streams	RA-12	3	12	5

3.7.3 Phosphorus: synthesis

Total phosphorus (TP) is widely used in lakes whilst both TP and "PO_4-P" are used in rivers either separately (10 countries) or together (15 countries).

As for TN in lakes, type appears to have a strong effect on TP standards (Fig. 3.41), with lowland calcareous lakes generally having the highest thresholds and siliceous lakes generally having the lowest thresholds. Once again, however, a strong country effect is overriding the effect of type (Table 3.24). When compared with EEA data some types seem to have standards that are likely to be adequate (LA-01 very large, LA-03 shallow lowland) whilst, for others, many standards still appear to be too lenient (LA-02 very shallow, LA-07 highland).

Strong effects related to type are also seen in rivers with similar patterns to lakes: rivers draining silicious catchments generally having lower thresholds than rivers draining calcareous ones. Many of these types show strong differences in concentrations associated with "good or better" versus "moderate or worse" status. The effectiveness of standards associated with different types varies: while the median values for both phosphate and TP are generally closer to the upper quartiles of sites in good or better status than for quality elements such as ammonium the majority are higher than the mid-point of the distributions of sites not in good status, particularly for PO4-P. There are exceptions, the lowland siliceous river types (RA-04, RA-05) and mid-altitude siliceous (RA-09) but the overall conclusion is that river phosphorus boundaries for many types/countries still require review.

There were very few changes in lake total phosphorus boundary values compared with values reported in 2014, with only a slight reduction in the maximum reported value, 400 µg P/L, compared with 500 µg P/L in 2014. Two countries (CY, RO) reported additional higher values, with one country (PL) reporting a lower range of boundaries.

As for nitrogen, there were few changes in river phosphorus boundaries, with the same high maximum values of 500 µg/L for ortho-phosphorus, but a higher value (1000 µg/L) for total phosphorus (compared with a maximum of 660 µg/L in 2014). Most boundary values remained the same as those reported in 2014 with only one country (PL) reporting a lower range of boundary values (both for ortho-phosphorus and total phosphorus). Some countries (BG, CY, PT) reported additional lower values for ortho-phosphorus, and total phosphorus. However, others (BE, FR, RO) reported additional higher values for ortho-phosphorus, and (CY, FR, NL, RO) for total phosphorus.

3.8 Salinity

3.8.1 Salinity (rivers)

13 countries have standards for parameters that relate to the salinisation of inland waters. 4 countries (BG, CY, PL, RO) use conductivity for this purpose and 5 (AT, CZ, DE, LU, NL) use chloride concentration. 3 countries (BE, ES, HU) report standards for both, whilst MT uses Practical Salinity Units. Salinity can also be a component of typology in countries where there are naturally brackish lakes (e.g. NL).

3.8.1.1 Chloride (rivers)

There were 306 records of chloride standards from 7 countries (Figure 3.46). Many countries use the annual mean ("AA-EQS") as a summary metric. 6 countries (AT, BE, DE, HU, LU, NL) use a single value for each national type and 2 countries (ES, HU) present standards as a range.

The data could be linked to 9 broad types (Figure 3.47 & Table 3.32). 3 of these (RW-01, RW-04, RW-05) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 3 countries (AT, BE, LU) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 20 mg/L (HU) to 600 mg/L (AT), with an interquartile range of 50 to 200 mg/L (Figure 3.47).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.31). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (38.6%) and type (0%)

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of Chloride based on classifications for phytobenthos and macroinvertebrates (Figure 3.48) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A5.1.

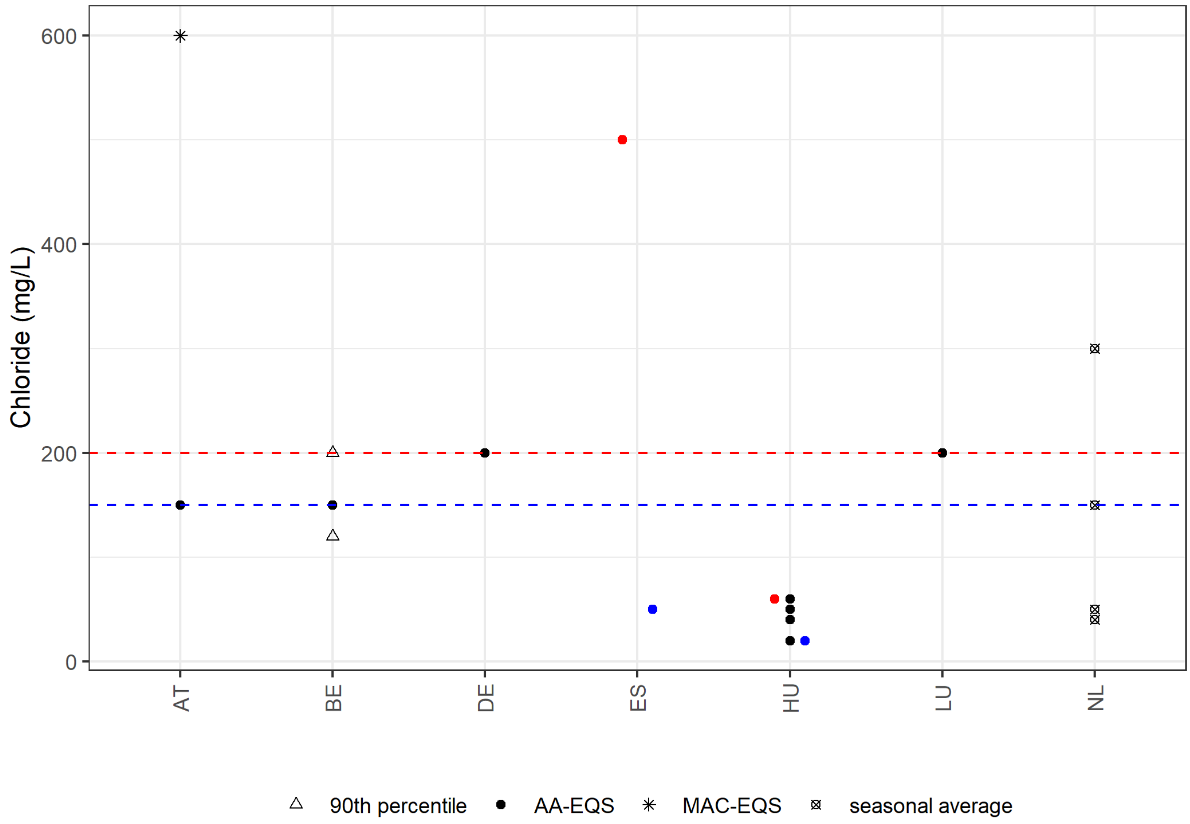

Figure 3.46. *Comparison of river Chloride standards by country. (single value black, minimum blue, maximum red symbols, dotted lines show interquartile range of mean or median values, (90th percentile=red, 75th percentile=orange (overlain by 90th percentile), 50th percentile = blue).*

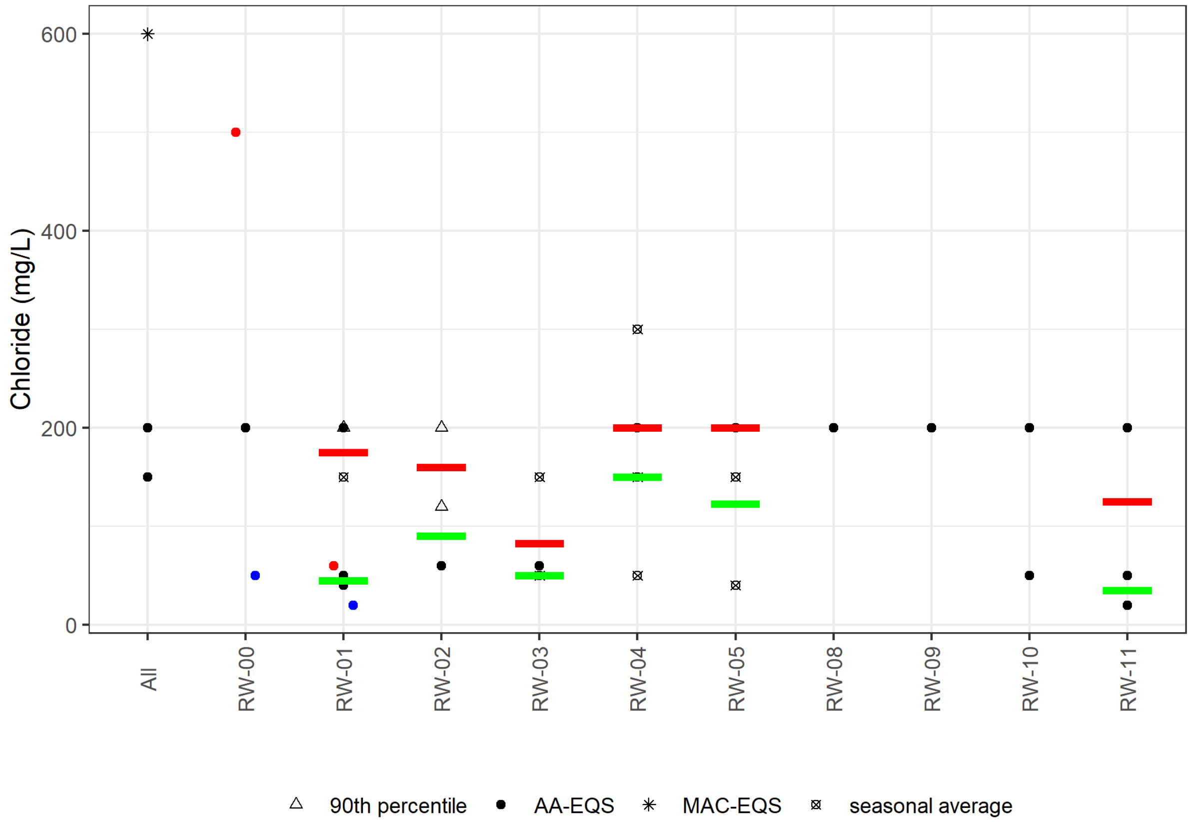

Figure 3.47: River Chloride standards by broad type (single value black, minimum blue, maximum red, Horizontal lines mark the 25th (green) and 75th (red) percentiles).

Table 3.31: Analysis of variance for factorial model relating country and broad type to Member State boundary values for log Chloride (Including main and partial effect sizes, Omega squared – see 1.2.5).

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			28.1	1	74.26	0.00001
Country	0.39	0.36	5.0	4	3.29	0.06357
CodeBT	-0.06	-0.1	0.2	2	0.30	0.74630
Residuals			3.4	9		

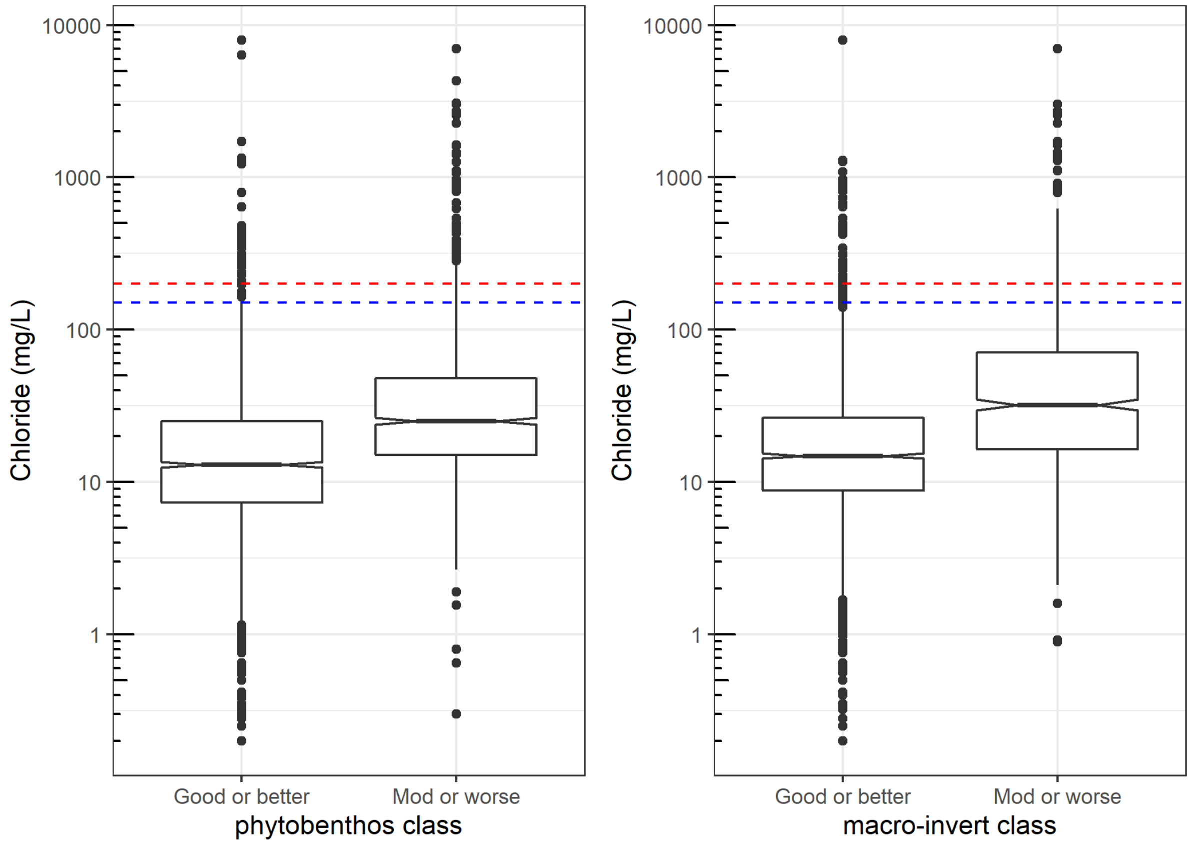

Figure 3.48: River Chloride standards (dotted lines) overlain on box plots showing the range of Chloride concentration for sites classified by phytobenthos and macro-invertebrates. (90th percentile=red, 75th percentile=orange (overlain by 90th percentile), median=blue). Significance of difference between groups, (phytobenthos) Wilcoxon p=<0.001 (invertebrates) Wilcoxon p= <0.001/

Table 3.32 Overview of common types and number of Member State/national types/distinct standards

Code	Broad type	Country	Type	Standard
All	All	3	1	3
RW-00	Not assigned	2	6	2
RW-01	Very large rivers	4	7	5
RW-02	Lowland siliceous medium-large	2	3	3
RW-03	Lowland siliceous very small-small	2	5	3
RW-04	Lowland calcareous or mixed medium-large	3	10	4
RW-05	Lowland calcareous or mixed very small-small	3	8	3
RW-06a	Lowland organic and siliceous very small-small			
RW-06b	Lowland organic and siliceous medium-large			
RW-08	Mid-altitude siliceous medium-large	2	2	1
RW-09	Mid-altitude siliceous very small-small	2	4	1
RW-10	Mid-altitude calcareous or mixed medium-large	2	5	2
RW-11	Mid-altitude calcareous or mixed very small-small	2	7	3
RW-12a	Mid-altitude organic and siliceous very small-small			
RW-12b	Mid-altitude organic and siliceous medium-large			
RW-13	Mid-altitude organic and calcareous or mixed			
RW-14	Highland (all Europe) siliceous incl. organic (humic)			
RW-15	Highland (all Europe) calcareous or mixed			
RW-16	Glacial rivers (all Europe)			
RW-17	Mediterranean lowland medium-large perennial			
RW-18	Mediterranean mid-altitude medium-large perennial			
RW-19	Mediterranean very small-small perennial			
RW-20	Mediterranean temporary or intermittent streams			

3.8.1.2 Conductivity (rivers)

There were 208 records of conductivity standards from 7 countries (Figure 3.49). Many countries use the annual mean ("AA-EQS") as a summary metric. 7 countries (BE, BG, CY, ES, HU, PL, RO) use a single value for each national type and 2 countries (ES, HU) present standards as a range.

The data could be linked to 18 broad types (Figure 3.50 & Table 3.34). 5 of these (RW-00, RW-01, RW-02, RW-10, RW-11) had type specific values from more than 2 countries allowing the range of standards in these types to be compared. 2 countries (BG, CY) apply the same standard to all national types found in one or more of their river basin districts.

The standards ranged from 20 µS/cm (ES) to 60,000 µS/cm (ES), with an interquartile range of 450 to 1000 (Figure 3.50).

A two-way analysis of variance was used to test the significance of country and type differences between standards (Table 3.33). The relative importance of the country and type effects can be judged from the Omega squared values which represent the proportion of variance explained by each of country (26.7%) and type (12.4%)

In order to link the reported standards to relevant BQEs their interquartile ranges are marked as horizontal lines on box plots showing the distribution of Conductivity based on classifications for phytobenthos and macroinvertebrates (Figure 3.51) using data taken from the EEA-WISE-SOE-DATABASE.

More information in Annex A5.1.

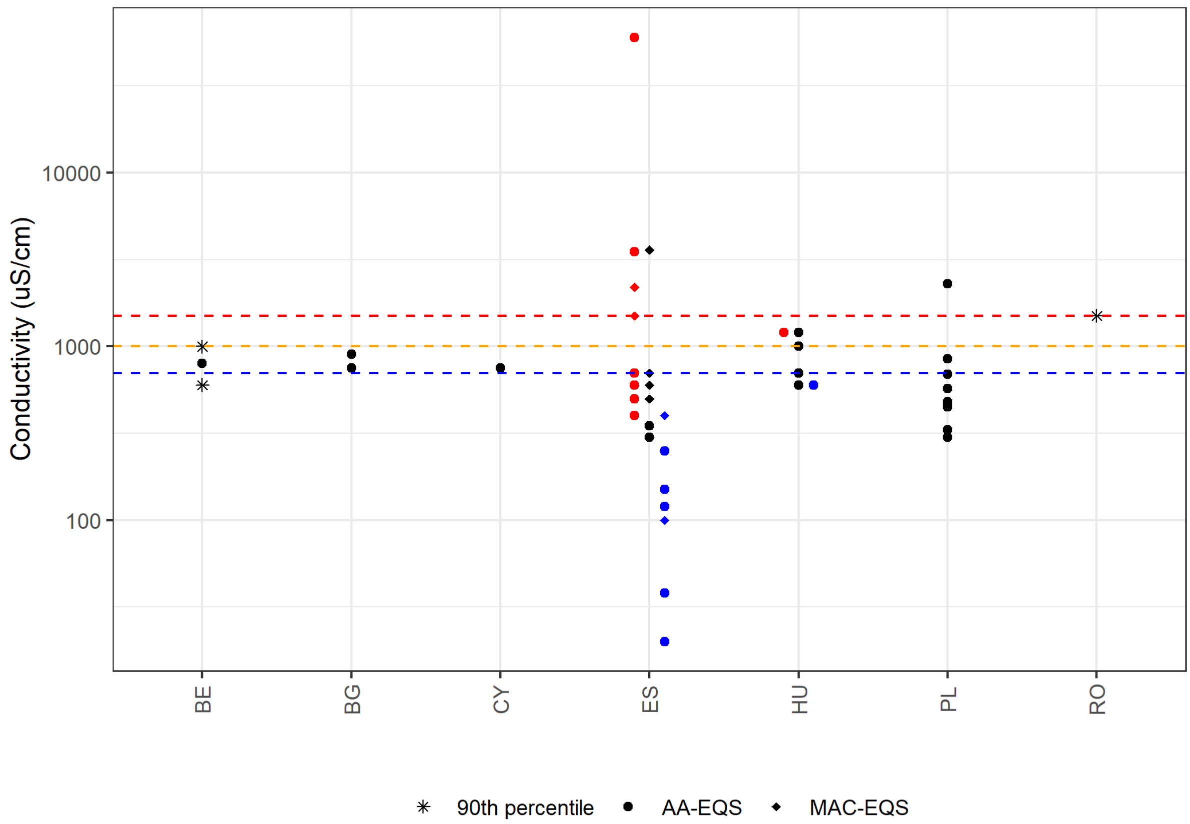

Figure 3.49: *Comparison of river Conductivity standards by country. (single value black, minimum blue, maximum red symbols, dotted lines show interquartile range of mean or median values, (90th percentile=red, 75th percentile=orange, 50th percentile = blue).*

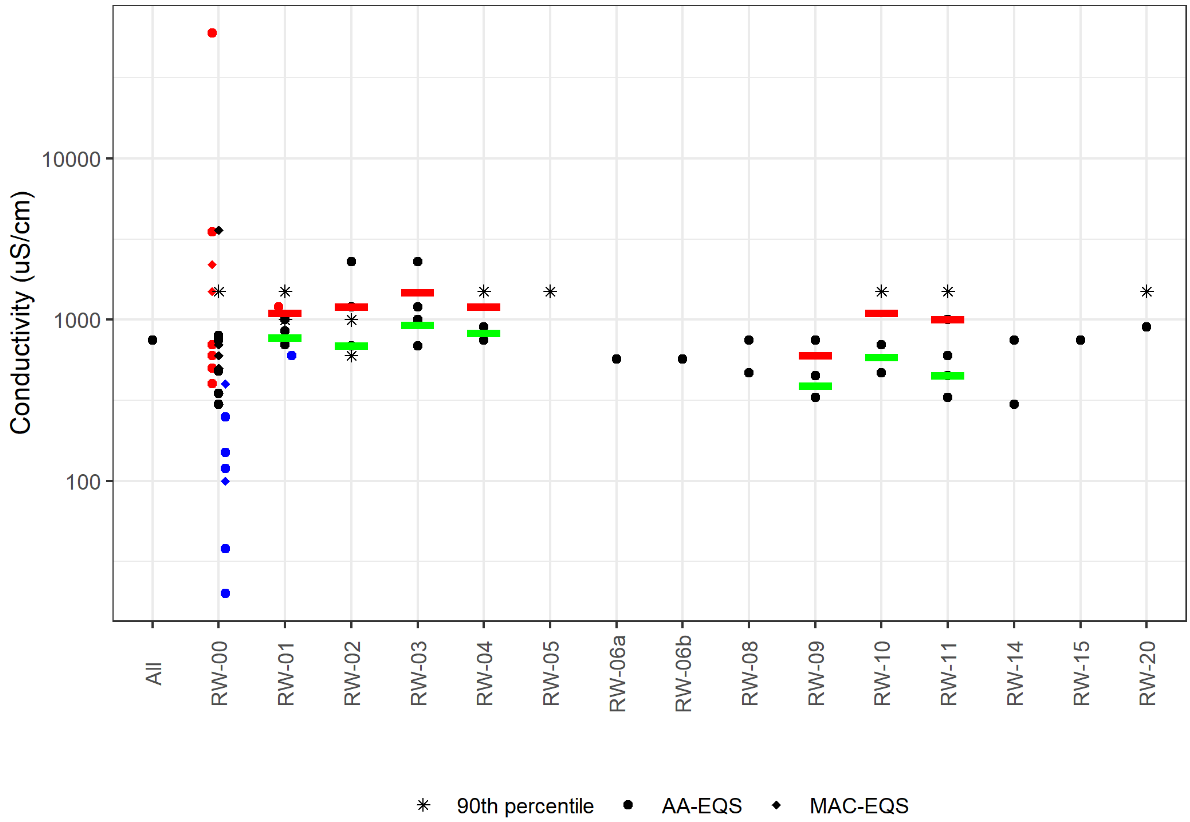

Figure 3.50: *River Conductivity standards by broad type (single value black, minimum blue, maximum red, Horizontal lines mark the 25th (green) and 75th (red) percentiles, (including standards based on AA-EQS, percentiles).*

Table 3.33: *Analysis of variance for factorial model relating country and broad type to Member State boundary values for log Conductivity (Including main and partial effect sizes and Omega squared – see 1.2.5).*

	Omega sq,	p Omega sq	Sum sq	Df	F value	Prob.
Intercept			81.9	1	522.98	0.00000
Country	0.27	0.31	1.8	3	3.93	0.03371
CodeBT	0.12	0.17	1.1	3	2.36	0.11866
Residuals			2.0	13		

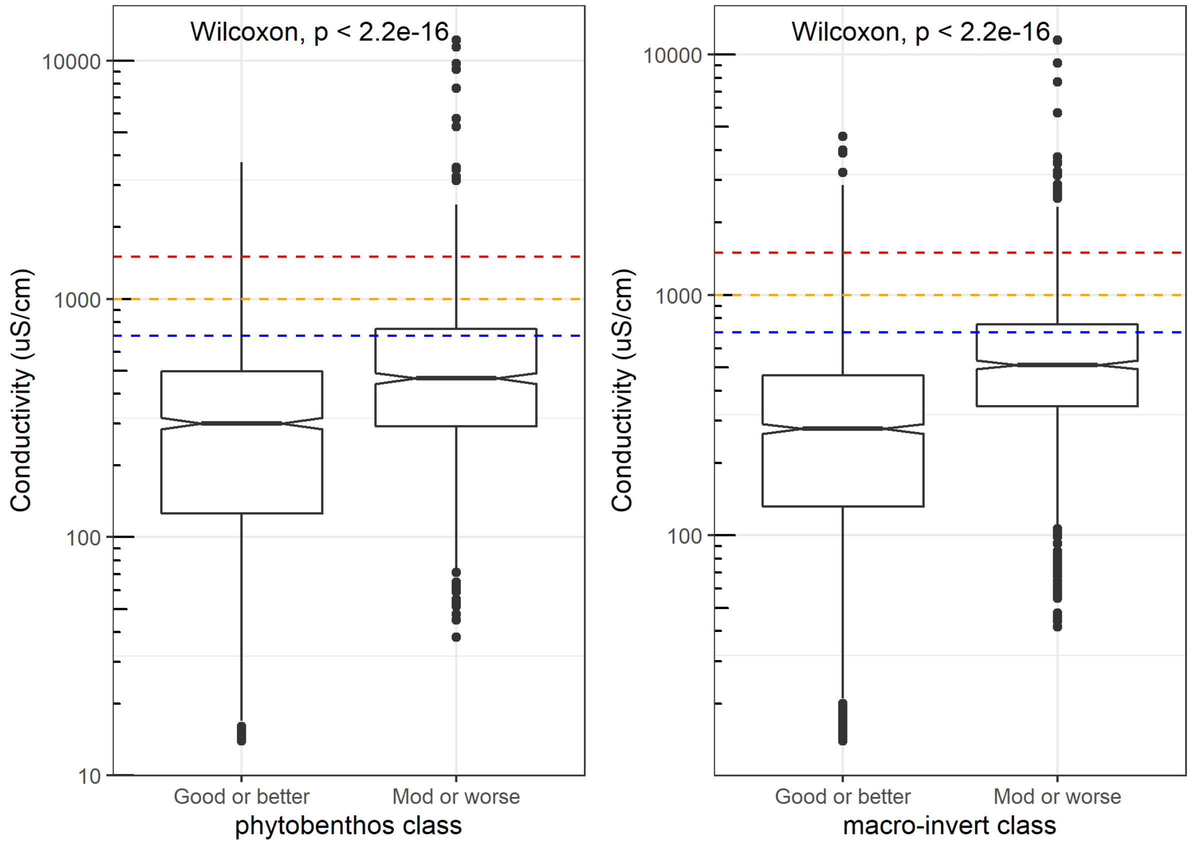

Figure 3.51: River Conductivity standards (dotted lines) overlain on box plots showing the range of Conductivity concentration for sites classified by phytobenthos and macro-invertebrates. (90th percentile=red, 75th percentile=orange, median=blue). Significance of difference between groups, (phytobenthos) Wilcoxon p=<0.001 (invertebrates) Wilcoxon p= <0.001

Table 3.34: Overview of common types for which conductivity standards are available, showing the number of Member State/national types/distinct standards for lakes.

Code	Broad Type	Country	Type	Standard
All	All	2	1	1
RW-00	Not assigned	5	33	17
RW-01	Very large rivers	4	10	5
RW-02	Lowland siliceous medium-large	3	5	5
RW-03	Lowland siliceous very small-small	2	5	4
RW-04	Lowland calcareous or mixed medium-large	2	25	3
RW-05	Lowland calcareous or mixed very small-small	1	4	1
RW-06a	Lowland organic and siliceous very small-small	1	1	1
RW-06b	Lowland organic and siliceous medium-large	1	1	1
RW-08	Mid-altitude siliceous medium-large	2	2	2
RW-09	Mid-altitude siliceous very small-small	2	3	3
RW-10	Mid-altitude calcareous or mixed medium-large	3	8	3
RW-11	Mid-altitude calcareous or mixed very small-small	3	13	5
RW-14	Highland (all Europe) siliceous incl. organic (humic)	2	3	2
RW-15	Highland (all Europe) calcareous or mixed	1	1	1
RW-20	Mediterranean temporary or intermittent streams	2	10	2

3.8.2 Salinity: synthesis

Just under half of all countries provided information on standards relating to salinity, with three different approaches being adopted, one of which (Practical Salinity Units) was only used by one country so could not be analysed further.

None of the metrics available for analysis were specifically calibrated against salinity gradients although some "general degradation" measures for river phytobenthos, at least, have been shown to correlated with salinity.

With these caveats in mind, chloride standards, especially, appear to be particularly lenient although the median position of conductivity standards, too, is also above the 75th percentile of sites at "good or better" status.

4 Discussion

4.1 General comments

The previous chapter catalogued standards used by Member States for different physico-chemical supporting elements and made some tentative comparisons between countries, between broad types and with available biological and physico-chemical data from monitoring sites in WISE. In some cases, there are clear differences between countries. These might be due to the way that the standard was set (e.g. expert judgment rather than derived from empirical data) but might also be due to differences in the methods used to collect data (which part of the water column was sampled, for example, in the case of oxygen) and the summary statistics used. All of this will complicate direct comparisons of national standards (Skarbøvik et al., 2020; Fölster et al., 2021).

Note that the comments offer an EU-wide overview of the situation for each supporting element, in order to focus the work of ECOSTAT and should not be interpreted as endorsing any particular national standard. That responsibility remains with Member States, although the EU Commission may ask the Member States to demonstrate the ability of the standards to support good ecological status for relevant sensitive biological quality elements.

Many of these supporting elements do not act in isolation: they may form part of a "cocktail" of stressors produced by a single pressure (e.g. urban waste water or diffuse pollution from agriculture causing elevated levels of nutrients and BOD, as well as reduced Secchi depth and reduced oxygen). The supporting elements may, themselves, also reflect the action of other stressors on one BQE (e.g. Secchi depth reflects the effect of phosphorus on phytoplankton) whilst, simultaneously, exerting a direct effect on another BQE (e.g. light limitation – indicated by Secchi depth – on lake macrophytes). The remainder of this section will evaluate these interactions in freshwaters, leading to a proposed plan of action for ECOSTAT to take this work forward.

4.2 Changes in nutrient standards

Given the attention that has been given to nutrients since the original report highlighting the extent of differences between national standards (Phillips & Pitt 2015) it might have been expected that this survey would have shown changes to the boundary criteria used by Member States. In general, this was not the case. Although differences in the coding of national types meant that it was not possible to make a direct comparison of national boundary values, Figures 3.28, 3.31, 3.34, 3.37, 3.40 & 3.43 demonstrate little evidence of any substantial change in the reported boundary values. For both nitrogen and phosphorus, the majority of the boundary values remain the same, with several countries still having relatively high values and a few even reporting additional higher values. One reason for this may be the lag in the reporting systems and the timing of the river basing planning process. The data reported in 2015 would have represented boundary values for the 1st WFD planning cycle whilst those in this report reflect the 2nd cycle, with values potentially established prior to the completion of the nutrient guidance document in 2018. However, the current conclusion is that nutrient boundary values in some countries are considerably higher than the nutrient concentrations found in waterbodies reported to be in good status for sensitive BQEs (see 4.3 below), and therefore require further consideration in order to ensure that they support good ecological quality.

4.3 Challenges involved in setting threshold values

The current guidance on establishing nutrient boundaries recommends the use of pressure response relationships between measures of biological status, such as EQR or WFD status class and nutrient concentrations. This approach can in theory be extended to include a wider range of supporting element variables. However, from preliminary work designed to test such an approach, a number of issues are starting to emerge. There are currently no clear solutions to these issues, but we highlight some of these in the following section to stimulate further discussion.

In order to test the application of the nutrient toolkit methods we used a pan-European data set extracted from the WISE-SoE-database to generate pressure response relationships between normalized EQRs and various supporting elements. Given the growing recognition of the role of multiple pressures we specifically considered the application of more complex multivariate relationships which included multiple pressure variables. However, one of the key requirements of regression modelling is the independence of predictor variables and the first issue that emerges is that in many cases the supporting element variables for which we require boundary values are significantly correlated with each other (Figure 4.1). In this respect, the present work differs from much research on multiple pressures, which assumes independent effects, albeit with the potential to interact.

Issue 1. Correlation of supporting element variables. How does this affect the development and interpretation of pressure response models?

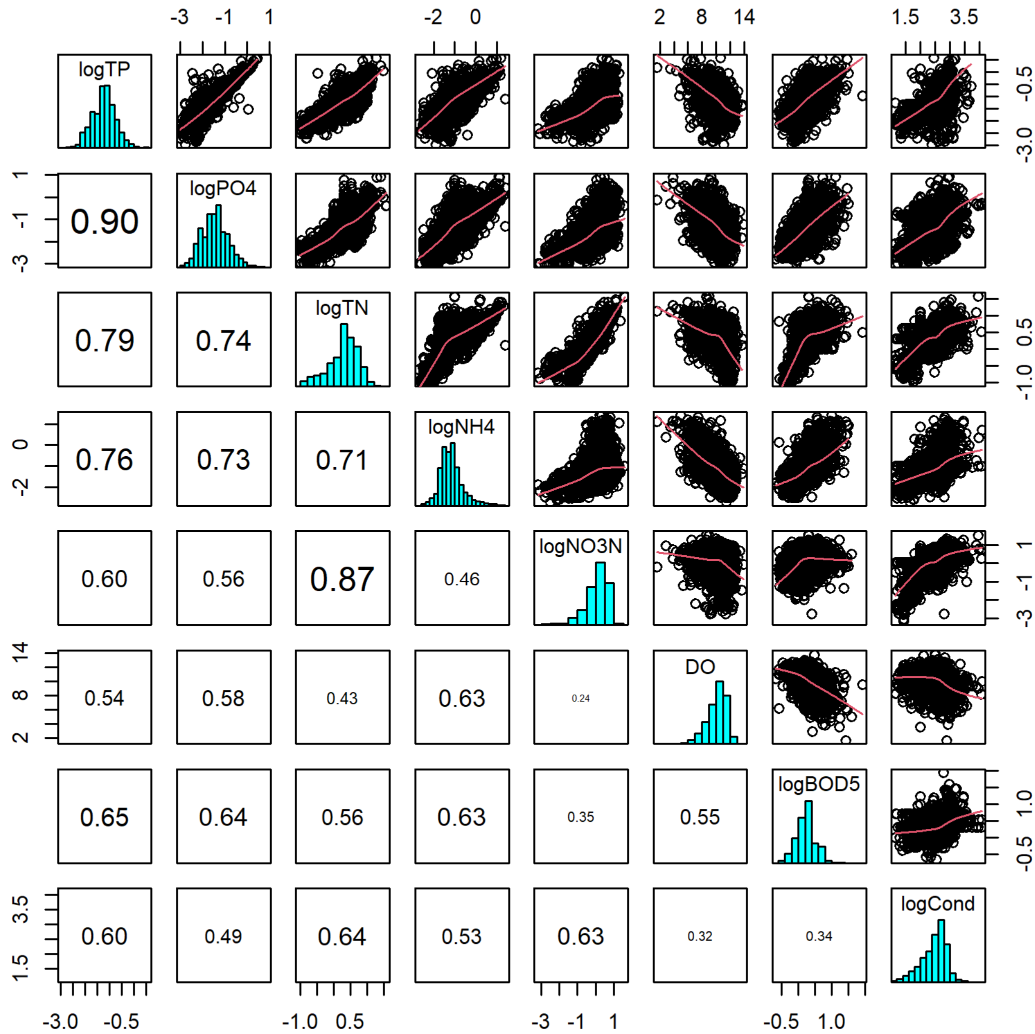

Figure 4.1: Correlations, distribution and scatter plot showing relationship between variables available for modelling.

Clearly, we would expect high correlations between some variables, for example ortho-phosphate and total phosphorus, but we also see that ammonium nitrogen is correlated with phosphorus (total and ortho-phosphorus), and also with biochemical oxygen demand. Thus, if there is a significant pressure-response relationship between total phosphorus and EQR, there will inevitably be a similarly good relationship between ammonium nitrogen and EQR and boundary values taken from the intersection of the good moderate EQR boundaries for each of these relationships will also, as a result, be related. However, the issue of causality cannot be determined: all that can be concluded is the most likely concentrations of both phosphorus and ammonium at the good moderate boundary.

Issue 2. Which are the most important variables for explaining variation in ecological quality?

One potentially useful method of investigating the importance of different variables that themselves have a degree of correlation are boosted regression trees (BRTs: Elith et al., 2008; Elith & Leathwick, 2017). This is a powerful technique, that differs from traditional regression methods which produce a single "best" model as they combine a large number or simple tree models to create a final model which is less influenced by correlations between variables. The approach can be used to determine which combination of predictor variables best predict EQRs and are thus likely to be important supporting elements for the BQE under consideration.   At this stage, we are not proposing BRTs as a means of setting standards; only as a means of understanding the factors responsible for shaping ecological communities and for identifying the dominant stressors.

This was explored using BRTs to predict EQR for river phytobenthos, river macro-invertebrates, lake phytoplankton and lake macrophytes were fitted to a common suite (except that transparency replaced DO for lake macrophytes) of variables. These models need further work, as it is important to simplify the models using pruning techniques, but the initial results illustrate the effect of using multiple variables to reduce uncertainty and the relative importance of each. The models explain 70-87% of the variability (Figure 4.2), a much higher value than simple univariate models. The model for phytoplankton EQR explains the most variance (87%) and that for river phytobenthos the least (70%). Total phosphorus is the most important predictor variable for both lake phytoplankton and river phytobenthos (Fig 4.2.3), but transparency (Secchi disk depth) is the most important factor for lake macrophytes and ammonium nitrogen and total phosphorus are equally important for river macro-invertebrates. This reflects our current understanding of the importance of phosphorus for the algal based metrics, but suggests that light availability is the key factor for lake macrophytes and that river macro-invertebrates are influenced by a more general organic pressure characterized by nutrients and ammonium nitrogen. Had we omitted TP from the phytoplankton and phytobenthos models the influence of ammonium N would have been substantially higher.

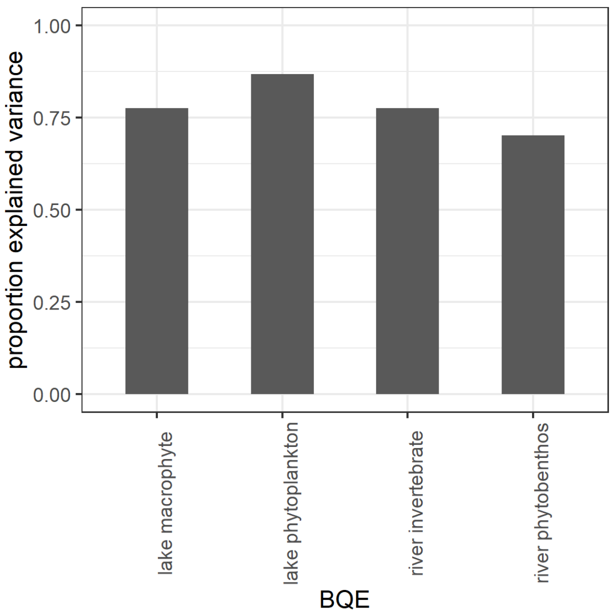

Figure 4.2 *Proportion of total variance in EQR-values explained by boosted regression tree models for different BQEs*

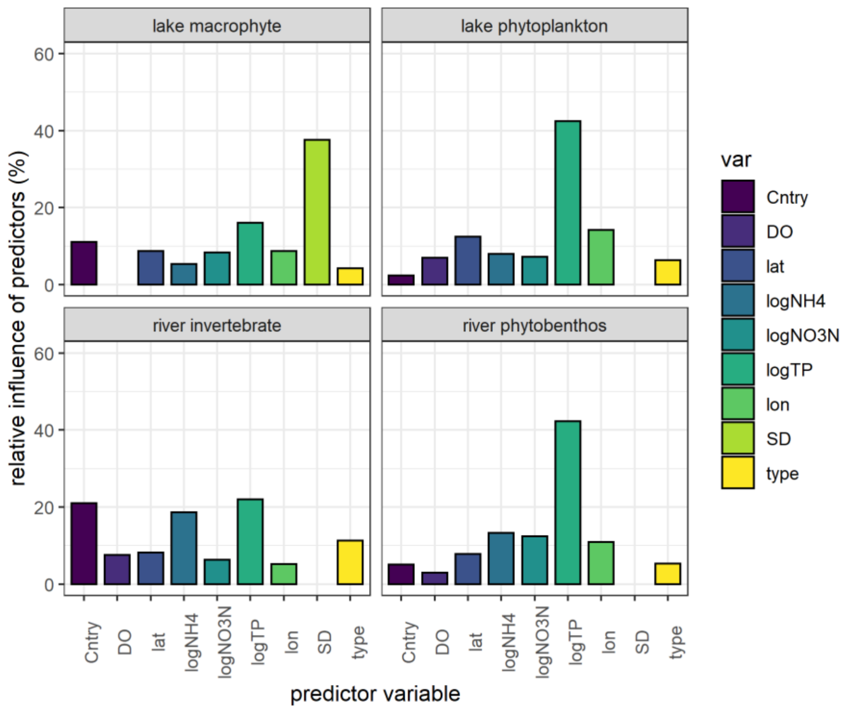

Figure 4.3: Relative contribution of predictor variable to boosted regression tree models for different BQEs. Cntry = Country; Lat = latitude; lon = longitude; SD = Secchi depth; type = broad type

Issue 3. Country specific and regional variation, should we expect consistent relationships between pressure variables and ecological quality?

The extent of the correlation between variables is not always consistent across different countries. Our initial examination of the data suggests that TP, ammonium-nitrogen and BOD are generally correlated with each other in all countries; however the relationship between these variables and nitrate-nitrogen is more variable. A scatter plot of river nitrate nitrogen and total phosphorus shows a wedge-shaped relationship. Nitrate-nitrogen concentrations are usually high at high concentrations of phosphorus whilst at lower levels of phosphorus a wide range of nitrate concentrations occur (Figure 4.4). However, our preliminary investigations of the data indicates that sites from different countries occupy different parts of the data cloud. For example sites in BE tend to always have high nitrate-nitrogen regardless of the TP concentration whilst Scandinavian countries tend to have lower nitrate-nitrogen concentrations for equivalent concentrations of TP. This probably reflects different pressures, but it represents an additional challenge for modelling. Clearly, model predictions which include both TP and nitrate-nitrogen using data from countries with different ranges of these supporting elements are likely to generate different results. This illustrates both the potential advantage of using pan-European data sets, by expanding the range of pressure variables, but also the difficulties of interpretation.

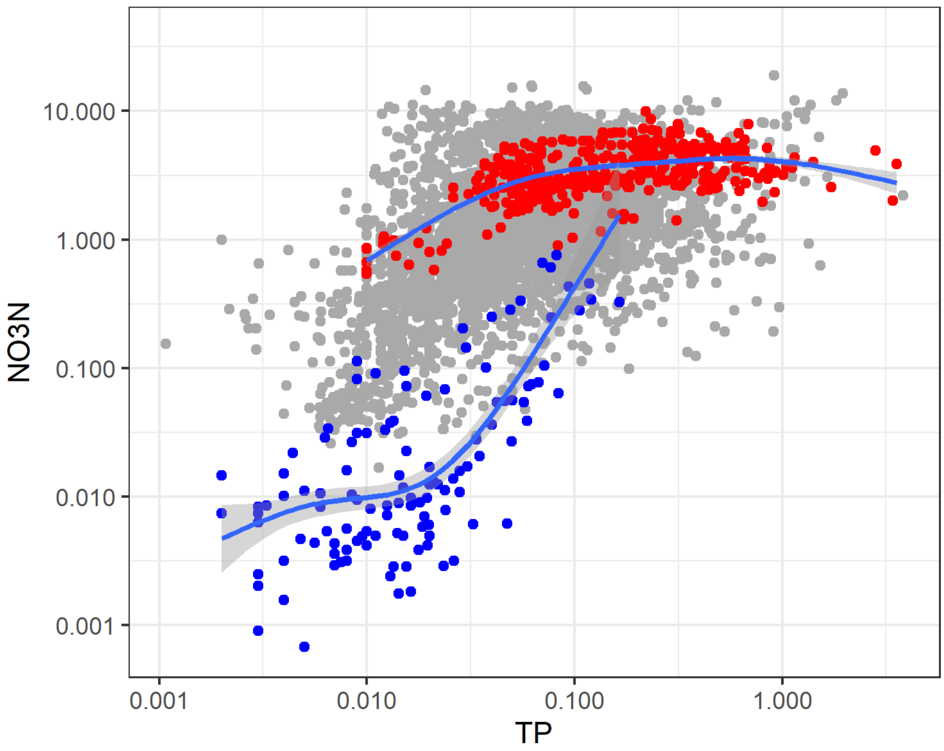

Figure 4.4: Scatter plots showing relationship between total phosphorus (TP mg/L) and nitrate nitrogen (NO3-N mg/L) in European rivers, illustrating overall shape of the relationship and how different countries occupy contrasting parts of the data cloud. (grey points all data, red points data from BE, blue points data from SE and FI).

In the BRT models mentioned above both country and water body type (Broad Type) were included in the models. In all cases typology contributed a relatively small amount to the explained variation (<10%), while for macro-invertebrates, country accounted for almost as much variability as ammonium-N and TP. The reason for this is not clear, particularly as the models also included latitude and longitude variables to allow for regional variation and normalised EQR values were used. Country effects were greatest for river invertebrates and this may reflect different scales of pressures such as hydromorphological alteration between countries as well as differing sensitivities of invertebrate metrics to this pressure. Diatom metrics, by contrast, are more consistent between countries and are mostly calibrated against chemical pressures, so it is not surprising that country effects are smaller; nor is it a surprise that country has less effect on lake phytoplankton assessments where all methods are calibrated against a eutrophication gradient

Given that multivariate models can explain significantly more variation than simple univariate models further consideration needs to be given to their use for establishing boundary values. One potential issue is that predictions from the model depends on the values of other variables. Thus, a range of boundary values emerges, each contingent on values of other predictors. This may explain why type is not an important predictor in these multivariate models and allow for different combinations of boundary values in different water body types.

Issue 4. Which BQEs should be selected when developing pressure response relationships?

Finally, it is important to recognise the different sensitivities of the BQEs to pressure. Because of this, we recommend that the most sensitive BQE to a supporting element is selected to set the threshold for that supporting element. Thus, models which use macro-invertebrates is likely to be more useful when establishing supporting element boundaries for quality elements reflecting organic pressures, whilst the plant based metrics are better suited to reflect the impact of nutrients. Dissolved oxygen and free ammonia, which itself is related to pH and total ammonia, may need to be related to the status of fish which requires access to other data, as fish are not yet adequately represented in the WISE-SOE data set.

4.4 Synthesis

A recurring theme in section 3 is that variation in standards between countries overrides differences between broad types. One key question, then, is the extent to which differences in national standards can be explained by biogeographical variation rather than as evidence that some countries have standards that are less effective at protecting good status. Even after acknowledging the relatively simple nature of the analyses presented in section 3, it appears that many standards for supporting elements are not set at levels that are likely to protect good status and, therefore, that the likelihood of achieving WFD aims is reduced.

In contrast, the comparison of standards in section 3 highlights the apparent lack of regional or even water body type specific differences in pressure-response relationships, suggesting that more uniformity might be expected. However, the clear differences in the relative importance of different pressures is clearly a complicating issue, as are differences in monitoring approach. Supporting elements can be divided into those that are direct drivers of status through primary effects on BQEs and those that are secondary effects, providing supplementary information that reinforces decision making. Ammonium-N and oxygen conditions, for example, reflect properties that directly influence fish and invertebrates, whilst Secchi depth and upper pH thresholds could be seen as secondary effects of nutrients (caused by high phytoplankton biomass and primary production) when determining risks to water bodies. Secchi depth is also affected by humic substances and by inorganic turbidity, which poses challenges when setting boundaries that protect against nutrient enrichment. Secchi depth can however directly influence macrophytes and is also an important parameter for human well-being through its effect on cultural ecosystem services, such as recreation and bathing water.

In terms of practical actions to support Member States, the following conclusions can be drawn:

1. Supporting element standards should not be considered in isolation but rather as part of an integrated decision-making system that enables Member States to make effective decisions about appropriate management strategies.

2. Considerable effort has already been spent on promoting best practice for nutrients, but this has not yet been translated into more effective standards (3.6.3 & 3.7.3). Generally, the process is in place although some Member States may need support as they apply this to their own situations. In this regard, the links shown in this report between the standards and the sensitive BQEs may help to identify a range of standards per broad type that is compatible with good status for the BQEs, and also to identify those standards that seem to be too lenient and which may need to be validated. ECOSTAT should also recognise that the democratic safeguards mean that the translation of science into policy may take some years to realise. We also recognise that setting effective N or P standards in situations where there are interactions from other stressors that may conceal the impact of nutrients still needs additional

work. These other stressors include siltation causing light limitation for river phytobenthos or macrophytes or habitat deterioration for fish and macroinvertebrates; the presence of pesticides degrading the BQEs due to toxicity; or hydromorphological pressures, such as water level fluctuations degrading the habitats of the littoral zone. This does not mean, however, that nutrients should not be managed to a level that would support good status in absence of the other pressures/stressors.

3. Low oxygen concentrations, BOD and ammonium-N often combine to form a "cocktail" of stressors (along with nutrients) associated with organic pollution. Evidence in this report suggests that current standards for several of these are too lenient. Organic pollution (which is still an important pressure across much of Europe) would be an obvious focus for ECOSTAT going forward. Some of the work on nutrients will be directly relevant to these stressors; but are also important in areas exposed to diffuse pollution from agriculture, which affects twice as many water bodies in Europe as the organic pollution from point sources (EEA 2018 report). However, the development of realistic standards should facilitate reduction of both organic pollution and diffuse nutrient pollution. Guidance on managing water resources subject to multiple stressors can be found in Schinegger et al. (2018). The main recommendation is to always prioritise measures to reduce the primary/dominant stressor first. This is, in many cases, nutrients/organic pollution and/or hydromorphological pressures.

4. In some cases (e.g. dissolved oxygen – 4.2.1), comparisons between countries are complicated by different approaches to monitoring and classification; in others, there are differences in how data are summarised. These issues will need to be considered when individual supporting elements are discussed in more detail. Whilst there are situations where a measure of central tendency is most appropriate (e.g. for nutrients, where the mean may be regarded as a useful proxy for the load to which the biota is exposed), there are also circumstances where an upper or lower percentile will be more relevant. Generally, those supporting elements that exert a toxic or fatal effect (e.g. pH, dissolved oxygen, free ammonia) should use upper/lower percentiles, reflecting the most extreme cases to which the biota is exposed. Questions about data aggregation lead naturally onto questions of appropriate sampling frequencies.

5. Following on from this, the present work cannot be considered in isolation from the broader process of classification. Whilst our mandate does not extend to formal interpretation of classification rules there is a need to make a scientific case for appropriate combinations of variables within a physico-chemical supporting element (i.e. when it is appropriate to include a nitrogen standard within "nutrient conditions" for inland waters). Again, the work on nutrients has suggested that a nuanced approach is necessary in order to give Member States confidence that programmes of measures are based on secure scientific foundations.

~~6.~~ Lower pH thresholds reflect acidification, a key pressure that applies in some regions of Europe but is less relevant in others. Further work on this supporting element is probably best devolved to a subgroup of countries with vulnerable water bodies, and which have metrics tuned to evaluate this pressure and should not duplicate efforts performed under the auspices of the LRTAP-convention.

7. Some countries are still using standards inherited from pre-WFD legislation: dissolved oxygen from Freshwater Fish Directive and nitrate-N from Nitrates Directive (see 4.2). In both cases, several countries continue to use these values without presenting evidence that they are appropriate for the more stringent requirements of the WFD. These both merit further evaluation using pan-European data.

8. Although not discussed in this report, we recognise the importance of having a suite of variables that will permit a pan-European approach to detecting effects of climate change. This suggests a need for a co-ordinated approach to variables that are likely to change as a result and which in turn will impact the biota. Scientific evidence suggests that climate change is likely to aggravate eutrophication problems and reduce oxygen concentrations, both due to increasing water temperature, as well as to increasing frequency of extreme rain events flushing nutrients and organic pollution from the catchment into rivers and lakes (Ho et al. 2019, Jane et al. 2021). This interaction raises a need to consider more protective nutrient standards and BOD and oxygen concentration standards, as well as more effective mitigation and adaptation measures.

4.5 The way forward

The workplan approved by ECOSTAT in October 2020 is as follows:

- Work on nutrient boundaries (2020-2021): Analysis of current nutrient boundaries, including comparison with previous boundaries (collated 2014); Identification of remaining issues and problems: are there still issues of comparability? Are there still Member States that are "outliers"? Do we still need to work on particular water categories / issues/ MS? Solving remaining issues: provide tailored support to individual Member States using IC and Member State datasets

  These issues are largely covered by this report and were discussed in more detail at the workshop in April 2021. It is clear that some countries remain as "outliers" with respect to nutrient boundaries, and these will need tailored support.

- Work on physico-chemical boundaries (2020-2021): Comparisons within broad types; Validation of boundary values: testing with EEA/Member State datasets to derive appropriate boundaries for physico-chemical elements; Extracting best practice from Member State case studies.

  The first part of this is covered by this report, and this includes some preliminary testing with EEA data, illustrating possible ranges of boundaries that will be compatible with good status. This has uncovered several instances where boundaries may be too lenient to protect good status; however, section 4.3 also indicates some of the problems that will be encountered when attempting to derive appropriate boundaries. More detailed analysis of at regional level, as well as Member State case studies will complement analyses performed at a pan-European level. We also need to look at how different combination rules can affect outcomes (does this explain apparently lenient standard setting in some cases?), using the ETC-ICM 2020 Comparability report as a basis.

- Updating the statistical tool-kit and guidance to derive boundaries for physico-chemical elements (as some supporting elements may require approaches not covered by the current versions of the tool-kit and guidance) (2020-2021);

Some of the methods included in the current version of the tool-kit will be applicable to other physico-chemcial elements. However, the statistical tool-kit and guidance recognised the problems associated with setting appropriate boundaries in multiple stressor situations but was not able to offer a comprehensive range of methods to address these. Ongoing work (see previous point) as well as guidance from the MARS project should provide some further options for dealing with multiple stressor situations.

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List of abbreviations

BOD – biochemical oxygen demand

BQE – Biological Quality Element

COD - chemical oxygen demand

EQR – Ecological Quality Ratio

RBD – River Basin District

RBMP – River Basic Management Plan

SRP – soluble reactive phosphorus

TN - total nitrogen

TP – total phosphorus

WFD – Water Framework Directive

WISE – Water Information System for Europe

Appendices

Extra information on each supporting element is provided in the charts and tables below.

Contents

Oxygen (lakes and rivers)

Oxygen Lakes

Dissolved oxygen concentration (lakes)

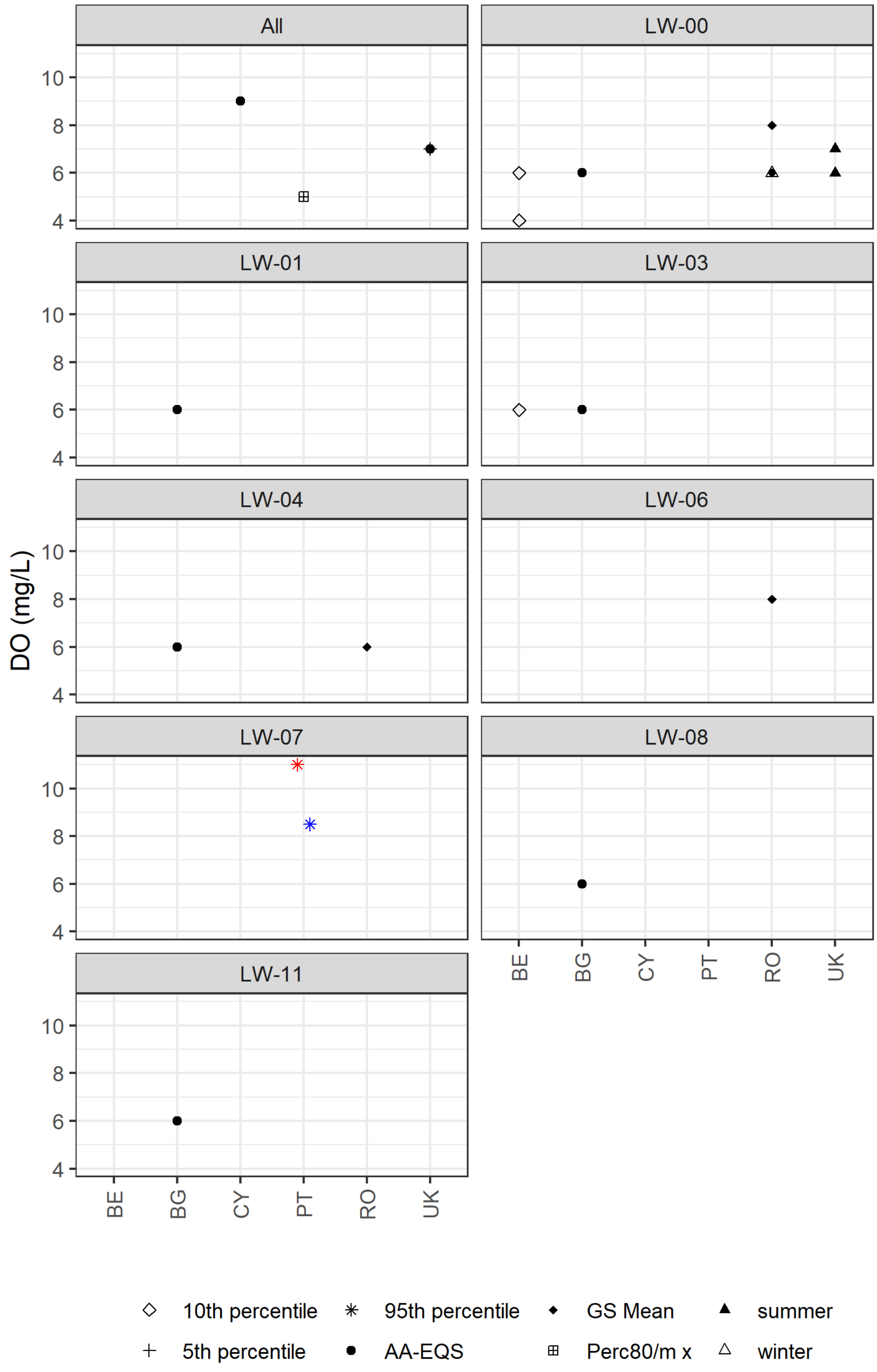

Figure A1 *Dissolved oxygen standards by country and broad type (single value black, minimum blue, maximum red), horizontal lines mark 25th and 75th quantiles for types with 2 or more countries contributing to the type.*

Table A1 *Dissolved oxygen metrics used by country*

	10th percentile	5th percentile	95th percentile	AA-EQS	GS Mean	Perc80/m x	summer	winter
BE	3	0	0	0	0	0	0	0
BG	0	0	0	6	0	0	0	0
CY	0	0	0	1	0	0	0	0
PT	0	0	1	0	0	1	0	0
RO	0	0	0	0	4	0	0	1
UK	0	1	0	1	0	0	2	0

Table A2 *records where Dissolved oxygen was reported as a value or a range*

Country	value	range
BE	3	
BG	18	
CY	1	
PT	8	1
RO	15	
UK	29	

Table A3 *Number of different Dissolved oxygen standards by country and broad type*

	BE	BG	CY	PT	RO	UK	Sum
All	0	0	1	1	0	2	4
LW-00	2	1	0	0	3	2	8
LW-01	0	1	0	0	0	0	1
LW-03	1	1	0	0	0	0	2
LW-04	0	1	0	0	1	0	2
LW-06	0	0	0	0	1	0	1
LW-07	0	0	0	1	0	0	1
LW-08	0	1	0	0	0	0	1
LW-11	0	1	0	0	0	0	1
Sum	3	6	1	2	5	4	21

Data set used *Ver12b* (2021-05-18)

% oxygen saturation concentration (lakes)

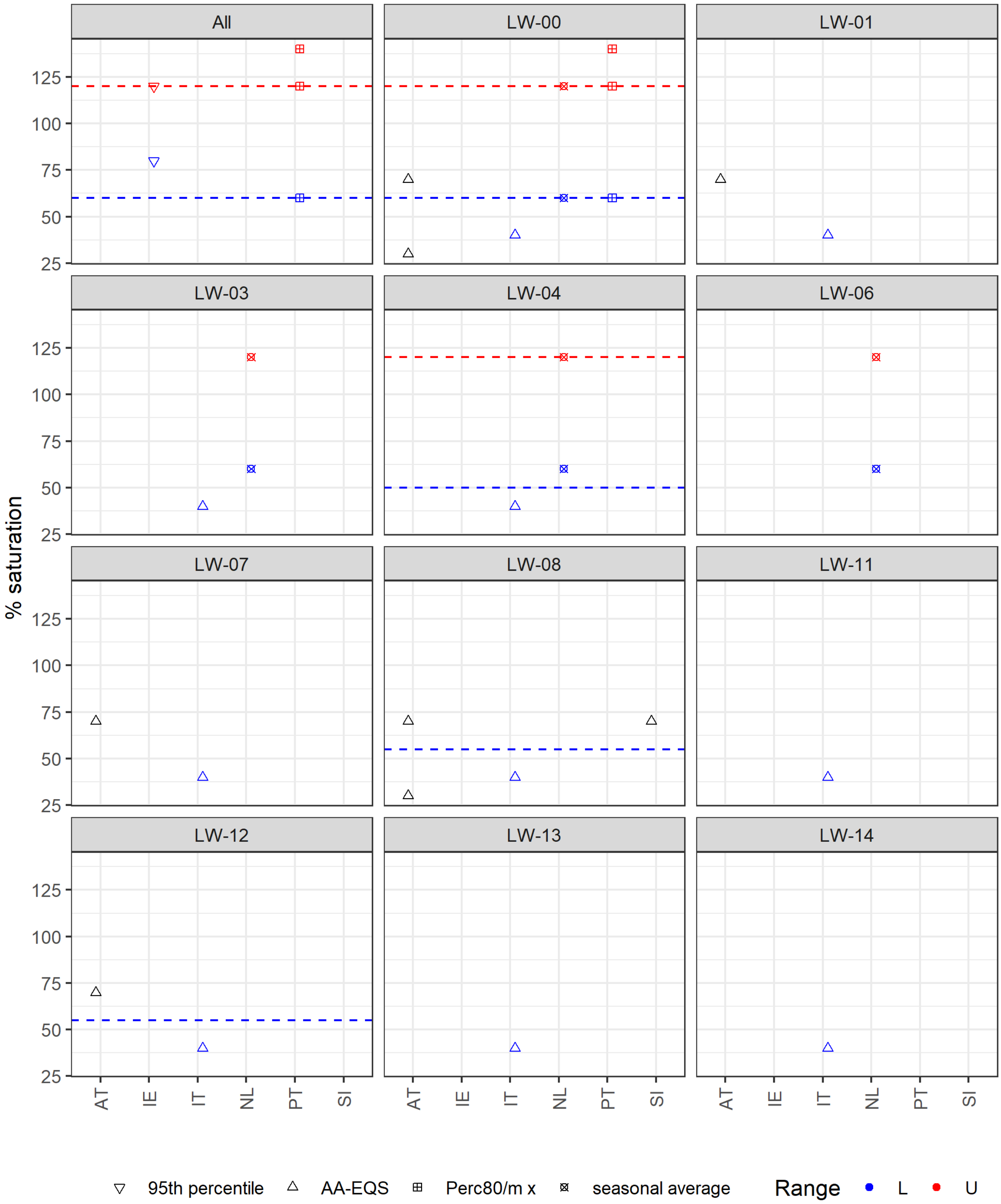

***Figure A2** % oxygen saturation standards by country and broad type (single value black, minimum blue, maximum red). Horizontal dotted lines show the median values for the uppder (red) and lower (blue) groups of standards*

Table A5 *% oxygen saturation metrics used by country*

	95th percentile	AA-EQS	Perc80/m x	seasonal average
AT	0	10	0	0
IE	1	0	0	0
IT	0	10	0	0
NL	0	0	0	4
PT	0	0	4	0
SI	0	1	0	0

Table A6 *records where % oxygen saturation was reported as a value or a range*

Country	value	range
AT	13	
IE		3
IT	21	
NL		9
PT		9
SI	2	

Table A7 *Number of different % oxygen saturation standards by country and broad type*

	AT	IE	IT	NL	PT	SI	Sum
All	0	1	0	0	2	0	3
LW-00	3	0	1	1	2	0	7
LW-01	1	0	1	0	0	0	2
LW-03	0	0	1	1	0	0	2
LW-04	1	0	1	1	0	0	3
LW-06	0	0	0	1	0	0	1
LW-07	1	0	1	0	0	0	2
LW-08	2	0	1	0	0	1	4
LW-11	0	0	1	0	0	0	1
LW-12	2	0	1	0	0	0	3
LW-13	0	0	1	0	0	0	1
LW-14	0	0	1	0	0	0	1
Sum	10	1	10	4	4	1	30

Data set used *Ver12b* (2021-05-18)

Oxygen (rivers)

Dissolved oxygen concentration (rivers)

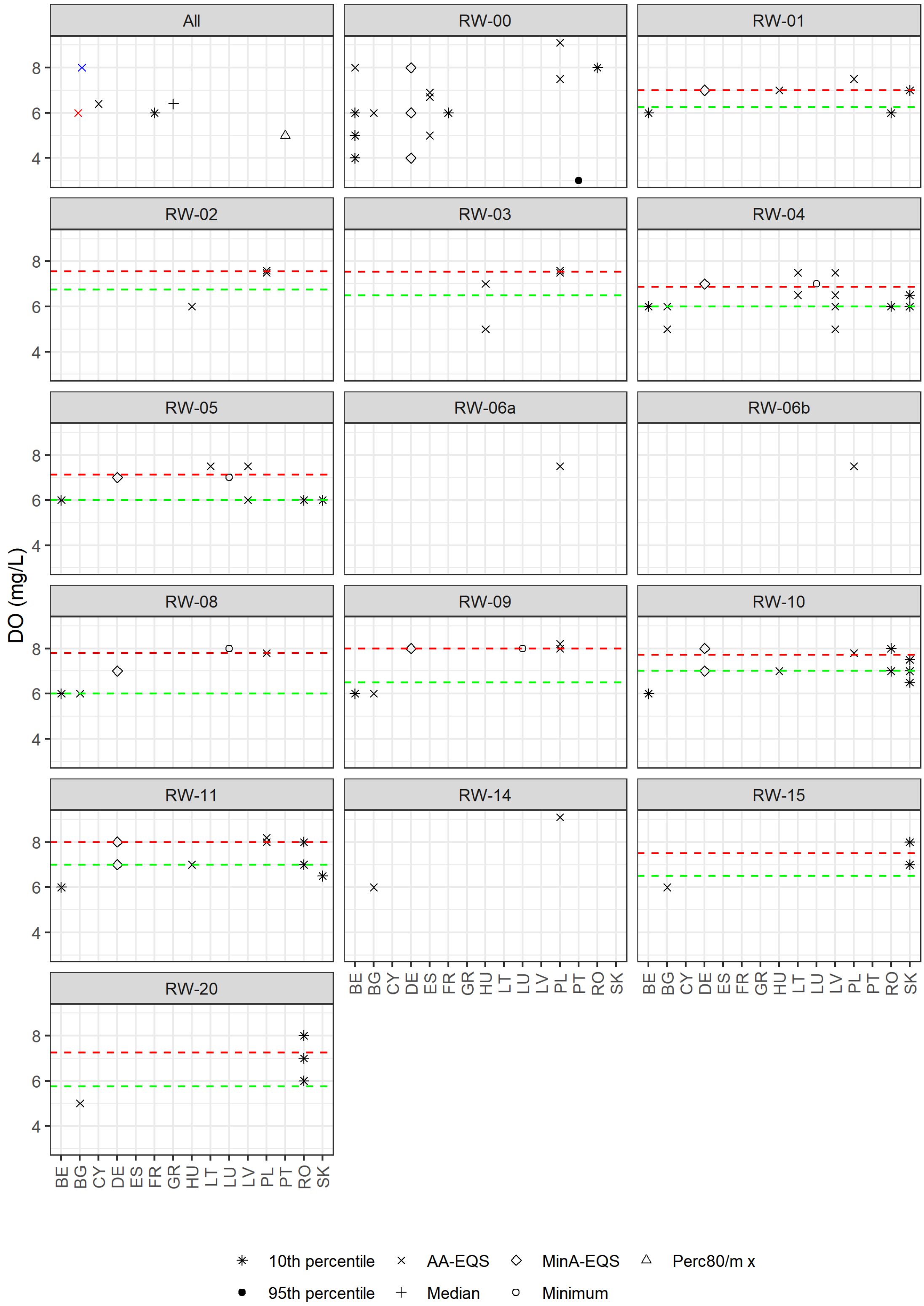

***Figure A3** Dissolved oxygen standards by country and broad type (single value black, minimum blue, maximum red)*

Table A7 *Dissolved oxygen metrics used by country*

	10th percentile	95th percentile	AA-EQS	Median	MinA-EQS	Minimum	Perc80/m x
BE	10	0	2	0	0	0	0
BG	0	0	9	0	0	0	0
CY	0	0	1	0	0	0	0
DE	0	0	0	0	12	0	0
ES	0	0	3	0	0	0	0
FR	2	0	0	0	0	0	0
GR	0	0	0	1	0	0	0
HU	0	0	6	0	0	0	0
LT	0	0	3	0	0	0	0
LU	0	0	0	0	0	4	0
LV	0	0	6	0	0	0	0
PL	0	0	16	0	0	0	0
PT	0	1	0	0	0	0	1
RO	11	0	0	0	0	0	0
SK	10	0	0	0	0	0	0

Table A8 *records where Dissolved oxygen was reported as a value or a range*

Country	value	range
BE	40	
BG	17	1
CY	1	
DE	30	
ES	37	
FR	11	
GR	1	
HU	10	
LT	5	
LU	7	
LV	23	
PL	65	
PT	10	
RO	55	
SK	28	

__Table A9__ Number of different Dissolved oxygen standards by country and broad type

	BE	BG	CY	DE	ES	FR	GR	HU	LT	LU	LV	PL	PT	RO	SK	Sum
All	0	1	1	0	0	1	1	0	0	0	0	0	1	0	0	5
RW-00	5	1	0	3	3	1	0	0	0	0	0	2	1	1	0	17
RW-01	1	0	0	1	0	0	0	1	0	0	0	1	0	1	1	6
RW-02	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	3
RW-03	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	4
RW-04	1	2	0	1	0	0	0	0	2	1	4	0	0	1	2	14
RW-05	1	0	0	1	0	0	0	0	1	1	2	0	0	1	1	8
RW-06a	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
RW-06b	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
RW-08	1	1	0	1	0	0	0	0	0	1	0	1	0	0	0	5
RW-09	1	1	0	1	0	0	0	0	0	1	0	2	0	0	0	6
RW-10	1	0	0	2	0	0	0	1	0	0	0	1	0	2	3	10
RW-11	1	0	0	2	0	0	0	1	0	0	0	2	0	2	1	9
RW-14	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2
RW-15	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	3
RW-20	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	4
Sum	12	9	1	12	3	2	1	6	3	4	6	16	2	11	10	98

Data set used *Ver12b* (2021-05-18)

Percent oxygen saturation (rivers)

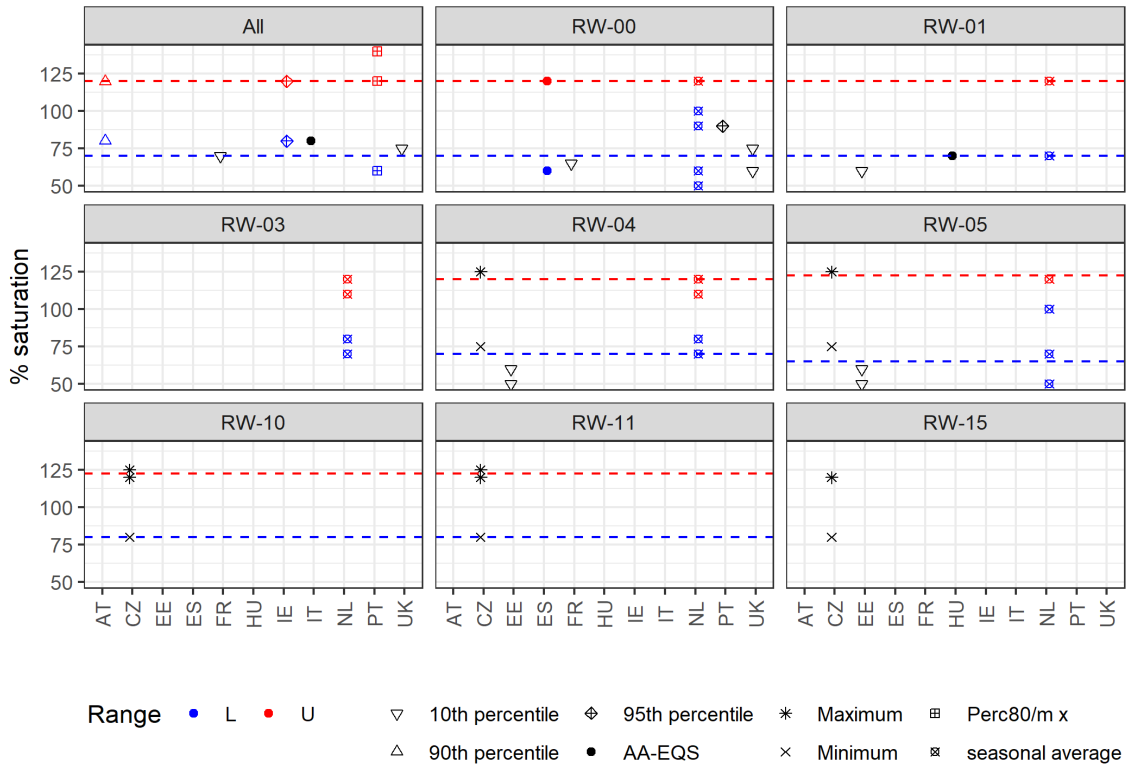

Figure A4 *% oxygen saturation standards by country and broad type (single value black, minimum blue, maximum red). Horizontal dotted lines show the median values for the uppder (red) and lower (blue) groups of standards*

Table A10 *% oxygen saturation metrics used by country*

	10th percentile	90th percentile	95th percentile	AA-EQS	Maximum	Minimum	Perc80/m x	seasonal average
AT	0	1	0	0	0	0	0	0
CZ	0	0	0	0	7	5	0	0
EE	5	0	0	0	0	0	0	0
ES	0	0	0	1	0	0	0	0
FR	2	0	0	0	0	0	0	0
HU	0	0	0	1	0	0	0	0
IE	0	0	1	0	0	0	0	0
IT	0	0	0	1	0	0	0	0
NL	0	0	0	0	0	0	0	11
PT	0	0	1	0	0	0	3	0
UK	3	0	0	0	0	0	0	0

Table A11 *records where % oxygen saturation was reported as a value or a range*

Country	value	range
AT		3
CZ	42	
EE	16	
ES		20
FR	11	
HU	1	
IE		3
IT	1	
NL		15
PT	1	10
UK	36	

Table A12 *Number of different % oxygen saturation standards by country and broad type*

	AT	CZ	EE	ES	FR	HU	IE	IT	NL	PT	UK	Sum
All	1	0	0	0	1	0	1	1	0	3	1	8
RW-00	0	0	0	1	1	0	0	0	3	1	2	8
RW-01	0	0	1	0	0	1	0	0	1	0	0	3
RW-03	0	0	0	0	0	0	0	0	2	0	0	2
RW-04	0	2	2	0	0	0	0	0	3	0	0	7
RW-05	0	2	2	0	0	0	0	0	2	0	0	6
RW-10	0	3	0	0	0	0	0	0	0	0	0	3
RW-11	0	3	0	0	0	0	0	0	0	0	0	3
RW-15	0	2	0	0	0	0	0	0	0	0	0	2
Sum	1	12	5	1	2	1	1	1	11	4	3	42

Data set used *Ver12b* (2021-05-18)

Transparency

Secchi disk depth (lakes)

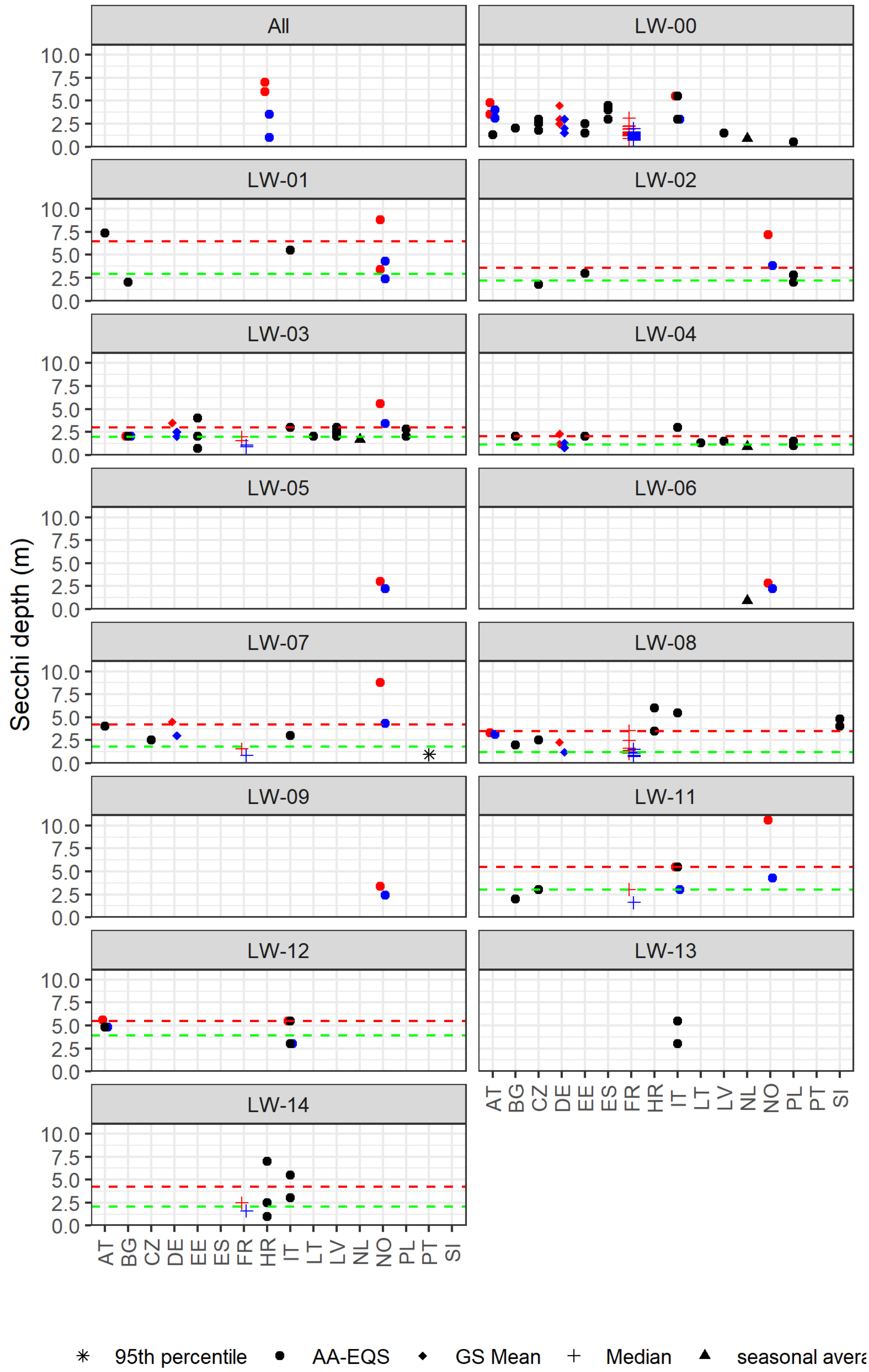

Figure A5 *Secchi disk depth standards by country and broad type (single value black, minimum blue, maximum red)*

Table A13 *Secchi disk depth metrics used by country*

	95th percentile	AA-EQS	GS Mean	Median	seasonal average
AT	0	10	0	0	0
BG	0	7	0	0	0
CZ	0	7	0	0	0
DE	0	0	9	0	0
EE	0	7	0	0	0
ES	0	3	0	0	0
FR	0	0	0	30	0
HR	0	7	0	0	0
IT	0	17	0	0	0
LT	0	2	0	0	0
LV	0	5	0	0	0
NL	0	0	0	0	4
NO	0	9	0	0	0
PL	0	7	0	0	0
PT	1	0	0	0	0
SI	0	2	0	0	0

Table A14 *records where Secchi disk depth was reported as a value or a range*

Country	value	range
AT	8	6
BG	18	2
CZ	16	
DE		14
EE	13	
ES	11	
FR		30
HR	6	2
IT	18	3
LT	3	
LV	14	
NL	9	
NO		23
PL	23	
PT	1	
SI	2	

Table A15 *Number of different Secchi disk depth standards by country and broad type*

	AT	BG	CZ	DE	EE	ES	FR	HR	IT	LT	LV	NL	NO	PL	PT	SI	Sum
All	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
LW-00	4	1	3	3	2	3	20	0	3	0	1	1	0	1	0	0	42
LW-01	1	1	0	0	0	0	0	0	1	0	0	0	2	0	0	0	5
LW-02	0	0	1	0	1	0	0	0	0	0	0	0	1	2	0	0	5
LW-03	0	2	0	2	3	0	2	0	1	1	3	1	1	2	0	0	18
LW-04	1	1	0	2	1	0	0	0	1	1	1	1	0	2	0	0	11
LW-05	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
LW-06	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2
LW-07	1	0	1	1	0	0	1	0	1	0	0	0	1	0	1	0	7
LW-08	1	1	1	1	0	0	5	2	1	0	0	0	0	0	0	2	14
LW-09	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
LW-11	0	1	1	0	0	0	1	0	2	0	0	0	1	0	0	0	6
LW-12	2	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	5
LW-13	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2
LW-14	0	0	0	0	0	0	1	3	2	0	0	0	0	0	0	0	6
Sum	10	7	7	9	7	3	30	7	17	2	5	4	9	7	1	2	127

Data set used *Ver12b* (2021-05-18)

pH

pH (lakes)

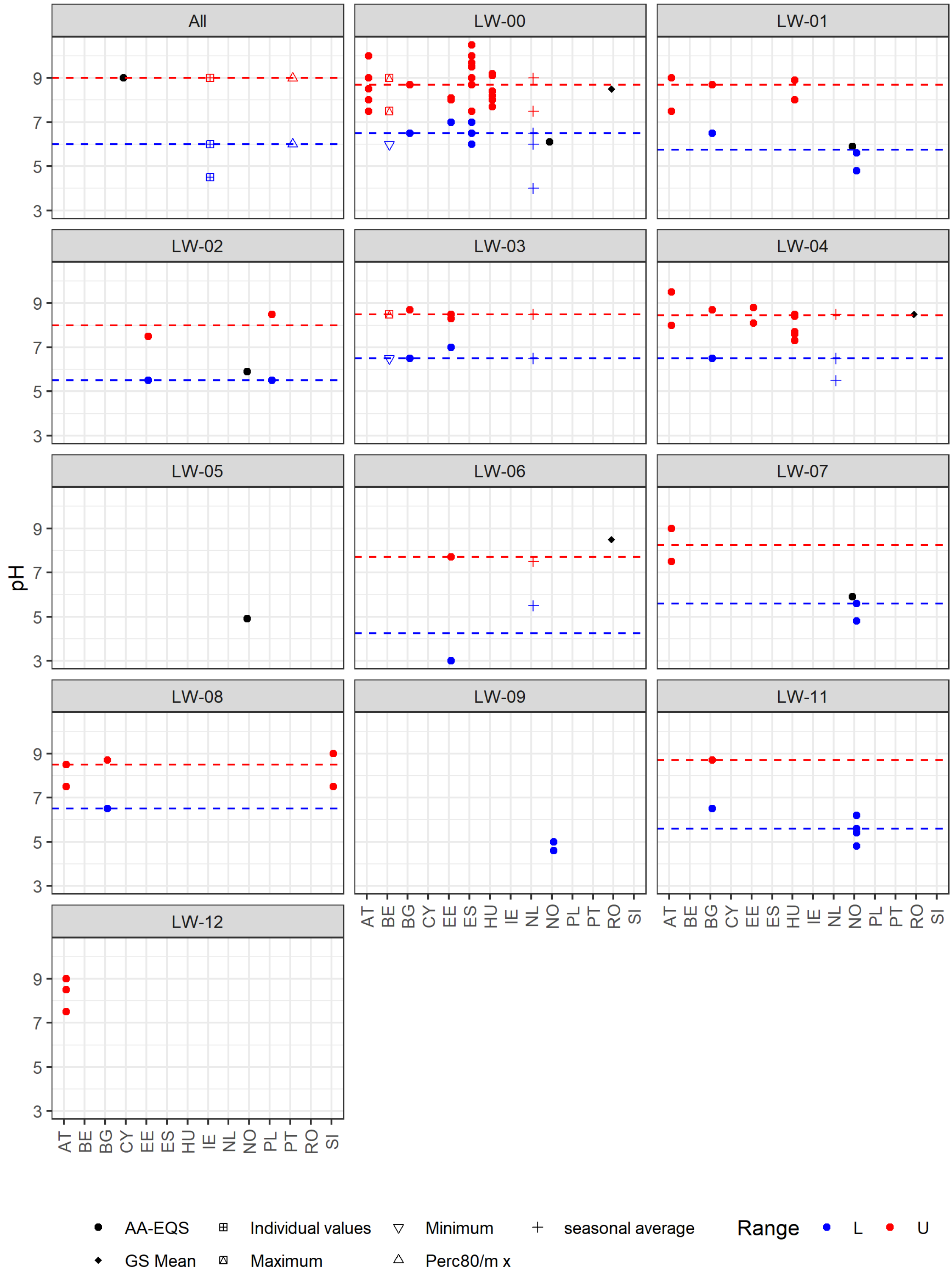

***Figure A6** pH standards by country and broad type (single value black, minimum blue, maximum red). Horizontal dotted lines show the median values for the uppder (red) and lower (blue) groups of standards*

Table A16 *pH metrics used by country*

	AA-EQS	GS Mean	Individual values	MAC-EQS	Minimum	Perc80/m x	seasonal average
AT	10	0	0	0	0	0	0
BE	0	0	0	3	3	0	0
BG	6	0	0	0	0	0	0
CY	1	0	0	0	0	0	0
EE	7	0	0	0	0	0	0
ES	9	0	0	0	0	0	0
HU	8	0	0	0	0	0	0
IE	0	0	2	0	0	0	0
NL	0	0	0	0	0	0	8
NO	10	0	0	0	0	0	0
PL	1	0	0	0	0	0	0
PT	0	0	0	0	0	1	0
RO	0	3	0	0	0	0	0
SI	1	0	0	0	0	0	0

Table A17 *records where pH was reported as a value or a range*

Country	value	range
AT		14
BE		8
BG		31
CY	1	
EE		15
ES		30
HU	1	7
IE		6
NL		9
NO	9	17
PL		4
PT		8
RO	15	
SI		2

Table A18 *Number of different pH standards by country and broad type*

	AT	BE	BG	CY	EE	ES	HU	IE	NL	NO	PL	PT	RO	SI	Sum
All	0	0	0	1	0	0	0	2	0	0	0	1	0	0	4
LW-00	4	4	1	0	2	9	4	0	4	1	0	0	1	0	30
LW-01	1	0	1	0	0	0	1	0	0	2	0	0	0	0	5
LW-02	0	0	0	0	1	0	0	0	0	1	1	0	0	0	3
LW-03	0	2	1	0	2	0	0	0	1	0	0	0	0	0	6
LW-04	1	0	1	0	1	0	3	0	2	0	0	0	1	0	9
LW-05	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
LW-06	0	0	0	0	1	0	0	0	1	0	0	0	1	0	3
LW-07	1	0	0	0	0	0	0	0	0	2	0	0	0	0	3
LW-08	1	0	1	0	0	0	0	0	0	0	0	0	0	1	3
LW-09	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
LW-11	0	0	1	0	0	0	0	0	0	2	0	0	0	0	3
LW-12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sum	10	6	6	1	7	9	8	2	8	10	1	1	3	1	73

Data set used *Ver12b* (2021-05-18)

pH (rivers)

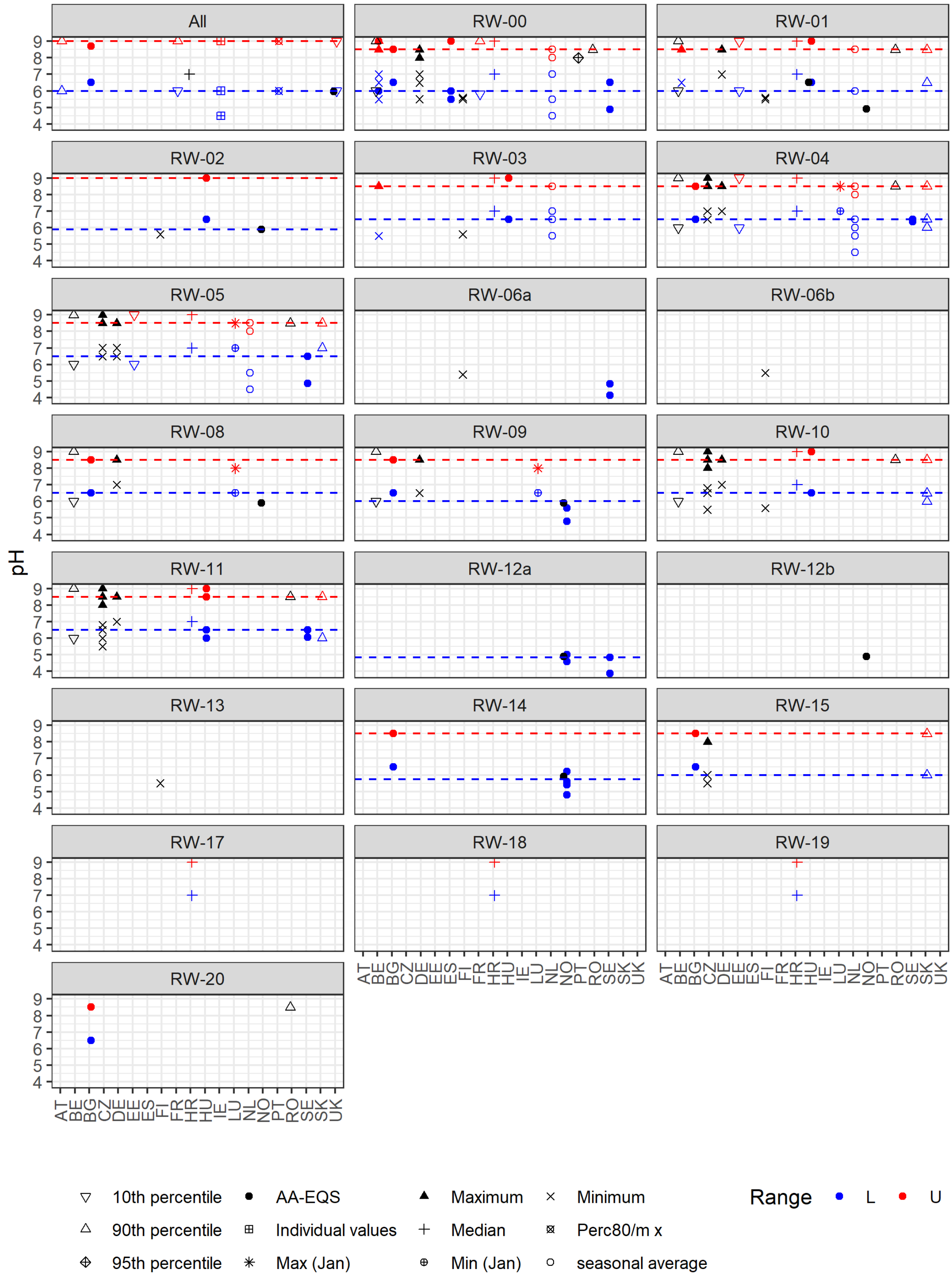

Figure A7 *pH standards by country and broad type (single value black, minimum blue, maximum red). Horizontal dotted lines show the median values for the uppder (red) and lower (blue) groups of standards*

***Table A19** pH metrics used by country*

	10&90thper	10th percentile	90th percentile	95th percentile	AA-EQS	Individual values	MAC-EQS	MaxA	Maximum	Median	Min/Jahr - Max/Jahr	MinA	Minimum	Perc80/m x	seasonal average
AT	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
BE	0	8	8	0	1	0	5	0	0	0	0	0	5	0	0
BG	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0
CZ	0	0	0	0	0	0	0	0	11	0	0	0	13	0	0
DE	0	0	0	0	0	0	0	9	0	0	0	11	0	0	0
EE	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
ES	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
FI	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
FR	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HR	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0
HU	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
IE	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
LU	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
NL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
NO	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0
PT	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0
RO	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
SE	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0
SK	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
UK	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0

Table A20 *records where pH was reported as a value or a range*

Country	value	range
AT		3
BE	66	11
BG		31
CZ	42	
DE	66	
EE		16
ES		35
FI	61	
FR		10
HR	2	28
HU	1	9
IE		6
LU		7
NL		16
NO	36	10
PT	1	10
RO	57	
SE		6
SK		28
UK	4	11

Table A21 *Number of different pH standards by country and broad type*

	AT	BE	BG	CZ	DE	EE	ES	FI	FR	HR	HU	IE	LU	NL	NO	PT	RO	SE	SK	UK	Sum
All	1	0	1	0	0	0	0	0	1	1	0	2	0	0	0	2	0	0	0	2	10
RW-00	0	9	1	0	5	0	2	2	1	1	0	0	0	3	0	1	1	1	0	0	27
RW-01	0	4	0	0	2	1	0	2	0	1	2	0	0	1	1	0	1	0	1	0	16
RW-02	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	3
RW-03	0	2	0	0	0	0	0	1	0	1	1	0	0	3	0	0	0	0	0	0	8
RW-04	0	2	1	4	2	1	0	0	0	1	0	0	1	4	0	0	1	1	2	0	20
RW-05	0	2	0	4	3	1	0	0	0	1	0	0	1	2	0	0	1	1	1	0	17
RW-06a	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	2
RW-06b	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
RW-08	0	2	1	0	2	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	7
RW-09	0	2	1	0	2	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	8
RW-10	0	2	0	6	2	0	0	1	0	1	1	0	0	0	0	0	1	0	2	0	16
RW-11	0	2	0	7	2	0	0	0	0	1	2	0	0	0	0	0	1	1	1	0	17
RW-12a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	3
RW-12b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
RW-13	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
RW-14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	4
RW-15	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5
RW-17	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
RW-18	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
RW-19	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
RW-20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2
Sum	1	27	8	24	20	3	2	10	2	11	7	2	4	13	11	3	7	6	8	2	171

Data set used *Ver12b* (2021-05-18)

BOD

BOD5 concentration (rivers)

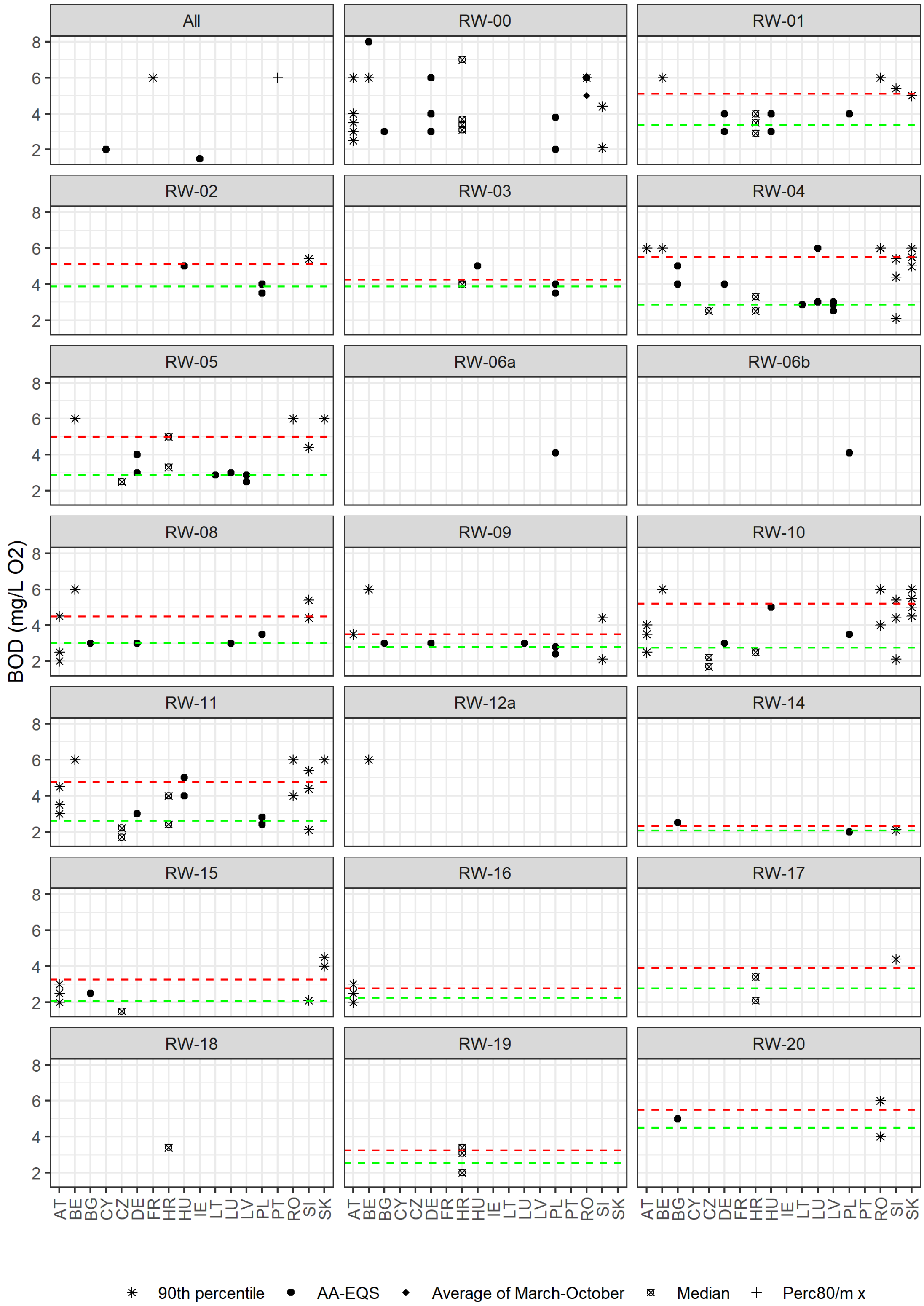

Figure A8 *BOD5 standards by country and broad type (single value black, minimum blue, maximum red)*

Table A22 *BOD5 metrics used by country*

	90th percentile	AA-EQS	Average of March-October	Median	Perc80/m x
AT	22	0	0	0	0
BE	9	1	0	0	0
BG	0	8	0	0	0
CY	0	1	0	0	0
CZ	0	0	0	7	0
DE	0	12	0	0	0
FR	1	0	0	0	0
HR	0	0	0	21	0
HU	0	7	0	0	0
IE	0	1	0	0	0
LT	0	2	0	0	0
LU	0	5	0	0	0
LV	0	5	0	0	0
PL	0	16	0	0	0
PT	0	0	0	0	1
RO	10	1	2	0	0
SI	21	0	0	0	0
SK	12	0	0	0	0

***Table A23** records where BOD5 was reported as a value or a range*

Country	value	range
AT	55	
BE	35	
BG	17	
CY	1	
CZ	21	
DE	31	
FR	9	
HR	28	
HU	10	
IE	3	
LT	5	
LU	7	
LV	23	
PL	65	
PT	8	
RO	71	
SI	74	
SK	27	

Table A24 *Number of different BOD5 standards by country and broad type*

	AT	BE	BG	CY	CZ	DE	FR	HR	HU	IE	LT	LU	LV	PL	PT	RO	SI	SK	Sum
All	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0	0	0	4
RW-00	5	2	1	0	0	3	0	4	0	0	0	0	0	2	0	4	2	0	23
RW-01	0	1	0	0	0	2	0	3	2	0	0	0	0	1	0	1	1	1	12
RW-02	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	1	0	4
RW-03	0	0	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	0	4
RW-04	1	1	2	0	1	1	0	2	0	0	1	2	3	0	0	1	3	3	21
RW-05	0	1	0	0	1	2	0	2	0	0	1	1	2	0	0	1	1	1	13
RW-06a	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
RW-06b	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
RW-08	3	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	2	0	10
RW-09	1	1	1	0	0	1	0	0	0	0	0	1	0	2	0	0	2	0	9
RW-10	3	1	0	0	2	1	0	1	1	0	0	0	0	1	0	2	3	4	19
RW-11	3	1	0	0	2	1	0	2	2	0	0	0	0	2	0	2	3	1	19
RW-12a	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
RW-14	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	3
RW-15	3	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2	8
RW-16	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
RW-17	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	3
RW-18	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
RW-19	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	3
RW-20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3
Sum	22	10	8	1	7	12	1	21	7	1	2	5	5	16	1	13	21	12	165

Data set used *Ver12b* (2021-05-18)

Ammonium-N

Ammonium N concentration (rivers)

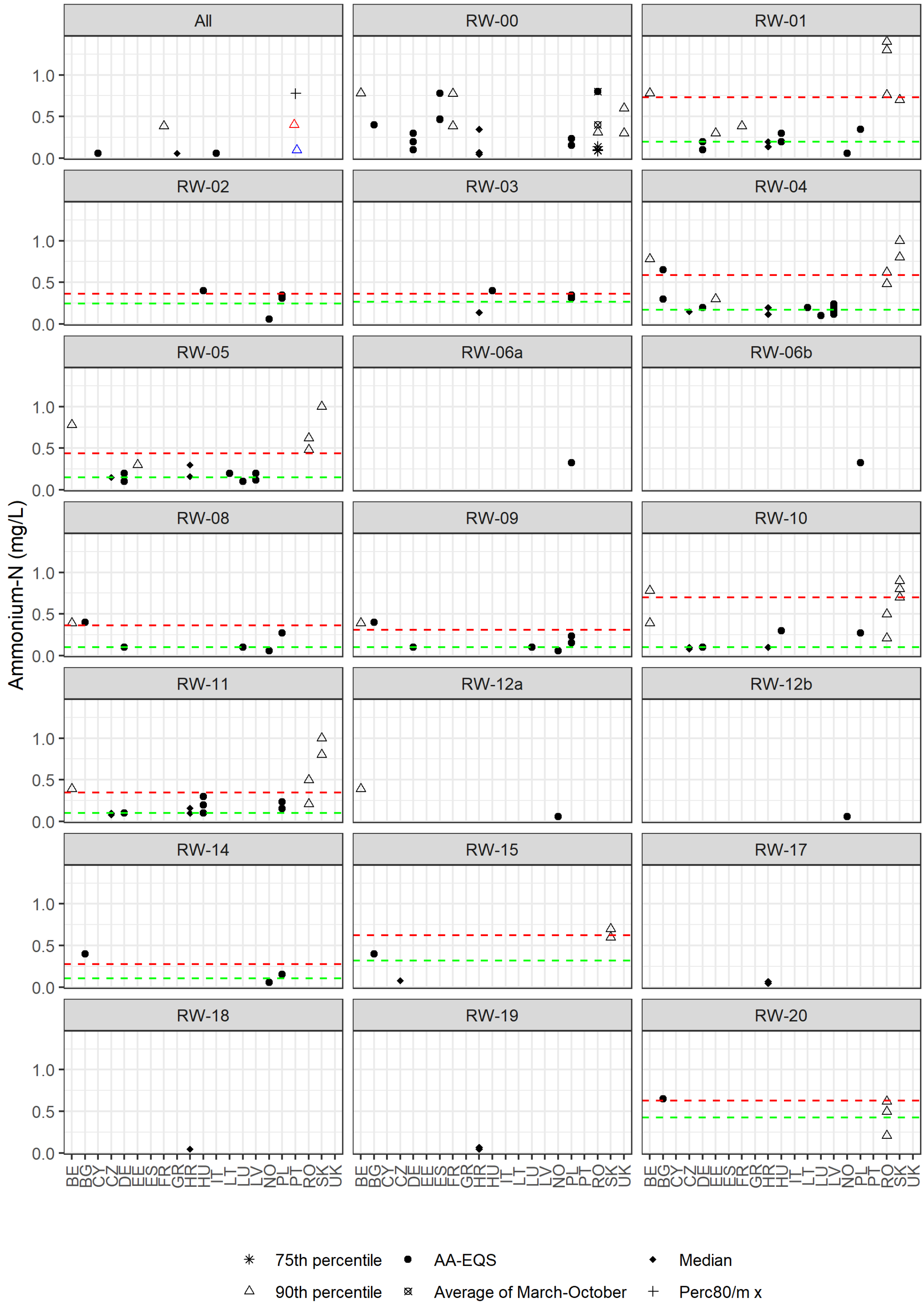

Figure A9 *Ammonium N standards by country and broad type (single value black, minimum blue, maximum red)*

Table A25 *Ammonium N metrics used by country*

	75th percentile	90th percentile	AA-EQS	Average of March-October	Median	Perc80/m x
BE	0	10	0	0	0	0
BG	0	0	8	0	0	0
CY	0	0	1	0	0	0
CZ	0	0	0	0	7	0
DE	0	0	12	0	0	0
EE	0	3	0	0	0	0
ES	0	0	4	0	0	0
FR	0	4	0	0	0	0
GR	0	0	0	0	1	0
HR	0	0	0	0	18	0
HU	0	0	8	0	0	0
IT	0	0	1	0	0	0
LT	0	0	2	0	0	0
LU	0	0	4	0	0	0
LV	0	0	6	0	0	0
NO	0	0	7	0	0	0
PL	0	0	16	0	0	0
PT	0	1	0	0	0	1
RO	3	15	1	2	0	0
SK	0	11	0	0	0	0
UK	0	2	0	0	0	0

Table A26 *records where Ammonium N was reported as a value or a range*

Country	value	range
BE	34	
BG	17	
CY	1	
CZ	21	
DE	35	
EE	16	
ES	32	
FR	10	
GR	1	
HR	28	
HU	10	
IT	1	
LT	5	
LU	7	
LV	23	
NO	13	
PL	65	
PT	8	1
RO	69	
SK	28	
UK	32	

Table A27 *Number of different Ammonium N standards by country and broad type*

	BE	BG	CY	CZ	DE	EE	ES	FR	GR	HR	HU	IT	LT	LU	LV	NO	PL	PT	RO	SK	UK	Sum
All	0	0	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	2	0	0	0	6
RW-00	1	1	0	0	3	0	4	2	0	3	0	0	0	0	0	0	2	0	7	0	2	25
RW-01	1	0	0	0	2	1	0	1	0	2	2	0	0	0	0	1	1	0	3	1	0	15
RW-02	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2	0	0	0	0	4
RW-03	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2	0	0	0	0	4
RW-04	1	2	0	1	1	1	0	0	0	2	0	0	1	1	4	0	0	0	2	2	0	18
RW-05	1	0	0	1	2	1	0	0	0	2	0	0	1	1	2	0	0	0	2	1	0	14
RW-06a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
RW-06b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
RW-08	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	6
RW-09	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	2	0	0	0	0	7
RW-10	2	0	0	2	1	0	0	0	0	1	1	0	0	0	0	0	1	0	2	3	0	13
RW-11	1	0	0	2	1	0	0	0	0	2	3	0	0	0	0	0	2	0	2	2	0	15
RW-12a	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2
RW-12b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
RW-14	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	3
RW-15	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4
RW-17	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
RW-18	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
RW-19	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2
RW-20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	4
Sum	10	8	1	7	12	3	4	4	1	18	8	1	2	4	6	7	16	2	21	11	2	148

Data set used *Ver12b* (2021-05-18)

Nutrients

Nitrate (rivers)

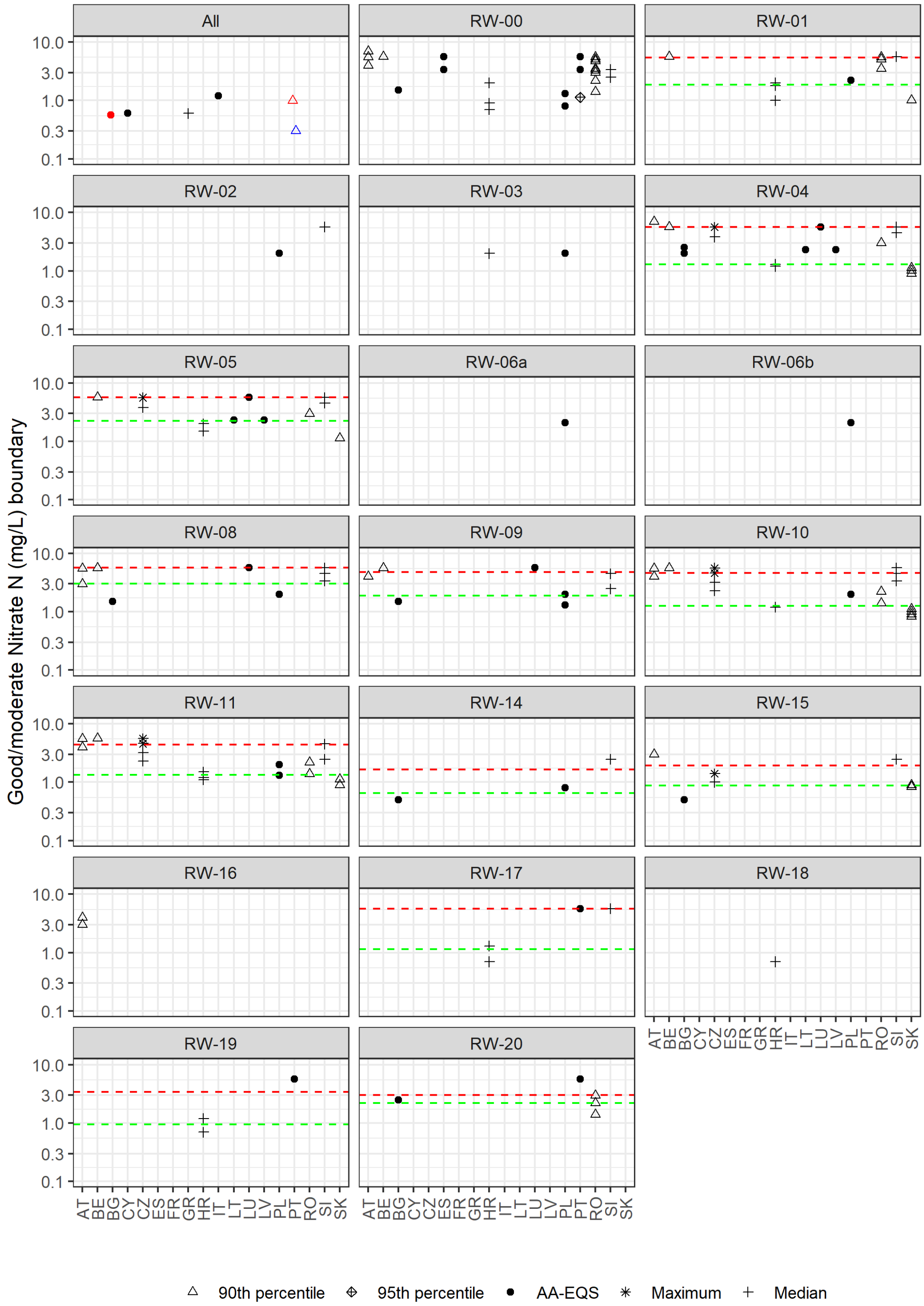

Figure A10 *Nitrate as N standards by country and broad type (single value black, minimum blue, maximum red). Horizontal lines mark 25th (green) and 75th (red) quantiles.*

Table A28 *Nitrate as N metrics used by country*

	90th percentile	95th percentile	AA-EQS	Maximum	Median
AT	14	0	0	0	0
BE	8	0	0	0	0
BG	0	0	9	0	0
CY	0	0	1	0	0
CZ	0	0	0	7	7
ES	0	0	3	0	0
FR	1	0	0	0	0
GR	0	0	0	0	1
HR	0	0	0	0	20
IT	0	0	1	0	0
LT	0	0	2	0	0
LU	0	0	4	0	0
LV	0	0	2	0	0
PL	0	0	14	0	0
PT	1	1	5	0	0
RO	20	0	0	0	0
SI	0	0	0	0	21
SK	13	0	0	0	0

Table A29 *Nitrate as N number of records where standard was reported as a value or a range*

Country	value	range
AT	52	
BE	34	
BG	17	1
CY	1	
CZ	42	
ES	37	
FR	9	
GR	1	
HR	28	
IT	1	
LT	5	
LU	7	
LV	7	
PL	65	
PT	18	1
RO	56	
SI	74	
SK	28	

Table A30 *Number of different Nitrate as N standards by country and broad type*

	AT	BE	BG	CY	CZ	ES	FR	GR	HR	IT	LT	LU	LV	PL	PT	RO	SI	SK	Sum
All	0	0	1	1	0	0	1	1	0	1	0	0	0	0	1	0	0	0	6
RW-00	3	1	1	0	0	3	0	0	3	0	0	0	0	2	3	8	2	0	26
RW-01	0	1	0	0	0	0	0	0	3	0	0	0	0	1	0	3	1	1	10
RW-02	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2
RW-03	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2
RW-04	1	1	2	0	2	0	0	0	2	0	1	1	1	0	0	1	2	3	17
RW-05	0	1	0	0	2	0	0	0	2	0	1	1	1	0	0	1	2	1	12
RW-06a	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
RW-06b	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
RW-08	2	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	3	0	9
RW-09	1	1	1	0	0	0	0	0	0	0	0	1	0	2	0	0	2	0	8
RW-10	2	1	0	0	4	0	0	0	1	0	0	0	0	1	0	2	3	4	18
RW-11	2	1	0	0	4	0	0	0	3	0	0	0	0	2	0	2	2	2	18
RW-14	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	3
RW-15	1	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	1	2	7
RW-16	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
RW-17	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	1	0	4
RW-18	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
RW-19	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	3
RW-20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	5
Sum	14	8	9	1	14	3	1	1	20	1	2	4	2	14	7	20	21	13	155

Data set used *Ver12b* (2021-05-18)

Total Nitrogen (lakes)

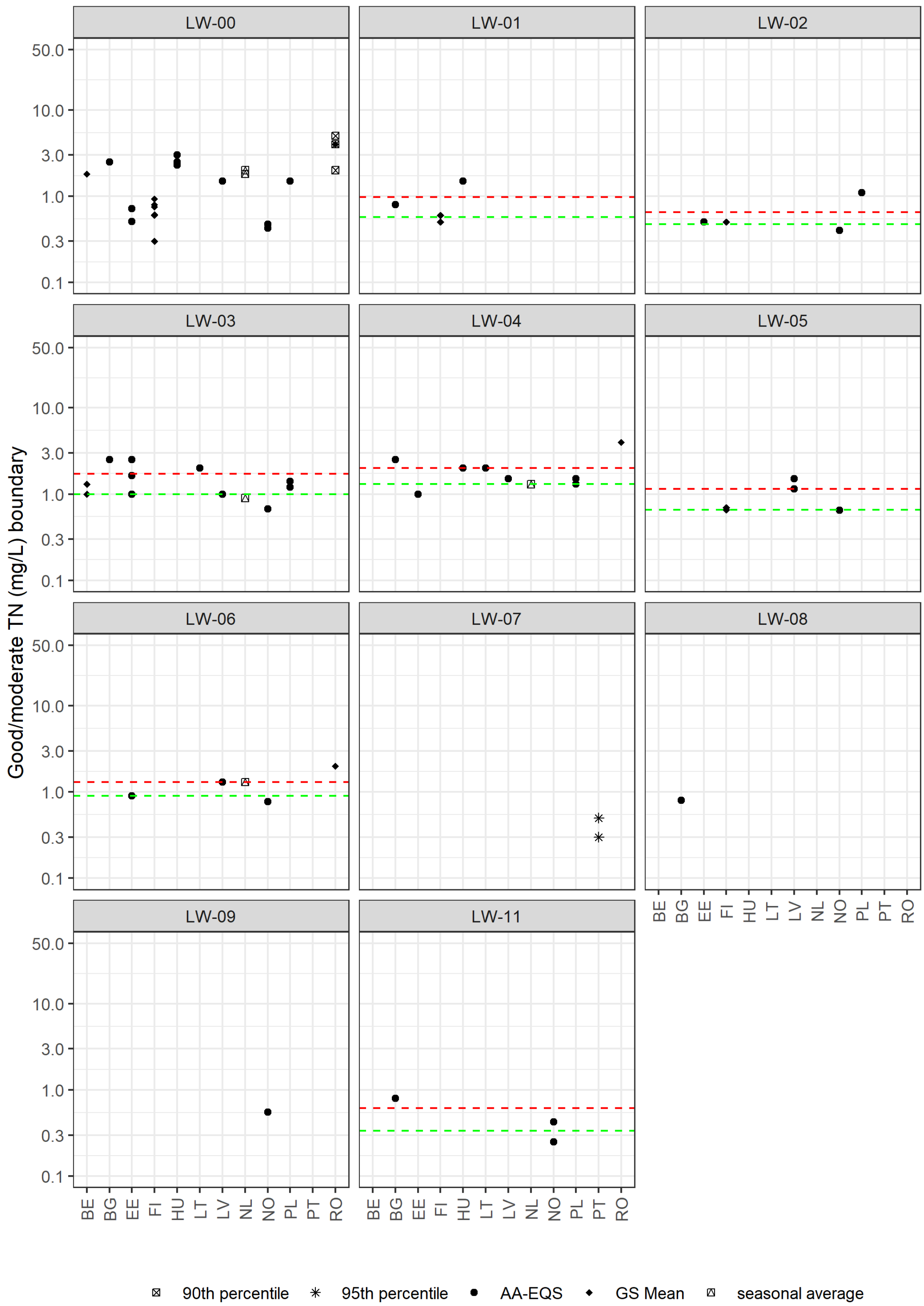

Figure A11 *TN standards by country and broad type (single value black, minimum blue, maximum red). Horizontal lines mark 25th (green) and 75th (red) quantiles.*

Table A31 *TN metrics used by country*

	90th percentile	95th percentile	AA-EQS	GS Mean	seasonal average
BE	0	0	0	3	0
BG	0	0	6	0	0
EE	0	0	8	0	0
FI	0	0	0	11	0
HU	0	0	5	0	0
LT	0	0	2	0	0
LV	0	0	6	0	0
NL	0	0	0	0	5
NO	0	0	9	0	0
PL	0	0	6	0	0
PT	0	2	0	0	0
RO	3	0	0	3	0

Table A32 *TN number of records where standard was reported as a value or a range*

Country	value	range
BE	4	
BG	18	
EE	15	
FI	197	
HU	7	
LT	6	
LV	26	
NL	9	
NO	13	
PL	23	
PT	2	
RO	15	

Table A33 *Number of different TN standards by country and broad type*

	BE	BG	EE	FI	HU	LT	LV	NL	NO	PL	PT	RO	Sum
LW-00	1	1	2	6	3	0	1	2	2	1	0	4	23
LW-01	0	1	0	2	1	0	0	0	0	0	0	0	4
LW-02	0	0	1	1	0	0	0	0	1	1	0	0	4
LW-03	2	1	3	0	0	1	1	1	1	2	0	0	12
LW-04	0	1	1	0	1	1	1	1	0	2	0	1	9
LW-05	0	0	0	2	0	0	2	0	1	0	0	0	5
LW-06	0	0	1	0	0	0	1	1	1	0	0	1	5
LW-07	0	0	0	0	0	0	0	0	0	0	2	0	2
LW-08	0	1	0	0	0	0	0	0	0	0	0	0	1
LW-09	0	0	0	0	0	0	0	0	1	0	0	0	1
LW-11	0	1	0	0	0	0	0	0	2	0	0	0	3
Sum	3	6	8	11	5	2	6	5	9	6	2	6	69

Data set used *Ver12b* (2021-05-18)

Total Nitrogen (rivers)

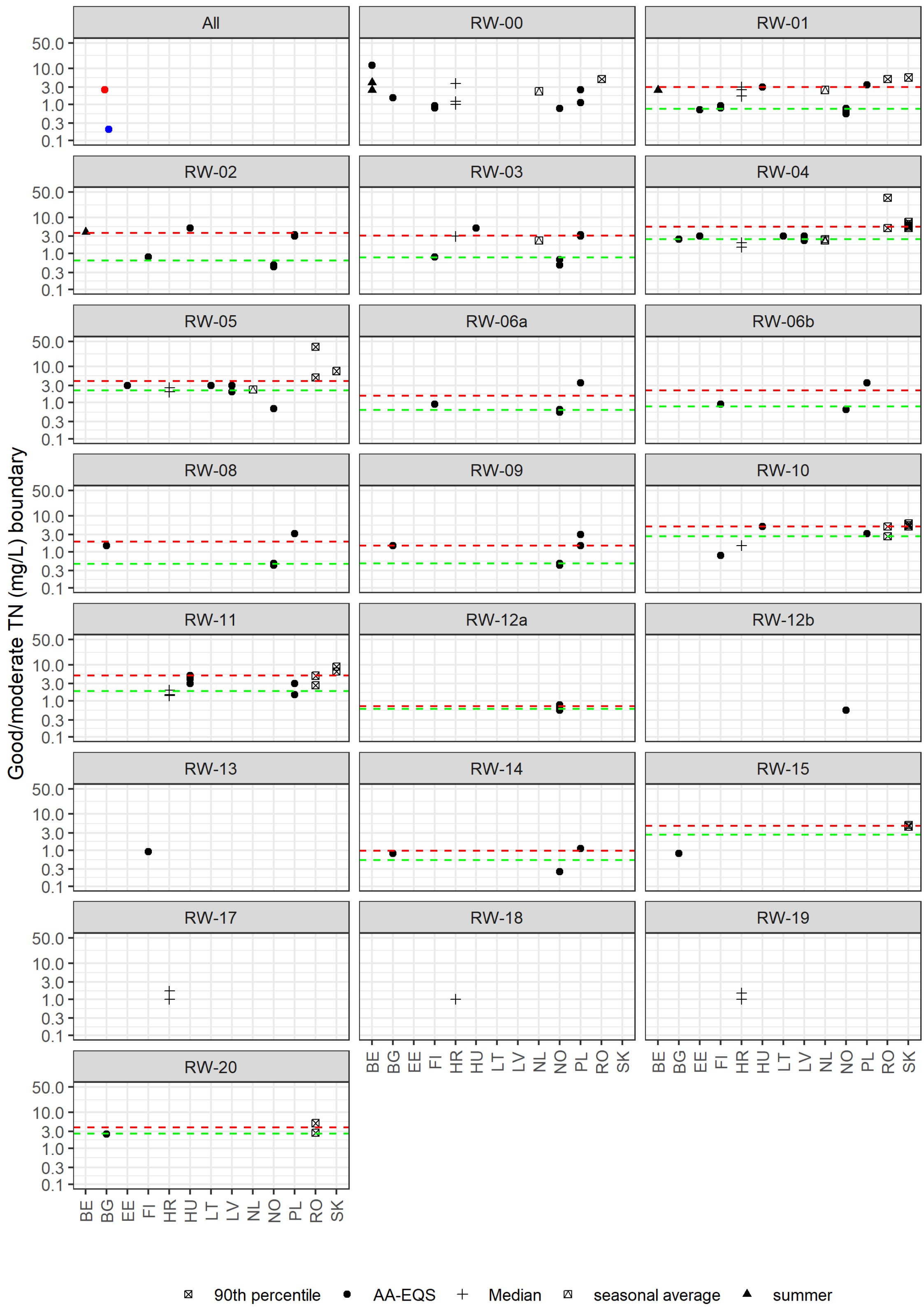

Figure A12 *TN standards by country and broad type (single value black, minimum blue, maximum red). Horizontal lines mark 25th (green) and 75th (red) quantiles.*

Table A34 *TN metrics used by country*

	90th percentile	AA-EQS	Median	seasonal average	summer
BE	0	1	0	0	4
BG	0	8	0	0	0
EE	0	3	0	0	0
FI	0	10	0	0	0
HR	0	0	20	0	0
HU	0	7	0	0	0
LT	0	2	0	0	0
LV	0	5	0	0	0
NL	0	0	0	6	0
NO	0	22	0	0	0
PL	0	16	0	0	0
RO	12	0	0	0	0
SK	14	0	0	0	0

Table A35 *TN number of records where standard was reported as a value or a range*

Country	value	range
BE	5	
BG	17	1
EE	16	
FI	61	
HR	28	
HU	10	
LT	10	
LV	23	
NL	14	
NO	75	
PL	65	
RO	57	
SK	28	

Table A36 *Number of different TN standards by country and broad type*

	BE	BG	EE	FI	HR	HU	LT	LV	NL	NO	PL	RO	SK	Sum
All	0	1	0	0	0	0	0	0	0	0	0	0	0	1
RW-00	3	1	0	2	3	0	0	0	1	1	2	1	0	14
RW-01	1	0	1	2	3	1	0	0	1	4	1	1	1	16
RW-02	1	0	0	1	0	1	0	0	0	2	2	0	0	7
RW-03	0	0	0	1	1	1	0	0	1	2	2	0	0	8
RW-04	0	1	1	0	2	0	1	3	2	0	0	2	5	17
RW-05	0	0	1	0	2	0	1	2	1	1	0	2	1	11
RW-06a	0	0	0	1	0	0	0	0	0	2	1	0	0	4
RW-06b	0	0	0	1	0	0	0	0	0	1	1	0	0	3
RW-08	0	1	0	0	0	0	0	0	0	2	1	0	0	4
RW-09	0	1	0	0	0	0	0	0	0	2	2	0	0	5
RW-10	0	0	0	1	1	1	0	0	0	0	1	2	3	9
RW-11	0	0	0	0	3	3	0	0	0	0	2	2	2	12
RW-12a	0	0	0	0	0	0	0	0	0	3	0	0	0	3
RW-12b	0	0	0	0	0	0	0	0	0	1	0	0	0	1
RW-13	0	0	0	1	0	0	0	0	0	0	0	0	0	1
RW-14	0	1	0	0	0	0	0	0	0	1	1	0	0	3
RW-15	0	1	0	0	0	0	0	0	0	0	0	0	2	3
RW-17	0	0	0	0	2	0	0	0	0	0	0	0	0	2
RW-18	0	0	0	0	1	0	0	0	0	0	0	0	0	1
RW-19	0	0	0	0	2	0	0	0	0	0	0	0	0	2
RW-20	0	1	0	0	0	0	0	0	0	0	0	2	0	3
Sum	5	8	3	10	20	7	2	5	6	22	16	12	14	130

Data set used *Ver12b* (2021-05-18)

Orthophosphate (Rivers)

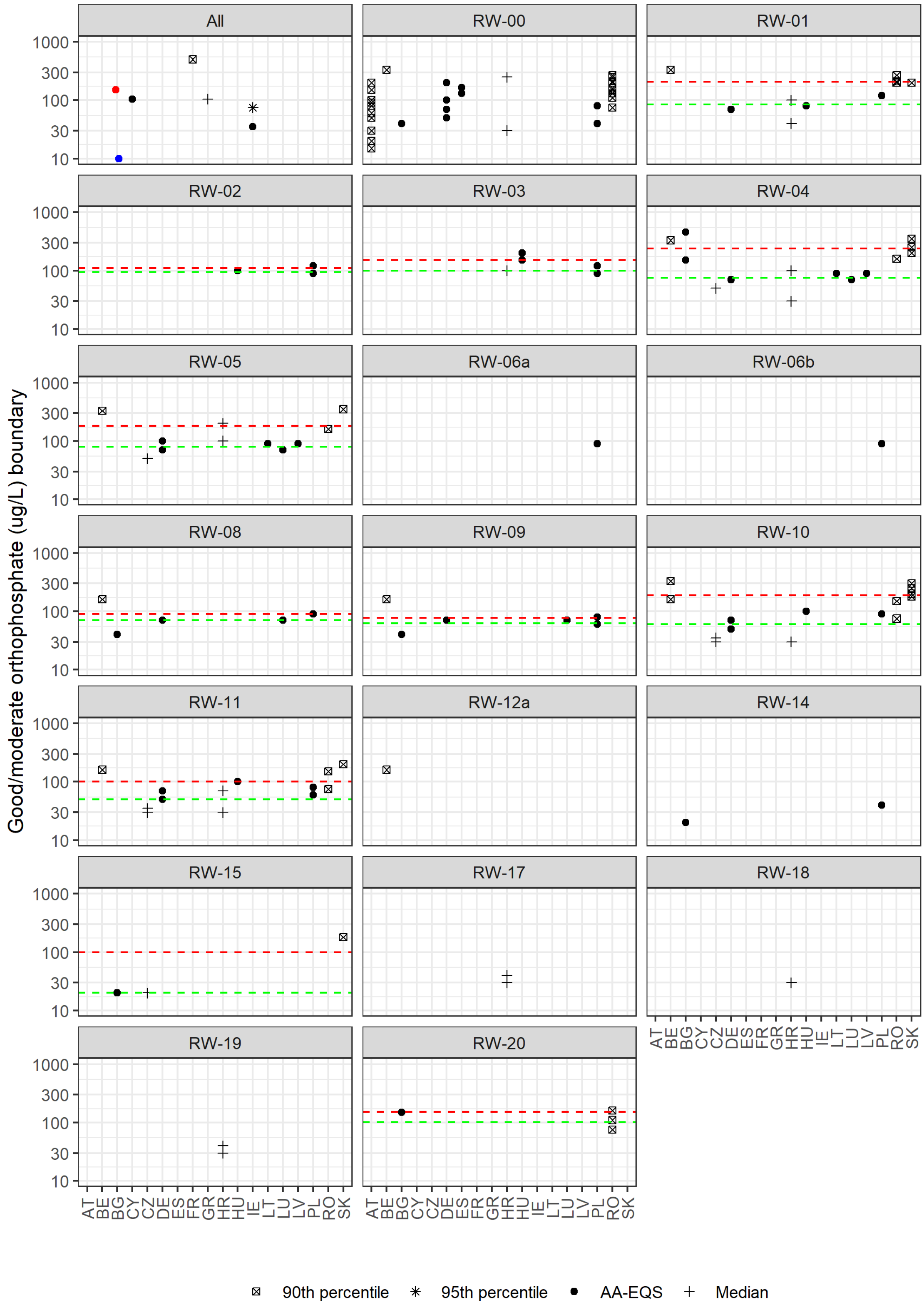

***Figure A13** Orthophosphate standards by country and broad type (single value black, minimum blue, maximum red). Horizontal lines mark 25th (green) and 75th (red) quantiles.*

***Table A37** Orthophosphate metrics used by country*

	90th percentile	95th percentile	AA-EQS	Median
AT	10	0	0	0
BE	10	0	0	0
BG	0	0	9	0
CY	0	0	1	0
CZ	0	0	0	7
DE	0	0	14	0
ES	0	0	2	0
FR	1	0	0	0
GR	0	0	0	1
HR	0	0	0	17
HU	0	0	6	0
IE	0	1	1	0
LT	0	0	2	0
LU	0	0	4	0
LV	0	0	2	0
PL	0	0	16	0
RO	21	0	0	0
SK	11	0	0	0

Table A38 *Orthophosphate number of records where standard was reported as a value or a range*

Country	value	range
AT	45	
BE	34	
BG	17	1
CY	1	
CZ	21	
DE	31	
ES	35	
FR	9	
GR	2	
HR	28	
HU	10	
IE	6	
LT	10	
LU	7	
LV	7	
PL	65	
RO	48	
SK	27	

Table A39 *Number of different Orthophosphate standards by country and broad type*

	AT	BE	BG	CY	CZ	DE	ES	FR	GR	HR	HU	IE	LT	LU	LV	PL	RO	SK	Sum
All	0	0	1	1	0	0	0	1	1	0	0	2	0	0	0	0	0	0	6
RW-00	10	1	1	0	0	4	2	0	0	2	0	0	0	0	0	2	9	0	31
RW-01	0	1	0	0	0	1	0	0	0	2	1	0	0	0	0	1	3	1	10
RW-02	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	3
RW-03	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	2	0	0	5
RW-04	0	1	2	0	1	1	0	0	0	2	0	0	1	1	1	0	1	3	14
RW-05	0	1	0	0	1	2	0	0	0	2	0	0	1	1	1	0	1	1	11
RW-06a	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
RW-06b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
RW-08	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	5
RW-09	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	2	0	0	6
RW-10	0	2	0	0	2	2	0	0	0	1	1	0	0	0	0	1	2	4	15
RW-11	0	1	0	0	2	2	0	0	0	2	1	0	0	0	0	2	2	1	13
RW-12a	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
RW-14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
RW-15	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3
RW-17	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
RW-18	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
RW-19	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2
RW-20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	4
Sum	10	10	9	1	7	14	2	1	1	17	6	2	2	4	2	16	21	11	136

Data set used *Ver12b* (2021-05-18)

Total phosphorus (lakes)

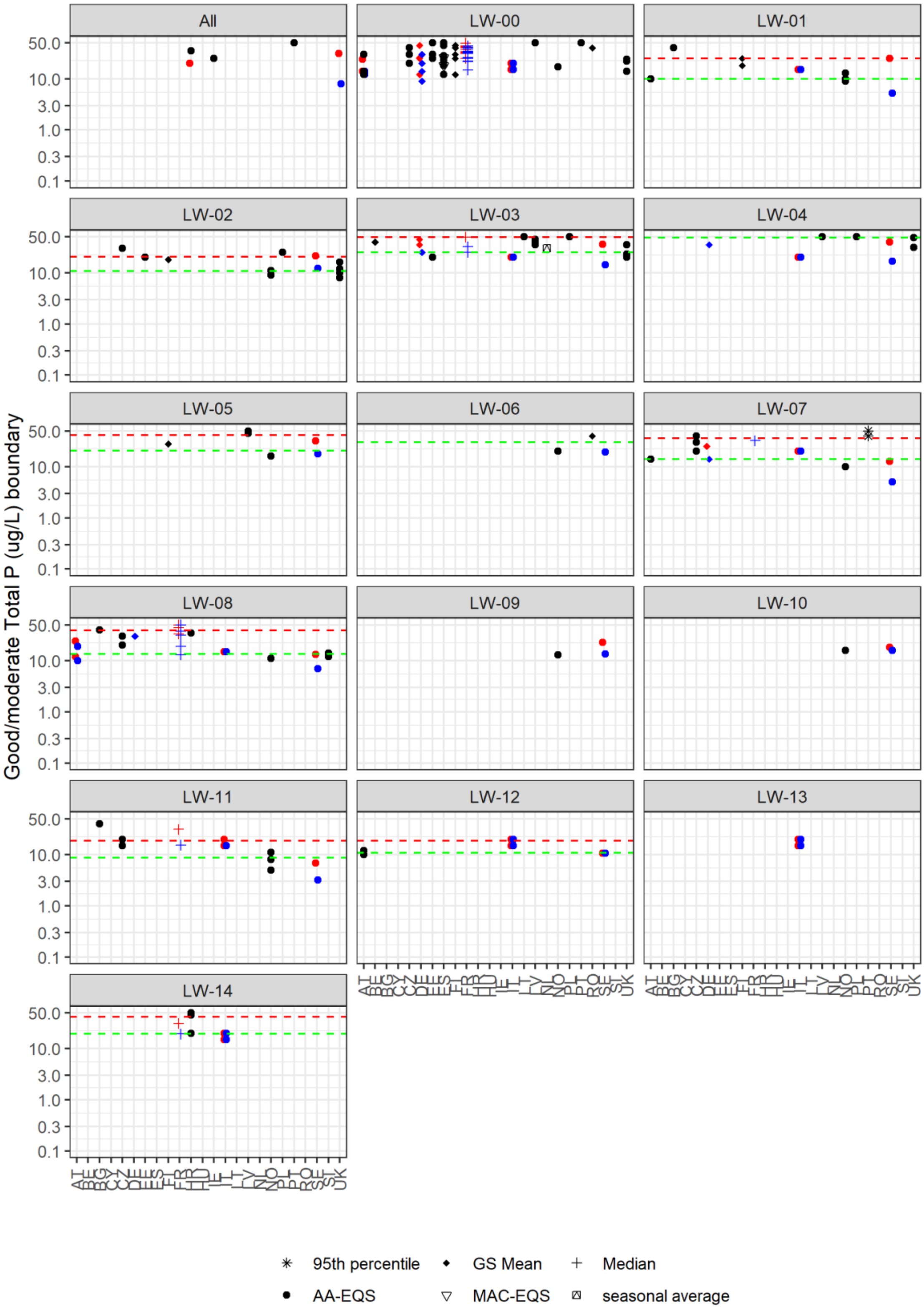

Figure A14 *TP standards by country and broad type (single value black, minimum blue, maximum red). Horizontal lines mark 25th (green) and 75th (red) quantiles.*

***Table A40** TP metrics used by country*

	95th percentile	AA-EQS	GS Mean	MAC-EQS	Median	seasonal average
AT	0	12	0	0	0	0
BE	0	0	5	0	0	0
BG	0	6	0	0	0	0
CY	0	1	0	0	0	0
CZ	0	12	0	0	0	0
DE	0	0	10	0	0	0
EE	0	8	0	0	0	0
ES	0	11	0	2	0	0
FI	0	0	10	0	0	0
FR	0	0	0	0	30	0
HR	0	7	0	0	0	0
HU	0	6	0	0	0	0
IE	0	1	0	0	0	0
IT	0	17	0	0	0	0
LT	0	2	0	0	0	0
LV	0	8	0	0	0	0
NL	0	0	0	0	0	6
NO	0	15	0	0	0	0
PL	0	6	0	0	0	0
PT	2	4	0	0	0	0
RO	0	0	12	0	0	0
SE	0	12	0	0	0	0
SI	0	2	0	0	0	0
UK	0	13	0	0	0	0

Table A41 *TP number of records where standard was reported as a value or a range*

Country	value	range
AT	8	4
BE	6	
BG	18	
CY	1	
CZ	16	
DE		14
EE	16	
ES	28	
FI	197	
FR		30
HR	7	1
HU	7	
IE	3	
IT		21
LT	3	
LV	26	
NL	9	
NO	66	
PL	23	
PT	11	
RO	15	
SE		12
SI	2	
UK	319	3

Table A42 *Number of different TP standards by country and broad type*

	AT	BE	BG	CY	CZ	DE	EE	ES	FI	FR	HR	HU	IE	IT	LT	LV	NL	NO	PL	PT	RO	SE	SI	UK	Sum
All	0	0	0	1	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	2	0	0	0	1	7
LW-00	5	2	1	0	4	4	3	13	6	20	0	3	0	3	0	1	2	1	1	2	8	0	0	3	82
LW-01	1	0	1	0	0	0	0	0	2	0	0	1	0	1	0	0	0	3	0	0	0	1	0	0	10
LW-02	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	2	1	0	0	1	0	4	11
LW-03	0	2	1	0	0	2	2	0	0	2	0	0	0	1	1	3	1	0	2	0	0	1	0	3	21
LW-04	1	1	1	0	0	2	1	0	0	0	0	2	0	1	1	1	2	0	2	0	3	1	0	2	21
LW-05	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	1	0	0	0	1	0	0	5
LW-06	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	6
LW-07	1	0	0	0	3	1	0	0	0	1	0	0	0	1	0	0	0	1	0	2	0	1	0	0	11
LW-08	2	0	1	0	2	1	0	0	0	5	1	0	0	1	0	0	0	1	0	0	0	1	2	0	17
LW-09	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2
LW-10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2
LW-11	0	0	1	0	2	0	0	0	0	1	0	0	0	2	0	0	0	3	0	0	0	1	0	0	10
LW-12	2	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	6
LW-13	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
LW-14	0	0	0	0	0	0	0	0	0	1	4	0	0	2	0	0	0	0	0	0	0	0	0	0	7
Sum	12	5	6	1	12	10	8	13	10	30	7	6	1	17	2	8	6	15	6	6	12	12	2	13	220

Data set used *Ver12b* (2021-05-18)

Total P (rivers)

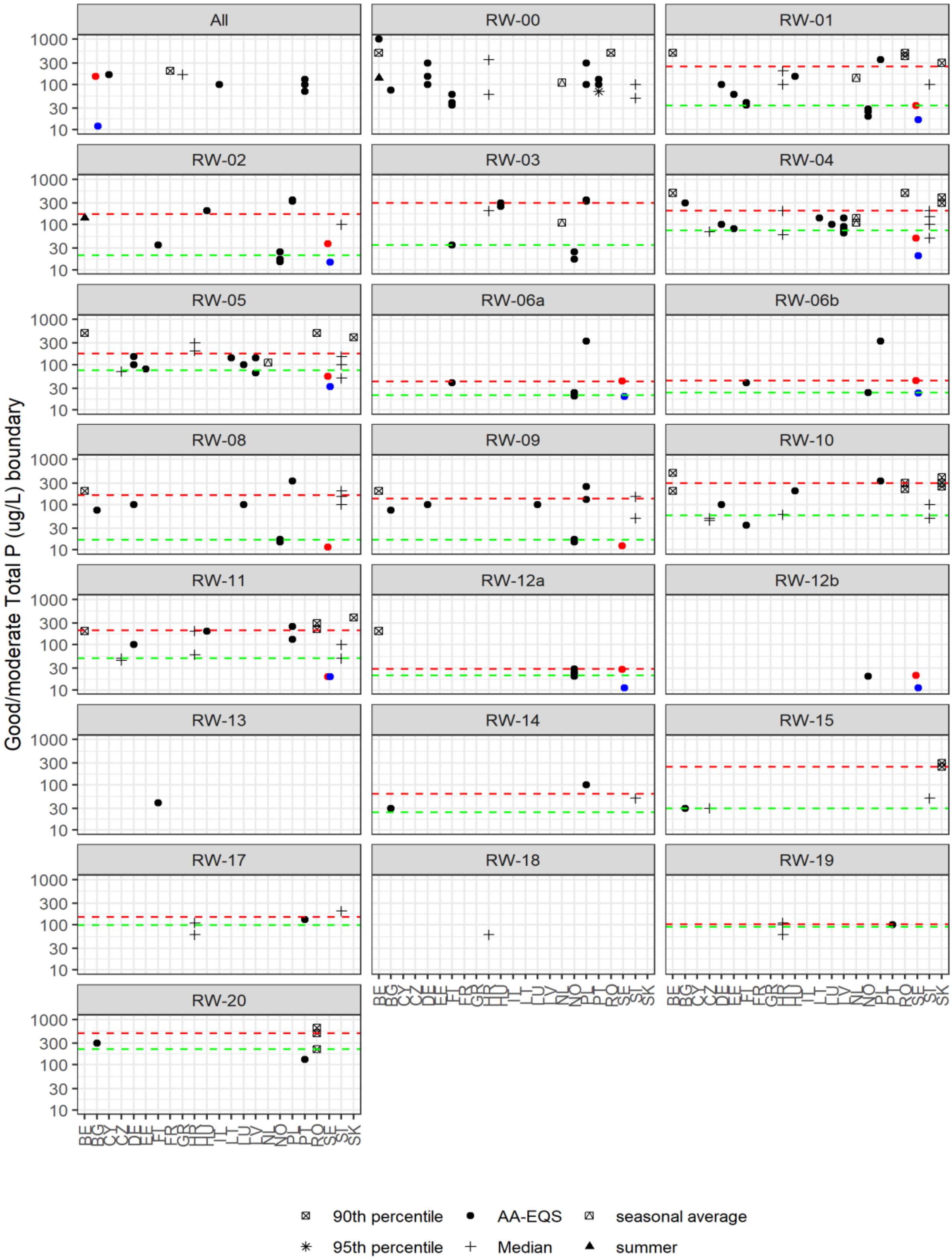

Figure A15 *TP standards by country and broad type (single value black, minimum blue, maximum red). Horizontal lines mark 25th (green) and 75th (red) quantiles.*

Table A43 *TP metrics used by country*

	90th percentile	95th percentile	AA-EQS	Median	seasonal average	summer
BE	10	0	1	0	0	2
BG	0	0	8	0	0	0
CY	0	0	1	0	0	0
CZ	0	0	0	7	0	0
DE	0	0	11	0	0	0
EE	0	0	3	0	0	0
FI	0	0	11	0	0	0
FR	1	0	0	0	0	0
GR	0	0	0	1	0	0
HR	0	0	0	18	0	0
HU	0	0	6	0	0	0
IT	0	0	1	0	0	0
LT	0	0	2	0	0	0
LU	0	0	4	0	0	0
LV	0	0	6	0	0	0
NL	0	0	0	0	6	0
NO	0	0	20	0	0	0
PL	0	0	16	0	0	0
PT	0	1	8	0	0	0
RO	12	0	0	0	0	0
SE	0	0	11	0	0	0
SI	0	0	0	23	0	0
SK	10	0	0	0	0	0

Table A44 *TP number of records where standard was reported as a value or a range*

Country	value	range
BE	37	
BG	17	1
CY	1	
CZ	21	
DE	28	
EE	16	
FI	70	
FR	9	
GR	1	
HR	28	
HU	10	
IT	1	
LT	5	
LU	7	
LV	23	
NL	14	
NO	69	
PL	65	
PT	24	
RO	55	
SE		11
SI	74	
SK	28	

***Table A45** Number of different TP standards by country and broad type*

	BE	BG	CY	CZ	DE	EE	FI	FR	GR	HR	HU	IT	LT	LU	LV	NL	NO	PL	PT	RO	SE	SI	SK	Sum
All	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	3	0	0	0	0	8
RW-00	3	1	0	0	3	0	3	0	0	2	0	0	0	0	0	1	0	2	3	1	0	2	0	21
RW-01	1	0	0	0	1	1	2	0	0	2	1	0	0	0	0	1	3	1	0	2	1	1	1	18
RW-02	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	3	2	0	0	1	1	0	10
RW-03	0	0	0	0	0	0	1	0	0	1	2	0	0	0	0	1	2	2	0	0	0	0	0	9
RW-04	1	1	0	1	1	1	0	0	0	2	0	0	1	1	4	2	0	0	0	1	1	4	2	23
RW-05	1	0	0	1	2	1	0	0	0	2	0	0	1	1	2	1	0	0	0	1	1	3	1	18
RW-06a	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	1	0	0	1	0	0	5
RW-06b	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	4
RW-08	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2	1	0	0	1	3	0	11
RW-09	1	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2	2	0	0	1	2	0	11
RW-10	2	0	0	2	1	0	1	0	0	1	1	0	0	0	0	0	0	1	0	2	0	2	3	16
RW-11	1	0	0	2	1	0	0	0	0	2	1	0	0	0	0	0	0	2	0	2	1	2	1	15
RW-12a	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	5
RW-12b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2
RW-13	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
RW-14	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	0	4
RW-15	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	5
RW-17	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	1	0	4
RW-18	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
RW-19	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0	0	4
RW-20	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	5
Sum	13	8	1	7	11	3	11	1	1	18	6	1	2	4	6	6	20	16	9	12	11	23	10	200

Data set used *Ver12b* (2021-05-18)

Salinity

Chloride concentration (rivers)

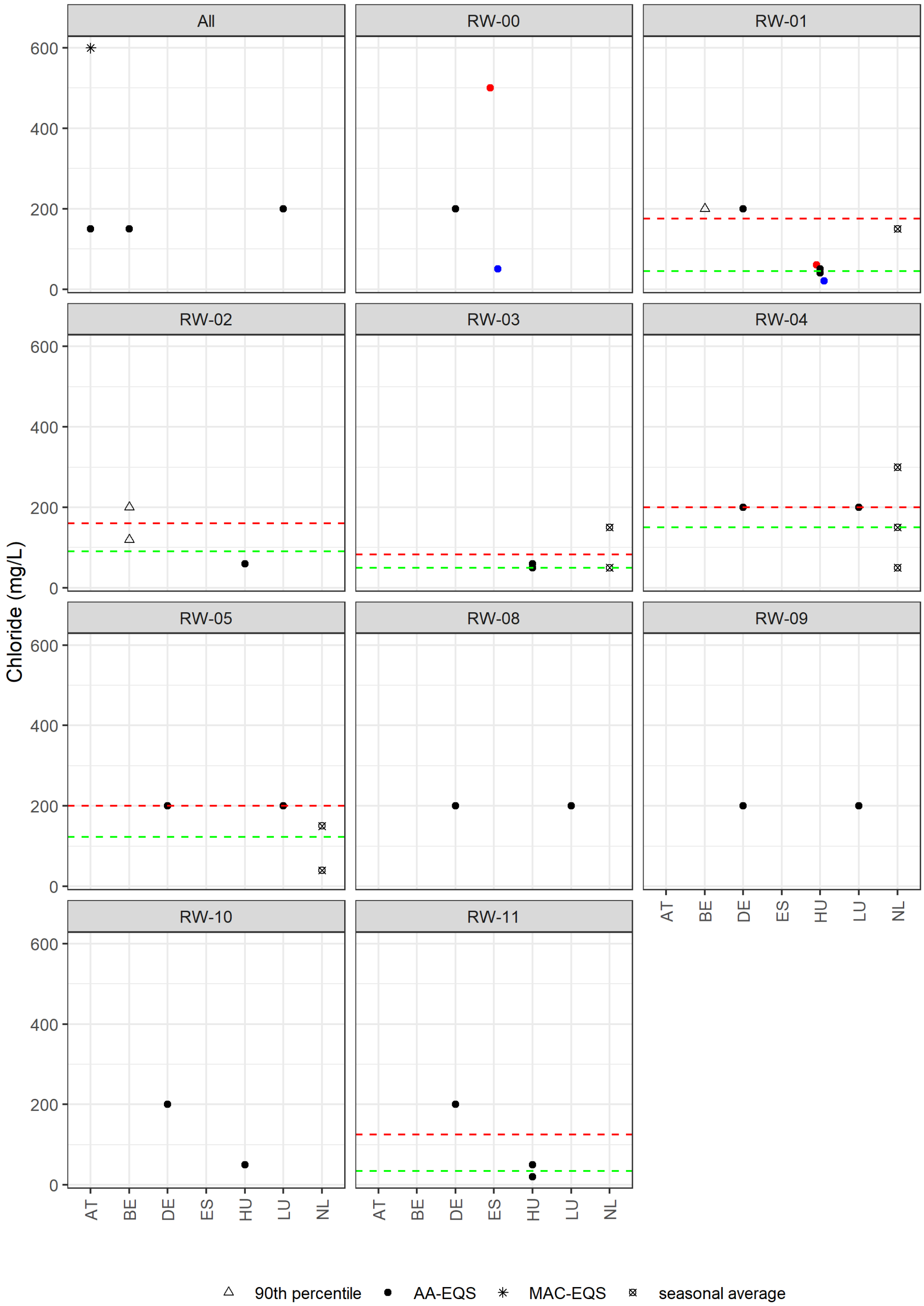

Figure A16 *Chloride standards by country and broad type (single value black, minimum blue, maximum red)*

Table A46 *Chloride metrics used by country*

	90th percentile	AA-EQS	MAC-EQS	seasonal average
AT	0	1	1	0
BE	3	1	0	0
DE	0	8	0	0
ES	0	1	0	0
HU	0	9	0	0
LU	0	5	0	0
NL	0	0	0	8

Table A47 *records where Chloride was reported as a value or a range*

Country	value	range
AT	6	
BE	8	
DE	26	
ES		1
HU	9	1
LU	9	
NL	246	

Table A48 *Number of different Chloride standards by country and broad type*

	AT	BE	DE	ES	HU	LU	NL	Sum
All	2	1	0	0	0	1	0	4
RW-00	0	0	1	1	0	0	0	2
RW-01	0	1	1	0	3	0	1	6
RW-02	0	2	0	0	1	0	0	3
RW-03	0	0	0	0	2	0	2	4
RW-04	0	0	1	0	0	1	3	5
RW-05	0	0	1	0	0	1	2	4
RW-08	0	0	1	0	0	1	0	2
RW-09	0	0	1	0	0	1	0	2
RW-10	0	0	1	0	1	0	0	2
RW-11	0	0	1	0	2	0	0	3
Sum	2	4	8	1	9	5	8	37

Data set used *Ver12b* (2021-05-18)

Conductivity (rivers)

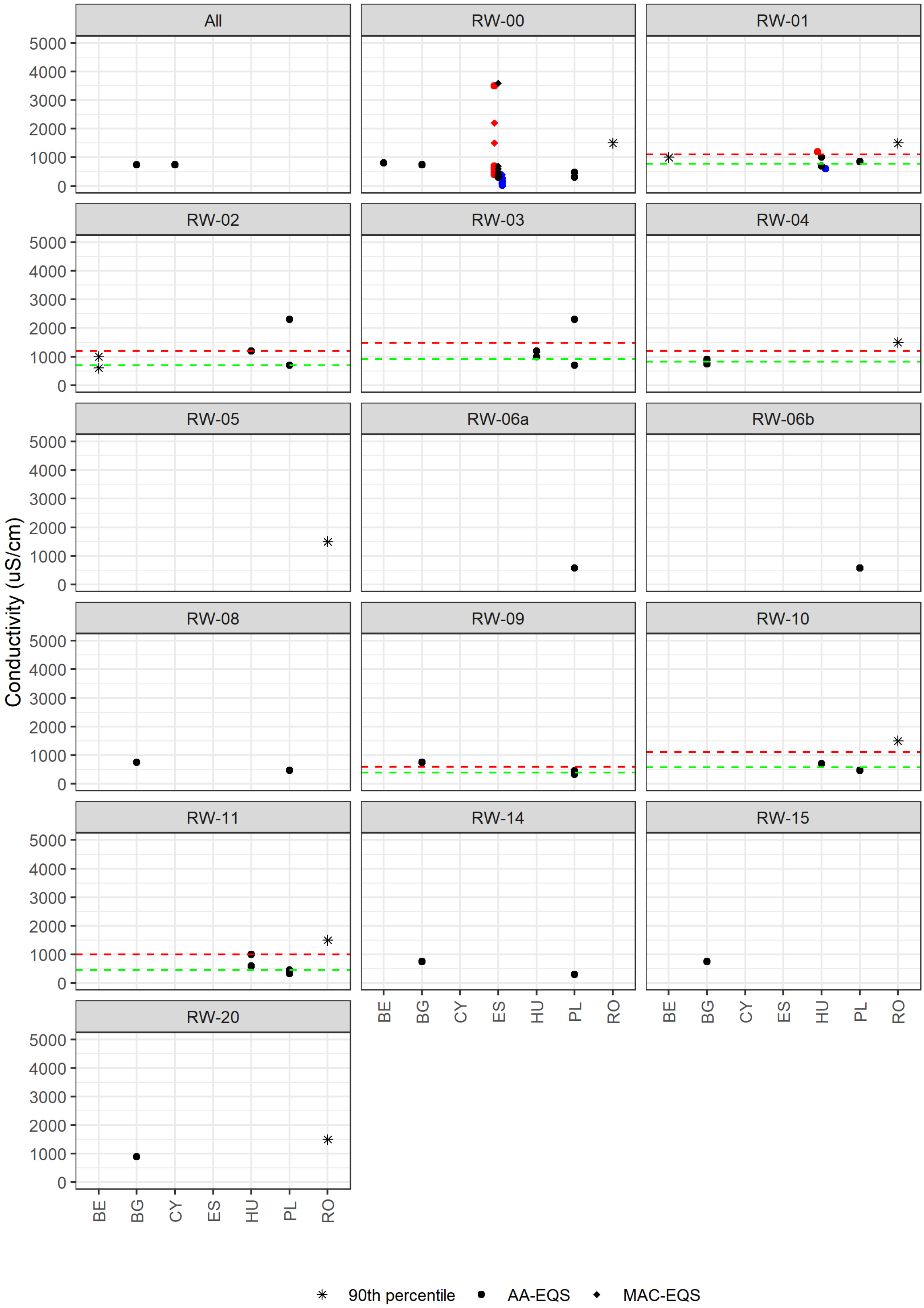

Figure A17 *Conductivity standards by country and broad type (single value black, minimum blue, maximum red) (scale excludes one extreme value (60,000 us/cm ES) for clarity*

Table A49 *Conductivity metrics used by country*

	90th percentile	AA-EQS	MAC-EQS
BE	3	1	0
BG	0	9	0
CY	0	1	0
ES	0	8	9
HU	0	9	0
PL	0	16	0
RO	7	0	0

Table A50 *records where Conductivity was reported as a value or a range*

Country	value	range
BE	5	
BG	31	
CY	1	
ES	27	12
HU	9	1
PL	65	
RO	57	

Table A51 *Number of different Conductivity standards by country and broad type*

	BE	BG	CY	ES	HU	PL	RO	Sum
All	0	1	1	0	0	0	0	2
RW-00	1	1	0	17	0	2	1	22
RW-01	1	0	0	0	3	1	1	6
RW-02	2	0	0	0	1	2	0	5
RW-03	0	0	0	0	2	2	0	4
RW-04	0	2	0	0	0	0	1	3
RW-05	0	0	0	0	0	0	1	1
RW-06a	0	0	0	0	0	1	0	1
RW-06b	0	0	0	0	0	1	0	1
RW-08	0	1	0	0	0	1	0	2
RW-09	0	1	0	0	0	2	0	3
RW-10	0	0	0	0	1	1	1	3
RW-11	0	0	0	0	2	2	1	5
RW-14	0	1	0	0	0	1	0	2
RW-15	0	1	0	0	0	0	0	1
RW-20	0	1	0	0	0	0	1	2
Sum	4	9	1	17	9	16	7	63

Data set used *Ver12b* (2021-05-18)

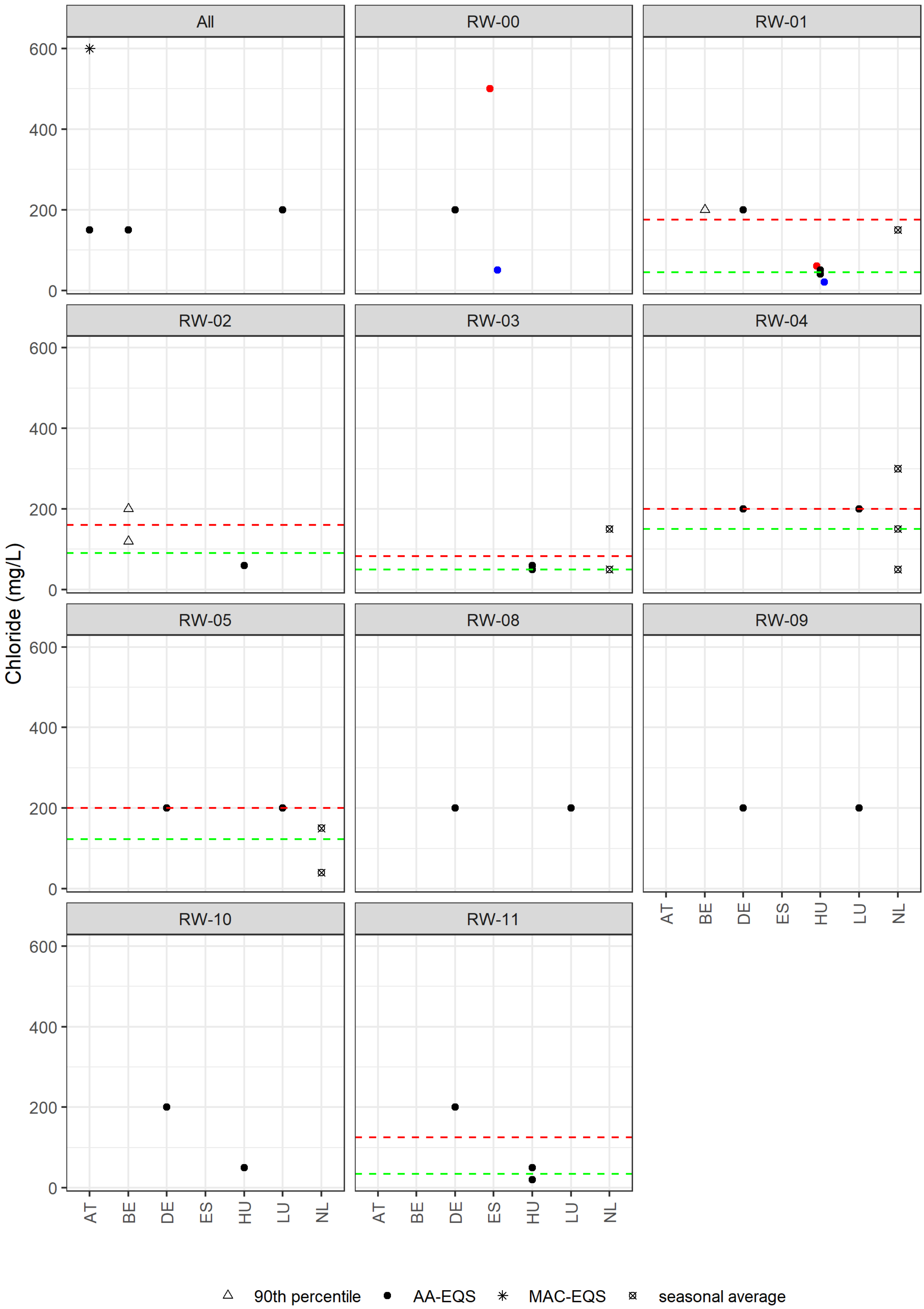

Figure A16 *Chloride standards by country and broad type (single value black, minimum blue, maximum red)*

Table A46 *Chloride metrics used by country*

	90th percentile	AA-EQS	MAC-EQS	seasonal average
AT	0	1	1	0
BE	3	1	0	0
DE	0	8	0	0
ES	0	1	0	0
HU	0	9	0	0
LU	0	5	0	0
NL	0	0	0	8

Table A47 *records where Chloride was reported as a value or a range*

Country	value	range
AT	6	
BE	8	
DE	26	
ES		1
HU	9	1
LU	9	
NL	246	

Table A48 *Number of different Chloride standards by country and broad type*

	AT	BE	DE	ES	HU	LU	NL	Sum
All	2	1	0	0	0	1	0	4
RW-00	0	0	1	1	0	0	0	2
RW-01	0	1	1	0	3	0	1	6
RW-02	0	2	0	0	1	0	0	3
RW-03	0	0	0	0	2	0	2	4
RW-04	0	0	1	0	0	1	3	5
RW-05	0	0	1	0	0	1	2	4
RW-08	0	0	1	0	0	1	0	2
RW-09	0	0	1	0	0	1	0	2
RW-10	0	0	1	0	1	0	0	2
RW-11	0	0	1	0	2	0	0	3
Sum	2	4	8	1	9	5	8	37

Data set used *Ver12b* (2021-05-18)

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