Proposed Nutrient Attribute tables for the NPS-FM

(22.05.2019)

Aim: To develop nationally applicable attribute criteria for nitrogen and phosphorus in rivers. The attribute tables are not intended to represent river specific thresholds that prevent eutrophication, rather they are to be nationally correlative of ecosystem health.

Procedures and results:

Principles

The Science and Technical Advisory Group (STAG) had substantial conversations on the attribute development and suggested the following principles:

- Multiple lines of evidence are used
- Nationally derived datasets
- Recognition that nationally correlative relationships do not always translate to site-specific thresholds
- Nutrient relationships are derived by correlating national datasets of nutrients against metrics of ecosystem health.
- Relationships for each trophic level and ecosystem processes are weighted equally.
- The bands derived for derived nutrient criteria are harmonised so they align with the existing and proposed bands for other metrics of ecosystem health.
- A single set of criteria apply nationally, and more stringent criteria derived locally if required.
- The nutrient species are in dissolved rather than total form, as this is the biologically available form.
- Medians and 95th percentiles are provided.

Collation of nutrient-ecosystem health relationships

Relationships between nutrient concentrations and a range of ecosystem health metrics, covering periphyton, invertebrates, fish and ecosystem processes were collated. All relationships were derived from national datasets and weighted equally to produce criteria for each trophic level & processes (Table 1). Nutrient criteria derived for periphyton, invertebrates, fish and ecosystem processes were then averaged equally to derive a single national nutrient criterion.

Table 1. Ecosystem health metrics/relationships used in nutrient criteria derivation

Periphyton	Macroinvertebrates	Fish	Ecosystem processes
• Biggs (2000) • Matheson et al (2016)	• MCI • QMCI • ASPM	• IBI	• GPP • ER • Cotton decay

Periphyton-nutrient relationships

Two periphyton-nutrient datasets were used. The relationships derived from both sources were used to provide nutrient criteria for bands that aligned with the periphyton attribute table in current NPS-FM that has A, B, C and D criteria of 50, 120 and 200 mg chlorophyll a m^2.

The first from Biggs (2000), who collected a variety of periphyton and nutrient measures from 30 rivers throughout New Zealand and derived regression equations for maximum chlorophyll a as predicted by nitrate-nitrogen (N) or dissolved reactive phosphorus (DRP).

The second relationships were sourced from Matheson et al (2016), whereby upper quantile regression was used to related nutrient concentrations with periphyton biomass from 871 and 981 sites for N and DRP respectively. With large datasets, an advantage of quantile regression is that it can elucidate relationships between variables without needing to control for other limiting factors where data may not be available (Cade & Noon, 2003). This is better explained graphically (Fig. 1.) with a figure reproduced from Cade & Noon (2003)

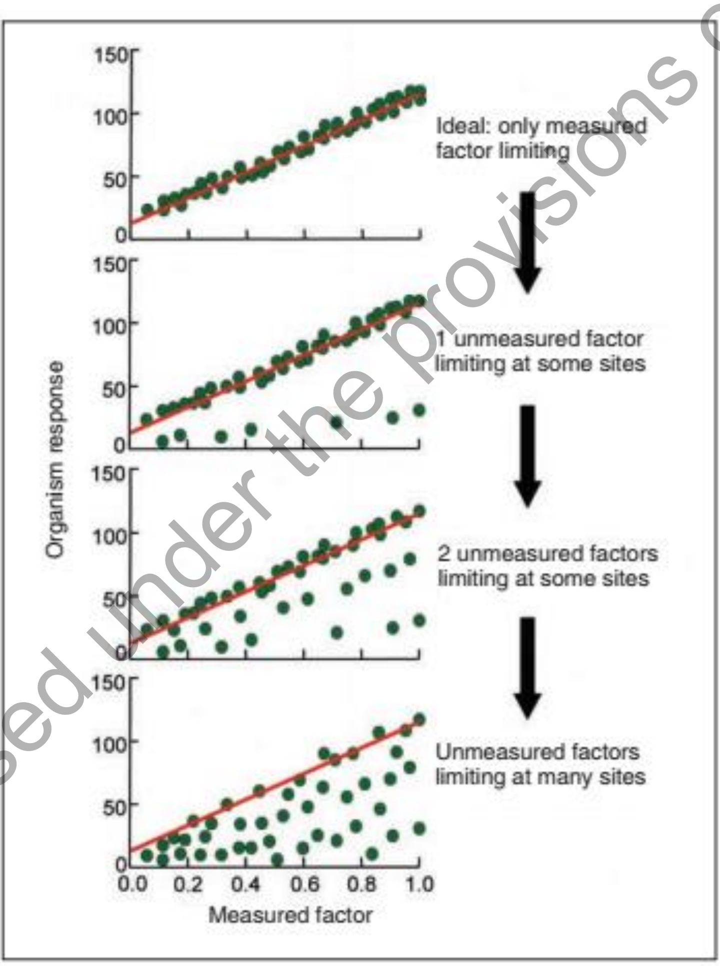

Figure 2. *The top graph represents the ideal statistical situation where an organism response is driven primarily by the measured factor(s) included in the linear regression model; ie all other potential limiting factors are at permissive levels. As we proceed from top to bottom, an increasing number of factors that were not measured become limiting at some sample locations and times, increasing the heterogeneity of organism response with respect to the measured factor(s) included in the regression model.*

Fig. 1. Hypothetical example of quantile regression detecting relationships in large datasets when there are other limiting variables. Copied from Cade & Noon (2003).

Invertebrate-nutrient relationships

STAG has recommended two invertebrate attribute tables are included in the proposed NPS. The first is based on QMCI & MCI (Macroinvertebrate Community Index) (Stark & Maxted, 2007), with bands A = 6.5 & 130, B = 5.5 & 110, and C = 4.5 & 90 respectively. The second is based on Collier's (2008) ASPM (average score per metric), with bands A=0.6, B=0.4 and C=0.3. Using a national dataset (1966 sites), collated and calculated from SoE monitoring data by Clapcott et al (2017), the average annual scores (2012-2016) for each site were correlated with predicted nutrient concentrations (natural log transformation) from Larned et al (2017), all relationships had significant correlations (Table 2). Both attribute tables had equal weighting in deriving nutrient bands for invertebrates.

Table 2. Regression statistics between invertebrate metrics and nutrient concentrations.

Relationship	R^2	p-value
MCI vs N	0.21	1.22 E^{-95}
MCI vs P	0.13	1.30 E^{-59}
QMCI vs N	0.18	1.77 E^{-68}
QMCI vs P	0.13	6.53 E^{-47}
ASPM vs N	0.21	1.41 E^{-95}
ASPM vs P	0.18	1.10 E^{-80}

Fish-nutrient relationships

The Fish Index of Biotic Integrity (Joy & Death, 2004) is a popular, nationally applicable fish based indicator of ecological health and has been recommended by STAG for inclusion in the proposed NPS. The fish IBI data was calculated for sites surveyed and logged in the NZ Freshwater Fish Database between 2010-2017. Only records that used electric fishing for at least 150m were used, as recommended in Joy, David, & Lake (2013), where sites were surveyed multiple times a random occasion was selected, this amounted to 2923 sites. The bands used for fish IBI were those STAG discussed that included trout as an 'honorary native' and correspond to the 75th, 50th and 25th percentiles, such that A=36, B=28 and C=20. Given that the IBI is a holistic indicator that responds to a range of pressures, nutrients being one, quantile regression was used to relate fish IBI with nutrients to capture the relationship when nutrients are likely to be the limiting factor. Consistent with Matheson et al (2016), the 85th percentile was chosen as this appeared a reasonable balance between capturing the upper quantile relationship yet not being driven by exceptionally high values. Figure 2 shows the relationship between nitrogen and IBI.

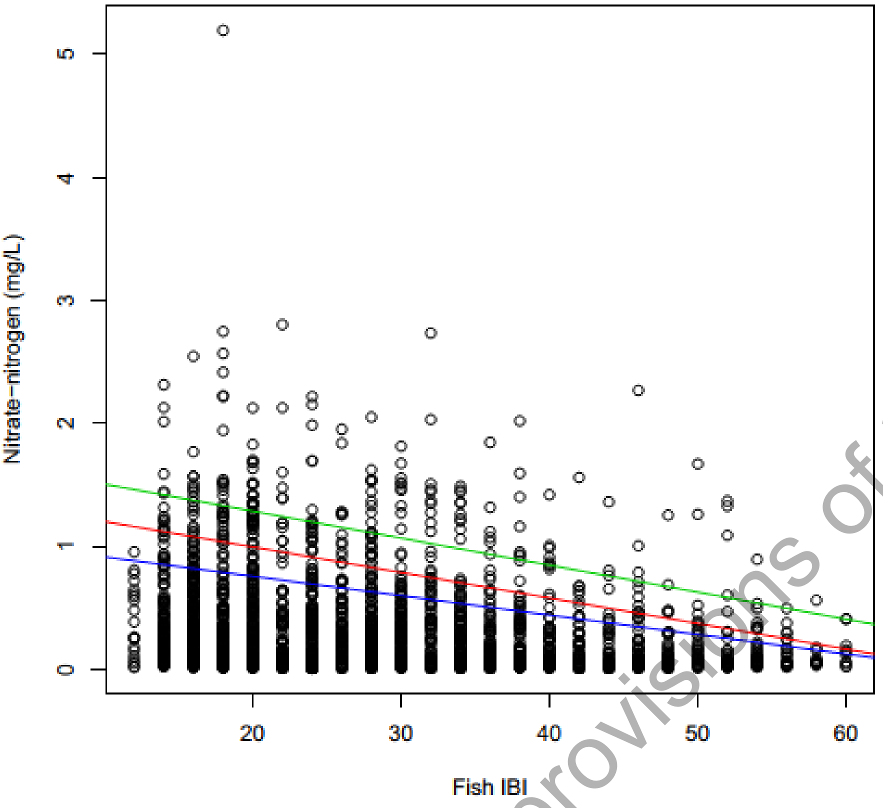

Fig. 2. Quantile regressions between Fish IBI and nitrate-nitrogen at the 90th (green), 85th (red) and 80th (blue) percentiles.

Ecosystem process-nutrient relationships

Three metrics of ecosystem processing were used, being gross primary production (GPP), ecosystem respiration (ER) and cotton cellulose decomposition potential. The data used comprised 84 sites across three main bioregions of NZ, as described by Clapcott et al (2010). Bands for GPP and ER were derived from those proposed by Young et al (2008). For cotton decomposition, there were no previously suggested bands, instead the 25th, 50th and 75th percentiles comprised the A, B and C bands respectively. Log-log transformations were applied to all metric and nutrient relationships, and all were statistically significant (Table 3). Figure 3 exemplifies the relationship between cotton decay and nitrogen.

Table 3. Regression statistics between ecosystem process metrics and nutrients.

Relationship	R^2	p-value
GPP vs N	0.15	0.0004
GPP vs P	0.06	0.02
ER vs N	0.13	0.001
ER vs P	0.13	0.0008
Cotton K dd vs N	0.16	0.0003
Cotton K dd vs P	0.10	0.004

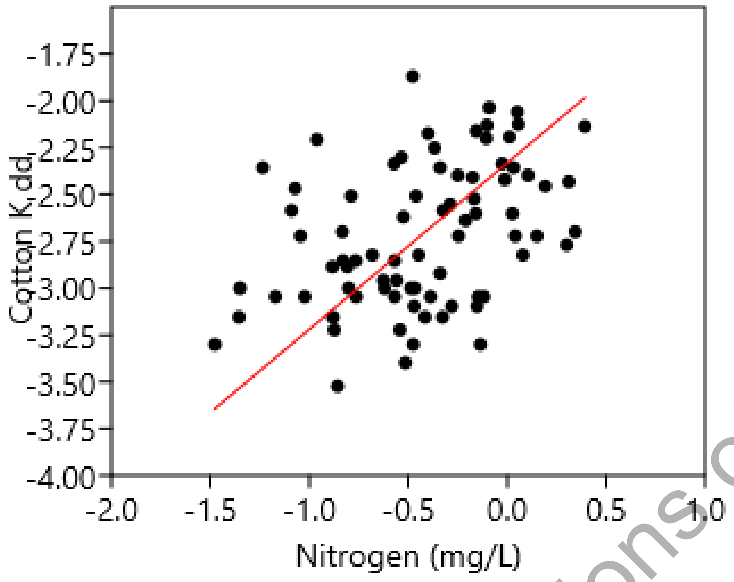

Fig. 3. Correlation between cotton cellulose decomposition potential and nitrogen concentration at 84 sites across New Zealand.

Aggregating nutrient relationships

Where multiple nutrient-metric relationships were used to derive criteria for a single trophic level, then these were averaged equally to produce nutrient bands for each trophic level. As a recap, Table 4, shows the summary bands used for each metric. The nutrient criteria for each trophic group were then combined into a single criterion by averaging equally. The trophic group specific nutrient criteria and the averaged overall criteria are presented in table 5.

Table 4. The bands used for each ecological metric used in nutrient band derivation.

Band	Chlorophyll a	MCI	QMCI	ASPM	IBI	GPP	ER	Cotton K dd
A	50	130	6.5	0.6	36	3.5	5.8	0.0009
B	120	110	5.5	0.4	28	5	7	0.0019
C	200	90	4.5	0.3	20	7	9.5	0.00395

Table 5. Nutrient criteria for each trophic group and the overall average (mg/L).

Nutrient	Band	Periphyton	Invertebrates	Fish	Ecosystem processes	**Average**
DIN	A	0.11	0.01	0.50	0.35	**0.24**
	B	0.53	0.16	0.63	0.50	**0.44**
	C	1.00	0.94	0.76	0.77	**0.88**
DRP	A	0.004	0.002	0.013	0.008	**0.006**
	B	0.009	0.011	0.016	0.009	**0.010**
	C	0.016	0.040	0.019	0.010	**0.021**

Deriving 95th percentiles

Given that all relationships derived used average annual median concentrations, to determine the 95th percentile a typical standard deviation expected for each band was estimated and the 95th percentile defined as two standard deviations from the median. For all SoE monitoring sites, the standard deviation of data collected between 2012-16 was correlated with the average annual median (N: $r^2=0.89$, $p<0.0001$, Fig. 4.; P: $r^2=0.95$, $p=<0.0001$). Using these correlations, typical standard deviations, and 95th percentiles, were derived for each band.

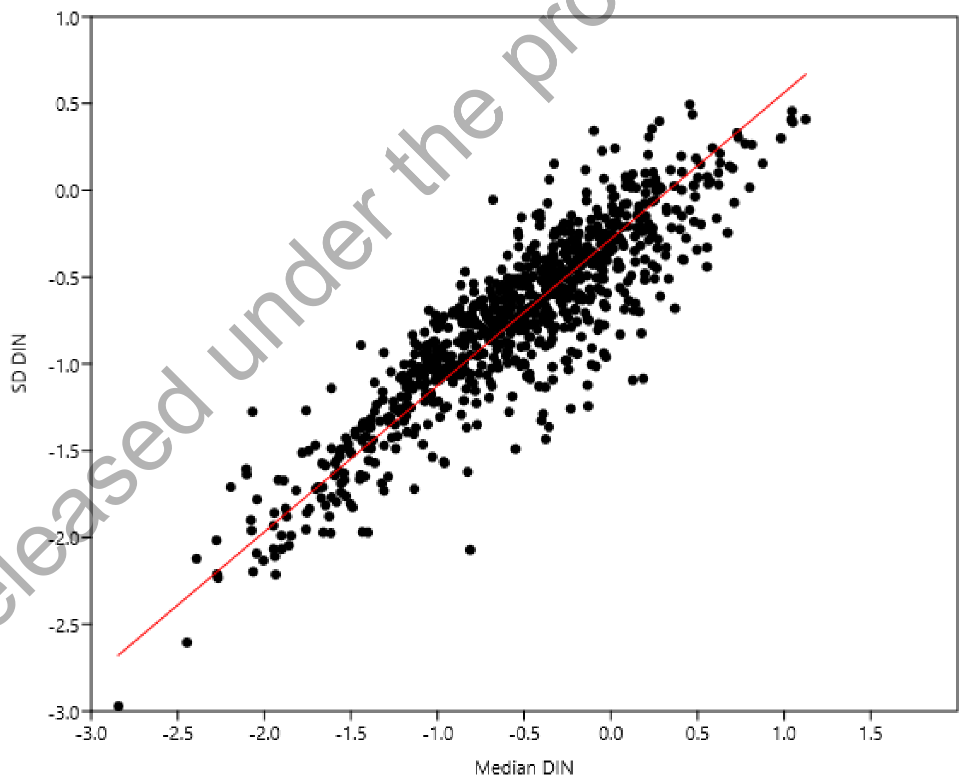

Fig. 4. Correlation between DIN median and standard deviation across SoE monitoring sites between 2012-2016.

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Using the 1230 SoE monitoring sites on LAWA with data between 2008-18, 21% exceeded the proposed bottom-line for N and 25% exceeded the proposed bottom-line for P (Table 6).

Table 6. The number (n) and proportion (%) of SoE monitoring sites that fall within each band for N & P.

	N		P	
Band	n	%	n	%
A	588	46	352	28
B	203	16	243	19
C	218	17	364	28
D	271	21	321	25

Conclusion

Using multiple lines of evidence, generic (not site specific) nutrient criteria have been proposed for the NPS-FM (Appendix A). Whilst many of the relationships had weak nutrient relationships and uncertainty is inevitable, using multiple lines of evidence provides strength – if one relationship is poor, then it is only a single line among numerous other lines. It is also encouraging that the nitrogen bottom-line is in line with Camargo & Alonso (2006) whom conducted a global review of inorganic nitrogen pollution in rivers and suggested levels should be less than 0.5-1 mg/L to prevent eutrophication and protect against toxicity. Furthermore, the B-band for both N and P align exactly (and coincidentally) with the ANZECC (2000) trigger values for lowland rivers of 0.444 mg/L and 0.010 mg/L respectively. They are also sufficiently protective to ensure that there are no toxic effects on sensitive species.

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Appendix A

Value	Ecosystem health		
Freshwater Body Type	Rivers[1]		
Attribute	Dissolved Inorganic Nitrogen (Ecosystem Health)		
Attribute Unit	Milligrams of Dissolved Inorganic Nitrogen (DIN) per litre		
Attribute State	**Numeric Attribute State[2]**		**Narrative Attribute State**
	Annual median	**95th percentile**	**Description**
A	≤ 0.24	≤ 0.56	Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to DIN enrichment are expected.
B	> 0.24 and ≤0.44	> 0.56 and ≤0.98	Ecological communities are slightly impacted by minor DIN elevation above natural reference conditions. If other conditions also favour eutrophication, sensitive ecosystems may experience additional algal and plant growth, loss of sensitive macroinvertebrate taxa, and higher respiration and decay rates.
C	> 0.44 and ≤ 0.88	> 0.98 and ≤ 1.81	Ecological communities are impacted by moderate DIN elevation above natural reference conditions, but sensitive species are not experiencing nitrate toxicity. If other conditions also favour eutrophication, DIN enrichment may cause increased algal and plant growth, loss of sensitive macroinvertebrate & fish taxa, and high rates of respiration and decay.
National Bottom Line	0.88	1.81	
D	>0.88	>1.81	Ecological communities impacted by substantial DIN elevation above natural reference conditions. In combination with other conditions favouring eutrophication, DIN enrichment drives excessive primary production and significant changes in macroinvertebrate and fish communities, as taxa sensitive to hypoxia and nitrate toxicity are lost.

1. Groundwater concentrations also need to be managed to ensure resurgence via springs and seepage does not degrade rivers through DIN enrichment.

2. Based on monthly monitoring.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	Dissolved Reactive Phosphorus (Ecosystem Health)		
Attribute Unit	Milligrams of Dissolved Reactive Phosphorus (DRP) per litre		
Attribute State	**Numeric Attribute State[1]**		**Narrative Attribute State**
	Annual median	**95th percentile**	**Description**
A	≤ 0.006	≤ 0.013	Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to DRP enrichment are expected.
B	> 0.006 and ≤0.010	> 0.013 and ≤0.021	Ecological communities are slightly impacted by minor DRP elevation above natural reference conditions. If other conditions also favour eutrophication, sensitive ecosystems may experience additional algal and plant growth, loss of sensitive macroinvertebrate taxa, and higher respiration and decay rates.
C	> 0.010 and ≤ 0.021	> 0.021 and ≤ 0.044	Ecological communities are impacted by moderate DRP elevation above natural reference conditions. If other conditions also favour eutrophication, DRP enrichment may cause increased algal and plant growth, loss of sensitive macro-invertebrate & fish taxa, and high rates of respiration and decay.
National Bottom Line	0.021	0.044	
D	>0.021	>0.044	Ecological communities impacted by substantial DRP elevation above natural reference conditions. In combination with other conditions favouring eutrophication, DRP enrichment drives excessive primary production and significant changes in macroinvertebrate and fish communities, as taxa sensitive to hypoxia are lost.

1. Based on monthly monitoring.