DairyNZ response to Snelder and Hodson memorandum date 26 February 2021[1] and other more generally the nutrient load reduction work of Snelder (2020 and 2021)

Craig Depree and Christophe Thiange (20 September 2022)

As part of the work supporting Plan Change (PC) Tuatahi, Environment Southland (ES) has convened an independent panel to review the technical work related to proposed nutrient load reductions required to meet proposed target attribute states (TAS) in Southland Freshwater Management Units (FMUs). As part of the consulting process, DairyNZ provided substantive technical feedback (Depree and Thiange 2021) on the proposed nutrient load reduction work of Snelder (2020) outlining several potential issues, their impacts, and recommendations to address. In response this document, ES provided a memorandum (Snelder and Hodson 2021)[2] responding to the issues raised in Depree and Thiange (2021). In August 2022, ES advised DairyNZ that the independent panel enquired whether DairyNZ had provided a written response to 'the ES response', which we advised that we had not. The reason we had not provided a written response to the Snelder and Hodson (2021) memorandum, was because that document was already a technical response to the DairyNZ technical review, and so replying to Snelder and Hodson (2021) memorandum would be a 'response to a response' – which in our opinion would have little benefit for either party.

DairyNZ's understanding was that unresolved/outstanding technical matters would be best mediated via workshopping with an independent panel. This preferred approach has not yet been undertaken by ES and an independent panel. Although we view it as a less efficient process, DairyNZ consider it important to further explain our technical position on the key concerns/issues that we do not consider were adequately addressed in the response document (Snelder and Hodson, 2021). To be clear, most of the issues raised in our technical review (Depree and Thiange 2021), which we consider resulted in an over-estimated of nutrient load reductions, are still valid and have not (to our best knowledge) been addressed.

It is important to point out that since the technical review of Depree and Thiange (2021) and response memorandum of Snelder and Hodson (2021), there have been major revisions[3] to the nutrient look-up tables (for periphyton), which have resulted in different instream nutrient thresholds being applied to Southland riverine receiving environments. These are referred to as the *2nd edition TN criteria*. This work is not yet publicly available, but we suspect it will show markedly lower nutrient load reductions for rivers because of the generally less stringent nature of the thresholds – particularly for managing for C-band periphyton. We believe these markedly higher TN thresholds (for B and C band periphyton) in the second edition 'look-up tables' support our assertion that the riverine nutrient criteria were overly stringent and resulting in an over-estimation of riverine nutrient load reductions. Because we have not seen the re-analysis, we have had to still make comments on the current work (Snelder 2020 and Snelder 2021), which used the original TN criteria, which we refer to as *1st edition TN criteria*.

Our main focus has been to provide additional information to support our position that target nutrient loads for estuaries and rivers (based on 1st edition periphyton TN criteria) have

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[1] The date on the memorandum has a date of 26 February 2020, which is incorrect.

[2] Snelder and Hodson (2021). Memorandum: Response to DNZ technical review of work undertaken to inform nutrient reduction requirements to achieve freshwater objectives in Southland catchments. (26 Feb 2021) 13p (+ appendices).

[3] Ministry for the Environment (2022). Guidance on look-up table for setting nutrient targets for periphyton: second edition. Wellington: Ministry for the Environment.

overestimated the magnitude of nutrient reductions required to meet the proposed TAS used for the Southland assessment.

Sections 2 and 3: Inconsistencies between TN load reductions estimated for PC Tuatahi workstream (Snelder 2020)[4] and a peer-reviewed study (Snelder et al 2020)[7]

Outstanding issue: The explanation provided does not account for the apparent disparity in TN load reduction targets. After accounting for the estimated TN load associated with the area excluded from the PC Tuatahi 'study area' there appears to be a two-fold discrepancy (higher reductions for PC Tuatahi).

(Original DairyNZ comment/issue) *Of concern is that the reductions suggested through the current work appear to be significantly larger than load reductions reported in comparable 'national-scale' studies that utilised similar methodologies.*

(ES response) *The explanation for this is that the previous national studies reported results for Southland in its entirety whereas the recent load reduction study is restricted to a "study area" that excludes all of Fiordland and the Islands FMU.*

(DairyNZ response Sep 2022). We have always understood that the nutrient work supporting PC Tuatahi (Snelder 2020)[4] had excluded Fiordland and off-shore Island FMUs. Our concern is that TN load contribution from the excluded land area does not account for the two-fold difference in estimated load reduction.[5] To better articulate our concerns about the potentially significant inconsistencies from studies using the same methods and TAS (in this case national bottom lines), we estimated how much of the unattenuated N-load was associated with:

1. Fiordland FMU
2. Stewart Island and other offshore islands
3. 90% of the Waiau catchment that is upstream of the Lake Manapouri outlet[6]

We estimate these excluded areas (45% of the total area) account for around 15% of the total Southland nitrogen load (unattenuated). Snelder et al . (2020)[7] reported an estimated **20%** reduction in TN load to meet riverine, lake and estuarine national bottom-line attribute states across the Southland region. However, as part of PC Tuatahi, Snelder (2020) estimated a **49%** reduction in TN was required to meet national bottom-line target attribute states for rivers, estuaries, and lakes across the 'study area' (i.e., exclusion of areas 1-3 above).

If the excluded areas account for 15% of the nitrogen load (unattenuated), then reducing the total estimated TN load by 15% (22,000[8] reduces to 18,700 t) and expressing the absolute load reduction

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[4] Snelder, T. (2020). Assessment of nutrient load reductions to achieve freshwater objective in the rivers, lakes and estuaries of Southland – to inform the Southland Regional Forum process. LWP Client report 2020-13. 77 p.

[5] This would require the excluded land area (i.e. Fiordland and offshore island FMUs) to contribute approximately 50% of the TN load to account for the >2-fold reported difference in N-load reductions (%) reported in Snelder 2020[4] (plan change Tuatahi) and Snelder et al. (2020)[7]

[6] We estimated that approximately 90% of the catchment load upstream of Manapouri is diverted out of the Waiau catchment to Fiordland (Doubtful Sound) via the Manapouri power scheme.

[7] Snelder T, Whitehead A, Fraser C, Larned S & Schallenberg M. (2020b): Nitrogen loads to New Zealand aquatic receiving environments: comparison with regulatory criteria, New Zealand Journal of Marine and Freshwater Research, DOI 10.1080/00288330.2020.1758168. Refer to Table 2 (p. 17).

[8] Refer to Table 1 in Depree and Thiange 2021

(4,600 t)[8] results in an adjusted percent load reduction of **25%** for the Tuatahi study area.[9] This estimate for the 'study area' is two-times lower than the 49% estimate of Snelder 2020. If our assumptions and calculations are correct, then this is a concern as it suggest that TN load reductions for the other modelled Tuatahi 'envelopes' (including Hauora) are also likely to be over-estimated relative to the peer-reviewed load reduction study of Snelder et al (2020).[7]

If our assumptions are incorrect, then as per the recommendation in Depree and Thiange (2021), would appreciate ES 'stepping us through' the necessary calculations to show that there is not a discrepancy between the TN load reductions (for the NBL scenario) estimated by ES (Snelder 2020)[3] and the published study of Snelder et al. (2020)[7]. For the avoidance of doubt, the explanation provided by Snelder and Hodson (2021), regarding excluded areas, does not account for the difference and therefore warrants further explanation to address our concerns. This would provide clarity and give transparency to the process.

Sections 5 - Estuaries

Issue: Concern that the nutrient load limits for meeting estuarine target attribute states has resulted in overly stringent nutrient reduction targets for Toetoes Estuary and Waituna Lagoon, and potentially overly stringent nutrient reductions for Jacobs River Estuary and New River Estuary.

Snelder and Hodson (2021) relied on, and agreed with, feedback provided from Dr Plew (NIWA) who responded[10] to the estuarine concerns raised by Depree and Thiange (2021).

We discuss each estuary separately below.

New River Estuary (NRE) – Oreti catchment[11]

The main issue for this estuary is that estuarine nutrient load reductions have been determined by phytoplankton as the '*determining primary indicator*'. We assert that this assessment is inconsistent with the screening guidance used to identify the likely "determining primary indicator" – that is, whether macroalgal or phytoplankton blooms are the likely primary trophic response to nutrient enrichment. This depends on the nature of the estuary – for example, residence time (flushing time) and intertidal area. Of relevance to New River Estuary is that for estuaries with >40% intertidal area, the determining primary indicator is macroalgal blooms. For the avoidance of doubt, we point out that the intertidal area of New River Estuary is 64%, which is well above the 40% threshold, that excludes phytoplankton as being the likely determining primary indicator. Accordingly, we believe that because of 'screening-nature' of the ETI Tool 1 assessment, the estuarine load reduction should be based exclusively on managing for most likely determining primary indicator (i.e., macroalgal blooms).

We emphasise that this was not just our interpretation of the ETI Tool 1 screening results, in his estuary report[12], Dr Plew shows in Table 3-2 that the *determining primary indicator* for New River Estuary is macroalgal blooms (Table 3-2 is reproduced as Table 1 below). Given that ES were reliant

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[9] Snelder et al. (2020) estimate a total TN load of 22,000 t and a load reduction of 4,600 t (20% reduction). Assuming the excluded areas account for 15% of the total TN load, the total load reduces to 18,700 t, and so the 4,600 absolute load reduction corresponds to a 25% relative load reduction.

[10] Refer to Appendix C of Snelder and Hodson (2021)

[11] Refer to Section 3.1 (p 7) in Depree and Thiange (2021).

[12] Plew D (2020). Model for evaluating impact of nutrient and sediment loads to Southland Estuaries – to inform the Southland Regional Forum process. NIWA Client Report 20020216CH prepared for Environment Southland. 30 p.

on Dr Plew's expertise to assess the nutrient susceptibility of Southland estuaries in Snelder (2020), it is unclear why the nutrient load reduction work (Snelder 2020 and Snelder 2021[13]) did not incorporate the identified *determining primary indicator* for New River Estuary (or other Southland estuary).

In appendix C of Snelder and Hodson (2021), Dr Plew points that just because an estuary exceeds 40% intertidal area does not mean that phytoplankton is never of concern. We do not disagree with this point; however, this is a screening level tool and hence the consistent approach, in our opinion, is that the assessment criteria should be applied objectively. In Plew (2020), under section 2.2.4 *Overall susceptibility*, Dr Plew states "the ETI tool 1 determines the overall eutrophication susceptibility of an estuary using either the macroalgal or phytoplankton susceptibility, depending on the estuary".

Moreover, Dr Plew states (under the same section), that "while larger systems may have long enough flushing times to allow phytoplankton to grow, secondary indicators of phytoplankton blooms such as low water column oxygen levels are not common because, being shallow, they are generally vertically well mixed".

We note that Dr Plew did not consider it appropriate to set a TP load threshold for the Oreti River (based on estuary phytoplankton). So it is a disappointing to see that a recommendation on estuarine nutrient management was not adopted in the November 2021 version of the ES nutrient load reduction report (Snelder 2021)[13].

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[13] Snelder T (2021). Assessment of nutrient load reductions to achieve Freshwater Objectives in the Rivers, Lakes and Estuaries of Southland Including Uncertainties To inform the Southland Regional Forum process. 113 p.

Table 1. Reproduced table (3-2) from Dr Plew's report on evaluating the impacts of nutrient loads on Southland Estuaries[12]

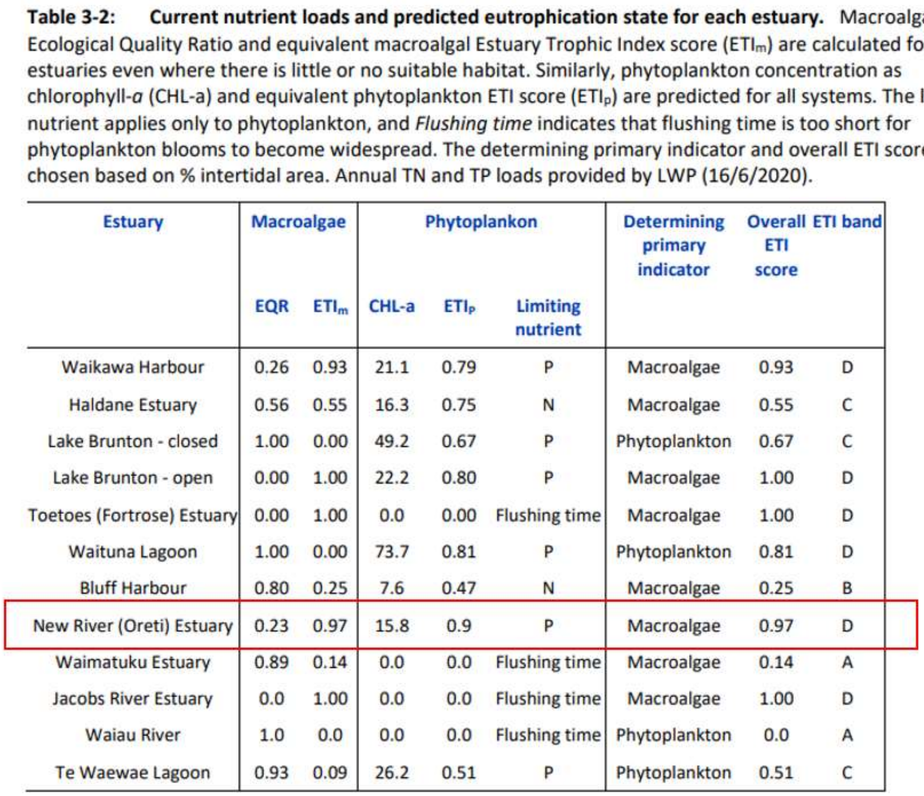

Table 3-2: Current nutrient loads and predicted eutrophication state for each estuary. Macroalgal Ecological Quality Ratio and equivalent macroalgal Estuary Trophic Index score (ETI_m) are calculated for all estuaries even where there is little or no suitable habitat. Similarly, phytoplankton concentration as chlorophyll-*a* (CHL-a) and equivalent phytoplankton ETI score (ETI_p) are predicted for all systems. The limiting nutrient applies only to phytoplankton, and *Flushing time* indicates that flushing time is too short for phytoplankton blooms to become widespread. The determining primary indicator and overall ETI score are chosen based on % intertidal area. Annual TN and TP loads provided by LWP (16/6/2020).

Estuary	Macroalgae		Phytoplankon			Determining primary indicator	Overall ETI score	ETI band
	EQR	ETI_m	CHL-a	ETI_p	Limiting nutrient			
Waikawa Harbour	0.26	0.93	21.1	0.79	P	Macroalgae	0.93	D
Haldane Estuary	0.56	0.55	16.3	0.75	N	Macroalgae	0.55	C
Lake Brunton - closed	1.00	0.00	49.2	0.67	P	Phytoplankton	0.67	C
Lake Brunton - open	0.00	1.00	22.2	0.80	P	Macroalgae	1.00	D
Toetoes (Fortrose) Estuary	0.00	1.00	0.0	0.00	Flushing time	Macroalgae	1.00	D
Waituna Lagoon	1.00	0.00	73.7	0.81	P	Phytoplankton	0.81	D
Bluff Harbour	0.80	0.25	7.6	0.47	N	Macroalgae	0.25	B
New River (Oreti) Estuary	0.23	0.97	15.8	0.9	P	Macroalgae	0.97	D
Waimatuku Estuary	0.89	0.14	0.0	0.0	Flushing time	Macroalgae	0.14	A
Jacobs River Estuary	0.0	1.00	0.0	0.0	Flushing time	Macroalgae	1.00	D
Waiau River	1.0	0.0	0.0	0.0	Flushing time	Phytoplankton	0.0	A
Te Waewae Lagoon	0.93	0.09	26.2	0.51	P	Phytoplankton	0.51	C

Our recommendation for nutrient load reduction for New River Estuary: Based on information provided in this response, and presented in Depree and Thiange (2021), we assert that the estuarine load reduction for New River Estuary is 27-29% for TN.[14] For reasons outlined above, we do not believe it is appropriate to use phytoplankton susceptibility to define TP and TN limits for New River Estuary as done in Snelder 2021. We emphasise that Dr Plew thinks it is inappropriate to set a TP load threshold for this estuary.[15] Finally, we note that although it may reflect a flood scouring event, we note that the latest macroalgal ecological quality rating (EQR) score from the most recent monitoring of the New River Estuary (Stevens and Forrest 2020) [16] was 0.48, corresponding to a C-band ('fair') state.

For catchment context (i.e., TN pressure from land use), the time-series of TN concentrations from the Oreti River are shown in Figure 1. Both the moving 5-year median and average (monthly time-step) are consistent with increasing concentration across the 8-year monitored period (2013 to 2020).

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[14] 27% is based on our calculated load for C-band of 2,614 t/y, and 29% is based on the C-band load in Plew (2020, refer Table 3-3)[12] of 2,570 t/y compared with the current TN load estimate of 3,580 t/y.

[15] Pg 43 of Snelder and Hodson (2021) 6th paragraph starting with "I agree with Dr Depree…"

[16] Refer to Table 7 in https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Macroalgal%20and%20Seagrass%20Monitoring%20of%20New%20River%20Estuary%202019-2020.pdf

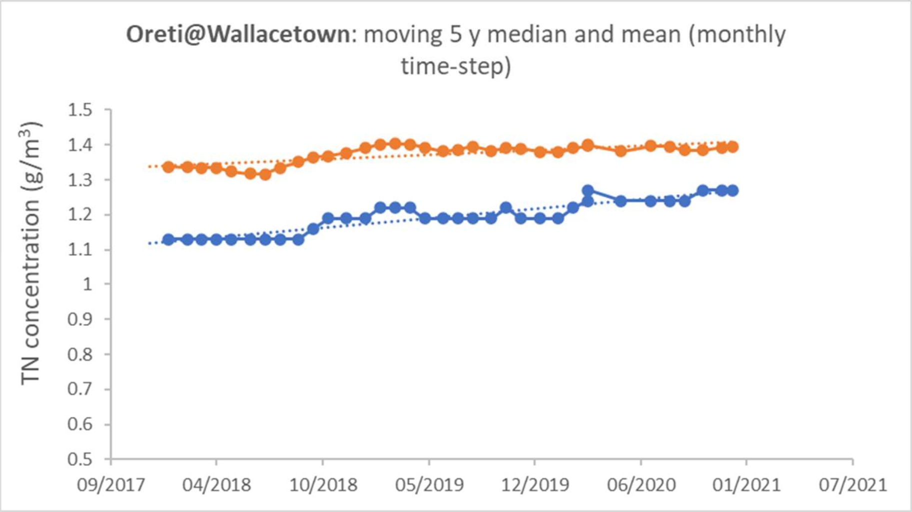

Figure 1. TN concentration time-series of Oreti River (at Wallacetown, LAWA) between 2013 and 2020 (inclusive). Orange line is 5-year (60-month) moving average (monthly time-step), and blue line is 5-year (60-month) moving average (monthly time-step). Dashed lines are lines of best fit (they are not trend slopes) to indicate the likely monotonic trend direction over the 8-year period.

Waituna Lagoon[17]

Our main concern in relation to nutrient load setting for the Waituna Lagoon related to the reliance of **modelled** phytoplankton concentrations, when there is robust **measured** phytoplankton concentration data taken monthly (some years more frequently) at four locations[18] since 2006. As per Clause 1.6 of the National Policy Statement for Freshwater Management 2020, and in 'Guidance on the National Objectives Framework of the NPS-FM 2020' document (page 28) it stipulates 'where possible use, real data, rather than modelled'.

Plew (2020) indicated that the determining primary indicator for this estuary (or coastal lake) is phytoplankton with the relevant TAS corresponding to B-band of the NOF lake phytoplankton (trophic state) attribute (Table 1, NPS-FM 2020). With B-band corresponding to a maximum annual median and maximum chlorophyll a (chla) concentration of 5 and 25 mg/m^3, respectively.

Based on a modelled 90th percentile concentration of chla (Plew 2020), for Waituna Lagoon of 74 mg/m^3, the nutrient load reductions to meet the target attribute state (i.e., 25 mg/m^3) were 90% and 60% for TN and TP respectively. The absolute nutrient loads based on the modelling of Plew (2020) were 20.25 t/y for TN and 2.78 t/y for TP.

Our concern (refer to Depree and Thiange 2021 for details), was that consistent with the requirement to use the best information (Clause 1.6), the limit setting work should have been informed by the large amount of real monitoring data. At the time, the LAWA data was complete to 2019 (inclusive) and comprised 713 measurements of chla sampled from four sites in the Waituna Lagoon across 14 years. Using this data, Depree and Thiange (2021) calculated that the 90th percentile concentrations of chla for all sites were less than the target state of 25 mg/m^3, ranging from 13 to 19 mg/m^3.

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[17] Refer to section 3.2 in Depree and Thiange (2021)

[18] Refer to Waituna Lagoon monitoring site on LAWA website: https://www.lawa.org.nz/explore-data/southland-region/lakes/waituna-lagoon/

For the avoidance of doubt, we are not implying that the results derived from using measured data means that no nutrient load reductions are required, we are merely demonstrating the discrepancies that exist in proposed reductions when 'real' and 'modelled' data are used. This appears to be the perception of Dr Plew in his response under section 3.2.3 (Appendix C, Snelder and Hodson, 2021) where he states:

"*…I do not agree that using the observed chla concentrations would lead to more robust nutrient load banding. Doing so would imply that the lagoon could comfortably tolerate higher nutrient loadings, when multiple lines of evidence as well as my own that show that load reductions are required to safe-guard this threatened lake/lagoon system*."

Dr Plew has misinterpreted our position regarding the nutrient allocation state of the Waituna Lagoon. We clearly stated this in section 3.2.3 (Depree and Thiange 2021):

"*Note that this approach does not imply that nutrient reductions are not needed for the Waituna Lagoon, but that reductions should be informed by biological indicator monitoring, and not modelled (and clearly inaccurate) phytoplankton concentrations.*"

Our point (which is still valid) was to show that the very high modelled phytoplankton (chla) concentrations of Plew (2020), which were responsible TN and TP reductions significantly more stringent than the outcome of the multiple lines of evidence assessed by independent experts (Schallenberg et al. 2017).[19] But moreover, that these modelled estimates of phytoplankton state significantly over-estimates the actual state, which can be, and should be, assessed using robust (and in our opinion, complete) measured data.

We reiterate, with respect to the importance of using (in fact prioritising) measured data, again refer to the recent guidance for the NPS-FM,[20] which clarifies the intent of using *best information*[21] and the use of models by stating (bold text is our emphasis):

*"**Where possible, use real data, rather than modelled**. However, models will be required to identify and understand relationships between values and attributes, and to calculate catchment-scale interactions. Only use modelled data where other types are not available."*

It is important to point out that the measured chla data do show that the lagoon is over-allocated with nutrients. The 90th percentiles used in Depree and Thiange (2021) and discussed further by Dr Plew (Table 1 in Appendix C, Snelder and Hodson, 2021) are not the correct measures for assessing compliance against the phytoplankton NPS-FM attribute, which use annual medians and annual maximum concentrations of chla. The annual median B-band threshold in 5 mg/m^3, which is similar to the 'primary indicator' threshold based on a mean chla concentration of 5 mg/m^3 (Schallenberg et al. 2017).[22]

Figure 2A shows that using measured annual maximum chla concentration data, the Waituna Lagoon (averaged across the four sites) exceeded the B/C band threshold of 25 mg/m^3 for 7 of the 15 years

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[19] M. Schallenberg, D. P. Hamilton, A. S. Hicks, H. A. Robertson, M. Scarsbrook, B. Robertson, K. Wilson, D. Whaanga, H. F. E. Jones & K. Hamill (2017) Multiple lines of evidence determine robust nutrient load limits required to safeguard a threatened lake/ lagoon system, New Zealand Journal of Marine and Freshwater Research, 51:1, 78-95, DOI: 10.1080/00288330.2016.1267651

[20] Ministry for the Environment. 2022. Guidance on the National Objectives Framework of the National Policy Statement for Freshwater Management. Wellington: Ministry for the Environment.

[21] Refer to Clause 1.6 – Best information in the NPS-FM (2020).

[22] Refer to Table 2 in Schallenberg et al. (2017)[19] – mean value applies to water column concentration of chla during closed periods.

between 2006 and 2020. This was consistent with the assessment based on the annual mean concentrations against the primary indicator threshold of 5 mg/m^3 (Schallenberg et al. 2017), which was also exceeded for 7 of the 15 years of monitoring data. Accordingly, we disagree with Dr Plew's assessment that relying on monitored data for nutrient banding would "*imply that the lagoon could comfortably tolerate higher nutrient loads".* This is clearly incorrect based on Figure 2. We are simply stating that when using **measured** data, the current state of the estuary is not as degraded as suggested by **modelled** data – this is not to say that nutrient reductions are not required and we advocate for continual improvement, but not to the levels being initially proposed.

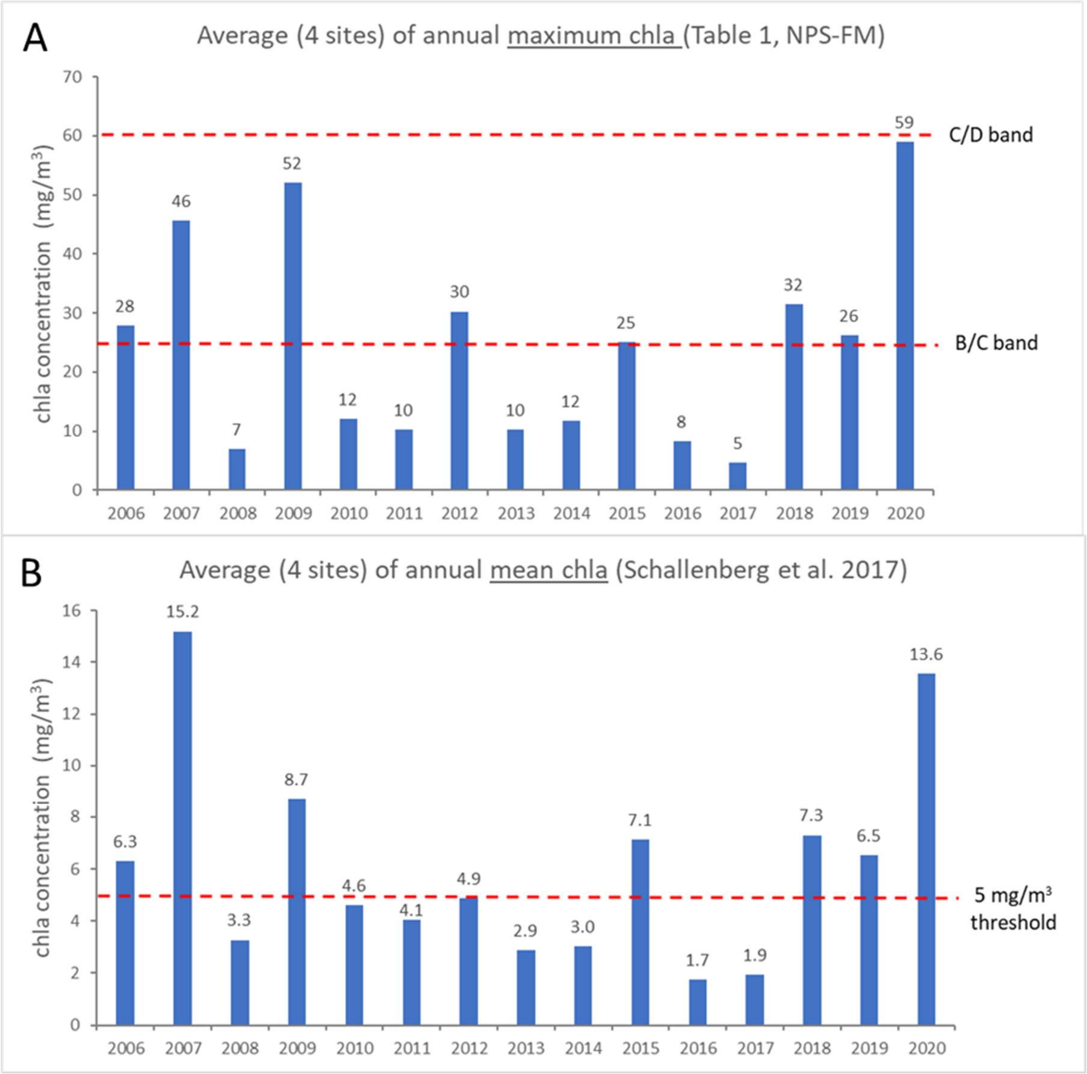

Figure 2. Summary of phytoplankton (chla) concentration measured from 4 sites in Waituna Lagoon between 2006 and 2020 (inclusive) showing (A) the average (n=4) annual maximum chla concentrations for grading against the NPS-FM B-band threshold value of 25 mg/m3; and (B) the average (n=4) annual mean chla concentrations for grading against the chlorophyll a 'primary indicator' threshold of 5 mg/m^3 (Schallenberg et al. 2017).[19]

The monitoring data clearly show that phytoplankton concentrations in Waituna Lagoon are not meeting the target attribute state of a B-band. So, the question is what suitable nutrient reductions need to be applied to this catchment? Dr Plew refers to a multiple lines of evidence approach (Schallenberg et al. 2017) which determined target nitrogen and phosphorus loads of 125 t/y and 7.7 t/y, respectively. How these absolute target loads translate into percent load reductions is complicated by the estimate of catchment loads, which vary significantly.

Scanes (2012)[23] determined N and P load limits in terms of areal loading rates based on the 13.5 km^2 size of Waituna Lagoon, and recommended N and P areal loads of 9 and 0.57 t/km^2/y, corresponding to total loads of around 122 t/y of TN and 7.7 t/y for TP. Using the estimated loads for 2010 of 250 t/y of TN and 10 t/y of TP, the percentage load reductions for TN and TP were estimated as **52%** and **23%**, respectively. Interestingly, the TAG (Schallenberg et al. 2017) recommended a reduction of **50%** phosphorus but this was based on the same target load (7.7 t/y) and reflected a larger estimated current state TP load of 14.4 t/y (Hamilton et al., 2012).[24] The final absolute nutrient loads adopted by the TAG were 125 t/y for TN and 7.7 t/y for TP.

We note that the current load estimates for PC Tuatahi used by Plew (2020) for Waituna Lagoon were 223 t/y and 8.18 t/y for TN and TP, respectively. Using the absolute target loads determined by the expert TAG group (i.e., 125 t/y TN and 7.7 t/y TP), corresponds load reduction targets of **44%** for TN, and **6%** for TP.

We note that the TN and TP reductions derived by Plew (2020) of **91%** for TN and **60%** for TP, which were adopted by Snelder (2021) for deriving load reduction targets for PC Tuatahi are inconsistent with the previous nutrient load setting work of Scanes (2012) and Schallenberg (2012). The absolute target loads for Waituna Lagoon by Plew (2020) were 20.25 t/y and 2.78 t/y for TN and TP, respectively. Compared to the TAG load reductions (Scanes 2012 and Schallenberg et al., 2017), the Plew (2020) TN and TP target loads for Waituna Lagoon are approximately 6- and 3-times more stringent. Importantly, Dr Plew recommended[25] use of the load threshold of the TAG (Schallenberg et al. 2017).

Because the NPS-FM (2020) TN and TP attributes[26] (i.e., Table 3 and 4, respectively of NPS-FM, 2020) also apply to coastal lakes (Table 3) and TP (Table 4), the 'in-lake' median concentrations of TN and TP in Waituna Lagoon are required to comply with the B/C band threshold. For TN, this is either 350 mg/m^3 (brackish lake) or 500 mg/m^3 (polymictic lake), and for TP is 20 mg/m^3.[27] We used the latest 5-year median concentrations of TN and TP (LAWA) for the 4 sites, and then took the average to yield a single estimate of the current state median TN and TP concentration in Waituna Lagoon. For TN, the 5-year median ranged from 700 to 795 mg/m^3 across the 4 sites with an average value of 726 mg/m^3. For TP, the 5-year median ranged for 25 to 36 mg/m^3 across the 4 sites with an average value of 29 mg/m^3.

Assuming that Waituna Lagoon is best assessed as a brackish lake, then based on achieving in-lake concentration targets of 350 mg/m^3, the current state concentration of TN in Waituna Lagoon needs

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[23] Scanes P. (2012). Nutrient Loads to Protect Environmental Values in Waituna Lagoon, Southland NZ. 12 p.

[24] Hamilton DP, Jones HFE, Özkundakci D, McBride C, Allen MG, Faber J, Pilditch CA. 2012. Waituna Lagoon modelling: developing quantitative assessments to assist with lagoon management. Report prepared for Environment Southland. Invercargill: Environment Southland.

[25] Refer to 4th paragraph (last sentence) on p 45 of Snelder and Hodson (2021).

[26] Refer to TN trophic state attribute Table 3 and TP trophic state attribute Table 4 of the NPS-FM (2020).

[27] Waituna Lagoon is an ICOLL, in which case, the NPS-FM indicates that monitoring data (nutrients and chla) should be analysed separately for closed and open periods, however information regarding the open/closed state of Waituna Lagoon is not provided in the LAWA dataset.

to be reduced by **52%** - which is the same reduction determined by Scanes (2012).[28] The average concentration of TP (29 mg/m^3) needs to be reduced by 31% to meet the B-band threshold of 20 mg/m^3. This is comparable to the 23% reduction determined by Scanes (2012).[28]

Based on the above, we strongly disagree with the proposed nutrient reductions for the Waituna catchment in Snelder (2021). We emphasise that Dr Plew in his response[25] to Depree and Thiange (2021) recommended using the load thresholds indicated by the TAG (i.e. Schallenberg et al. 2017) for Waituna Lagoon. Despite Snelder and Hodson (2021) stating that they agree with Dr Plew's responses, this recommendation seems to have been ignored when setting limits for the Waituna catchment (Snelder 2021).

For catchment context (i.e., TN pressure from land use), the time-series of TN concentrations from the Waituna Creek are shown in Figure 3. Neither the moving 5-year median and average (monthly time-step) show a monotonic trend over the 15-year period (2006-2020). The time-series seems to show a cyclical pattern that may reflect climate. In contrast, the median and average TP time-series data for Waituna both indicate a pronounced decreasing monotonic trend in concentrations (Figure 4).

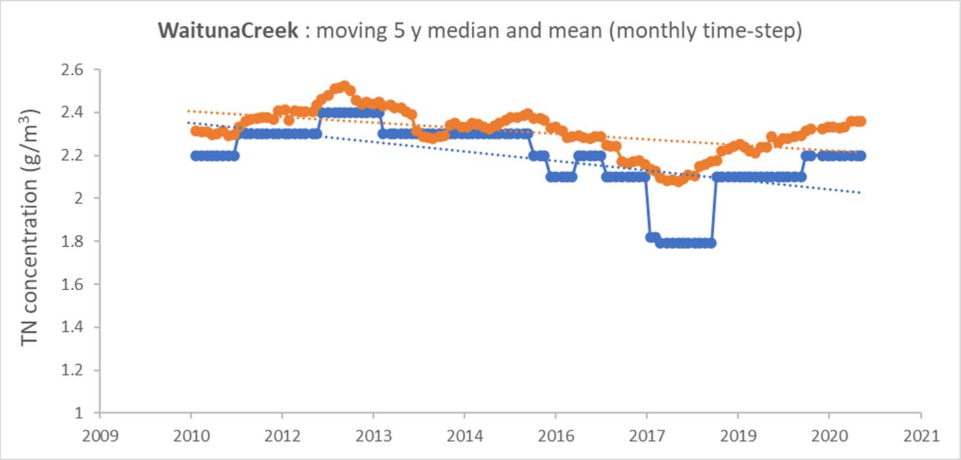

Figure 3. TN concentration time-series of Waituna Creek (LAWA) between 2006 and 2020 (inclusive). Orange line is 5-year (60-month) moving average (monthly time-step), and blue line is 5-year (60-month) moving average (monthly time-step). Dashed lines are lines of best fit (they are not trend slopes) to indicate the likely monotonic trend direction over the 15-year period.

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[28] Refer to Table 4 in Scanes (2012).[23]

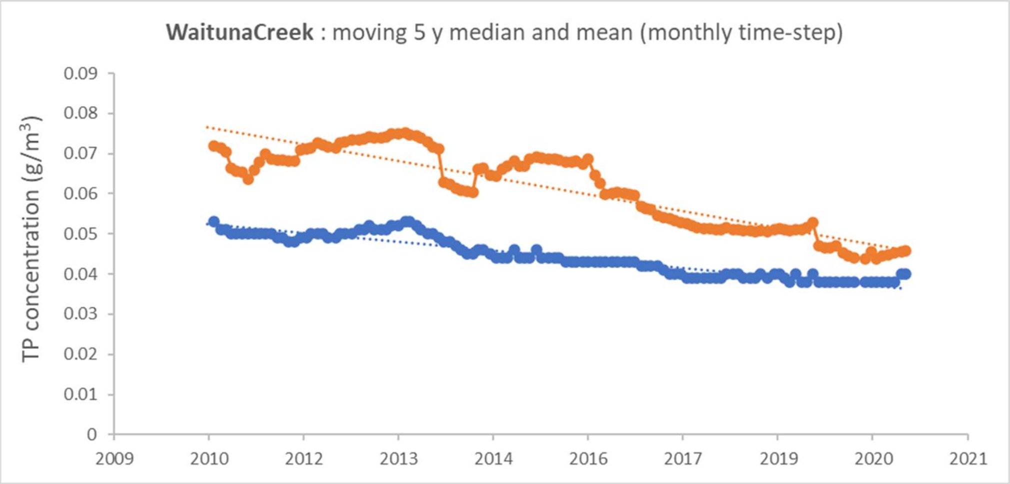

Figure 4. TP concentration time-series of Waituna Creek (LAWA) between 2006 and 2020 (inclusive). Orange line is 5-year (60-month) moving average (monthly time-step), and blue line is 5-year (60-month) moving average (monthly time-step). Dashed lines are lines of best fit (they are not trend slopes) to indicate the likely monotonic trend direction over the 15-year period.

Jacobs River Estuary (JRE - Aparima)[29]

Main issue is that the calculated TN concentration of 1,305 mg/m^3 to the JRE used by Plew (2020) was significantly largely than measured or modelled (NZ river maps – NIWA)[30] estimates. Depree and Thiange (2021) indicated that the measure median and average riverine TN concentration[31] to JRE were 940 and 915 mg/m^3, respectively. If using modelled median concentrations and mean flows from NZ river maps, the weighted riverine concentrations of TN to JRE is 1,024 mg/m^3.

Dr Plew indicates that concentrations use to develop the ETI tool 1 are calculated by dividing annual load by mean flow.[32] We are a little confused by this, as the key requirement for determining the potential TN concentration in an estuary is the riverine TN concentrations and the dilution factor. The equation to calculate the TN concentration is:[33]

$$\textit{Potential TN} = ({}_{rverine}TN \times {}_{riverine}fraction) + ({}_{oceanic}TN \times {}_{oceanic}fraction)$$

Our understanding is the concentrations estimated by dividing the mean load by the mean flow are because the method relied on concentration estimated from the CLUES model. Of course, to be meaningful, these estimated concentrations should closely approximate to the actual (i.e., measured) mean concentration.

We could accept this point if the methodology always used the same method to estimate attenuated (instream) load and mean river flow (e.g., CLUES), but this is not the case. The southland assessment was performed with load estimates provided by ES (via Dr. Snelder), these loads being calculated from modelled concentrations.

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[29] Refer to section 3.4 in Depree and Thiange (2021).

[30] https://shiny.niwa.co.nz/nzrivermaps/

[31] Note that this is a flow weighted average based on average flows from Pourakino and Aparima rivers.

[32] Refer to Appendix C – comment under Section 3.4.1 (p 48) in Snelder and Hodson (2021).

[33] Original equation on p13 of Plew (2020)

Dr Plew has undertaken assessments before where he has not used CLUES loads/flows to derive an average concentration. Many NIWA estuarine ETI assessment reports appear to use median riverine concentrations estimated from NZ river maps. In these cases, the reports use estimated flows (also from NZ river maps), and then use these data to estimate loads. These loads are used to communicate current versus target loads for catchment management purposes; however, the CLUES-Estuary estimation of susceptibility uses the median riverine concentration obtained from NZ RiverMaps. For example, for the assessment of three Canterbury estuaries, Plew et al. (2017)[34] state:

"Okains Bay Estuary N-loads were estimated from the mean annual inflow (0.324 m^3/s) and median total nitrogen concentrations (595 ug/L) predicted by NZRiverMaps. We assume for the purpose of this report, that median and mean TN concentrations are similar and that all N is potential available for uptake by algae."

Also in the same report, for Le Bons Bay Estuary:

"*Le Bons Bay Estuary N-loads were also calculated from NZRiverMaps' mean annual flow (0.381 m^3 /s) and median nitrogen concentration (464 µg/l). The mean annual N-load of 5580 kg/yr is smaller than the 13 320 kg/y estimated from CLUES. CLUES also gives higher estimates for both inflow volume (0.628 m^3/s) and concentration (672 µg/l). However, we use the NZRiverMaps estimates, rather than CLUES, as it appears CLUES over-estimates flow and, possibly, concentration, in the neighbouring Okains Bay catchment.*

Based on this, we consider that it is completely acceptable to use an alternative estimate of riverine TN concentrations, especially, if in the example of Le Bons and Okains, where the estimate of mean concentrations from load and flow appears to over-estimate the 'true' concentration.

To better align with Plew (2020) calculations, we have recalculated our scenario having derived the correct tuning factors. In addition to the measured median scenario in Depree and Thiange (2021), we have also included scenarios using modelled concentrations and flows using NZRiverMaps. For the 2nd NZRiverMap scenario, we adjusted the estuarine tuning factor to reflect the lower estimate mean riverine inflow (22 vs 29 m^3/s).

Table 2: Different scenarios (relative to Plew 2020) using measured (LAWA) and/or modelled (NZRiverMaps) for assessing the eutrophication susceptibility (for C-band) of Jacobs River Estuary (JRE).

Scenario	mean riverine flow, Q (m3/s)	dilution factor (D)	freshwater fraction (f)	tuning factor	riverine TN concen-tration	Ocean TN (mg/m3)	estuary potential TN	Riverine TN concentration required for Target estuarineTN (320 mg/m3)	% reduction to meet target TN concentration
Plew (2020)	29.3	2.83	0.35	0.747	1,305	70	506	779	40%
measured median	29.3	2.83	0.35	0.747	940	70	377	779	17%
measured mean	29.3	2.83	0.35	0.747	915	70	368	779	15%
NZRiverMaps - median	29.3	2.83	0.35	0.747	1,024	70	407	779	24%
NZRiverMaps - median	21.8	3.03	0.33	0.796	1,024	70	385	827	19%

Table 2 shows that if lower estimates are used, that we argue are more representative of the current state mean riverine concentration of JRE, then reductions in TN concentrations to meet the estuarine threshold concentration of 320 mg/m^3 range from **15 to 24%**. Based on this, we assert that the nutrient reduction for JRE is more likely to be around **20%**, as opposed to the **40%** value determined by Plew (2020). Like Okains and Le Bron estuaries, we believe that the load ES provided to Plew has over-estimated the mean riverine TN concentration to JRE. Measure current state 5-year

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[34] Plew et al. (2017). Canterbury region estuary eutrophication susceptibility assessment. NIWA Client Report 2017154CH prepared for Environment Canterbury Regional Council (May 2017).

median TN concentrations in the Aparima and Pourakino rivers are 0.98 and 0.41 mg/m^3, respectively. Estimated TN median TN concentrations at Aparima and Pourakino river are 1,065 and 852 mg/m^3. Based on these measured and estimated concentrations, it is difficult to reconcile the 1,305 mg/m^3 (flow weighted) riverine TN concentration used by Plew (2020).

For catchment context (i.e., TN pressure from land use), the time-series of TN concentrations from the Aparima River are shown in Figure 5. Both the moving 5-year median and average (monthly time-step) are consistent with decreasing concentration across the 15-year monitored period (2006 to 2020).

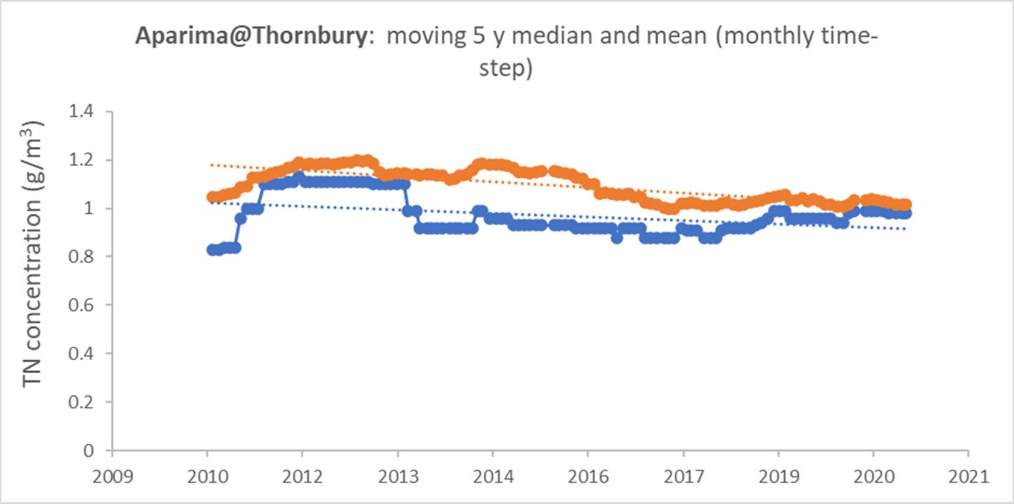

Figure 5. TN concentration time-series of Aparima River (at Thornbury, LAWA) between 2006 and 2020 (inclusive). Orange line is 5-year (60-month) moving average (monthly time-step), and blue line is 5-year (60-month) moving average (monthly time-step). Dashed lines are lines of best fit (they are not trend slopes) to indicate the likely monotonic trend direction over the 15-year period.

Toetoes Lagoon (Fortrose - Mataura)[35]

Main issue outstanding relates to the inappropriate application of TN thresholds derived for tidal lagoon estuaries to Toetoes Estuary which is a tidal river estuary. There is consensus that tidal river estuaries are markedly less susceptible to eutrophication (i.e., macroalgal or phytoplankton blooms) than tidal lagoon estuaries. This consensus is summarised by the water quality expert signatories to the Joint Witness Statement for Water Quality and Ecology (2019)[36] for the current Southland Water and Land Plan Environment Court process, who state the following about Tidal River estuaries (underlined text is our emphasis):

"These estuaries are dominated by river flow so that the majority of fine sediment and nutrients are exported to the sea. This <u>reduces their susceptibility to eutrophication compared to tidal lagoons</u>. <u>They often can tolerate nutrient loads an order of magnitude greater than tidal lagoons</u>. Waterbodies in this class include Toetoes (Fortrose) Estuary."

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[35] Refer to section 3.3 in Depree and Thiange (2021).

[36] Joint Witness Statement (Oct 2019). Expert conference – water quality and ecology (rivers, estuaries and lakes). ENV-2018-CHC. Topic: Proposed Southland Water and Land Plan – Southland Regional Council.

Despite this, Plew (2020) identified macroalgae as the *determining primary indicator* (which we agree with) and used a TN threshold for sensitive tidal lagoon estuaries to determine the target TN load for Toetoes estuary. Moreover, because the TAS for Toetoes Estuary is higher (B-band) than for tidal lagoon estuaries like NRE and JRE (C-band), Plew (2020) has resulted in the somewhat 'perverse outcome' of an estuary with a lower susceptibility to macroalgal blooms having more stringent TN thresholds applied than to more susceptible estuaries. To be clear, the target TN load for Toetoes Estuary is based on potential TN threshold of 200 mg/m^3, compared to loads for JRE and NRE being based on TN threshold concentrations of 320 mg/m^3. This is summarised in Figure 6. We consider that this figure makes it exceptionally clear that the tidal lagoon 'macroalgal-TN response' relationship has little (if any relevance) in managing for a target EQR state for Toetoes Estuary of 0.6 (B-band). We even note that the most recent macroalgal EQR score for Toetoes Estuary was 0.58, very close to the target state, we also note that the modelled macroalgal EQR state for Toetoes estuary is 0 – again emphasising that the tidal lagoon thresholds bear little relevance to managing for macroalgal target attribute states in Toetoes Estuary.

In our opinion, the 'nuanced' justification provided by Dr Plew[37] do not address our fundamental concern that thresholds for 'higher susceptible' estuaries have been applied to a 'lower susceptible' estuary. Dr Plew talks about 'scouring' from the main river channel, but in our opinion, this is a key property of SSRTRE (tidal river) estuaries that result in lower susceptibility. An analogy here are the nutrient lookup tables for periphyton (MfE 2022)[3]. These consider the different 'susceptibilities' of river type to exhibiting nuisance blooms of periphyton, of which flushing flows/frequency are an important consideration. So, using a 20% 'under protection risk', for unshaded sites, a *cool-dry-low* (CDL) classified river has a default look-up TN threshold concentration of 164 mg/m^3 – this indicates a river that is very sensitive to expression of periphyton in response to anthropogenic nutrient enrichment. By contrast, for a *cool-extremely wet-low* (CXL) classified river, the equivalent TN threshold concentrations is 20-times higher at 3,205 mg/m^3. In our opinion, the intent is to set meaningful limits on resource use in the Mataura, and that requires the use of meaningful (relevant) thresholds to assess the target TN load. In the same way that it would be incorrect to apply CDL nutrient concentration thresholds for managing trophic state response (i.e., periphyton) in a CXL class river, we strongly assert that it is incorrect to apply high susceptible nutrient criteria to a low susceptible estuary. This is especially relevant given that these estuary target loads dictate the load targets for the Mataura catchment (Snelder 2021).[38] The TN target loads correspond to a79% reduction. Although we have some concerns with the way in which periphyton has been used to estimate riverine target loads, we believe that the TN load reductions for pSWLP/Hauora-30% scenarios of around 30% are more consistent with providing for the B-band attribute state sought for Toetoes Estuary.

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[37] Refer to appendix C (p 46) of Snelder and Hodson (2021).

[38] Refer to Table 22 (p 100).

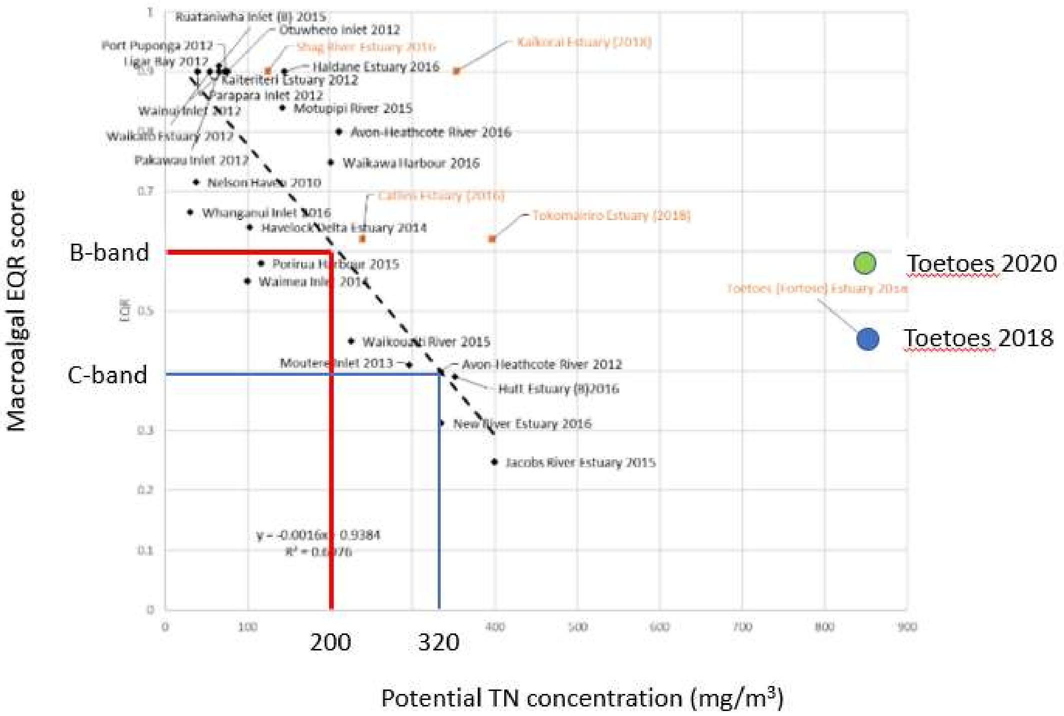

Figure 6: Relationship between macroalgal Ecological Quality Rating (EQR) scores and potential TN concentration for NZ estuaries (modified from Plew 2020). The figure shows how far removed Toetoes estuary (C-band) is from the dose-response relationship between macroalgal EQR and TN developed from estuaries that are much more highly susceptible to eutrophication from TN enrichment. The latest estuarine monitoring score for Toestoes is shown as the green dot (2020), which has a score of 0.58 (target EQR state for Toetoes is 0.6).

Summary data from latest monitoring season in Toetoes Estuary (Salt Ecology 2020)[39]. The 2019 and 2020 years show improved 'high enrichment conditions' to 'good' status, and the 2020 monitoring showed an improved macroalgal EQR score of 0.58 – noting that the target attribute state is 0.60.

Table 3. Summary of condition rating scores for Toetoes Estuary over the last four surveys based on key indicators and criteria. (taken from Salt Ecology 2020, their Table 6).

Broad scale indicator	Unit	2016	2018	2019	2020
Macroalgae (OMBT)[1]	Ecological Quality Rating (EQR)	0.447	0.453	0.473	0.581
High Enrichment Conditions	Ha	7.19	7.18	4.92	3.29
Seagrass[2]	% decrease from baseline	75	86	87	90

[1] OMBT = Opportunistic Macroalgal Blooming Tool [2] Data for 2003 used as baseline for seagrass

Condition rating colour key:

Very Good	Good	Fair	Poor

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[39] https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/document-library/reports/science-reports/Fortrose%20%28Toetoes%29%20Estuary%202019_2020%20Macroalgal%20Mapping.pdf

For catchment context (i.e., TN pressure from land use), the time-series of TN concentrations from the Mataura River are shown in Figure 5. Both the moving 5-year median and average (monthly time-step) are consistent with slightly increasing concentration across the 15-year monitored period (2006 to 2020).

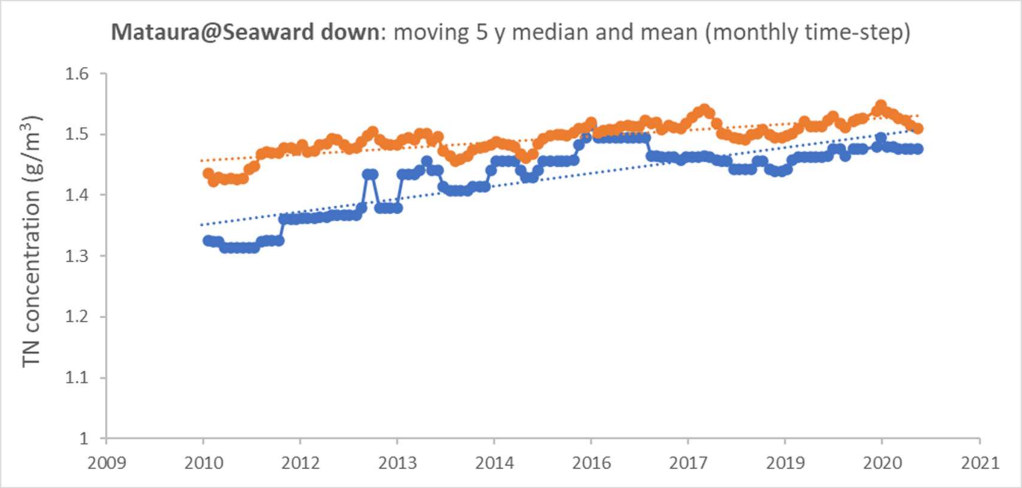

Figure 7. TN concentration time-series of Mataura River (at Seaview Downs, LAWA) between 2006 and 2020 (inclusive). Orange line is 5-year (60-month) moving average (monthly time-step), and blue line is 5-year (60-month) moving average (monthly time-step). Dashed lines are lines of best fit (they are not trend slopes) to indicate the likely monotonic trend direction over the 15-year period.

Section 7 – Application of periphyton nutrient criteria to lowland soft-bed streams

Issue: We assert that for streams correctly classified as soft-bottom (aka soft-bed), then it is inconsistent with national guidance for setting instream concentrations (clause 3.13) to apply periphyton-based instream nutrient concentration criteria.

Outstanding issues: ES do not appear to have a fit-for-purpose classification for lowland soft-bed rivers, or more broadly, soft bed rivers (regardless of REC source typography). Our position is that periphyton-based nutrient criteria should be applied to hard-bed streams, and not to soft-bed streams. It appears that many soft-bed streams may have hard bed substrates. In these instances, ES need to correctly classify these streams as hard bottom. For rivers the are correctly classified as soft-bed, then we assert that it is inconsistent (and hence incorrect) to apply periphyton-based criteria to such streams. We consider that this is explicitly outlined in the NPS-FM (clause 3.13(3)(a)) and national guidance for setting nutrient criteria and applying look-up table values for periphyton nutrient targets.

For the avoidance of doubt, where ES has delineated a class of rivers as having a soft-bed, then our assumption (and subsequent position) is that these rivers classified as soft-bed in regional mapping, are, in fact, soft-bed rivers. As such, national guidance on how to approach the setting of instream nutrient concentrations for soft-bed rivers (as opposed to hard-bed rivers) will be applied to these streams/stream reaches.

The information provided in Appendix B in Snelder and Hodson (2021) provides robust data that many hard-bed streams have been incorrectly classified as soft-bed streams. In these cases (incorrectly classified streams), our position is that if a stream has a hard-bed, then consistent with clause 3.13(3)(a)(i), that these streams potentially support nuisance periphyton and must have periphyton-based nutrient criteria derived/applied. However, these streams should not be classified as soft-bed streams because soft-bed and hard-bed streams are treated differently when deriving instream nutrient concentrations (aka criteria) under 3.13. This policy differentiation is apparent from the key point in the 3.13 guidance document that states:

1) *Clause 3.13(3)(a)(i)*[40] *applies to hard-bottom streams and rivers while step (a)(ii) applies to soft-bottom streams and rivers*

The differentiation of hard and soft bottom streams with respect to setting instream nutrient concentrations is summarised in Figure 8.

Figure 1: Flow diagram of the process outlined by clause 3.13(3)

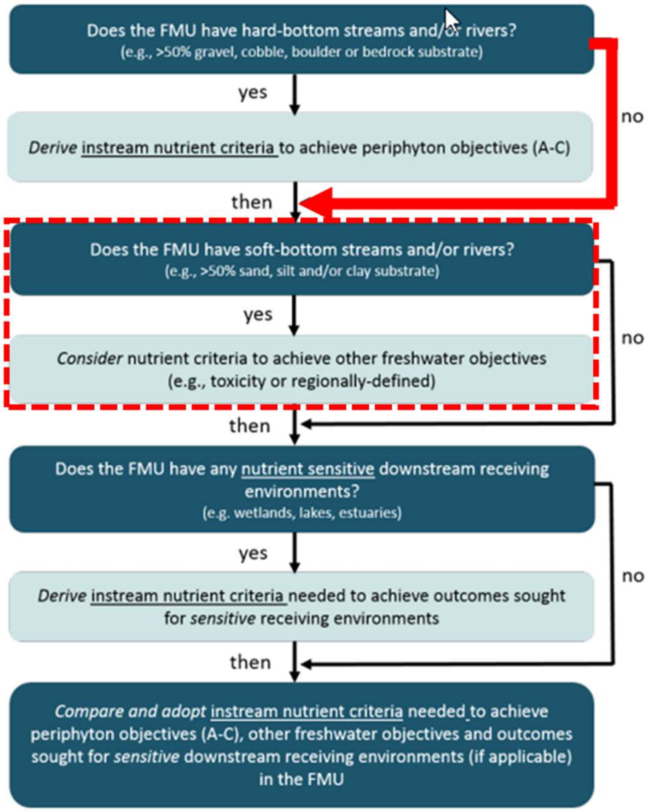

Figure 8. Flow diagram of the process outlined by clause 3.13(3) (MfE 2021[41] , note red arrow and box have been added to emphasis different pathways for hard vs soft-bed rivers).

Under 3.12, limits on resource use must be set that provide for the instream nutrient concentrations derived as part of 3.13. Accordingly, the differentiation of hard and soft bottom streams is important.

Snelder and Hodson (2021) suggest that 29 of 31 lowland soft-bed streams have substrates comprised of >50% gravel/cobbles. Given that this is the operational definition of a hard-bed stream, what they appear to be saying is that around 90% of the classified soft-bed streams are, in-fact, hard-bed streams. The fact that they are monitoring periphyton in many of these 'soft bed' classified

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[40] 3.13(3)(a)(i) requires setting DIN and DRP instream concentrations for periphyton, and 3.13(3)(a)(ii) requires setting instream nutrient concentrations for other attributes.

streams is compelling evidence that these streams have hard-bottoms (as the method involves selecting and scrubbing periphyton for cobbles).

Based on the information presented of substrate, we struggle to reconcile why ES persist with a stream classification that their own data shows are >90% incorrect, and therefore not fit-for-purpose in a regulatory setting where soft vs hard-bed differentiation has important implication regarding the process for setting limits on resource use (based on riverine effects).

For the avoidance of doubt, for Southland rivers correctly classified as soft-bed, then even if periphyton is observed growing on the silt substrate, this is not justification for applying periphyton-based nutrient criteria under clause 3.13(3)a. The reasons for this are:

1) Guidance on setting instream nutrient concentrations[41] (pg 13)

"Clause 3.13(3)(a)(i) applies to hard-bottom streams and rivers while step (a)(ii) applies to soft-bottom streams and rivers."

"*Soft-bottom rivers are those with mainly sand, silt or clay substrates. These rivers can sometimes support conspicuous growths of periphyton; for example, on sand or silt deposits following long periods of stable river flow, or adhering to macrophytes or other instream debris. However, the ecosystem health effects of such periphyton growths are less well studied and understood and are not addressed in this document. Step (a)(ii) applies to soft-bottom streams and rivers."*

2) Guidance on look-up tables for setting nutrient targets for periphyton[42] (2nd edition, pg 5))

"The criteria were developed using data from hard-bottomed stream sites. This guidance does not apply to soft-bottomed streams as these streams do not normally support conspicuous periphyton."

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[41] Ministry for the Environment. 2021. A guide to setting instream nutrient concentrations under clause 3.13 of the National Policy Statement for Freshwater Management 2020. Wellington: Ministry for the Environment.

[42] Ministry for the Environment. 2022. Guidance on look-up tables for setting nutrient targets for periphyton: second edition. Wellington: Ministry for the Environment.

Section 8 – Comments related to the use of default nutrient criteria for assessing load reductions to meet periphyton target attribute states (TAS).

Depree and Thiange (2021) raised numerous valid concerns about the way in which riverine target loads had been derived using look-up nutrient thresholds as proxies for periphyton biomass target attribute states.

Key concerns included:

1) the use of modelled nutrient thresholds (look-up table values) to determine target load reductions for Southland FMUs despite the threshold concentrations (for a 20% 'under protection risk')[43] markedly over predicting the spatial extent of non-compliance with proposed periphyton TAS[44] – although not addressing our concerns regarding use of measured data (refer to point 2 below), but if using the 'look-up table' approach, then a 30% 'under protection risk' would at least be more consistent with the extent of non-compliance in measured periphyton.[45]
2) the failure to use measured periphyton data to inform (sense check) target nutrient loads (i.e., riverine) for Southland catchments. Nutrients – notably, measured Southland data showed that 90% of monitored sites (including many mainstem rivers) were meeting the proposed periphyton TAS
3) Application of periphyton nutrient thresholds to rivers classified as soft -bottom streams, which national guidance consider to be receiving environments that do not support conspicuous periphyton growth. Note that this issue has been addressed in the previous section (Section 7).
4) The combination of points 1-3 resulting in Snelder (2021) markedly over-estimating the riverine nutrient load reductions required to provide for periphyton TAS.

Snelder and Hodson (2021) responded at length to our concerns, but we do not consider that the commentary offered addressed our concerns – that is, that first and foremost, the approach taken has not been consistent with national guidance for setting instream nutrient concentrations, and their subsequent use in deriving target nutrient loads for riverine receiving environments.

Release of revised 20% TN nutrient criteria (2nd edition)

An important development that has occurred since submitting our technical review (Depree and Thiange, 2021) is the release a revised set (i.e., 2nd edition) of *guidance on look-up tables for setting nutrient targets for periphyton.*[42] The revised nutrient look-up tables contain instream concentration for 5, 10 and 20% 'under protection risk' levels, for shaded and unshaded, and for DIN, TN, DRP and TP. For consistency with Depree and Thiange (2021) we have focus on TN, for unshaded sites using an 'under protection risk' of 20%. Importantly, the revised TN concentration criteria (aka thresholds) for the main Southland REC classes are around 2- to 4-times less stringent than the equivalent 20% under protection TN criteria (i.e., 1st edition)[46] used to determine riverine load reductions in Snelder (2021) (Table 4). The markedly less stringent nature of the revised TN criteria is clear confirmation that our concerns regarding overly stringent Southland riverine load targets in Snelder (2021) were

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[43] Note in Depree and Thiange (2021), and consistent with terminology in the 1st edition MfE look-up tables, 'under protection risk' was referred to as 'spatial exceedance risk', which mean the same thing.

[44] Note that Depree and Thiange (2021) used the term freshwater objective (FWO) rather than target attribute state (TAS).

[45] The selection of 20% vs 30% 'under protection risk' is no longer relevant with the introduction of the 2nd edition nutrient look-up tables (MfE 2022)[42]

[46] Ministry for the Environment. 2020. Action for healthy waterways: Guidance on look-up tables for setting nutrient targets for periphyton. Wellington: Ministry for the Environment.

indeed overly stringent. Table 4 shows that the 30% TN criteria (1st edition) advocated for in Depree and Thiange (2021) are more consistent with the revised (2nd edition) criteria.

Table 4. Comparison of 1st edition[46] 20% TN periphyton criteria used in Snelder (2021) with 2nd edition[42] values for the same 20% 'under protection risk' (the first edition 30% TN criteria are shown as these were advocated for in Depree and Thiange, 2021).

REC river class	Periphyton TAS (Band)	1st edition 20%[a]	1st edition 30%	2nd edition 20% (unshaded)	Relative increase in revised 20% TN criteria
CDL	C	0.542	1.474	2.252	4.2x
CWL	C	0.874	2.426	3.527	4.0x
CDH	B	0.217	0.589	0.858	4.0x
CWH	B	0.488	1.428	0.809	1.7x

[a] Note that Snelder (2021) appears to have used an earlier set of TN criteria that were less stringent than MfE 1st edition guidance[47]. The thresholds used in Snelder for CDL, CWL, CDH and CWH were 0.811, 1.325, 0.316 and 0.781 g/m^3, respectively. Accordingly, the riverine load reductions were probably underestimated relative to MfE lookup table values (1st edition).

We understand that Dr Snelder has recalculated the riverine load reductions using the revised nutrient criteria. Based on these criteria being 2-4 times less stringent, we assume that the revised riverine nutrient load reductions (to meet the same periphyton TAS) will be markedly lower than those in Snelder 2021.[48] If this is the case, then this validates our concerns that the approach taken by ES had resulted in much more stringent outcomes that what we indicated by their own multi-year periphyton monitoring dataset comprising 30 sites. We note that in response to Depree and Thiange (2021) asserting that the methodology (Snelder 2020, Snelder 2021) had resulted in larger over-estimation of the of TN load reductions, Snelder and Hodson responded as follows:

"*We have assumed that once a criterion is set, an exceedance is treated or acted on as a failure. We think this is consistent with best practice*."[49]

It is difficult to see how rigidly adhering to a modelled approach, especially when we clearly outlined (Depree and Thiange, 2021) that the use of 20% TN criteria as proxy measures for assessing compliance against the relevant periphyton biomass TAS (i.e., A, B or C band) had resulted in much higher 'rates' of non-compliance when compared with measured data from 30 Southland rivers. With respect to using best information, Clause 1.6(1) of the NPS-FM directs council to use "if practicable, complete and scientifically robust data". This intent of Clause 1.6 was further clarified in MfE (2022) NOF guidance[20] which states (under the section Best Practice – *Best information available and use of models*):

> *"Where possible, use real data, rather than modelled data"*

In our opinion, the interpretation of this is unambiguous – if a regional council has measured data, then this should be prioritised over modelled data.[50] This is particularly important given the concerns we raised (Depree and Thiange 2021) about the poor performance of predicted periphyton

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[47] Refer to Appendix A (Table 25, p110) in Snelder 2021, which are different to the original MfE look-up tables (1st edition) – refer to Table 1 (pg 11) in MfE 2020.

[48] Refer to table 23 in Snelder (2021).

[49] Refer to 1st paragraph (pg 6) in Snelder and Hodson (2021)[2]

[50] Although not the focus here, we would also argue that the Ministry should adopt this prioritization when it comes to reporting on the national state of water quality. Councils have >1,000 state of the environment monitoring sites, but they report modelled state.

compliance (using TN criteria) when compared to measured periphyton data. For example, of the 30 monitored periphyton sites, 27 sites (90%) were compliant[51] with the periphyton TAS (a mix of A-C bands). When the same 30 sites were assessed using 20% risk TN thresholds as a proxy for periphyton biomass, only 7 sites (23%) were compliant with their periphyton TAS; 23 sites (77%) were assessed as non-compliant. This disparity was illustrated in Figure 9 of Depree and Thiange (2021) with non-compliant sites shown above the dashed red line (i.e., the periphyton TAS expressed as mg chla/m^2 or as the TN concentration proxy from periphyton biomass). Snelder and Hodson (2021) thought that the interpretation of data in this figure was "too simplistic". We do not understand this response and point out that this comparison (reproduced in Figure 9) between modelled and measured 'compliance' is very similar to what is outlined in the 2nd edition look-up guidance tables under Step 3: *Assess confidence in the nutrient criteria*.[52] If we limit the assessment to the 15 monitored CDL class rivers, then the proportion of sites meeting periphyton TAS based on assessments of measured periphyton biomass was 87% (13 of 15), whereas compliance when assessed using 20% TN criteria (as a proxy measure for periphyton biomass) was 7% (just 1 of 15 sites meeting the periphyton TAS).

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[51] Note that re-analysing the Southland data (complete to March 2021) using Hazen percentiles, the number of sites with measured periphyton biomass reduced from three to two.

[52] Refer to pg 34 in MfE guidance on setting nutrient targets for periphyton (2nd edition)[3]

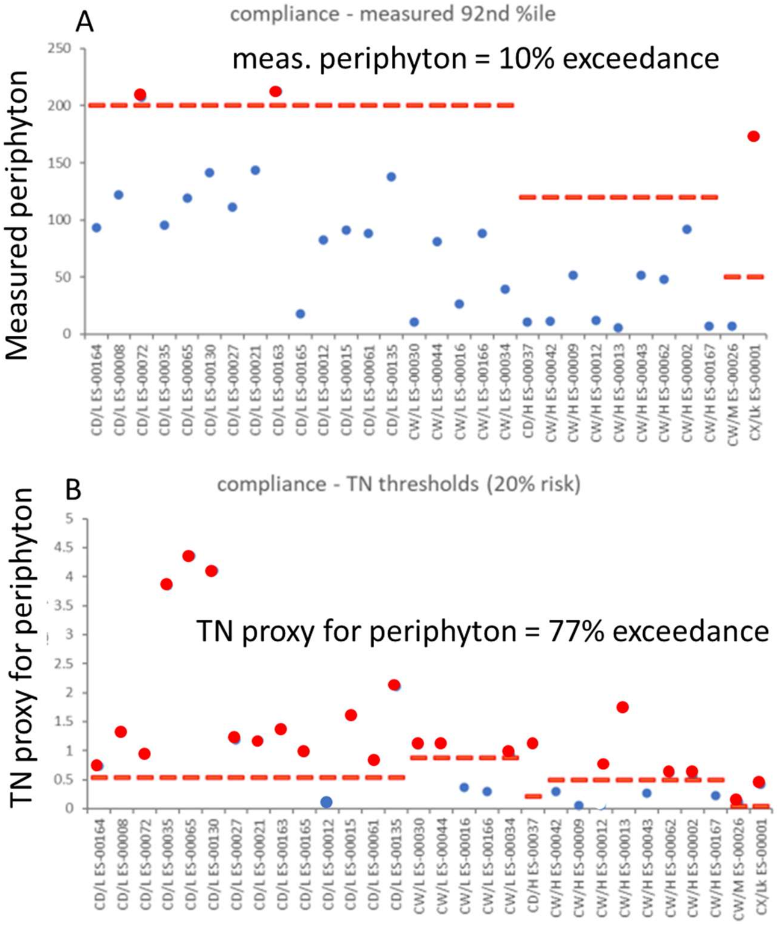

Figure 9. Comparison of periphyton TAS assessment according to A) measured periphyton biomass, and B) using 1st edition 20% risk TN criteria as a proxy measure of periphyton biomass (modified from Depree and Thiange, 2021).

We consider that measured periphyton biomass data is an example of robust data. This is consistent with Kilroy et al. (2019)[53] who state (underlined text is our emphasis):

"<u>Robust periphyton data are being collected by several regional councils following inclusion of periphyton standards</u> and guidelines in regional plans and inclusion of periphyton as an attribute in the National Objectives Framework of the National Policy Statement for Freshwater Management (NPS-FM), which became operational in 2014."

Southland periphyton monitoring at 30 sites commenced in 2016 - currently a 6-year dataset. Note that we re-evaluate the extent of compliance of Southland rivers using the most recently available data set (complete to March 2021) below.

For the avoidance of doubt, we have very low confidence in the riverine TN reduction targets based on the 20% risk TN thresholds (1st edition). However, we suspect that these concerns are largely a moot point given 2nd edition periphyton nutrient criteria developed using periphyton biomass data

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[53] Kilroy et al. (2019). Modelling periphyton in New Zealand rivers Part 1. An analysis of current data and development of national predictions. NIWA Client report prepared for the Ministry for the Environment (98 p). https://environment.govt.nz/assets/Publications/Files/modelling-periphyton-in-nz-rivers-part1.pdf

from around 250 regional monitoring sites. TN criteria for B and C band periphyton thresholds in Southland REC class rivers have increased markedly (i.e., 2-4-fold, refer to Table 4). Accordingly, we anticipate that riverine TN load reductions to meet periphyton TAS will have decreased markedly.[54]

Clarification on MfE (2020) '1st edition' TN criteria and TN criterion used by Snelder (2020,2021)

We noted that Dr Snelder used 20% risk nutrient criteria that were different to those published by MfE (2020). We suspect the criteria used in Snelder (2021) are the first set of recalibrated nutrient criteria; we understand the calculation were repeated to replace 50% with a 30% under-protection risk. This resulted in TN criteria that were lower (more stringent) that made up the MfE (2020) nutrient lookup tables.[56] A comparison of these TN criteria (MfE 2020 vs Snelder 2021) for the main Southland REC source of flow (SoF) classes is shown in Table 5. TN criteria used by Snelder for the Southland work were 50-60% higher than the MfE (2020) "1st edition' nutrient criteria. It seems unusual that the original nutrient criteria values could not be reproduced – the differences seem very significant in a limit setting context.

Table 5. Comparison of MfE (2020) 20% risk TN criteria (g/m3) compared with those used to estimate Southland TN target loads for rivers in Snelder (2020 and 2021).

	Periphyton TAS	MfE 'look-up' 20% risk TN criteria [55]	ES 20% risk TN criteria (Snelder 2021)[56]	% difference (ES relative to MfE)
CX/Lk	A	0.068	0.105	54%
CW/H	B	0.488	0.781	60%
CD/H	B	0.217	0.316	46%
CD/L	C	0.542	0.811	50%
CW/L	C	0.874	1.325	52%

Variation in periphyton response to nutrients not accounted for by REC grouping

The intent of a limit setting process should be to set meaningful nutrient targets that provide for a given TAS. In this case, the TAS is periphyton biomass in hard bottom streams.

Different rivers can have very different susceptibilities to periphyton blooms – some are very sensitive to relatively low concentrations of nutrients, while others show very low susceptibilities to periphyton growth even at high nutrient concentrations. Some of the factors that account for this variation in susceptibility are accounted for by REC SoF class. However, there is still considerable variation in 'dose-response' at sites within the same REC SoF classes. For example, the 15 monitored CD/L class Southland rivers show that within a relatively narrow range of median TN concentrations (c. 0.7-1 g/m^3, green rectangle in Figure 10), measured data for the sites range from 30 mg/m^2 (A-band) through to 188 mg/m^2 (upper limit of C-band).[57]

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[54] With the possible exception of the Waiau FMU given that this has an A-band periphyton TAS and these are still very stringent in the 2nd edition look-up tables. Note that we disagree with the mainstem Waiau River being classified as lake-fed given that 85-90% of lake-fed water is diverted out of the Waiau mainstem.

[55] Ministry for the Environment. 2020. Action for healthy waterways: Guidance on look-up tables for setting nutrient targets for periphyton. Wellington: Ministry for the Environment.

[56] Refer to Appendix A, Table 25 in Snelder 2021.[13]

[57] Note that if using Excel 'exclusive' percentile function (as opposed to 'inclusive'), the chla percentile of 188 mg/m^2 increased to 204 mg/m^2 (this site is for Aparima at Thornbury).

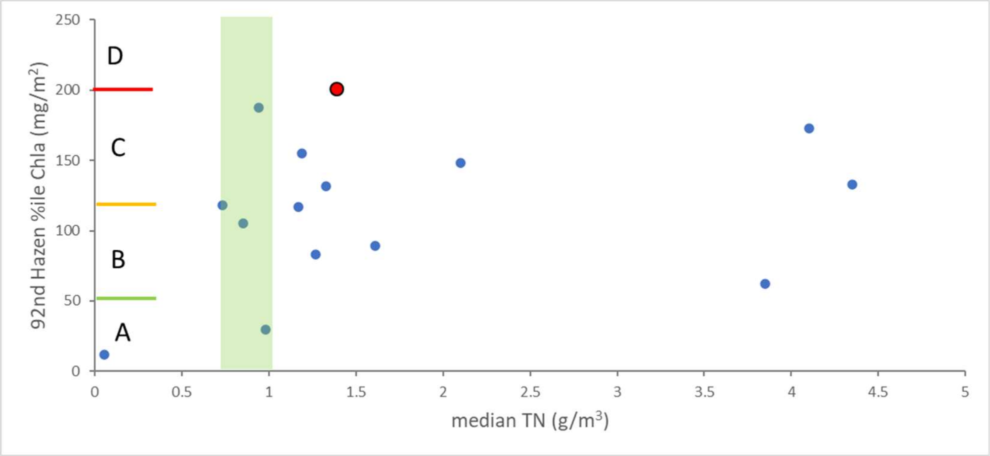

Figure 10. Measured periphyton biomass vs. measured median TN (g/m³) at the 15 CD/L classified Southland rivers. Red marker indicates the only Southland CD/L class river (Dipton Stream) that is currently not meeting the C-band periphyton TAS.

This variation is relevant because thresholds are derived at the REC SoF level, and so a TN criterion derived for a specific periphyton threshold (i.e., C-band for CD/L) for one of 21 SoF classes, would hopefully apply to a reasonably narrow 'dose-response' range. This does not appear to be the case for Southland CD/L sites. For example, the CD/L TN criterion value of 0.811 g/m^3 used by Snelder (2020, 2021) to define C-band periphyton TAS corresponds to a broad response area where measured sites range from A-band to C-band (Figure 10). Presumably this may reflect varying levels of nutrient saturation, but this is still something needs to be considered to define meaningful TN criteria for assessing compliance with periphyton TAS.

A limitation of the look-up nutrient criteria is that they do not adequately account for 'within REC class' variation in nutrient susceptibility to periphyton blooms (refer to Figure 10). Rather they select an arbitrary 'risk value' that provides over stringent criteria to 'over-protected' sites, and overly permissive criteria to 'under protected' sites. A concern we raised previously (Depree and Thiange, 2021) was the high degree of over-protection when applying "1st edition" 20% TN criteria to Southland rivers (refer to Figure 9).

We have provided additional commentary around some of the pitfalls of the 'over-protection' and 'under-protection' concept that underpin NZ's nutrient concentration criteria (**Appendix A**). This needs to be applied in a meaningful way, so that the inherent variability does not translate into overly protective reductions being applied at most sites.

Updated assessment using most recent data (up to Mar 2022) and comparing predicted compliance using 1st edition and 2nd edition TN criteria

<u>1st edition 20% risk TN criteria (as used in Snelder 2020 and 2021)</u>

Using the Southland CD/L data, Figure 11 and Table 6 compares the extent of modelled compliance using the 1st edition 20% TN criterion of 0.542 g/m^3 with measured periphyton biomass.

Figure 11 shows that only one CD/L site is exceeding the periphyton band C TAS (site C, Dipton Stream) when using measured data. Moreover, only one Southland CD/L site was below the TN criteria used to assess compliance with the periphyton TAS. Measured data show the other 14 CD/L sites are currently meeting the C-band TAS for periphyton biomass (measured as Chla). But, the ES modelled approach (Snelder 2020,2021) determines any Southland site with a median TN concentration greater than the 20% TN criterion value of 0.542 g/m^3 to be non-compliant with respect to the periphyton TAS, and therefore over-allocated for TN (Figure 11). The modelling approach assumes that the FMU will only be compliant with the periphyton biomass TAS when all instream concentrations are reduced to at least 0.542 g/m^3. The ES requirement for all sites to reduce to 0.542 g/m^3 is illustrated by the green arrows in Figure 11, which shows considerable median TN reductions for sites that are currently graded as A, B and C-band sites using 5-6 years of monitoring data from Southland CD/ rivers. Because of the over-protective TN criterion value, this has resulted in the perverse outcome where most sites (and hence the contributing catchment area) require (on paper) substantive reductions of instream TN to meet a periphyton TAS that has already been met –**based on robust measured data**.

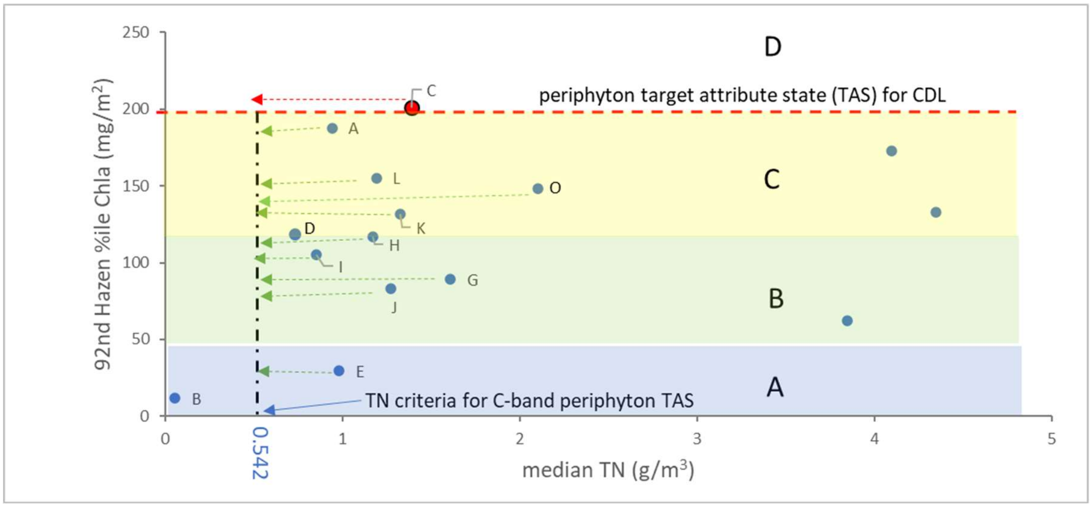

Figure 11. Measured periphyton biomass vs. measured median TN (g/m^3) at the 15 CD/L classified Southland rivers showing the result of applying the single 20% under-protection risk TN criterion value of 0.542 g/m^3 (green arrows are the required reductions in TN concentrations to make currently compliant CD/L sites 'compliant' with respect to the modelled TN criterion. Note that the three sites >3g/m^3 have not been included, and although these are meet the CD/L periphyton TAS (i.e., B and C-band sites), they would require around 30% reductions to meet the national bottom-line for nitrate-toxicity.

For example, site H (Mataura River @ Island Bridge) is B-band for periphyton biomass, which means current state TN concentrations are providing for the periphyton TAS (i.e., C-band). However, the assessment based on TN criteria as proxies for periphyton biomass indicate that the site is D band because the current TN concentration of 1.17 g/m^3 exceeds the default CD/L 20% risk TN criteria (C-band) of 0.542 g/m^3. This site currently complies with the periphyton TAS (**when using measured data**) but using a '**modelled'** look-up TN criterion of 0.542 g/m^3, the sites is assessed as failing to meet the periphyton TAS and requires a reduction in instream TN concentration of 54% (Table 6).

Excluding the three sites that exceed the national bottom-line for nitrate toxicity (i.e., >2.4 g/m^3), the use of a single REC-based TN criterion value (0.542 g/m^3) results reductions of 26 to 74% (average of 50% reduction) at sites that are currently meeting the proposed periphyton TAS of C-band based on measured data, consistent with Clause 1.6 (Table 6). It is important to emphasise that we are not implying that at the sites currently meeting the periphyton TAS (Figure 11 and Table 6) that they will not require reductions, as many of these sites will require reduction to meet target loads determined by estuaries. However, the assessment of target loads to meet the relevant in-stream periphyton TAS is an important part of the process as in some FMUs, or part of FMUs, riverine target loads will be what determines the overall load reduction targets.

Table 6. Measured periphyton state and TN reductions for Southland CD/L stream based on assessments using the ‘1st edition’ CD/L 20% risk TN criteria (MfE 2020[60] and Snelder[58] 2021). Red text indicate site where measured data indicates site is non-compliant with the periphyton TAS, blue text is site where instream TN is less than the 20% TN criteria, and black text are sites where measured data confirms they comply with periphyton TAS (i.e., C-band or better), but they are assessed as being ‘non-compliant’ using either of the look-up TN criteria.

site	Name	Measured current state periphyton biomass[59]	Measured current state median TN	Reduction in river TN to meet the TN instream criteria	
				MfE[55] 0.542 g/m^3	ES (Snelder)[13] 0.811 g/m^3
A	Aparima River at Thornbury	C	0.94	42%	14%
B	**Cromel Stream at Selbie Road**	**A**	**0.055**	**0%**	**0%**
C	**Dipton Stream at South Hillend-Dipton Road**	**D**	**1.39**	**61%**	**42%**
D	Hamilton Burn at Affleck Road	B	0.73	26%	0%
E	Hedgehope Stream 20m u/s Makarewa Confl	A	0.98	45%	17%
G	Makarewa River at Counsell Road	B	1.61	66%	50%
H	Mataura River at Mataura Island Bridge	B	1.17	54%	31%
I	Orauea River at Orawia Pukemaori Road	B	0.85	36%	5%
J	Oreti River at Branxholme	B	1.27	57%	36%
K	Otautau Stream at Otautau-Tuatapere Road	C	1.325	59%	39%
L	Waikaka Stream at Gore	C	1.19	54%	32%
O	Waituna Creek at Marshall Road	C	2.1	74%	61%

Revised (2nd edition) 20% risk TN criteria (ES have used these to update their load targets to meet river TAS, but we have not yet seen this report).

For the river class CD/L with C-band periphyton TAS, the latest (MfE 2022)[42] nutrient look-up tables for periphyton increased the 20% risk criterion from **0.542 g/m^3** (or 0.811 g/m^3 as used by Snelder 2020) to **2.252 g/m^3**.

This has had a significant effect on the assessment of riverine target loads, as the new TN criterion is now 4-times higher than the one it replaced (0.542 g/m^3). It also supports the many concerns we repeatedly raised to ES about the over stringent nature of the 1st edition TN criteria when applied to Southland (Figure 12).

Compared with Figure 11 (using criteria of 0.542 g/m^3) where 14 CD/L sites assessed as non-compliant, the 2nd edition 20% risk TN criteria predicts that only three sites with TN concentrations >3 g/m^3 are not meeting the modelled periphyton TAS (Figure 12, TN criteria of 2.52 g/m^3). We note that the only way we know the 1st edition TN criteria were too stringent, and the 2nd edition criteria were better estimates of ‘compliance rates’ is because of **measured data**. While we appreciate the

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[58] We do not know why ES / Snelder[4,13] (2020 and 2021) used criteria that were different to those published by the Ministry (MfE 2020).[60]

[59] TAS for periphyton is C-band, therefore sites with C-band or better are meeting the TAS for CD/L class Southland rivers.

scientific uncertainty, this ‘fast moving numerical feast’ of TN criteria does little in the way of providing confidence when setting resource use limits for FMUs (or part of FMUs).

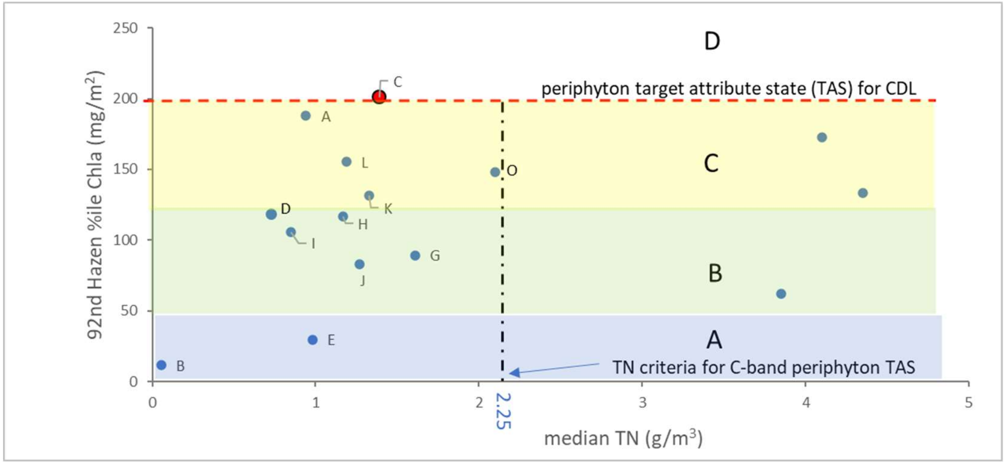

Figure 12. Measured periphyton biomass vs. measured median TN (g/m³) at the 15 CD/L-classified Southland rivers showing the result of applying the revised (2nd edition) 20% under-protection risk TN criterion value of 2.25 g/m³. Reductions in TN from the 3 sites with TN >3 g/m3 are not shown, as these do not exceed the CD/L periphyton TAS, and reductions (c. 30%) for these sites (and contributing catchments) are likely to be driven by the nitrate-toxicity national bottom-line of 2.4 g/m³. Most notably, compared with Figure 11, the revised TN criterion value results in all previously ‘non-compliant sites’ now being consider compliant (including site C which measured data indicated is non-compliant, i.e., D-band).

Based on the TN criteria of 2.252 g/m^3, all other Southland CD/L sites are classified as meeting the C-band periphyton TAS. Accordingly, all sites list in Table 6 would not require a reduction in median instream TN concentration. This compares to a mean reduction of around 50% when using the ‘1st edition 20% risk TN criteria’. We note that the three CD/L sites with >3 g/m^3 (Longridge, Waimatuku and Waimea streams) would require reductions of 29-34% to meet national bottom-line for nitrate toxicity.

A comparison of the modelled compliance with periphyton TAS using the 1st edition[60] (0.542 g/m^3) and 2nd edition[61] (2.25 g/m^3) TN criteria against measured periphyton state for all sites and CD/L sites is provided in Table 7. The results yet again highlight how poorly the ‘1st edition 20% TN criteria’ aligned with measured periphyton compliance data, and the closer alignment of the ‘2nd edition 20% TN criteria’ assessment with measured periphyton compliance with TAS.

Table 7. Comparison of the proportion of complying sites (total n=30; and CD/L n=15) as assessed by measured periphyton biomass, original (1st edition) 20% risk TN criteria, and the 2022 (2nd edition) 20% TN risk criteria.

	All sites (n=30)		**CD/L REC sites (n=15)**	
Periphyton assessment	**No. sites meeting/ exceeding periphyton TAS**	**No. sites failing periphyton TAS**	**No. sites meeting/ exceeding periphyton TAS**	**No. sites failing periphyton TAS**
Measured (Hazen 92nd %ile)	28 (93%)	2 (7%)	14 (93%)	1 (7%)
1st edition 20% TN criteria (MfE 2020)[60]	7 (23%)	23 (77%)	1 (7%)	14 (93%)
2nd edition 20% TN criteria (MfE 2020)[61]	24 (80%)	6 (20%)	12 (80%)	3 (20%)

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[60] Ministry for the Environment. 2020. Action for healthy waterways: Guidance on look-up tables for setting nutrient targets for periphyton. Wellington: Ministry for the Environment.

[61] Ministry for the Environment. 2022. Guidance on look-up tables for setting nutrient targets for periphyton: second edition. Wellington: Ministry for the Environment.

The role of TN criteria for councils that have long-term periphyton monitoring data?

It is encouraging to see the revisions to the look-up nutrient criteria (with the latest version derived from a new model based on c. 250 regional measured sites) show improved agreement with the measured periphyton compliance data. However, we assert that given the magnitude of change between 1st and 2nd edition iterations of the TN criteria (up to 4-fold increase in TN criteria), that this validates one of our key concerns about riverine TN load reductions having been over-estimated, which we raised (exhaustively) with ES in our technical review (Depree and Thiange, 2021) to no avail. It also is an important reminder that the default nutrient criteria are intended as "a *starting point for defining nutrient criteria for managing target periphyton attribute states*".[62] And that they are continually being made more relevant by "recalibration" **with measured data** – we emphasise and further reiterate, that in both the 1st edition and 2nd edition TN guidance on using the nutrient look-up tables, the importance of using measured data for confirming 'compliance/non-compliance' with periphyton TAS. For example, the 2nd edition guidance states (MfE 2022):

"Only monitoring of periphyton can confirm the actual biomass at a site and therefore the site's grading relative to the periphyton attribute"

Given that measured data is used to develop models, recalibrate thresholds and is the only way to assess sites against community-set periphyton TAS, it is difficult to then understand how ES (Snelder 2020 and 2021) relied exclusively on nutrient criteria to assess region-wide compliance (at reach-scale) of river against periphyton TAS. Given that the TN criteria proxy assessments of periphyton were so inconsistent with measured data from 30 sites (now with almost 6 years of data), how did ES have any confidence in the 'proxy assessments' when carried out on over 40,000 Southland stream reaches. Put quite simply, if the proxy TN assessment for periphyton compliance with TAS were largely incorrect at the 30 sites[63] where periphyton biomass could be confirmed, then they are likely to be largely incorrect at >40,000 reaches. That is, very large numbers of poor predictions (which we would argue are not fit for purpose for limit setting) are not more informative nor robust than data from monitored Southland sites that represent 'periphyton pressure' from upstream catchment land use.

We do not believe that to manage periphyton ES needs to be able to model/predict periphyton in every reach within an FMU. This 'requirement' has introduced considerable uncertainty (refer to Table 7). We believe that it would be more robust for ES to use their measured periphyton monitoring data to assess whether that site, and the upstream contributing catchment area, is meeting the periphyton TAS.

1) If it is meeting the periphyton TAS: (noting that of 30 monitoring sites >3 years duration, 28 sites (93%) had measured biomass that met the TAS, with one of these being in the Waiau catchment with an A-band TAS,)[64]
2) Consistent with 3.13 guidance, current state median nutrient concentrations could be used to define riverine nutrient concentration criteria for that part of the FMU.

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[62] Refer to Section 4 under the heading "Purpose of the look-up tables" (pg 29) of MfE (2022)[3]

[63] Here we are referring to "1st edition" 20% TN proxies used by Snelder (2020, 2021)

[64] Note that we do not agree that the Waiau should be classified as a Lake-fed catchment given that approximately 85-90% of the Waiau River's flow is diverted out of the catchment. Dr Snelder agreed with these concerns are recommended that an alternative REC class be applied (this recommendation was not actioned by ES). Moreover, the power scheme means the Waiau River falls within clause 3.31. Because this allows councils to set target attribute states below the national bottom-line, we assuming that A-band periphyton TAS is not enforceable.

If it is not meeting the periphyton TAS:

3) Then nutrient criteria need to be set at concentrations lower than the current state nutrient concentrations, these may:
    - be achieved by the requirement to reduce nutrient loads to estuary
    - be informed by nutrient criteria – either national look-up tables or other regionally developed guidance
    - pragmatic reduction (e.g., 20%) which may be the first in a series of iterative reductions until the site meets the periphyton TAS

Our understanding is that Dr Snelder has concerns that monitoring sites are too few to adequately characterise the state of periphyton in FMUs (or part of FMUs). We accept that there are limitations in the spatial resolution of monitoring networks, and this may be more problematic for periphyton (due to heterogeneous nature of distribution), but then we assume that similar challenges also apply to other biological response-type attributes.[65]

Because periphyton was introduced as an attribute in 2014, and its importance in determining whether river (hard bed) catchments are over allocated with nutrients, we assume that regional councils like ES have a good understanding of where periphyton blooms occur and have included these sites into their periphyton monitoring networks. Conceptually, we believe that if councils have identified and monitor periphyton at susceptible sites, then this should largely address the risk of 'under protection'. Just as model criteria have uncertainty and risk, and this is accepted, then the same concepts should apply to monitoring networks. For example, in any FMU or part of FMU, there could be sites (in the 'mainstem' or smaller tributaries) that are more susceptible to periphyton blooms than the monitoring site. So just as with TN criteria models, there is a risk of 'under protection' by basing the nutrient criteria on the monitored sites and assuming the periphyton state (and compliance with TAS) at that site reflects the state (and TAS compliance) in the upstream waterways.

For pragmatic reasons we do not really see this as a major disadvantage (relative to TN criteria assessments) for the following reasons:

1) Through council or community knowledge of the FMU (part of FMU) we assume that a significant site with non-complying periphyton biomass would be known and likely to be monitored – sites with high susceptibilities to periphyton blooms should be included in the monitoring. If not, they should be.
2) If minor (low order) tributaries in the FMU exceeded the periphyton TAS, but these exceedances did not result in non-compliance of larger tributaries, then the catchment-scale risk of such 'under-protection' seems low
3) non-compliance with periphyton TAS based on exceedance of TN criteria does not mean the site well exceed the biomass threshold (i.e. TAS), as "*only monitoring of periphyton can confirm the actual biomass at a site and therefore the site's grading relative to the periphyton attribute*". Moreover:
    a. overly stringent TN criteria, such as the 1st edition (MfE 2020) thresholds used in Snelder (2020, 2021), incorrectly identifies a lot of non-compliance because of 'excessive' over-protection.

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[65] For example, macroinvertebrates and fish in rivers; macrophytes in lakes and cyanobacteria in lakes

b. using 2nd edition criteria (MfE 2022), particularly for C-band TAS class river, the TN criteria are typically much higher[66] than receiving environment concentrations, and so these TN criteria are unlikely to identify upstream reaches that do not comply with periphyton TAS

We looked at the part FMU scale resolution provided by Southland periphyton monitoring data using the 10 sites in the Mataura catchment. **Appendix B** includes a catchment map, showing the periphyton 'part of FMU' subcatchments provided by the 10 sampling sites. We also provide a summary of the measured data and subsequent nutrient reduction based on riverine periphyton and nitrate toxicity assessment. We also considered whether the approach by Snelder (2020, 2021), which used periphyton-based nutrient criteria gave effect to Clause 3.13 which requires councils to set instream nutrient concentrations for any other attribute potential affect by nutrients. Based on the conceptual diagram of nutrient impacts on relevant riverine attributes, we believe that at least conceptually, managing for periphyton TAS will generally provide for other trophic levels and secondary effects (**Appendix C**).

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[66] 20% under protection risk criteria for CD/L and CW/L are 2.2 and 3.5 g/m^3, respectively.

Appendix A: Comments on the under- and over-protection concept that underpin the nutrient criteria

A limitation of the nutrient criteria is that they are based on a theoretical probability of under and over-protection of sites – a spatial concept that we still argue is inconsistent with the intent of the NPS-FM (2020).[67] under protective of a relatively small percentage of sites, and over-protective for a large proportion of sites. For example, the 'default' 'under protection risk' of 20% is based on 20% of a population (REC class) being under protected (i.e., exceeding the TAS at the criterion value), and 80% of the population being 'over protected'.

"Over-protection" means that the TN-criteria are more stringent than what is required to achieve the periphyton TAS. This seems inconsistent with the intent of the NPS-FM which is ultimately to set limits on resource use provide for freshwater outcomes/objective (via meeting TAS). To illustrate this, we have reproduced diagrams from MfE guidance on the nutrient look- up table (Figure 13), which shows made up data of periphyton biomass versus TN concentrations where the periphyton TAS is B-band (120 mg/m^2 chla). The left graph shows the line of best fit where the upper periphyton limit corresponds to a TN concentration of 0.445 g/m3 – this line of best fit corresponds to a 50% under-protection risk, and 50% over-protection risk. The graph on the right shows how by translating the line of best fit upwards progressively moves more data below the line and decreases the TN criteria corresponding to the periphyton TAS (120 mg/m^2). This increases the extent of 'over-protection' and decreases the extent of 'under protection'.

The problem with this approach is that REC classes to do account for the observed differences in periphyton response to TN, and as such, the lower the under-protection risk, the more unjustifiably stringent the TN criteria comes for sites with relative low susceptibility. For example, the site indicated by the large blue marker in Figure 13 is A-band periphyton (i.e., better than the B-band TAS in this example) and has a TN concentrations of 1.05 g/m^3. Consistent with national guidance that prioritises measured data, we consider that it would be reasonable (justifiable in fact) to set instream TN criteria (riverine) based on current state[68] of 1.05 g/m^3. If a 50% under-protection TN threshold was used (0.772 g/m^3), then this would correspond to a 26% reduction in instream TN. However, when a lower under protection risk is applied (Figure 13, right) the TN criteria need to achieve the periphyton TAS decreases to 0.445 g/m^3. In this example, the blue site, which currently meets the periphyton TAS, is required to reduce instream TN concentration by 58%.

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[67] With perhaps the exception of Human Health (table 9, NPS-FM), which in conjunction with national targets in Appendix 3, allow for spatial exceedance of human health TAS (i.e., accepting that 10-20% of lakes / rivers will not be swimmable).

[68] Current state, or the current state as at 2017 (consistent with setting of baseline states – refer to NPS-FM 2020)

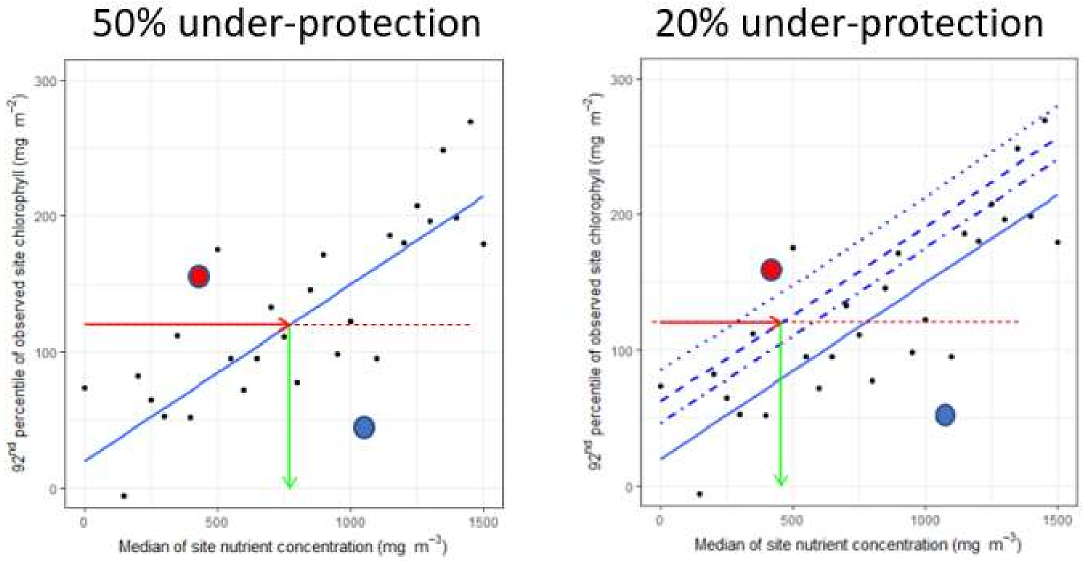

Figure 13. Explanation of the concept of decreasing the under-protection risk, and consequently increasing the over-protection risk for an under protected site (red) and over-protected site (blue). Modified from Figures 1 and 2 from Guidance of look-up table for setting nutrient targets for periphyton (MfE 2022)[3]

Another problem with the approach to deriving the criteria is that a proportion of sites will be *under protected* – in other words, the TN criteria will not provide for the periphyton TAS set by the community. This is illustrated in Figure 13 using the red site which has a TN concentration of around 0.42 g/m^3 and has C-band periphyton biomass that is exceeding the TAS. In this example, the 20% under-protection risk TN criteria 0.45 g/m^3, meaning that the red site is meeting the periphyton TAS (although from monitored data we know that it is not). So, from the perspective of 'the community' that want to see sites meeting the periphyton TAS, in this example, the FMU (or part of FMU) represented by the red site would not require a reduction in TN (based on riverine assessment). This is because the red site is one of 20% of sites (reaches) that are theoretically expected to exceed the periphyton TAS because it is one of the 20% of under protected sites.

In this example, the only way that the community would be able to 'force' a nitrogen reduction at this site would be to accept a lower level of under-prediction risk (e.g., 10%). In Figure 13, if this corresponded to the outer most dotted line, this would correspond to a TN-criteria of around 0.25 g/m^3. This TN criteria would require a 40% reduction at the red site, however, for the low susceptible 'blue site' (that is A-band) would be required to have a 76%. We note that this is a similar scenario to sites like the Mataura at Gore, which has a B-band TAS, measured periphyton A-band site, but would be required to reduce TN concentration by around 80% to make the MfE look-up TN criterion of 0.217 g/m^3 (refer to Depree and Thiange 2021).

Appendix B: Periphyton monitoring sub-catchments (part of FMU) in the Matarua FMU

Figure 14 shows the Mataura FMU (excluding Waituna) and the location of 10 periphyton monitoring sites. The size of the upstream catchments ranges from 518,000 ha (lower Mataura River mainstem site), down to 6,400 ha (Longridge Stream). An assessment of the measure periphyton state and compliance with relevant periphyton TAS is provided in Table 88. Given limitations around the use, and arguably how well the theoretical concepts of under and over-protection risk can be communicated to communities/stakeholder, it is unclear to us what the advantages are of applying the 2nd edition TN criteria across the 9,150 reaches of the Mataura catchment. We anticipate the reductions will be driven by:

1) CDH and CWH class reach that have modelled concentrations greater than the TN criteria of 0.858 and 0.809 g/m3, respectively (e.g., Mataura at Gore)
2) lowland CD/L reaches with high TN concentrations (e.g., Longridge, Waimea streams) that require significant reductions to meet the TN criterion of 2.25 g/m^3.

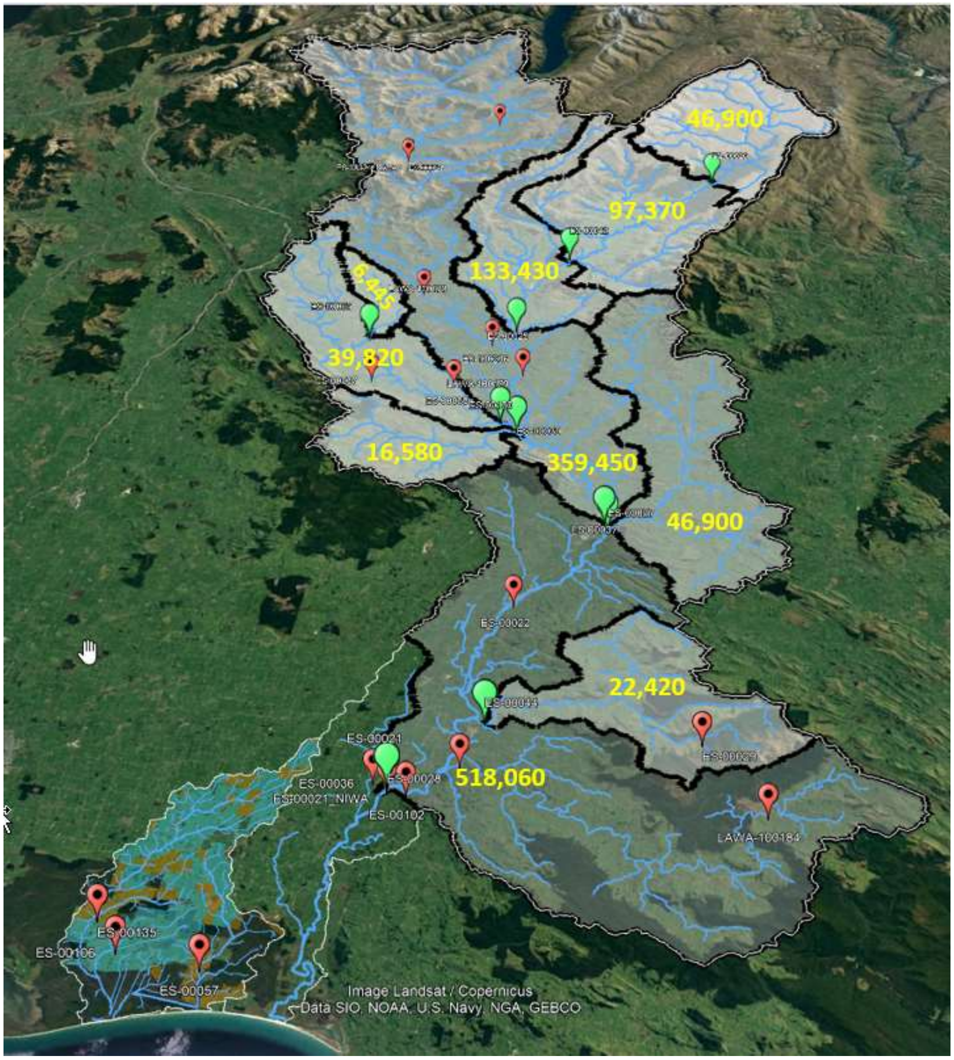

Figure 14. The Mataura catchment showing the parts of the FMU that are defined by the current periphyton monitoring sites (green marker, n=10). Red markers indicate water quality monitoring sites where periphyton is not monitored. The yellow numbers are the area (ha) of each subcatchment (part of FMU).

With respect to 1), measured periphyton biomass at CD/H site Mataura (at Gore) shows this site is current A-band. However, we acknowledge that the reductions based on a criterion value of 0.858 g/m^3 are much more realistic than those based on the 1st edition criterion threshold of 0.229 g/m^3. Although the percent TN reduction decreases from around 80% (1st edition) to 23% (2nd edition), the point is that this site is current A-band periphyton, with a periphyton biomass TAS of B-band.

With respect to 2), despite high TN concentration, measured periphyton biomass indicates that these sites are likely meeting the CD/L periphyton TAS (refer to Figure 11 or Figure 12). Regardless of periphyton status, these sites would need to reduce by at least 30% to meet the national bottom-line for nitrate toxicity (2.4 g/m^3).

Table 8. Summary of measured periphyton data and comparison with relevant periphyton TAS for 10 sites defining parts of the Mataura FMU.

site	**catchment (ha)**	**REC**	**periphyton TAS**	**measured 92nd %ile**	**periphyton Band**	**compliant with TAS**	**current TN**	**indicative TN reduction (%)**[1]
Longridge Stream at Sandstone	6,445	CD/L	200 (C)	133	C	yes	4.35	33%
Mataura River at Gore	359,447	CD/H	120 (B)	11	A	yes	1.115	0%
Mataura River at Mataura Island Bri	518,059	CD/L	200 (C)	117	B	yes	1.17	0%
Mimihau Stream at Wyndham	22,419	CW/L	200 (C)	111	B	yes	1.13	0%
Otamita Stream at Mandeville	16,579	CW/L	200 (C)	44	A	yes	1.095	0%
Waikaia River at Waikaia	97,370	CW/H	120 (B)	12	A	yes	0.3	0%
Waikaia River u/s Piano Flat	133,430	CW/M	120 (B)	9	A	yes	0.11	0%
Waikaka Stream at Gore	47,179	CD/L	200 (C)	155	C	yes	1.19	0%
Waikawa River at Progress Valley	46,886	CW/L	200 (C)	39	A	yes	0.925	0%
Waimea Stream at Mandeville	39,817	CD/L	200 (C)	173	C	yes	4.1	29%

[1] TN concentration reductions for Longridge and Waimea based on meeting the national bottom-line for nitrate toxicity of 2.4 g/m^3. Note the 0% for the other sites reflects that current instream TN concentrations are providing for the periphyton biomass TAS. Reductions may be required if current state define at 2017 is less than current state TN shown here. These reductions are only for meeting riverine periphyton or nitrate toxicity, they do not include reductions that may be required to achieve estuarine TAS in Toetoes Estuary.

Appendix C: Comment on whether riverine nutrient loads to meet periphyton TAS adequately gives effect to clause 3.13(1) to set instream nutrient criteria to achieve target attribute states for "any other attribute that is affected by nutrients".

Clause 3.13(1) requires regional councils to set instream nutrient concentrations to achieve a target attribute state for periphyton, any other nutrient attribute, and any attribute that is affected by nutrient. Clause 3.13(4) provides examples of attributes affected by nutrients, which for rivers include dissolved oxygen, fish, macroinvertebrates and ecosystem metabolism.

For rivers, Snelder (2020,2021) included periphyton and nitrate toxicity, accordingly there may be some concerns that the approach does not properly give effect to 3.13(1) and (4). While it seems like councils would need to derive criteria for all these attributes, if periphyton is the primary response to nutrients, then conceptually, if periphyton is managed (in hard bottom streams), then so will the other nutrient affected (albeit indirectly) attributes.

The Ministry's 3.13 guidance document "*Setting instream nutrient exceedance criteria for nutrient-affected attributes in rivers" (MfE)*[70] provides a useful simplified conceptual model for the linkages between nutrients and other riverine, ecosystem health attributes (Figure 15). This model shows that the direct effect of nutrients is on peripyton, with nutrient effects on other attributes being indirect – that is, mediate by periphyton, or other secondary effects. The guidance document states:

Dissolved nutrients (ie, DIN and DRP) have a more direct effect on periphyton (comprising algae and heterotrophic microbes) than on other ecosystem constituents. DIN and DRP are essential raw materials for the growth of algae. Thus fewer mediating variables separate water column nutrients from periphyton growth than from (for example) macroinvertebrate growth (see Figure 15). This conceptualisation is appropriate within the context of this guidance because:

- *Dissolved nutrients affect macroinvertebrates through their effects on algae and heterotrophic microbes.*
- *the direct effects of dissolved nutrients on macroinvertebrates and fish are manifest as toxicity effects, which are out of scope*
- *excluding toxicity effects, dissolved nutrients will affect macroinvertebrates and fish through their effects on food web processes (ie, food quality and quantity)*
- *dissolved nutrients affect dissolved oxygen via the influence of nutrients on periphyton growth rates and biomass, and on subsequent secondary production (eg, in macroinvertebrates), and thence respiration and photosynthesis of these species assemblages*

Based on this, and on the assumption that periphyton band states correspond (or provide for) other attribute band states[69], we consider that the approach taken by Snelder (2020,2021) does (at least conceptually) give effect to Clause 3.11(1) and 3.11(4).

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[69] That is, a C-band periphyton attribute state provides for a C-band (or better) macroinvertebrate state and C band (or better) dissolved oxygen state etc.

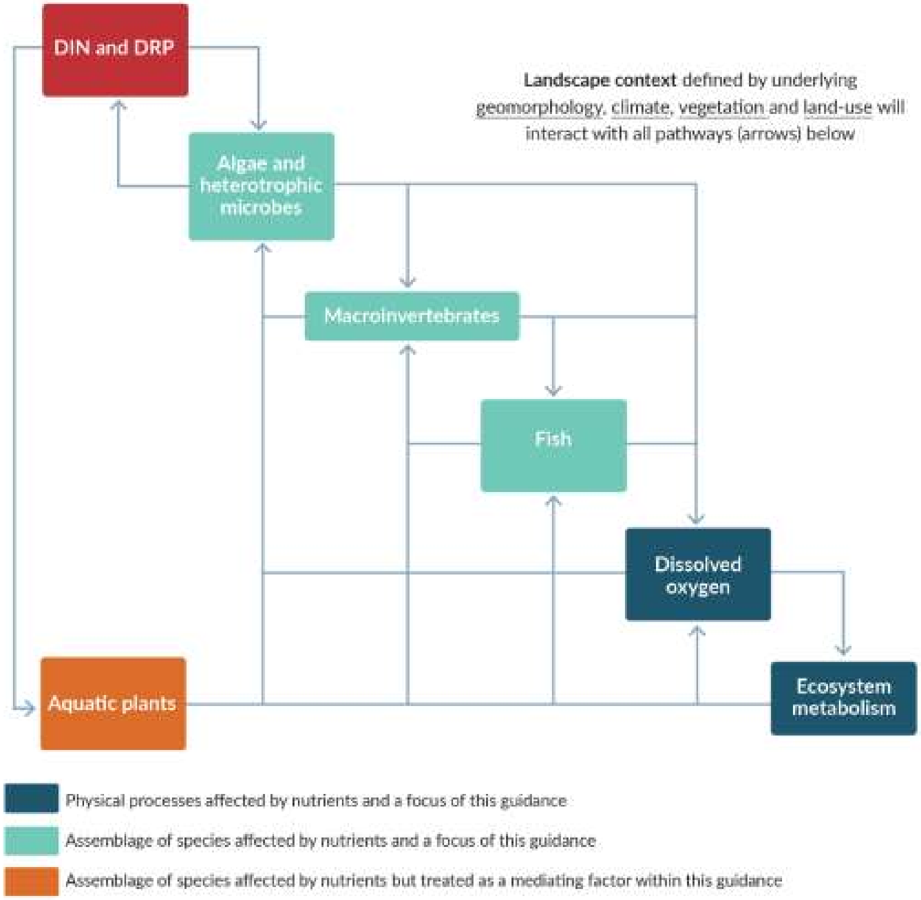

Figure 15. Simple conceptual model summarising the primary link between nutrients, periphyton and other potentially nutrient-affect attributes of river ecosystems (Figure 2-1 taken from MfE 2022[70] 3.13 guidance document)

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[70] Ministry for the Environment 2022. Setting instream nutrient concentration thresholds for nutrient-affected attributes in rivers: Guidance on implementing Clause 3.13 of the NPS-FM. Wellington: Ministry for the Environment.