

Phosphorus as a supporting element for the Water Framework Directive

How do we establish appropriate boundaries that effectively underpin water quality management?

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Outline

- Background on use of supporting elements for the Water Framework Directive
- Brief summary of range of Member State river P standards (ECOSTAT project)
- Explanation of approach used to set river phosphorus standards in UK
 - 1st and 2nd river basin planning cycle standards
- Highlight uncertainty associated with pressure response relationships
- Difficulty of establishing values that are no more and no less stringent than required by the WFD

Views expressed are those of the authors and do not necessarily reflect those of the UK environment agencies, who sponsored this work and provided the data used.

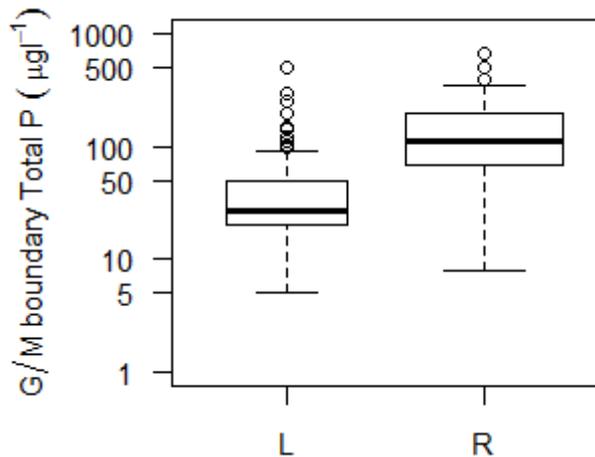
WFD Annex V

Quality Element: Nutrient conditions

- Part of the assessment of Ecological Status
 - *chemical and physico-chemical elements supporting the biological status*
- High status: *Nutrient concentrations remain within the range normally associated with undisturbed conditions*
- Good status: *nutrient concentrations do not exceed the levels established so as to ensure the functioning of the ecosystem and the achievement of the values specified for the biological quality elements*

- The WFD stipulates (Annex V section 1.4.2) that the worst of biology or supporting element should be used to determine ecological status
- The classification guidance section 4.2 makes it clear that supporting elements are likely to be type specific, although several types may share the same ranges or levels
- Challenge thus is to determine type specific P concentrations that are no more and no less stringent than required by the WFD

Majority of Member States have determined type specific phosphorus boundary values for lakes/rivers



There is a substantial range of boundary values in use

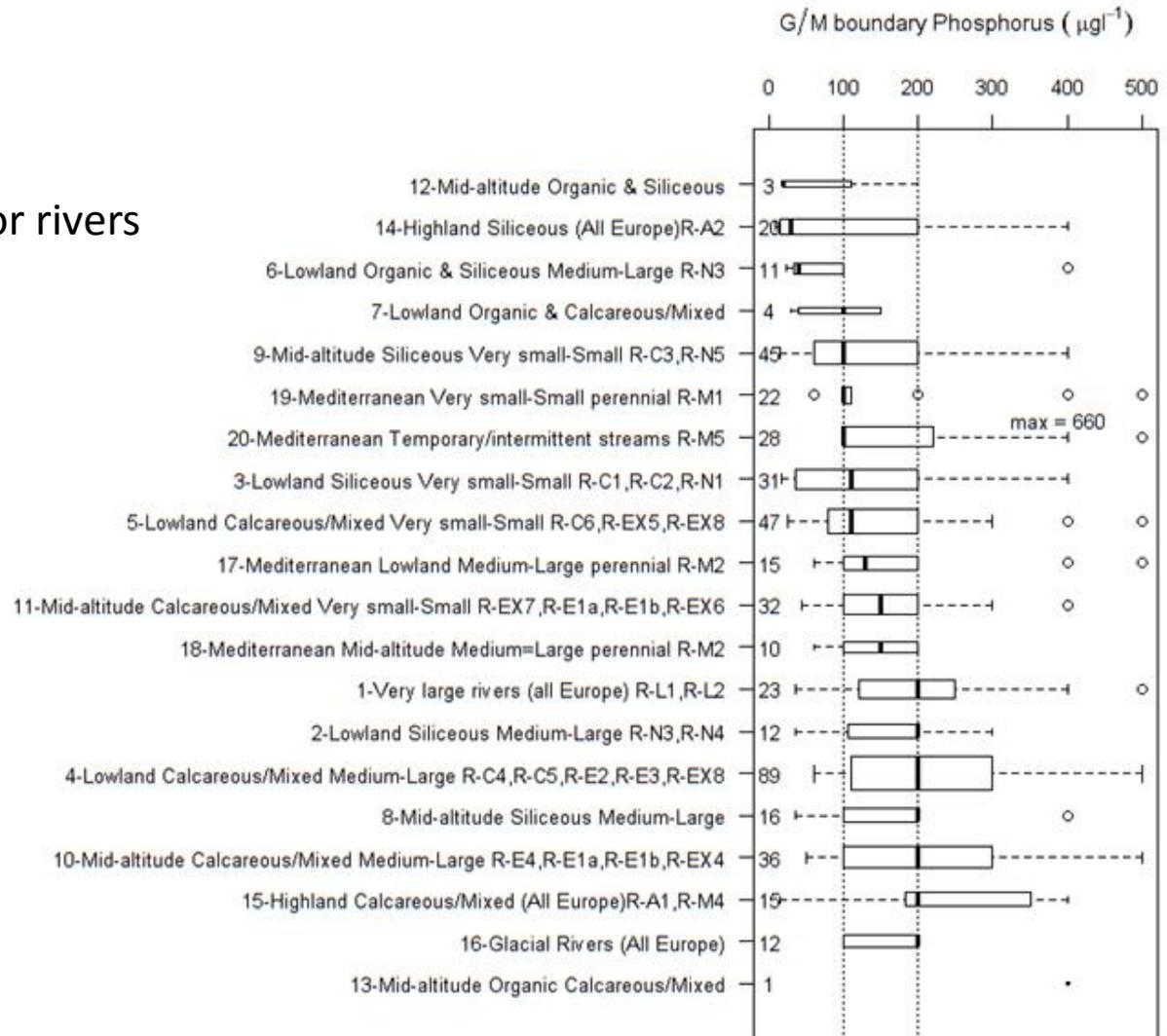
- Differences in type sensitivity
- Differences in methods used to determine values

And potentially

- Different approaches to interpretation of statistical summaries when ensuring that values are no more and no less stringent than are required by WFD

Range of MS boundary P values by river type

Comparison of national good/moderate boundary phosphorus concentration for rivers by broad river type (ECOSTAT April 2015)

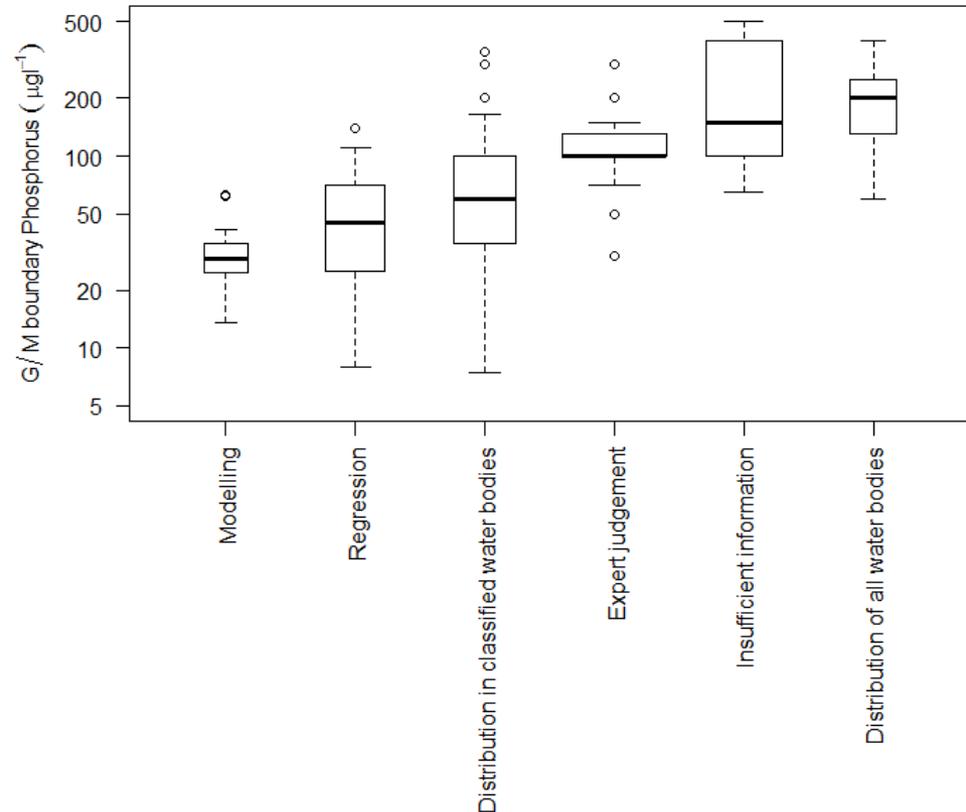


Range of MS boundary P values by method used

Modelling and regression methods have lowest boundary values

Substantial range of values for all methods, including the regression approach

What is the best approach to determining appropriate levels for phosphorus ?



Range of good/moderate boundary values by method used to set boundary (ECOSTAT April 2015)

UK approach 1st river basin plan

Boundary values were set using the upper 95th percentile of phosphorus concentration in rivers classified at

- a) High status
- b) Good status

Using diatoms (phytobenthos)

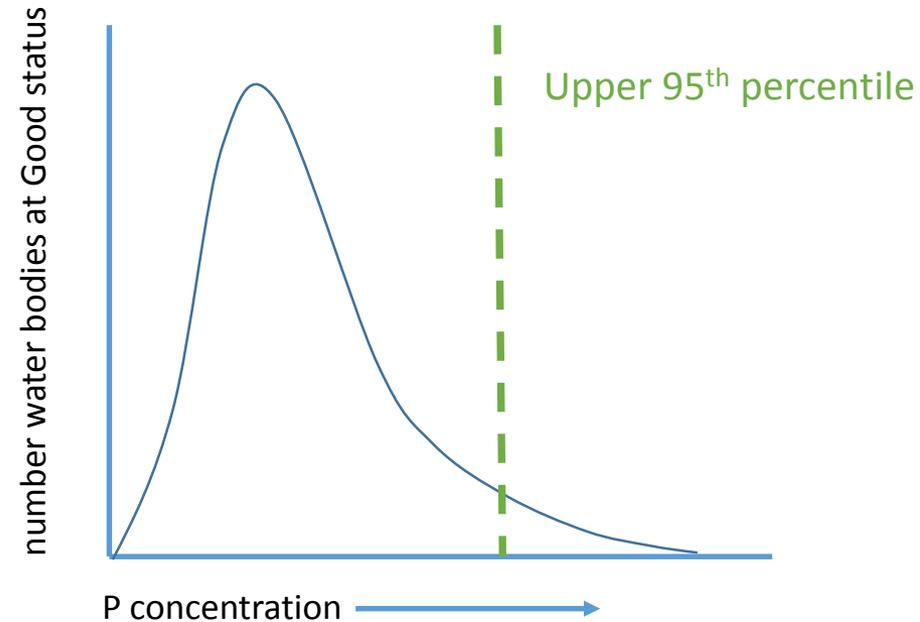
Values established for 4 river types

- <80m altitude, <50 mgCaCO₃ alkalinity
- <80m altitude, >50 mgCaCO₃ alkalinity
- >80m altitude, <50 mgCaCO₃ alkalinity
- >80m altitude, >50 mgCaCO₃ alkalinity

Resulted in a high mis-match of classifications
e.g. for England & Wales

- 65% river sites High or Good for phosphorus
- 35% river sites High or Good for diatoms

In addition concentrations used did not match ecological expectations.



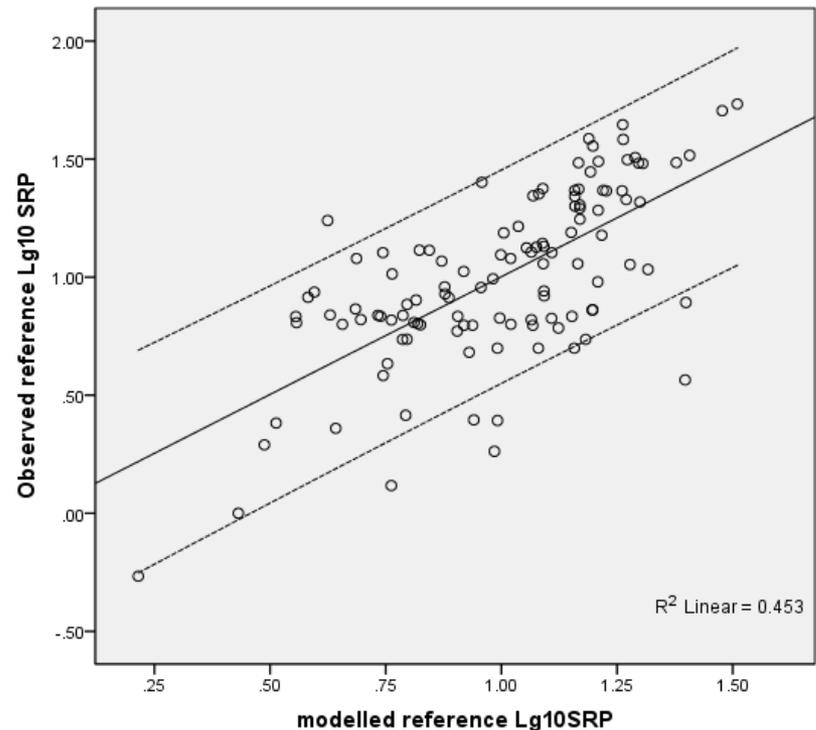
New approach for 2nd river basin planning cycle

- Used data from 620 sites (matched space and time) across UK
 - Mean annual total reactive phosphorus
 - WFD status for diatoms (DARLEQ EQR)
 - WFD status for macrophytes (LEAFPAC EQR)
- Developed regression relationships between P and worst of diatom/macrophyte EQRs (normalised to same scale)
 - Type specific relationships with P concentration
 - Global relationship with P EQR

Developing an EQR for phosphorus (1)

- Reference P concentration
 - Selected reference sites (Pardo *et.al.* 2012)
 - Stepwise regression with range of environmental variables showed **log alkalinity** and **site altitude** were significant predictors of P concentration in reference sites ($R^2 = 0.45$ $p < 0.001$)

1. Parameter estimates						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.341	.093		3.672	.000
	log_alk	.450	.060	.574	7.446	.000
2	(Constant)	.476	.088		5.382	.000
	log_alk	.454	.055	.579	8.287	.000
	site_altitude_m	-.002	.000	-.353	-5.048	.000



Developing an EQR for phosphorus (2)

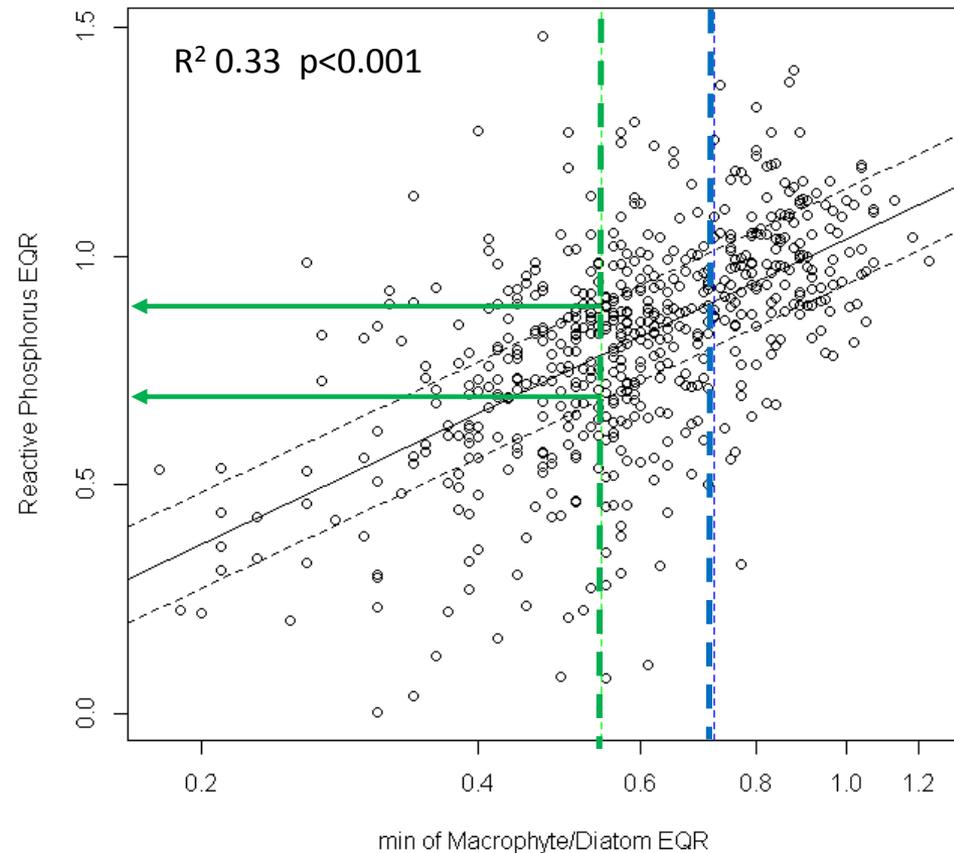
- Calculate an EQR using observed and reference phosphorus concentration
 - $SRP_{EQR} = (\log(P_{obs}) - \log(\text{Upper Anchor})) / (\log(P_{ref}) - \log(\text{Upper Anchor}))$
 - Upper Anchor was taken as $3500 \mu\text{gl}^{-1}$

Relationship between biological EQR and P EQR

Fit regression with upper and lower 25th quantiles of residuals

Predict range of P EQR values for intercalibrated biological boundary EQR

For each site convert these P EQR values into P concentration using predicted reference P value



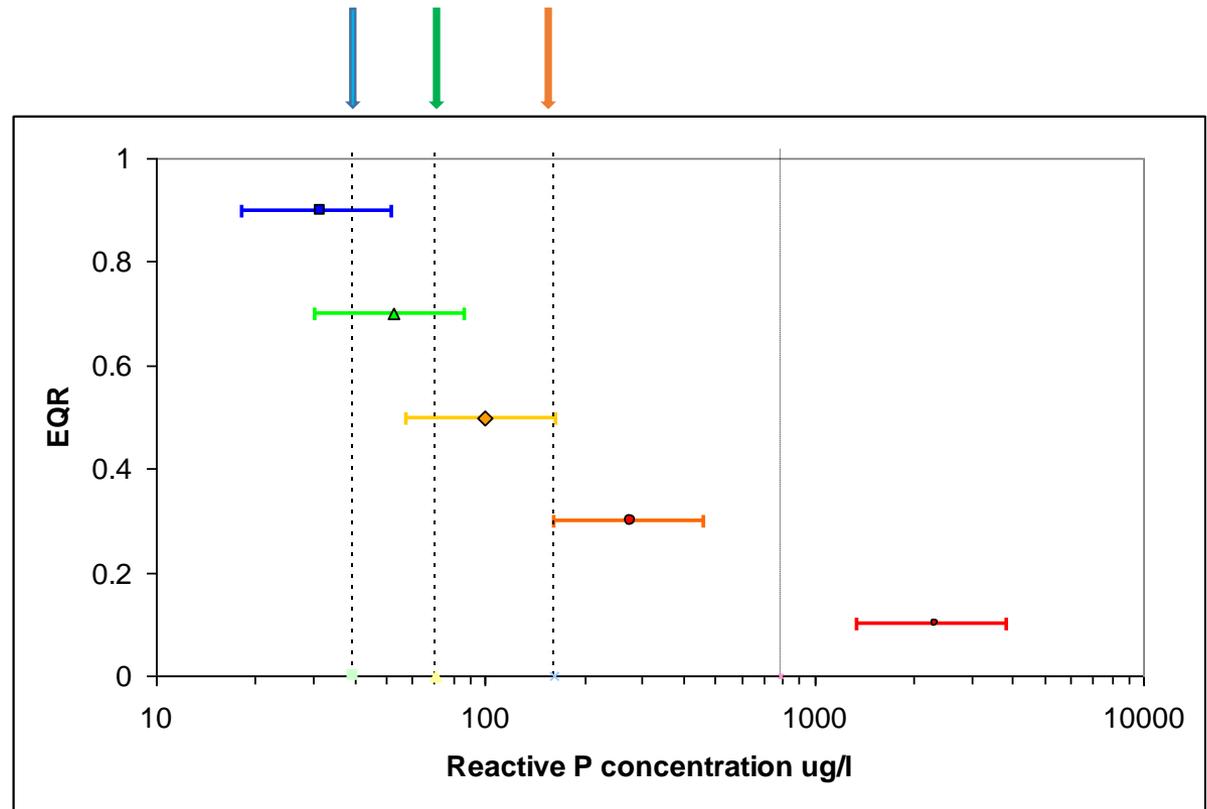
Range of P boundary values for mid-point of each biological class

P class boundary values at point where error bars overlap

Provides site specific P boundary values for all UK rivers

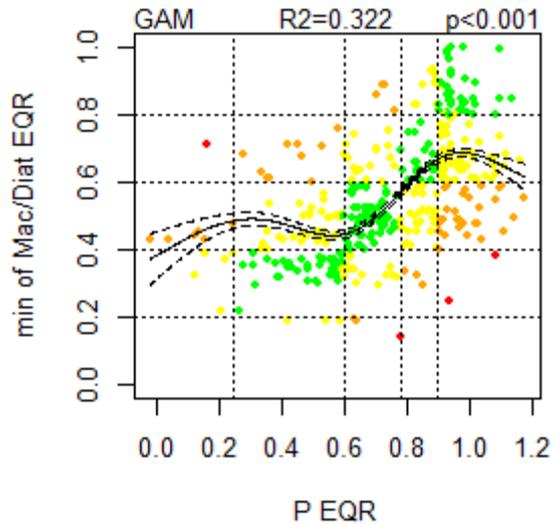
Values “most likely” P concentration that will support good status for macrophytes & diatoms

Method reduced the number of mis-matched classification and reduced bias

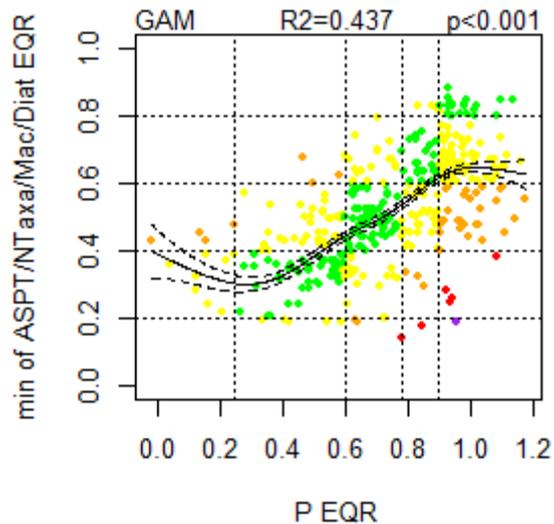


lowland high alkalinity river (alkalinity $130 \text{ mgCaCO}_3\text{l}^{-1}$, altitude 28m)

Validation data set



- Relationship linear for good and high status
- Substantial, number of mis-classifications (± 1 or 2 classes), and no bias
- Inevitable result given uncertainty of the relationship between P and macrophyte and phyto benthos status



- Including invertebrate EQR extends the range of P EQR values with a linear relationship
- Decrease in number of water bodies where biology better than P, but an increase where worse (other pressures)

Conclusions

- Use of objective relationships will always produce a range of P concentrations that can support good ecological status.
 - Categorical methods, e.g use of UK upper 95th percentile of P in sites with diatoms at good status.
 - Regression methods, eg use of UK regression
- Range of values may reflect different environmental conditions for type specific boundaries (sub-types)
- More likely they reflect the many other factors influencing response
 - River flow, shade, grazing, habitat modification etc

Issues that need further discussion

- Some Member States still using expert judgement and arbitrary statistical division of P concentration in all water bodies to determine values.
- But different approaches to the interpretation of objective relationships are also likely to account for range of values in current use.
- Need for improved understanding of nutrient pressure response relationships in rivers if type specific P concentrations that are no more and no less stringent than required by the WFD are to be achieved.
- Perhaps greater attention to *ensure the functioning of the ecosystem* in determining boundary values, which may not be adequately captured within current scope of intercalibrated WFD biological assessment methods.