Freshwater Science and Technical Advisory Group

Report to the Minister for the Environment

June 2019

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Part 1: Overview and introduction

1.1 Executive summary

Mandate, process and focus

The Science and Technical Advisory Group (STAG) was engaged to support officials with science and technical advice on the Water Taskforce work programme, as requested by the Water Taskforce officials. We were tasked specifically with providing expert advice on existing science, ensuring officials were interpreting the science accurately, and identifying data gaps to direct future focus/research efforts.

The STAG was not engaged to develop attributes or policy responses appropriate for amending the NPS-FM. We have chosen deliberately, however, to follow the same format and use the same terms as the NPS-FM to emphasise that the measures and thresholds we are recommending in this report are of equal importance to the existing measures and thresholds currently included within the national framework for managing fresh water.

Freshwater indicators of habitat or aquatic life that have complex relationships with multiple stressors have not, to date, been the focus of the NPS-FM. Accordingly, this report highlights a strong focus by STAG on the health of the environment and the waterbody. Its content and recommendations provide additional metrics for the national freshwater management framework to strengthen the relationship between this national direction and ecosystem health and functioning.

We recognise that recommendations in this report could, depending on the way they are incorporated into policy, have very significant economic and social implications for individuals and communities in some parts of New Zealand. At the same time, they will require substantial investment in both capacity and capability in freshwater science and management in New Zealand, especially in relation to regional council monitoring and reporting. However, it is explicitly not within our remit to consider such implications in developing our recommendations. Our focus has been on the freshwater ecosystems themselves and in this respect our recommendations are aligned with the first obligation of Te Mana te Wai – *the first obligation is to the water, to protect its health and its mauri.*

Greater clarity needed

New Zealand's freshwater management framework needs to be clear for it to avoid further degradation of aquatic ecosystems. The intent of the NPS-FM to maintain or improve water quality is not given effect to by the requirement to merely maintain water quality within an Attribute band. Such a definition of 'maintain' could have the perverse effect of allowing material declines in ecosystem health should water quality decline within (sometimes broad) bands.

The current 'maintain or improve' objective and policies are vague and open to interpretation. We believe that freshwater objectives should be set to maintain the current state of ecosystem health (as opposed to maintaining water quality within a band) and regional councils should report on their performance in terms of achieving freshwater objectives alongside a wider range of information – providing a more comprehensive picture of the state of water and effectiveness of management actions.

To support this clarity, guidance will need to be provided on:

- exactly what constitutes the 'current' state of fresh water and the extent of variability that will be acceptable when defining this state
- monitoring and statistical methods and reporting tools, to ensure consistency
- the value of collecting other information that will allow interpretation of any ecosystem health and water quality changes observed
- how to apply Mātauranga Māori and Māori indicators of ecosystem health
- how to account for unavoidable or predicted declines due to past management activities (i.e., lag effects) – this issue exists with the current 'band test' but would become more acute with the more stringent test being proposed here
- how to determine what level of monitoring is enough to inform analysis, supported by worked examples of how this should be done.

Additional ecosystem health metrics required

In developing our recommendations on ecosystem health metrics, we have recognised the importance of taking a much more integrated and holistic view of the things we need to measure and manage, to protect and enhance our shared values for water.

The process we followed was guided by a Biophysical Ecosystem Health Framework[1] prepared for the Ministry for the Environment by a multidisciplinary team of freshwater scientists to help practitioners understand overall biophysical ecosystem health. That framework identifies five biophysical components that contribute to freshwater ecosystem health, all of which are necessary to consider when defining the health of a water body and designing management interventions:

1. Water quality – the physical and chemical measures of the water, such as temperature, dissolved oxygen, pH, suspended sediment, nutrients and toxicants.
2. Water quantity – the extent and variability in the level or flow of water.
3. Habitat - the physical form, structure and extent of the waterbody, its bed, banks and margins, riparian vegetation and connections to the floodplain.
4. Aquatic life – the abundance and diversity of biota including microbes, invertebrates, plants, fish and birds.
5. Ecological processes – the interactions among biota and their physical and chemical environment such as primary production, decomposition, nutrient cycling and trophic connectivity.

In our report we have identified a series of additional metrics and tables relating to these components of ecosystem health, which we think are necessary to understand if we are to adequately manage New Zealand's fresh water (Table 1). For each metric we have developed tables providing numeric and narrative attribute states and identifying 'bottom lines' at the points at which impacts on the health and functioning of aquatic ecosystems shift from moderate to severe.

[1] http://www.mfe.govt.nz/publications/fresh-water/freshwater-biophysical-ecosystem-health-framework

Ecosystem component	Metric
Water quality	Lakes – dissolved oxygen Rivers – dissolved oxygen, DIN, DRP, suspended sediment (turbidity)
Water quantity	-
Habitat	Wetland extent and condition index Rivers – deposited sediment
Aquatic life	Lake Submerged Plant Index Rivers – macroinvertebrates (MCI, QMCI, ASPM), Fish (IBI)
Ecological processes	Rivers – ecosystem metabolism

Table 1: Ecosystem components and associated metrics for understanding and managing ecosystem health

One member expressed the view that, rather than introducing attribute limits for nitrogen and phosphorus for ecosystem health protection, the NPS-FM should be amended to clarify the process for setting nutrient limits for ecosystem health using existing attributes. This would require amendments to describe how to consider the ammonia toxicity, nitrate toxicity and periphyton requirements as well as those of downstream environments in a catchment or freshwater management unit.

Additional work required

In this report we identify a series of topics that urgently require additional work. While all these areas of work are important, we are particularly concerned that the current framework for freshwater management has serious gaps relating to:

- Ecological flows and levels for all freshwater systems (rivers, lakes, wetlands and groundwater) which have an influence over all other ecological health metrics and attributes.
- Monitoring methods for identifying faecal bacteria in recreational waters and the direct measurement of human pathogens (as opposed to indicator bacteria).
- Toxic cyanobacteria in rivers, monitoring methods, tools for and evaluating risks, and thresholds for management action.
- Understanding and protecting groundwater quality and ecosystems, preventing nitrate-nitrogen elevation in spring-fed streams and rivers, and understanding the effect of groundwater contamination on human health (either directly as drinking water or indirectly through food production).
- Nationally consistent methods for monitoring compulsory values, guidance on the design of systems for data generation and analysis (including system design, data collection, storage and analysis, and reporting protocols), and applied science to describe what is required to lift ecosystem health to meet community objectives and support adaptive management.

1.2 Recommendations

Recommendation 1:

Amend current national direction on freshwater management to ensure that any future national direction:

a. is designed to protect and enhance ecosystem health, defined as the extent to which a freshwater management unit supports an ecosystem appropriate to that freshwater body type (river, lake, wetland, or aquifer).
b. recognises that five biophysical components contribute to freshwater ecosystem health:
    i. Water quality,
    ii. Water quantity,
    iii. Habitat,
    iv. Aquatic life, and
    v. Ecological processes

Recommendation 2:

Amend the national direction in freshwater management to better bring mātauranga Māori into the management framework by supporting the development of mātauranga-based indicators and facilitating better engagement between scientists and kaitiaki in freshwater monitoring and management.

Recommendation 3:

Amend national direction on freshwater management to clarify the intent of the current policy expectation that the 'overall quality of fresh water within a freshwater management unit will be maintained or improved' by requiring:

a. freshwater objectives to be set to maintain or improve the current state of all metrics (as opposed to maintaining metrics within a NOF band),
b. regional councils to report on freshwater quality and the achievement of freshwater objectives alongside a wider range of information, including: pressures (e.g. changes in land use, human inputs, invasive species and climate); higher-level measures of state (e.g. ecosystem health); the effectiveness of management plan rules and methods; and progress towards implementing management plans, and
c. guidance on how to determine what level of monitoring is enough to inform analysis and reporting, supported by worked examples of how this should be done.

Recommendation 4:

All bottom line numbers in proposed attribute tables should be read as being subject to the qualification: 'unless it can be shown reliably that the natural state does not meet the bottom line'.

Recommendation 5:

Amend national direction on freshwater management to ensure the dissolved oxygen (in rivers) attribute applies in all river reaches and is not limited to "below point sources" of pollution.

Recommendation 6:

Amend national direction on freshwater management to:

a. introduce numeric tables for bottom water dissolved oxygen in lakes specifying a national bottom line of 0.5 mg/L; and

b. address mid-hypolimnetic dissolved oxygen in naturally seasonally-stratifying lakes with reference to specified numeric attribute bands.

Recommendation 7:

Amend national direction on freshwater management to introduce numeric biophysical tables for ecosystem metabolism, without specifying a national bottom line.

Recommendation 8:

Amend national direction on freshwater management by changing the table specifying numeric biophysical values for periphyton (trophic state) to:

a. replace the exclusion allowing rivers in the 'productive class' to exceed bottom lines 17 per cent of the time, and

b. require councils use the default nutrient criteria provided in the absence of robust, locally suitable, independently peer reviewed criteria.

Recommendation 9:

Amend national direction on freshwater management to introduce a table specifying numeric biophysical values for fish biotic integrity, specifying a national bottom line of 18 when measured using the Fish Index of Biotic Integrity

Recommendation 10:

Amend national direction on freshwater management to introduce tables specifying numeric values for a Macroinvertebrate Community Index, Quantitative Macroinvertebrate Community Index, and an Average Score Per Metric, specifying national bottom lines of 90, 4.5 and 0.3 respectively.

Recommendation 11:

Amend national direction on freshwater management to introduce numeric attribute tables for Lake ecosystem health by reference to the Lake Submerged Plant Index (LakeSPI), specifying a national bottom line for the native plant condition of at least 20% of the maximum potential score, and a national bottom line for invasive plants of less than 90% of the maximum potential score.

Recommendation 12:

Amend the national framework for freshwater management to introduce tables specifying numeric biophysical values for deposited and suspended sediment.

Recommendation 13:

Amend the national framework for freshwater management to introduce numeric biophysical tables for dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) and specifying national bottom lines of 1 mg/L DIN as an annual median (and 2.05 mg/L as a 95th percentile) and 0.018 mg/L DRP as an annual median (and 0.054 mg/L as a 95th percentile).

Recommendation 14:

Amend the national framework for freshwater management to require regional councils to:

a. identify the extent and evaluate the condition of existing wetlands
b. prevent any further reductions in the extent of existing wetlands
c. address the management of wetlands with reference to specified numeric bands, introducing a requirement to lift the wetland condition index to at least 10 and to maintain or improve the condition of existing wetlands where the condition score is greater than 10

Recommendation 15:

Undertake urgent work to fill the identified knowledge gaps which currently constrain our ability to effectively manage fresh water and the health of freshwater ecosystems.

1.3 Introduction

Attribute development in the National Policy Statement for Freshwater Management (NPS-FM) has, to date been based on an intervention logic that enables limits to be set on resources. With a couple of exceptions, mechanistic links to single stressors and land use, and management practicality have been the focus. Attributes have tended to be developed around metrics that can be easily measured and where management responses can be readily identified.

Conversely, freshwater indicators of habitat or aquatic life that have complex relationships with multiple stressors, have not been the focus of the NPS-FM. The content and recommendations of this report provide additional metrics that strengthen the ability to manage for ecosystem health.

Aquatic biosecurity and biodiversity are key gaps in the NPSFM. Species management is complex due to the different agencies involved, but the effects of freshwater pest species can be significant – sometimes overwhelming – in some areas and native aquatic species and habitats are in widespread decline. There is an urgent need for clarification of the roles and responsibilities of agencies with responsibilities for biosecurity and biodiversity, and revision of the regulatory regime for managing fresh water for controlling pervasive invasive aquatic pests and providing for fish passage.

In addition to the need to increase our understanding of mātauranga Māori and how to introduce it into the national framework for freshwater management, we have identified many areas for further work. Aside from the need to introduce additional metrics for ecosystem health into the management system, four glaring omissions require urgent action: ecological water flows and levels, groundwater dependent ecosystems, toxic cyanobacteria in rivers, and the relationship between waterborne pathogens and human health outcomes. To address these gaps central and regional government will need to work together to enable national consistency in monitoring methodology, site selection, data collation and decision making, and to increase research effort and generate applied science to inform adaptive management options.

1.4 Purpose of this report

This report presents the recommendations of the STAG for addressing questions and responding to issues presented to it by officials from the Ministry for the Environment.

1.5 Process followed

Scope and input

The process we followed was not an autonomous one whereby STAG members were asked or empowered to drive the direction and focus of discussion. Rather, government officials tabled topics and requested specific advice. Inevitably, given the nature of the STAG's role and the scale and urgency of the issues facing freshwater management in New Zealand, some important matters were not addressed or not addressed in the depth necessary to make specific recommendations. We have noted the most obvious and pressing of these matters in Part 4 of our report and recommend further work be undertaken in these areas as a priority.

The membership of the STAG represents a cross-section of New Zealand's science community. While the group has both broad and deep expertise, there are some important matters the group doesn't feel competent to comment on (i.e. indicator bacteria and the relationship between pathogens and human health) and there has been limited time to consider and provide recommendations on some topics.

We understand the Ministry for the Environment will consider our recommendations prior to providing advice to the Minister for the Environment on possible changes to the NPS-FM and the broader framework for freshwater management. We also understand these proposed changes will be subject to a public submission process. This process will bring public and practitioner experience to bear as well as enable the contribution of scientists employed in the various sectors of the economy impacted by our recommendations. While a public submission process is essential many of our recommendations are based on scientific judgements and should be subject to peer review.

Format and terminology

It is important to note we were not engaged to develop attributes or policy responses appropriate for amending the National Policy Statement for Freshwater Management (NPS-FM). We have chosen, however, to present our recommendations largely in the form of tables like the attribute tables included in the NPS-FM.

In taking this approach we have also chosen to use the term ‘attributes’ and ‘bottom lines’. These terms are currently used in the NPS-FM and we have chosen to adopt them here to emphasise that the measures and thresholds we are recommending in this report are of equal importance to the measures and thresholds currently included within the national regulatory framework. Presenting our information in table format has three benefits.

- First, it highlights the relationship between our national values for water, and the measures (or metrics) that are relevant to their maintenance or enhancement.

- Second, it provides a clear quantitative differentiation of the various states or levels of environmental quality, the characterisation of what constitutes a ‘good’ environmental state, as well as the placement of the “bottom line” distinguishing acceptable from unacceptable ecosystem health.

- Third, it provides narrative descriptions of what levels of quality each of those states represent and allows a generalised perception of what we consider a good environment to look like. In most cases, what members would consider ‘good’ is some level above the national bottom line, hence the use of attribute-like bands facilitates a degree of independent judgement regarding where to set management objectives.

Evidence requirements

The current attributes in the National Objectives Framework (NOF) were designed and introduced following advice from the previous Science Review Panel. This panel developed criteria it used to determine which attributes should be introduced to the NOF and how they should be designed. These criteria continue to be helpful for determining matters that should be considered.

Given the complex and dynamic relationships between attributes and ecosystem health, however, we have used these criteria for guidance rather than as prerequisites, choosing to consider somewhat broader implications and imperatives our selection of attributes.

While we have worked hard to define ecologically meaningful bottom lines derived from empirical research, we are conscious that defining bottom lines will in some cases be as much a normative process as it is a scientific one. In providing our recommendations we have attempted to define our bottom lines considering both our understanding of New Zealanders' views as to the bounds of acceptability and, from a technical perspective, the points at which impacts on the health and functioning of aquatic ecosystems shift from moderate to severe.

A copy of the Terms of Reference of the STAG can be found in Appendix 1.

Part 2: Overarching recommendations

2.1 Biophysical Ecosystem Health Framework

Recommendation 1:

Amend current national direction on freshwater management to ensure that any future national direction:

a. is designed to protect and enhance ecosystem health, defined as the extent to which a freshwater management unit supports an ecosystem appropriate to that freshwater body type (river, lake, wetland, or aquifer).

b. recognises that five biophysical components contribute to freshwater ecosystem health:
   i. Water quality,
   ii. Water quantity,
   iii. Habitat,
   iv. Aquatic life, and
   v. Ecological processes

Discussion

Freshwater ecosystems, and all their components, are not being adequately recognised and safeguarded in Aotearoa New Zealand. The management focus in the NPSFM has tended to be narrow, concentrating on water quality and quantity without explicitly considering aquatic life, habitat and ecosystem processes.

Recently a Biophysical Ecosystem Health Framework[2] was prepared for the Ministry by a multidisciplinary team of freshwater scientists to help practitioners understand overall biophysical ecosystem health. The framework has five core components: aquatic life, physical habitat, water quality, water quantity, and ecological processes – with longitudinal river connectivity being a cross-cutting feature relating to aquatic life, habitat and ecological processes.

Some of our members were authors of the Framework: Dr Joanne Clapcott, Dr Adam Canning and Dr Chris Daughney. We have collectively endorsed that Framework, summarised below, and used it to develop a series of ecosystem metrics and attributes that we recommend should be reflected in the national framework for freshwater management.

> *Ecosystem health – The extent to which a freshwater management unit supports an ecosystem appropriate to that freshwater body type (river, lake, wetland, or aquifer).*
>
> *Five biophysical components contribute to freshwater ecosystem health, all of which are necessary to consider when defining the health of a water body and designing management interventions:*

[2] http://www.mfe.govt.nz/publications/fresh-water/freshwater-biophysical-ecosystem-health-framework

- *Water quality – the physical and chemical measures of the water, such as temperature, dissolved oxygen, pH, suspended sediment, nutrients and toxicants.*
- *Water quantity – the extent and variability in the level or flow of water.*
- *Habitat - the physical form, structure and extent of the waterbody, its bed, banks and margins, riparian vegetation and connections to the floodplain.*
- *Aquatic life – the abundance and diversity of biota including microbes, invertebrates, plants, fish and birds.*
- *Ecological processes – the interactions among biota and their physical and chemical environment such as primary production, decomposition, nutrient cycling and trophic connectivity.*

These components complement and clarify the definition of the compulsory national value of 'ecosystem health' currently included within Appendix 2 of the NPS-FM:

> *Matters to take into account for a healthy freshwater ecosystem include the management of adverse effects on flora and fauna, the presence of toxicants, excessive nutrients, altered sediment levels, temperatures, pH, oxygen, algal blooms, invasive species, harvesting, altered riparian vegetation and changes in flow regime. Other matters to take into account include the essential habitat needs of flora and fauna and the connections between water bodies.*

2.2 Mātauranga Māori

Recommendation 2:

Amend the national direction in freshwater management to better bring mātauranga Māori into the management framework by supporting the development of mātauranga-based indicators and facilitating better engagement between scientists and kaitiaki in freshwater monitoring and management.

Discussion

In developing our recommendations on ecosystem health, we have recognised the importance of taking a much more integrated and holistic view of the things we need to measure and manage to protect and enhance our shared values for water. In that sense we can start to see opportunities to view our ecosystems (and the interrelationships between all living things) through a Te Ao Māori lens, via Te Mana o te Wai.

We have benefited from the input of experts in mātauranga and Māori indicators, and are confident there is real potential for complementarity between mātauranga Māori and science. It is essential that more work is done to bring mātauranga Māori into the management framework and to enhance scientific assessments with mātauranga-based monitoring. The Kahui Wai Māori report to the Minister 'Te Mana o te Wai' provides a useful structure to achieve this.

Upholding Te Mana o te Wai in each Freshwater Management unit (FMU) requires upholding Te Hauora o te Taiao, Te Hauora o te Tangata and Te Hauora o te Wai. Plans for achieving objectives in each Freshwater Management unit (FMU) can draw on mātauranga to identify and include tangata whenua values when providing for the specific aspects of mauri. Mātauranga Māori experts continue to propose measurable attributes of these integrated values. The integrated approach of Te Mana o te Wai suggests that we should seek to better understand the relationship between Māori attributes of freshwater health and the numeric biophysical attribute states and regulatory measures dealt with here. Where the available information doesn't yet support this kind of direct relationship, further research is required.

2.3 The requirement to 'Maintain or Improve'

Recommendation 3:

Amend national direction on freshwater management to clarify the intent of the current policy expectation that the 'overall quality of fresh water within a freshwater management unit will be maintained or improved' by requiring:

a. freshwater objectives to be set to maintain or improve the current state of all metrics (as opposed to maintaining metrics within a NOF band),
b. regional councils to report on fresh water quality and the achievement of freshwater objectives alongside a wider range of information, including: pressures (e.g. changes in land use, human inputs, invasive species and climate); higher-level measures of state (e.g. ecosystem health); the effectiveness of management plan rules and methods; and progress towards implementing management plans, and
c. guidance on how to determine what level of monitoring is enough to inform analysis and reporting, supported by worked examples of how this should be done.

Discussion

New Zealand's freshwater management framework needs to be clear for it to avoid further degradation of aquatic ecosystems. The current 'maintain or improve' objective and policies are vague and open to interpretation. Key concerns with the current requirement are:

- Outcomes for ecosystem health change significantly within (sometimes broad) bands. A definition of 'maintain' that merely requires water quality to be maintained within an attribute band could have the perverse effect of allowing material declines in ecosystem health.
- There is limited ability to link changes in ecosystem health to causes and generate a meaningful picture of the health of the ecosystem, and confusion over whether compliance with this requirement means all attributes must be maintained or improved, and
- The NOF is incomplete – we are considering what 'maintaining' ecosystem health means without a 'complete' set of attributes that need to be managed, which can create scientific uncertainty.[3]

[3] For a more comprehensive description of these concerns see Appendix 2

There are statistical tests that can be applied for determining whether measures of ecosystem health and water quality have been maintained, improved, or have declined. Guidance protocols on these statistical tests and how to interpret them will need to be provided to ensure consistent use and reporting. Matters that need to be addressed during the development of this guidance include:

- The value of collecting other information that will support better interpretation of any ecosystem health and water quality changes observed.

- Policy clarity on what, if anything, the word 'overall' means within Objective A2 of the NPSFM. From a technical perspective, testing to determine compliance of a Freshwater Management Unit (FMU) with the 'no decline' policy intent will require clarity on whether the 'maintain or improve' test means all attributes at all sites must be maintained or improved.

- Determining how unavoidable or predicted declines due to past management activities (i.e., lag effects) are accounted for within this framework. This issue exists with the current 'band test' but would become more acute with the more stringent test being proposed here.

- Direction on how to determine what level of monitoring is enough to inform analysis, supported by worked examples of how this should be done.

In broad terms, we believe that freshwater objectives should be set to maintain the current state of ecosystem health (as opposed to maintaining water quality within a band) and regional councils should report on their performance in terms of achieving freshwater objectives alongside a wider range of information – providing a more comprehensive picture of the state of water and effectiveness of management actions. To support this, exactly what constitutes the 'current' state of freshwater will need to be defined and there will need to be guidance regarding the extent of variability that will be acceptable when defining this state.

All the recommended metrics and tables presented in this paper should be interpreted in light of this recommendation.

2.4 Accounting for environmental variability

Recommendation 4:

All bottom line numbers in proposed attribute tables should be read as being subject to the qualification: 'unless it can be shown reliably that the natural state does not meet the bottom line'.

The requirement to provide recommendations that apply at a national level means we have not always been able to account for the full range of naturally occurring conditions and the full extent of variability in conditions (i.e. the conditions one would find in a geothermal stream or in the headwaters of a glacier-fed stream). Nor have we been able to reflect the influence of different catchment geologies and the natural character of specific catchments.

In some cases, exclusions will be required to reflect this variation, especially in more extreme environments.

Part 3: Recommended additional ecosystem metrics and attributes

3.1 Dissolved oxygen – rivers

Recommendation 5:

Amend national direction on freshwater management to ensure the dissolved oxygen (in rivers) attribute applies in all river reaches and is not limited to "below point sources" of pollution.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	Dissolved Oxygen		
Attribute Unit	mg/L		
Attribute State	Numeric Attribute State		Narrative Attribute State
	7-day mean minimum[1]	1-day minimum[1]	
A	≥8.0	≥7.5	No stress caused by low dissolved oxygen on any aquatic organisms that are present at matched reference (near-pristine) sites.
B	≥7.0 and <8.0	≥5.0 and <7.5	Occasional minor stress on sensitive organisms caused by short periods (a few hours each day) of lower dissolved oxygen. Risk of reduced abundance of sensitive fish and macroinvertebrate
C	≥5.0 and <7.0	≥4.0 and <5.0	Moderate stress on a number of aquatic organisms caused by dissolved oxygen levels exceeding preference levels for periods of several hours each day. Risk of sensitive fish and macroinvertebrate species being lost.
National Bottom Line	5.0	4.0	
D	<5.0	<4.0	Significant, persistent stress on a range of aquatic organisms caused by dissolved oxygen exceeding tolerance levels. Likelihood of local extinctions of keystone species and loss of ecological integrity.

1. Seven-day continuous dissolved oxygen monitoring to be collected at least once during summer (December to March inclusive). Objectives apply year-round.

Discussion

Rationale

- The dissolved oxygen attribute was originally applied to point sources as there is a direct and obvious cause-effect relationship and knowledge of how to manage them, which fits with the intervention logic used at the time the NPS-FM was developed.
- Dissolved oxygen is fundamental to provide for aquatic life. Accordingly, the dissolved oxygen measure should apply in all river reaches including, but not limited to, below point sources of pollution.

Guidance and caveats

- Key management actions to improve dissolved oxygen concentrations in rivers are to:
    - increase shading and reduce nutrients to decrease growths of nuisance periphyton and submerged macrophytes,
    - provide adequate minimum and variable flows across complex habitats that encourage aeration,
    - reduce ecosystem respiration, and
    - manage high periphyton biomass as per the Periphyton Attribute Table.
- To support the consistent and effective implementation of the river dissolved oxygen attribute, it will be important to provide guidance on dissolved oxygen measurement protocols and analytical protocols for establishing whether sites meet the attribute band thresholds. This guidance should be developed considering existing guidance on DO available through the NEMS.
- Measurement of dissolved oxygen in rivers is ideally undertaken using continuously recording sensors coupled to data loggers. Lowest oxygen concentrations typically occur just before dawn, a time when spot measures are rarely made. An additional advantage of continuous dissolved oxygen measurements is that, with a few minor additions they provide the raw data for derivation of river metabolic function, including respiration and gross/net photoautotrophic productivity (key ecological processes advocated for measurement elsewhere in this document).
- There is a need for further research to inform decisions on what is required to address breaches of desired attribute states and to address the lack of science available to help define and quantify the level of effort required to move a site from Band D to Band C or above.

Additional STAG member comments

- There is a high level of confidence in the dissolved oxygen concentrations in the current attribute table in the NPS-FM and these are widely applicable to rivers, not just downstream of point sources.

3.2 Dissolved oxygen – lakes

Recommendation 6:

Amend national direction on freshwater management to:

a. introduce numeric tables for bottom water dissolved oxygen in lakes specifying a national bottom line of 0.5 mg/L; and

b. address mid-hypolimnetic dissolved oxygen in naturally seasonally-stratifying lakes with reference to specified numeric attribute bands.

Value	**Ecosystem Health**	
Freshwater body type	**All Lakes**	
Attribute	Bottom[1] dissolved oxygen	
Attribute Unit	mg/L (milligrams/litre)	
Attribute State	**Numeric attribute state**	**Narrative attribute state**
Time period	Measured or estimated annual minimum[2]	
A	≥7.5	No risk from bottom DO of biogeochemical conditions causing nutrient release from sediments.
B	≥2.0 and < 7.5	Minimal risk from bottom DO of biogeochemical conditions causing nutrient release from sediments.
C	≥0.5 and < 2.0	Risk from bottom DO of biogeochemical conditions causing nutrient release from sediments.
National Bottom line	**0.5**	
D	<0.5	Likelihood from bottom DO of biogeochemical conditions resulting in nutrient release from sediments.

1. Recorded *ca.* <1m above sediment surface at the deepest part of the lake
2. Measured from continuous monitoring sensors or estimated from interpolation of discrete DO profiles.

Note: For seasonally stratified lakes, minimum oxygen concentrations are likely to occur in late summer and autumn. For polymictic lakes, minimum oxygen concentrations are more likely to occur transiently, anytime from spring to autumn.

Value	Ecosystem Health	
Freshwater body type	Lakes (seasonally stratifying)	
Attribute	Mid-hypolimnetic dissolved oxygen	
Attribute Unit	mg/L (milligrams/litre)	
Attribute State	Numeric attribute state	Narrative attribute state
Time	Measured or estimated annual minimum[1]	
A	≥7.5	No stress caused to any fish species by low dissolved oxygen.
B	≥ 5.0 & <7.5	Minor stress on sensitive fish seeking thermal refuge in the hypolimnion. Minor risk of reduced abundance of sensitive fish and macro-invertebrate species.
C	≥ 4.0 & <5 .0	Moderate stress on sensitive fish seeking thermal refuge in the hypolimnion. Risk of sensitive fish species being lost.
National Bottom line[2]	4.0	
D	< 4.0	Significant stress on a range of fish species seeking thermal refuge in the hypolimnion. Likelihood of local extinctions of fish species and loss of ecological integrity.

1. Rapid DO changes in lakes are not expected. Monthly sampling may be adequate in most cases and we recognise that continuous sensor-enabled monitoring is always advantageous.
   Note: For seasonally stratified lakes, minimum oxygen concentrations are likely to occur in late summer and autumn. For polymictic lakes, minimum oxygen concentrations are more likely to occur transiently, anytime from spring to autumn.
2. Band thresholds align with the River DO attribute bands

Discussion

Rationale

- It’s important to consider both the catchment and internal loads of nutrients when managing lakes for eutrophication and lake health. The bottom dissolved oxygen lake attribute provides a means for managing for internal loads.
- Ecosystem respiration provides a holistic ecosystem indicator, that includes the large, yet often forgotten about, microbial component. Ecosystem respiration not only signals changes in microbial processing but can also indicate changes in invertebrates and fish communities/population demographics as body size, temperature, nutrients and food supplies can all impact on their respiration.
- These attributes would provide a good fore-warning about declining lake conditions before they become severely degraded. The bottom lines are set at the cusp of severe degradation (internal nutrient load threshold).
- There will be time lags in restoration due to legacy effects of past nutrient inputs and eutrophication. Recovery of lakes can take a long time, making it important to generate

information that can be used to predict and avoid sever and long-lasting degradation before it occurs.

Guidance and caveats

- Some lakes may exhibit naturally low bottom water dissolved oxygen concentrations (even though they are minimally degraded). Such lakes include those with unusual chemical conditions, high natural organic loading (some peat lakes and forested lakes rich in dissolved inorganic carbon) and a small hypolimnetic volume relative to lake volume. Exceptions might be needed for these lakes.
- More work is required to adequately interpret and understand the national characteristics of lake thermal profiles to assist with appropriate sampling of water masses – particularly for medium sized lakes (10-50 m deep) – gain insight into how their oxygen regimes may have been under historic conditions.
- Minimum oxygen concentrations are likely to occur in late summer and autumn. Determination of mid-hypolimnetic DO requires that temperature and oxygen profiles are recorded.
- Different lake types (depths, areas, exposure, altitude and latitude) have significantly different thermal stratification profiles and this can add some complexity to the definition which requires the assessment of the mid-point of the hypolimnion.
- Achieving the biogeochemical bottom line may also achieve the habitat bottom line, obviating the need to have two separate dissolved oxygen attributes. However more work is needed to confirm this. Thus, we have provided two dissolved oxygen attributes as a precautionary measure.
- Anoxia in the hypolimnion could prevent aquatic species from accessing cooler waters that provide a thermal refuge from overly warm surface waters in summer in some lakes.
- The DO habitat measure builds on the other lake NOF trophic level components by adding one that is also related to lake morphometry and hence vulnerability to eutrophication.
- These measurements require only monthly temperature/dissolved oxygen profiles measured to just above the lake bed, obtained from datasondes and from moored lake monitoring buoys with temperature and DO sensors.
- There will need to be specific provisions to allow for naturally deoxygenating lakes. For example, in Lake Tikitapu, an oligotrophic lake, the hypolimnion deoxygenates despite minimum catchment modification.
- We currently do not know how many naturally low dissolved oxygen lakes there are but the current, monitored database (biased in favour of lowland lakes) suggest there may be many of them, especially in the class of lakes with a max. depth between 10m and 50m.
- The onus would be on regional councils to demonstrate this for specific lakes for the lakes to be exempt from the bottom line.
- There is a need for guidance and applied science to inform councils what to do when results are found to be lower than the national bottom line.

Additional STAG member comments

- Although there is a high degree of confidence in the ecological imperatives of the threshold numbers included in this attribute table, we don't yet have a solid understanding of natural variation in bottom water dissolved oxygen concentrations and depletion rates and further work would be helpful to confirm our understanding of the robustness of the thresholds we have identified, especially with regard to pristine lakes.

- With the very small number of lakes that have reliable water-column dissolved oxygen records, there is considerable uncertainty as to the number of lakes that may naturally exceed the bottom lines suggested in the attribute tables for lake dissolved oxygen.
- Several profiles of dissolved oxygen over a stratified period will allow an additional metric, hypolimnetic oxygen depletion rates, to be estimated. This is a valuable metric of ecosystem processes and meets the holistic goals of the NPS-FM and related te mana o te wai considerations.
- It is non-trivial to require councils to identify lakes that have naturally hypoxic or anoxic conditions. The reverse requirement might be easier.

3.3 Ecosystem metabolism

Recommendation 7:

Amend national direction on freshwater management to introduce numeric biophysical tables for ecosystem metabolism, without specifying a national bottom line.

Value	Ecosystem health				
Freshwater Body Type	Rivers				
Attribute	Ecosystem metabolism				
Attribute Unit	g O_2 m^{-2} d^{-1} (grams of dissolved oxygen per square metre per day)				
Attribute State	Numeric Attribute State[1]				Narrative Attribute State
	Gross primary production		Ecosystem respiration		
	Non-wadeable	Wadeable	Non-wadeable	Wadeable	
A	≤3.0	≤3.5	1.6-3.0	1.6-5.8	No evidence of an impact on ecosystem metabolism.
B	>3.0 and <5.5	>3.5 and <5.0	>1.0 and <1.6 Or >3.0 and >8	>1.2 and <1.6 Or >5.8 and <7	Mild effect on ecosystem metabolism.
C	≥5.5 and ≤8.0	≥5.0 and ≤7.0	≥0.6 and ≤1.0 Or ≥8.0 and ≤13.0	≥0.8 and ≤1.2 Or ≥7.0 and ≤9.5	Moderate effect on ecosystem metabolism.
D	>8.0	>7.0	<0.6 or >13.0	<0.8 or >9.5	Severely impaired ecosystem metabolism.

1. Derived from 7 consecutive days of continuous dissolved oxygen monitoring. Objective applies year-round.

Discussion

Rationale

- There are currently no measures of ecosystem production in the NPS-FM, despite it being one of the five key components of the ecosystem health framework.
- Ecosystem respiration provides a holistic ecosystem indicator, that includes the large, yet often ignored, microbial component. Ecosystem respiration not only signals changes in microbial processing but can also indicate changes invertebrates and fish communities/population demographics as body size, temperature, nutrients and food supplies can all impact their respiration.

Guidance and caveats

- The bands we have proposed are based on International literature, as well as research from New Zealand. Whilst some members are confident that ecosystem metabolism metrics are robust indicators, the database of information for this metric in New Zealand is currently small and relationships between driving variables, such as land use, organic load and periphyton biomass, are not well understood. The group is less certain regarding where the bottom-line should lie; therefore, we do not recommend setting a bottom-line at this stage. This recommendation will need to be revisited as more data become available.
- This metric should be calculable whenever there are continuous dissolved oxygen measurements available and more data will allow these relationships to be refined.

Additional STAG member comments

- These processes have been measured in only a small number of streams. It is unclear how representative those streams and rivers are and how transferrable any conclusions from these measurements.
- Further work is required to develop a national bottom-line for ecosystem metabolism, and these bottom-lines may need to vary with river type.

3.4 Periphyton – rivers

Recommendation 8:

Amend national direction on freshwater management by changing the table specifying numeric biophysical values for periphyton (trophic state) to:

a. replace the exclusion allowing rivers in the ‘productive class’ to exceed bottom lines 17 per cent of the time, and

b. require councils use the default nutrient criteria provided in the absence of robust, locally suitable, independently peer reviewed criteria.

<table>
<tr><td>Value</td><td colspan="2">Ecosystem health</td></tr>
<tr><td>Freshwater Body Type</td><td colspan="2">Rivers</td></tr>
<tr><td>Attribute</td><td colspan="2">Periphyton (Trophic state)</td></tr>
<tr><td>Attribute Unit</td><td colspan="2">mg chl-a/m² (milligrams chlorophyll-a per square metre)</td></tr>
<tr><td>Attribute State</td><td>Numeric Attribute State</td><td>Narrative Attribute State</td></tr>
<tr><td></td><td>Exceeded no more than 8% of samples[1,2]</td><td></td></tr>
<tr><td>A</td><td>≤50</td><td>Rare blooms reflecting negligible nutrient enrichment and/or alteration of the natural flow regime or habitat.</td></tr>
<tr><td>B</td><td>>50 and ≤120</td><td>Occasional blooms reflecting low nutrient enrichment and/ or alteration of the natural flow regime or habitat.</td></tr>
<tr><td>C</td><td>>120 and ≤200</td><td rowspan="2">Periodic blooms reflecting moderate nutrient enrichment and/ or moderate alteration of the natural flow regime or habitat.</td></tr>
<tr><td>National Bottom Line</td><td>200</td></tr>
<tr><td>D</td><td>>200</td><td>Regular and/or extended-duration nuisance blooms reflecting very high nutrient enrichment and/or very significant alteration of the natural flow regime or habitat.</td></tr>
</table>

1. May be exceeded in up to 17% of samples if shown that the exceedance would have happened at that site in natural nutrient, flow and riparian cover conditions (defined as pre-human or estimated based on no catchment modification).
2. Must be derived from the rolling median of monthly monitoring over five years.

Note: To achieve a freshwater objective for periphyton within a freshwater management unit, regional councils must at least set appropriate instream concentrations and exceedance criteria for dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP). Where there are nutrient sensitive downstream receiving environments, criteria for nitrogen and phosphorus will also need to be set to achieve the outcomes sought for those environments. Regional councils must use the following process, in the following order, to determine instream nitrogen and phosphorus criteria in a freshwater management unit:

a) either –

i) if parts of the freshwater management unit support, or could support, conspicuous periphyton, derive instream concentrations and exceedance criteria for DIN and DRP to achieve a periphyton objective for the freshwater management unit; or

ii) if parts of the freshwater management unit do not support, and could not support, conspicuous periphyton, consider the nitrogen and phosphorus criteria (instream concentrations or instream loads) needed to achieve any other freshwater objectives:

b) if there are nutrient sensitive downstream environments, for example, a lake and/or estuary, derive relevant nitrogen and phosphorus criteria (instream concentrations or instream loads) needed to achieve the outcomes sought for those sensitive downstream environments:

c) compare all nitrogen and phosphorus criteria derived in steps (a) – (b) and adopt those necessary to achieve the freshwater objectives for the freshwater management unit and outcomes sought for the nutrient sensitive downstream environments

d) Use the following table to calculate default nutrient criteria for the periphyton objective in the absence of robust, locally suitable, independently peer reviewed criteria:

	TN (mg/L)			DRP (mg/L)		
REC Source of Flow:	**Bottom of band:** **A**	**B**	**C**	**Bottom of band:** **A**	**B**	**C**
CX/GM	0.07	0.34	0.82	0.0018	0.056	0.161
CX/M	0.12	0.58	1.43	0.0082	0.114	0.289
CX/H	0.12	0.61	1.44	0.0072	0.107	0.273
CX/L	0.09	0.43	1.03	0.0024	0.067	0.187
CX/Lk	0.03	0.13	0.32	0.0002	0.007	0.043
CW/GM	0.03	0.16	0.37	0.0003	0.013	0.069
CW/M	0.03	0.17	0.41	0.0003	0.015	0.069
CW/H	0.04	0.19	0.45	0.0003	0.016	0.069
CW/L	0.03	0.14	0.35	0.0002	0.005	0.038
CW/Lk	0.02	0.09	0.22	0.0002	0.002	0.022
CD/M	0.02	0.10	0.24	0.0002	0.002	0.024
CD/H	0.02	0.09	0.21	0.0002	0.001	0.013
CD/L	0.02	0.09	0.22	0.0002	0.001	0.013
CD/Lk	0.02	0.08	0.19	0.0002	0.001	0.012
WX/L	0.03	0.16	0.39	0.0002	0.009	0.051
WX/H	0.04	0.18	0.43	0.0003	0.013	0.064
WW/H	0.05	0.26	0.64	0.0006	0.027	0.095
WW/L	0.02	0.10	0.23	0.0002	0.002	0.016
WW/Lk	0.02	0.09	0.22	0.0002	0.001	0.014
WD/L	0.01	0.05	0.11	0.0001	0.0002	0.002
WD/Lk	0.02	0.11	0.26	0.0002	0.001	0.013

Discussion

Rationale

- When the periphyton attribute table for the NPSFM was initially developed there were little data available. There are now much more data, and this has enabled development of a default table relating the periphyton biomass thresholds in the attribute table to DIN and DRP thresholds by river class. This should be used to strengthen the note to the current periphyton table.
- There is concern that the current attribute table in the NPS-FM allows episodic point source dischargers to take advantage of the 8 and 17% exceedance criteria and creates the risk that councils could apply the existing criteria incorrectly.
- There has historically been considerable difficulty creating robust nutrient criteria that apply nationally. Although this is beginning to change and there are some robust models

emerging both nationally and regionally, it is considered prudent to provide default national nutrient criteria as a backstop. While supporting their inclusion the STAG recommends the default nutrient table and any regional models used be subject to peer review prior to being introduced into regulation. The peer review of the default national table should contribute to clear guidance on the applicability of the model and guidance on how to develop regional or catchment specific models for application.

Guidance and caveats

- The default criteria table is presented using TN rather than DIN as this measure of nitrogen has been found to have a strong relationship to biomass.
- Greater clarity is necessary on the circumstances when the exceedance criteria apply, particularly in relation to the definition of natural conditions and how to modify the definition of 'natural' in the face of climate change.
- Nutrient limits of REC classes have now been calculated (see table embedded in the note attached to proposed Attribute Table above) and should be made available to guide regional councils in their attempt to prevent periphyton growth through nutrient control.
- All breaches of periphyton attribute states need to be considered carefully as reference sites do experience exceedances in some circumstances (e.g. unusual low flows due to drought conditions).
- Monitoring requirements will need to be consistent with those promoted in guidance developed by the Ministry for the Environment relating to the assessment of whether freshwater values are being maintained or improved (see STAG Recommendation 3 c). As a default requirement, the numeric attribute state should be derived from a monthly monitoring regime with a data record of at least five years and reported annually as a rolling average.

Additional STAG member comments

- The current note attached to the recommended Periphyton Attribute Table 'note' directs regional councils to control nutrient levels in rivers to manage periphyton. There is a direct link between this requirement and the attribute tables recommended for nitrogen and phosphorus elsewhere in this working paper.
- It would be useful to examine datasets to see where and how often exceedances occur and to analyse the relationship between dissolved oxygen concentrations and instances of exceedances of periphyton biomass objectives.

3.5 Fish biotic integrity

Recommendation 9:

Amend national direction on freshwater management to introduce a table specifying numeric biophysical values for fish biotic integrity, specifying a national bottom line of 18 when measured using the Fish Index of Biotic Integrity

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	Fish Index of Biotic Integrity (F-IBI)[1]	
Attribute Unit	Score between 0-60	
Attribute State	Numeric Attribute State	Narrative Attribute State
	Average	
A	≥34	High integrity of fish community. Habitat and migratory access have minimal degradation.
B	<34 and ≥28	Moderate integrity of fish community. Habitat and/or migratory access are reduced and show some signs of stress.
C	<28 and ≥18	Low integrity of fish community. Habitat and/or migratory access is considerably impairing and stressing the community.
National Bottom Line	18	
D	<18	Severe loss of fish community integrity. There is substantial loss of habitat and/or migratory access, causing a high level of stress on the community.

1. The F-IBI as defined by Joy, M. K., & Death, R. G. (2004). Application of the Index of Biotic Integrity Methodology to New Zealand Freshwater Fish Communities. *Environmental Management, 34*(3), 415-428. The calculation has been changed to exclude salmonids to ensure they have no positive or negative weighting on the IBI score.

2. Applies only to wadeable rivers and fish are to be surveyed at least annually between December and March (inclusive) following the protocols in:
Joy M, David B, and Lake M. 2013. *New Zealand Freshwater Fish Sampling Protocols (Part 1): Wadeable rivers and streams.* Palmerston North, New Zealand: Massey University.

Discussion

Rationale

- The recent ‘Environment Aotearoa 2019’ report indicated a significant decline in fish species. According to that report “In 2017, 76 percent of our native freshwater fish were either threatened with or at risk of extinction.”
- There is clearly an urgent need to monitor fish populations, identify the causes of declines in populations and develop immediate and ongoing management plans. Under

the status quo and if we wait for further research to establish a declining trend before acting there are likely to be fish extinctions.

- There are currently no metrics for habitat. Whilst fish IBI is not a direct measure of habitat, some functional groups are based on habitat and would respond to the loss or addition of habitat.
- Fish IBI is based on presence/absence of fish within different functional groups and takes existing conditions into account. It also considers altitude and distance inland (the two dominant drivers of fish species richness), as well as downstream impediments to longitudinal river connectivity (such as dams), mesohabitat composition and pest fish. As such, it is considered to be a holistic metric that responds to pressures that other attributes do not and a suitable attribute for managing native fish communities.

Guidance and caveats

- Fish IBI would need to be standardised in a national model as not all the data collected by and input to the national fish information database were intended to inform analysis of this kind. Because of this there are variations in how data are generated and input into the national database by contributing agencies. An easy to use Excel Macro spreadsheet can be provided for ease of calculation. About half of the regional councils have a fish IBI in place already and members believe it will be possible to develop a fish IBI based on abundance data that have been collected using existing fish monitoring protocols. It is possible that a move to nationally standard methods may change the results gained from current programmes, which may have implications for the data record in some regions.
- Fish IBI could be incorporated into the management regime in the same way as MCI is currently reflected in the NPSFM.
- If objectives relate to monitoring specific taonga species, then an additional, separate metric for taonga species would be required though the same collection data could be used.
- There may be some situations where river reaches naturally depart from the IBI bottom-line (e.g., acidic and geothermal areas and where waterfalls or other natural features create a barrier to fish passage). In these instances, it is recommended that a general standard be applied and the onus placed on regional councils to identify where natural departures occur and where exclusions to bottom lines may be appropriate.

STAG perspectives

- The group unanimously supports removing trout from the IBI for this metric and notes that, while there is work going on to produce an IBI for lake fish, this is in its beginning stages and there are no established protocols yet.
- The IBI uses a national “reference” that is based on altitude and distance from the sea. Members also all agree that Fish IBI can be measured in a consistent manner, but some members note that we do not understand the scale of natural variation, how to take this into account and question whether some degree of region-specific modification may be required. Waterfalls and natural pH changes, for instance, can influence fish populations and it may be appropriate to apply guidance but place the onus on regional councils to identify where natural departures occur and consider where exclusions to bottom lines may be appropriate.

3.6 Macroinvertebrates

Recommendation 10:

Amend national direction on freshwater management to introduce tables specifying numeric values for a Macroinvertebrate Community Index, Quantitative Macroinvertebrate Community Index, and an Average Score Per Metric, specifying national bottom lines of 90, 4.5 and 0.3 respectively.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	Macroinvertebrate Community Index and Quantitative Macroinvertebrate Community Index (Ecosystem Health)		
Attribute Unit	QMCI and MCI scores		
Attribute State	Numeric Attribute States		Narrative Attribute State
	QMCI	MCI	Description
A	≥6.5	≥130	Macroinvertebrate community, indicative of pristine conditions with almost no organic pollution or nutrient enrichment.
B	≥5.5 & <6.5	≥110 & <130	Macroinvertebrate community indicative of mild organic pollution or nutrient enrichment. Largely composed of taxa sensitive to organic pollution/nutrient enrichment.
C	≥4.5 & <5.5	≥90 & <110	Macroinvertebrate community indistinctive of moderate organic pollution or nutrient enrichment. There is a mix of taxa sensitive and insensitive to organic pollution/nutrient enrichment.
National Bottom Line	4.5	90	
D	<4.5	<90	Macroinvertebrate community indistinctive of severe organic pollution or nutrient enrichment. Communities are largely composed of taxa insensitive to inorganic pollution/nutrient enrichment.

1. Applies only to wadeable streams and rivers.
2. Refer to Stark JD, Maxted, JR 2007. A user guide for the Macroinvertebrate Community Index. Prepared for the Ministry for the Environment. Cawthron Report No. 1166. 58
3. Objectives should not be set higher than is attainable in reference conditions, with guidance from:

Clapcott, J. E., Goodwin, E. O., Snelder, T. H., Collier, K. J., Neale, M. W., & Greenfield, S. (2017). Finding reference: a comparison of modelling approaches for predicting macroinvertebrate community index benchmarks. New Zealand Journal of Marine and Freshwater Research, 51(1), 44-59.

4. MCI and QMCI to be determined using fixed counts with at least 200 individuals surveyed using at least five Surber samplers per site annually between December and March inclusive). Sites with sediment state classes 1, 5 & 11 are to use the soft-sediment sensitivity scores. Taxonomic resolution and sensitivity scores to be use is that from Table A1.1 from: Clapcott, J., Wagenhoff, A., Neale, M., Storey, R., Smith, B., Death, R., Young, R. (2017). *Macroinvertebrate metrics for the National Policy Statement for Freshwater Management*. Cawthron: Nelson, New Zealand.
5. Measured annually with current state calculated as the five-year rolling average score.

Value	Ecosystem health	
Freshwater Body Type	Rivers	
Attribute	Macroinvertebrate Average Score Per Metric (Ecosystem Health)	
Attribute Unit	0-1 score	
Attribute State	Numeric Attribute State	Narrative Attribute State
	ASPM	Description
A	≥0.6	Macroinvertebrate communities have high ecological integrity, similar to that expected in reference conditions.
B	<0.6 & ≥0.4	Macroinvertebrate communities have mild-to-moderate loss of ecological integrity.
C	<0.4 & ≥0.3	Macroinvertebrate communities have moderate-to-severe loss of ecological integrity.
National Bottom Line	0.3	
D	<0.3	Macroinvertebrate communities have severe loss of ecological integrity.

1. Applies only to wadeable streams and rivers.
2. ASPM to be determined using fixed counts with at least 200 individuals surveyed using at least five Surber samplers per site annually between December and March inclusive). Sites with sediment state classes 1, 5 & 11 are to use the soft-sediment sensitivity scores. Taxonomic resolution and sensitivity scores to be use is that from Table A1.1 from: Clapcott, J., Wagenhoff, A., Neale, M., Storey, R., Smith, B., Death, R.,Young, R. (2017). *Macroinvertebrate metrics for the National Policy Statement for Freshwater Management*. Cawthron: Nelson, New Zealand.
3. Current state is calculated as the five-year rolling average score.
4. When normalising scores for the ASPM, use the following minimums and maximums: %EPT-abundance (0-100), EPT-richness (0-29), MCI (0-200). Collier, K. J. (2008). Average score per metric: an alternative metric aggregation method for assessing wadeable stream health. *New Zealand Journal of Marine and Freshwater Research*, *42*(4), 367-378.

Discussion

Rationale

- The current NPS-FM contains an MCI value of 80, which was described by Stark as "gross pollution and possible severe pollution". This group does not believe "possible severe pollution" to be an appropriate place to set a national bottom line. Setting the MCI bottom line at 80 has the additional problem of reducing discriminatory ability at this value, i.e. there is little change in the community with further degradation.
- A change in the bottom line from 80 to 90 is likely to have a significant effect on the number of sites that breach the national bottom line and are captured by the requirement to develop an action plan.
- MCI primarily measures organic enrichment and ASPM is a more general measure of invertebrate community health. A score for ASPM of 0.3 is equivalent to an MCI of 90.

Guidance and caveats

- All members consider it is crucial that we follow standardised sampling and scoring methods across the country as per the existing guidance note. Moving to standardised protocols will break the cycle of data collection in some areas and will have implications for reporting on the 5-year rolling average and the ability to calculate trends for a transitional period. One option for addressing this would be to run dual monitoring during this period of transition.
- There may be a case for exceptions to the numbers recommended in these attribute tables if it can be shown that the streams naturally have values lower than 90 (which will be the case in some geothermal streams, high-altitude streams close to glaciers, and low pH streams.)

Additional STAG member comments

- STAG members were unified in their strong support for introducing this suite of macroinvertebrate metrics to the freshwater management framework and including them in the NPS-FM.
- Members were most confident in the thresholds and bands in the MCI metric, given it has been established and operating since the 1980s.
- Some members expressed uncertainty regarding the bands for ASPM but all were comfortable with the proposed bottom lines and with the proposal to progress QMCI/MCI and APSM metrics – they provide complementary insights and can be calculated using the same data.
- There was a view that it could be more appropriate to introduce metrics (not tables) and to specify thresholds (not national bottom lines) to trigger reporting requirements, consistent with the existing approach

3.7 Macrophytes – lakes

Recommendation 11:

Amend national direction on freshwater management to introduce numeric attribute tables for Lake ecosystem health by reference to the Lake Submerged Plant Index (LakeSPI), specifying a national bottom line for the native plant condition of at least 20% of the maximum potential score, and a national bottom line for invasive plants of less than 90% of the maximum potential score.

Value	Ecosystem health	
Freshwater Body Type	Lakes	
Attribute	Lake Submerged Plant Index (LakeSPI)[1] - **Native Condition Index**	
Attribute Unit	LakeSPI Scores as a percentage of maximum potential score (%)	
Attribute State	Numeric Attribute State (% of maximum potential score)	Narrative Attribute State
A	>75%	Excellent ecological condition. Native submerged plant communities are almost completely intact
B	>50 & ≤75%	High ecological condition. Native submerged plant communities are largely intact
C	≥20 & ≤50%	Moderate ecological condition. Native submerged plant communities are moderately impacted
National Bottom Line	20%	
D	<20%	Poor ecological condition. Native submerged plant communities are largely degraded or absent

1. To be calculated every three years following: Clayton J, and Edwards T. 2006. LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2. Hamilton, New Zealand: National Institute of Water & Atmospheric Research Ltd p57.
2. Lakes in a devegetated state receive LakeSPI scores of 0.

Value	Ecosystem health

Freshwater Body Type	Lakes	
Attribute	Lake Submerged Plant Index (LakeSPI)[1] – **Invasive Impact Index**	
Attribute Unit	% of maximum potential impact	
Attribute State	**Numeric Attribute State (% of maximum potential score)**	**Narrative Attribute State**
A	0%	No invasive plants present in the lake. Native plant communities remain intact.
B	>1 & ≤25%	Invasive plants having only a minor impact on native vegetation. Invasive plants will be patchy in nature co-existing with native vegetation. Often major weed species not present or in early stages of invasion.
C	≥26 & ≤90%	Invasive plants having a moderate to high impact on native vegetation. Native plant communities likely displaced by invasive weed beds particularly in the 2 – 8 m depth range. Species concerned likely lagarosiphon, egeria and hornwort.
National Bottom Line	90%	
D	>90%	Tall dense weed beds exclude native vegetation and dominate entire depth range of plant growth. Species concerned likely hornwort and Egeria.

1. To be calculated annually following:
   Clayton J, and Edwards T. 2006. *LakeSPI: A method for monitoring ecological condition in New Zealand lakes. User Manual Version 2.* Hamilton, New Zealand: National Institute of Water & Atmospheric Research Ltd p57.

Discussion

Rationale

- Lake macrophyte communities are key habitats for many aquatic plants and animals. They also play an important role in regulating lake functioning and metabolism by: (i) competing with phytoplankton for nutrients, (ii) suppressing wind-induced sediment resuspension, (iii) oxygenating sediments, (iv) intercepting nutrients and sediments discharged to lakes from tributaries and overland flow, etc.
- LakeSPI is a submerged aquatic plant indicator developed by NIWA which has been used to assess the macrophyte communities of over 300 of the 3820 lakes in New Zealand.
- The LakeSPI sub-indices which we propose as attributes provide information on both the condition of the native macrophyte community and the impact of invasive macrophytes on lakes.

Guidance and caveats

- The LakeSPI scores proposed for the numeric attribute state are indicative and may need further definition and refinement as this framework is applied.
- Percentages used in the Attribute Table for Native Plant Condition are the same as the narrative categories developed by the NIWA LakeSPI team for interpretation of LakeSPI scores:

LakeSPI Index score	Category
>75%	Excellent
>50-75%	High
>20-50%	Moderate
>0-20%	Poor
0%	Non-vegetated

- Using the recommended bottom line of 20% of the maximum potential Native Condition score, 38% of lakes in which LakeSPI assessments have been made breached the bottom line.
- Factors other than lake depth can influence LakSPI scores. As specified in the LakeSPI user manual (Clayton and Edwards 2006)). LakeSPI is not an appropriate method for situations where vegetation development in lakes is strongly constrained by:
    - High altitude (i.e. > 1300m a.s.l),
    - Strong geothermal influence,
    - Extremely low pH (e.g., < 4.5)
    - water level fluctuation (e.g., > 10m)
    - salinity (i.e. ICOLLs)
    - Lakes to which grass carp have been added
- Accordingly, lakes with some extreme conditions may not be appropriately assessed using LakeSPI. Guidance is required to determine those instances where LakeSPI is not appropriate.

Additional STAG member comments

- Members agreed that the macrophyte indices are useful attributes for assessing lake health and that they provide information on lake health that doesn't overlap with information provided by the other lake attributes. The LakeSPI method assess lake ecosystem health from an entirely different perspective to that of the existing lake attributes in the NPS-FM that measure water quality in the 'centre' of lakes. LakeSPI assesses the health of the lake littoral zone, the shallow waters round the lake edges, and the water that the public generally come into contact with. LakeSPI assessments add considerably to our understanding of whole-lake ecosystem health. This method also provides an assessment of biosecurity status and risks from invasive plants.
- Monitoring every five years may be suitable for picking up changes in the extent of macrophyte communities, but a three-yearly cycle of monitoring may be valuable if combined with a surveillance programme for invasive species and if sites vulnerable to invasion were included in the monitoring programme (i.e. boat ramps). Further, lake macrophyte communities can sometimes collapse suddenly, resulting in rapid changes in ecosystem state and water quality.
- Change can also be assessed over longer time frames and multiple surveys. Guidelines (See LakeSPI Manual – Clayton and Edwards, 2006) based on expert judgement suggest a scale of probabilities for determining the ecologically significance of change in lake condition, using averaged LakeSPI indices over repeated surveys. These guidelines have considered variation

by different observers and the response of LakeSPI scores to major ecological events in lakes.

3.8 Sediment

Recommendation 12:

Amend the national framework for freshwater management to introduce tables specifying numeric biophysical values for deposited and suspended sediment.

Value	Ecosystem Health												
Freshwater Body Type	Rivers												
Attribute	Suspended fine sediment												
Attribute Unit	Turbidity (NTU/FNU)												
Attribute State	SSC class[1]												Narrative Attribute State
	1	2	3	4	5	6	7	8	9	10	11	12	
	Site median[2]												
A	<2.0	<6.2	<1.3	<3.3	<7.5	<4.8	<2.3	<4.3	<1.2	<1.1	<1.1	<2.4	Minimal impact of suspended sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.
B	<2.5	<7.9	<1.6	<3.9	<9.8	<6.3	<2.8	<5.2	<1.4	<1.3	<1.3	<2.7	Low to moderate impact of suspended sediment on instream biota. Abundance of sensitive fish species may be reduced.
C	≤3.2	≤10.5	≤2.0	≤4.8	≤13.1	≤8.3	≤3.3	≤6.4	≤1.6	≤1.5	≤1.6	≤3.1	Moderate to high impact of suspended sediment on instream biota. Sensitive fish and macroinvertebrate species may be lost.
National Bottom Line[3]	3.2	10.5	2.0	4.8	13.1	8.3	3.3	6.4	1.6	1.5	1.6	3.1	
D	>3.2	>10.5	>2.0	>4.8	>13.1	>8.3	>3.3	>6.4	>1.6	>1.5	>1.6	>3.1	High impact of suspended sediment on instream biota. Ecological communities are significantly altered, and sensitive fish and macroinvertebrate

													species are lost or at high risk of being lost.

[1] Classes are streams and rivers defined according to the fourth level of aggregation(L4) of the suspended sediment Sediment State Classification (SSC).
[2] The minimum record length for grading a site is 24 samples (i.e. 2 years of monthly sampling).
[3] Bottom-line thresholds are anticipated to provide a sufficient level of protection at an overall fish community level (i.e. will cause <20% decrease in the fish community deviation metric), however, they may not always be sufficient for the protection of specific life-stages or habitat requirements in specific locations.

Value	Ecosystem Health												
Freshwater Body Type	Rivers												
Attribute	Deposited fine sediment												
Attribute Unit	% fine sediment cover (percentage cover of the streambed in a run habitat determined by the instream visual method, SAM2)												
Attribute State	**SSC class[1]**												**Narrative Attribute State**
	1	2	3	4	5	6	7	8	9	10	11	12	
	Site median[2]												
A	<84	<9	<42	<12	<80	<30	<41	<22	<48	<15	<76	<27	Minimal impact of deposited fine sediment on instream biota. Ecological communities are similar to those observed in natural reference conditions.
B	<90	<15	<50	<17	<86	<38	<48	<33	<54	<22	<82	<36	Low to moderate impact of deposited fine sediment on instream biota. Abundance of sensitive macroinvertebrate species may be reduced.
C	≤97	≤21	≤60	≤23	≤92	≤46	≤56	≤45	≤61	≤29	≤89	≤45	Moderate to high impact of deposited fine sediment on instream biota. Sensitive macroinvertebrate and fish species may be lost.
National Bottom Line[3]	97	21	60	23	92	46	56	45	61	29	89	45	
D	>97	>21	>60	>23	>92	>46	>56	>45	>61	>29	>89	>45	High impact of deposited fine sediment on instream biota. Ecological communities are significantly altered and sensitive fish and macroinvertebrate species are lost or at high risk of being lost.

[1] Classes are streams and rivers defined according to the fourth level of aggregation(L4) of the suspended sediment Sediment State Classification (SSC).
[2] The minimum record length for grading a site based on an instream visual assessment of % fine sediment cover (SAM2) is 2 years based on a monthly monitoring regime.
[3] Limit-setting needs to account for impacts on downstream receiving environments. Bottom-line thresholds are anticipated to provide a sufficient level of protection at an overall macroinvertegrate community level (i.e. will cause <20% decrease in the macroinvertebrate community deviation metric), however, they may not always be sufficient for the protection of specific life-stages or habitat requirements in specific locations (for example, salmonid spawning habitats may require sediment cover of <10%). Fine sediments with high organic enrichment may also result in higher levels of impacts on macroinvertebrate communities or sensitive fish life-stages).

Discussion

Rationale

- One of the largest threats to our benthic invertebrates and fish is increasing deposited fine sediment in-filling the interstitial places between substrate, thereby reducing habitat.
- Suspended sediment can clog the gills of fish and invertebrates, reduce the ability of visual feeders to sight their food, and disrupt migration patterns.
- The levels of suspended and deposited fine sediment in rivers and streams have reached ecological tipping points in many parts of New Zealand.
- While some of the problem is due to historical practices and management approaches, current management does not sufficiently reduce ecosystem health degradation due to sediment.
- Councils currently do not require maintenance of specific, region-wide in-stream sediment thresholds to provide for overall ecosystem health.
- Given New Zealand's diverse geology and landscape, rivers need to be classified and graded differently to account for natural variation.

Guidance and caveats

- The attribute tables are those proposed by Franklin *et al* (2019).[4] Deriving potential fine sediment attribute thresholds for the National Objectives Framework. Prepared for Ministry for the Environment, June 2019. Even splits between the expected reference state and the proposed bottom line were used to set attribute band thresholds.
- There is a need to define the sediment state classification (SSC) prior to assessing attribute state. The recommended SSC definitions are given in Appendix 3.
- We recognise that as our understanding of natural systems and ecological effects improves, some of these thresholds may change. It is important that a site-specific relationship between turbidity and suspended sediment concentration be established before turbidity is used as the only metric.
- There is a major need to conduct further research on event-based sediment loading generally and especially in relation to receiving environments, and to improve understanding of the effects of sediment on downstream environments.

Additional STAG member comments

- All members agreed that there is a need to manage for both suspended and deposited sediment. They also supported the proposed band and bottom line thresholds, the spatially explicit classification systems proposed and Franklin *et* al's (2019) recommendation of using the least aggregated classification system for both suspended and deposited sediment.
- Members unanimously supported incorporating the suspended sediment thresholds in the NPS-FM as an attribute. They also agreed that there is no need to include both visual clarity and turbidity as indicators of suspended sediment, and that turbidity is the preferred indicator, based on currently available science. The need for further testing by councils and/or using council data to develop a better understanding of turbidity, suspended sediment and clarity relationships was recognised.
- Members supported the development of deposited sediment numeric thresholds but were undecided on whether deposited sediment should be included as an attribute or monitoring plan requirement. All members agreed that in-stream areal-coverage is a suitable indicator for assessing deposited fine sediment.

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[4] https://www.niwa.co.nz/sites/niwa.co.nz/files/NZ-FishPassageGuidelines-upto4m-NIWA-DOC-NZFPAG.pdf NIWA Client Report no. 2019039HN

- Some members believe there is an urgent requirement for national guidance to councils on how to track sediment source, determine sediment loads and model/map deposited sediment.

3.9 Nutrients – rivers

Recommendation 13:

Amend the national framework for freshwater management to introduce numeric biophysical tables for dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) and specifying national bottom lines of 1 mg/L DIN as an annual median (and 2.05 mg/L as a 95th percentile) and 0.018 mg/L DRP as an annual median (and 0.054 mg/L as a 95th percentile).

Value	Ecosystem health		
Freshwater Body Type	Rivers [1]		
Attribute	Dissolved inorganic nitrogen		
Attribute Unit	DIN mg/L		
Attribute State	Numeric Attribute State[2]		Narrative Attribute State
	Median	95th percentile	Description
A	≤ 0.24	≤ 0.56	Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to DIN enrichment are expected.
B	> 0.24 and ≤0.50	> 0.56 and ≤01.10	Ecological communities are slightly impacted by minor DIN elevation above natural reference conditions. If other conditions also favour eutrophication, sensitive ecosystems may experience additional algal and plant growth, loss of sensitive macroinvertebrate taxa, and higher respiration and decay rates.
C	> 0.5 and ≤ 1.0	> 1.10 and ≤ 2.05	Ecological communities are impacted by moderate DIN elevation above natural reference conditions, but sensitive species are not experiencing nitrate toxicity. If other conditions also favour eutrophication, DIN enrichment may cause increased algal and plant growth, loss of sensitive macroinvertebrate & fish taxa, and high rates of respiration and decay.
National Bottom Line	1.0	2.05	

D	>1.0	>2.05	Ecological communities impacted by substantial DIN elevation above natural reference conditions. In combination with other conditions favouring eutrophication, DIN enrichment drives excessive primary production and significant changes in macroinvertebrate and fish communities, as taxa sensitive to hypoxia and nitrate toxicity are lost.

1. Groundwater concentrations also need to be managed to ensure resurgence via springs and seepage does not degrade rivers through DIN enrichment.
2. Must be derived from the rolling median of monthly monitoring over five years.

Value	Ecosystem health		
Freshwater Body Type	Rivers		
Attribute	Dissolved reactive phosphorus		
Attribute Unit	DRP mg/L		
Attribute State	Numeric Attribute State[1]		Narrative Attribute State
	Median	95th percentile	Description
A	≤ 0.006	≤ 0.021	Ecological communities and ecosystem processes are similar to those of natural reference conditions. No adverse effects attributable to DRP enrichment are expected.
B	> 0.006 and ≤0.010	> 0.021 and ≤0.030	Ecological communities are slightly impacted by minor DRP elevation above natural reference conditions. If other conditions also favour eutrophication, sensitive ecosystems may experience additional algal and plant growth, loss of sensitive macroinvertebrate taxa, and higher respiration and decay rates.
C	> 0.010 and ≤ 0.018	> 0.030 and ≤ 0.054	Ecological communities are impacted by moderate DRP elevation above natural reference conditions. If other conditions also favour eutrophication, DRP enrichment may cause increased algal and plant growth, loss of sensitive macro-invertebrate & fish taxa, and high rates of respiration and decay.
National Bottom Line	0.018	0.054	
D	>0.018	>0.054	Ecological communities impacted by substantial DRP elevation above natural reference conditions. In combination with other conditions favouring eutrophication, DRP enrichment drives excessive primary production and significant changes in

			macroinvertebrate and fish communities, as taxa sensitive to hypoxia are lost.

1. Must be derived from the rolling median of monthly monitoring over five years.

Discussion

Rationale

- Elevated nutrient concentrations are widespread and can alter ecological communities and processes through multiple complex pathways.
- The current provisions for managing nutrients in rivers in the NPS-FM are insufficient for maintaining or improving ecosystem health in rivers in which there is no conspicuous periphyton.
- The national bottom lines for ammonia and nitrate toxicity are not sufficient for protecting ecosystem health, yet objectives for these may be applied to rivers which do not experience conspicuous periphyton growth. A healthy ecosystem should not be experiencing toxic effects.
- The inclusion of both DIN and DRP attributes is recommended because both impact the structure and functioning of healthy ecosystems. Reducing DIN and DRP will contribute to improvements in ecosystem health by potentially reducing the prevalence of macrophytes, organic matter processing, conspicuous and non-conspicuous periphyton, changes in trophic structure and function, assimilation efficiency, and changes in fish and invertebrate communities. While there may not always be a direct link and well-defined mechanistic models between nutrients and components of a healthy ecosystem, ecosystems are dominated by indirect relationships and the framework for managing the health of fresh water must account for this.
- Nationally applicable dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) tables will capture ecosystem effects in soft-bottomed waterways not captured by the periphyton attribute.
- The thresholds proposed are based on multiple lines of evidence of multiple ecological responses to nutrients across different trophic levels. A summary of the approach used to derive the numbers we have recommended has been provided in Appendix 4.
- The proposed bottom-line for DIN is exactly the same as the current A-band for 99% species protection from nitrate-nitrogen toxicity and consistent with the recommendations of Camargo & Alonso (2006) who conducted a comprehensive, global literature review of effects of inorganic nitrogen pollution in rivers and suggested levels should be less than 0.5-1 mg/L to prevent eutrophication and protect against toxicity.
- The B and C bands align with the upper and lower bands of the recommended range identified by Camargo & Alonso (2006).
- The B-band for DRP is consistent with the ANZECC (2000) trigger values for lowland rivers of 0.010 mg/L.

Guidance and caveats

- If the tables we have recommended are incorporated in national direction and given equal importance to existing attributes in the NPS-FM, the current nitrate and ammonia toxicity attribute tables in the NPS-FM can be deleted.
- Trophic state is one component of ecosystem health (as is the presence of toxic compounds). Although both nutrient attributes for ecosystem health and the periphyton attribute are included in the NOF, and some other attributes may require nutrient limit setting to achieve them, the most stringent of these must be applied during limit-setting.

- Councils must still account for downstream receiving environments (e.g. lakes and estuaries) as per the note accompanying the periphyton attribute table in the NPS-FM.
- A flow chart has been provided in Appendix 5 to describe the process almost all members believe should be followed to determine maximum in-stream nutrient concentrations in a Freshwater Management Unit (FMU) to support periphyton and ecosystem health objectives and meet the objectives of downstream receiving environments.
- In some rivers, natural levels of phosphorus are high, and the numbers presented in the recommended tables may be difficult to meet. Exceptions may be required in these circumstances to reflect the natural influence of geography or geology. We believe this is covered under the allowance for natural variability, which is articulated in the NPS-FM.
- Conversely, some streams do not support periphyton growth and, in others, algae are able to gather phosphorus from sources other than the water column so controls on DRP may have little material effect on ecosystem health.
- The recommended tables have been developed based upon the relationships between nutrients and metrics of macroinvertebrates, fish, periphyton and ecosystem metabolism, which have been combined through a 'multiple lines of evidence' approach.
- Professor David Hamilton (Griffith University, Brisbane) peer reviewed the analysis undertaken during the process of developing the nutrient attribute tables. A summary of the points raised by Professor Hamilton and our response can be found in Appendix 6.
- Monitoring requirements will need to be consistent with those promoted in guidance developed by the Ministry for the Environment relating to the assessment of whether freshwater values are being maintained or improved (see STAG Recommendation 3 c). As a default requirement, the numeric attribute state should be derived from a monthly monitoring regime with a data record of at least five years and reported annually as a rolling average.
- The bottom-line also represents the 99% species protection threshold for nitrate-nitrogen toxicity (current A band) – thereby providing a direct, mechanistic link that applies in all rivers alongside the other ecosystem health links, ensuring consistency across all river and stream environments with previously proposed attributes for nitrate.

Additional STAG member comments

- Almost all members supported the introduction of attribute limits for nitrogen and phosphorus for ecosystem health protection as outlined above. This approach is attractive because it is difficult to model nutrient-periphyton (and other ecosystem components) relationships due to considerable variation in the natural characteristics of rivers and the complex interacting factors affecting periphyton growth. A periphyton biomass that is suitable for providing invertebrate and fish health at one site, for instance, may not be suitable at another because ecosystems are complex networks and there are multiple ways nutrients can affect ecosystems.
- A view was expressed that:
    - There should be four controls for nutrient impacts on ecosystem health in the NPS-FM. These should be based on the mechanisms that nutrients impact on ecosystem health, to enable controls to be applied in an effects-based manner, customisable to catchments.
    - Three types of control are currently in the NPS-FM, the ammonia toxicity table, the periphyton attribute and associated notes and the nitrate toxicity attribute. The level of toxicity allowed for as the national bottom line is a policy call. The science is clear about what percentages of species protection is provided for at differing concentrations. Lowering the concentration that is the national bottom line for

toxicity is a potential way to strengthen protection for ecosystem health with a clear set of evidence to back up the setting of the thresholds.
- The fourth control, which is partially in the NPS-FM is consideration of downstream nutrient sensitive environments. This should be applied to the toxicity criteria as well.
- The NPS-FM should be amended to clarify the process for setting nutrient limits for ecosystem health. For example, to describe how to consider the ammonia toxicity, nitrate toxicity and periphyton requirements as well as those of downstream environments in a catchment or freshwater management unit.

3.10 Wetland extent and condition

Recommendation 14:

Amend the national framework for freshwater management to require regional councils to:

a. identify the extent and evaluate the condition of existing wetlands
b. prevent any further reductions in the extent of existing wetlands
c. address the management of wetlands with reference to specified numeric attribute bands, introducing a requirement to lift the wetland condition index to at least 10 and to maintain or improve the condition of existing wetlands where the condition score is greater than 10

<table>
<tr><td>Value</td><td colspan="2">Ecosystem health</td></tr>
<tr><td>Freshwater Body Type</td><td colspan="2">Wetlands</td></tr>
<tr><td>Attribute</td><td colspan="2">Wetland Extent</td></tr>
<tr><td>Attribute Unit</td><td colspan="2">Percent of original wetland area remaining[1]</td></tr>
<tr><td>Attribute State</td><td>Numeric Attribute State</td><td>Narrative Attribute State</td></tr>
<tr><td>A</td><td>≥60%</td><td>Large area of wetland habitat remaining. Biodiversity and ecological processes are essentially intact, resulting in high ecosystem resilience.</td></tr>
<tr><td>B</td><td><60% & ≥30%</td><td>Wetland extent reduced markedly but still retains an adequate range of habitats and species required for a healthy ecosystem. Ecosystem processes and resilience show low to moderate impacts.</td></tr>
<tr><td>C</td><td><30% & ≥10%</td><td rowspan="2">The extent of wetlands is substantially reduced, although there is sufficient habitat to minimize species extinctions. Ecosystem processes are largely impacted, resulting in minimal levels of resilience.</td></tr>
<tr><td>National Bottom Line</td><td>10%</td></tr>
</table>

D	<10%	Wetlands are reduced to fragments, and at very high risk of species extinctions, loss of resilience, and ecosystem collapse.

1. Ausseil A-GE, Gerbeaux P, Chadderton WL, Stephens RT, Brown DJ, Leathwick J 2008. Ranking wetland ecosystems of national importance for biodiversity: criteria, methods and candidate list of nationally important inland wetlands. Landcare Research contract report for Department of Conservation. And updateshttps://data.mfe.govt.nz/layer/52677-prediction-of-wetlands-before-humans-arrived/).

Value	Ecosystem health	
Freshwater Body Type	Wetlands	
Attribute	Wetland Condition Index (WCI)	
Attribute Unit	Score 0 – 25	
Attribute State	**Numeric Attribute State**	**Narrative Attribute State**
	Wetland Condition Index [1,2]	**Description**
A	≥20	Ecological condition essentially intact. Little or no loss in original wetland area. High hydrological and physico-chemical integrity. No or minimal feral or domestic animal access. Natural native plant, invertebrate, bird and fish assemblages intact or mainly intact.
B	≥15 and <20	Ecological condition indicates a small degree of degradation. Loss in wetland area is typically low to moderate. Minor impact from hydrological modifications and nutrient enrichment. Light damage from feral or domestic animal access. Natural plant, invertebrate, bird and fish assemblages show minor deviation and dryland species are mainly confined to the margins.
C	≥10 and <15	Ecological condition moderately impacted. Wetland typically much reduced in extent. Moderate impact from hydrological modifications and nutrient enrichment. Moderate-high damage from feral or domestic animal access. Natural plant, invertebrate, bird and fish assemblages show moderate-high deviation and dryland species are locally common.
National Bottom Line	10	

D	<10	Ecological condition approaching severe degradation. Wetland is typically reduced to fragments, with high-very high impacts from hydrological modifications and increased nutrient levels. Heavy damage from pest or domestic animal access, large deviations in natural plant, invertebrate, bird and fish assemblages, and dryland species are usually common.

1. To be assessed 5-yearly or more regularly as needed following: Clarkson BR, Sorrell BK, Reeves PN, Champion PD, Partridge TR, and Clarkson BD. 2003. Handbook for monitoring wetland condition (Revised October 2004). Hamilton, New Zealand: Landcare Research.
2. WCI breakpoints for states and national bottom line follow Clarkson BR, Overton JM, Robertson HA, Ausseil A-G E. 2015. Towards quantitative limits to maintain the ecological integrity of freshwater wetlands: Interim report. Landcare Research Report LC1933 for Department of Conservation. 29 p. https://www.landcareresearch.co.nz/__data/assets/pdf_file/0018/104454/LC1933-wetland-quantitative-limits.pd

Discussion

Rationale

- The extent of New Zealand's wetlands is still declining. Some regions have currently depleted wetland extent well below 10% of pre-human extent and many wetland ecosystems have collapsed or are on the brink of collapse. One of the key determinants of wetland ecological condition is their current extent compared to original area. The thresholds for species extinction are 10–30% of original extent and 60% for percolation (persistence/ ecological processes) (Desmet 2018).[5]
- In addition to the significant ecological value of wetlands, they also have many others benefits such as mitigating the effects of climate change, nutrient attenuation, carbon storage, sediment capture and flood protection.
- To support recommended targets of 'no loss' of existing wetlands and 'increase in wetland extent' (through restoration), the 'maintain or improve' concept is essential to prevent any further drainage or degradation of wetlands i.e. no decrease in attribute score even if within the same state. We emphasise that the attribute must not be achieved by draining natural wetlands and creating larger constructed wetlands.
- Wetland extent alone is insufficient to ensure wetlands are healthy. They also need to be managed appropriately, this involves (but not limited to) appropriate fencing, keeping nutrient enrichment and hydrological changes low, reducing the influx of weeds and damage from pests.

Guidance and caveats

- There will need to be nationally consistent guidance and/or national direction on the definition of wetlands and evaluation of their condition. Regional councils should set regional targets for wetland restoration and identify and prioritise potential areas for restoration effort.

[5] Desmet PG 2018. Using landscape fragmentation thresholds to determine ecological process targets in systematic conservation plans. Biological Conservation 221:257–260.

- Government should complete the wetland delineation national protocol by developing the wetland hydrology tool to complement the wetland vegetation and hydric soil tool (Clarkson 2014,[6] and Fraser et al 2018[7]).
- At this stage, given the level of loss of wetlands in most regions in New Zealand, no recommendation is made on the composition of wetlands and our recommendation relates to all wetland types and regions. There may be a need to consider region-specific direction, given the pattern and extent of wetland loss varies from region to region. It is significant to note, however, that the wetland-type that has suffered the greatest loss, swamps, are usually the easiest to restore.

STAG perspectives

- The scale at which this attribute is applied needs to be defined to avoid the risk that some wetlands can be lost and replaced by restored wetlands in other catchments or freshwater management units.
- Some members believe that wetland restoration and construction should be included in provisions relating to Farm Environment Plans. These wetlands tend to be the swamp wetland type, which has undergone the largest loss nationally (6% of original extent remaining: Ausseil et al. 2008), and these wetlands are relatively easy to reconstruct/restore.
- Some regions have currently depleted wetland extent well below 10%. Representativeness of current wetland types compared to original wetlands, should be used to guide priorities for protection and restoration of a full range of wetlands.

[6] Clarkson BR 2014. *A vegetation tool for wetland delineation in New Zealand*. Landcare Research Contract Report LC1793. 42 p. Available: http://www.landcareresearch.co.nz/__data/assets/pdf_file/0003/71949/vegetation_tool_wetland_delineation.pdf

[7] Fraser S, Singleton P, Clarkson B 2018. Hydric soils – field identification guide. Envirolink Tools Contract C09X1702. Landcare Research Contract Report LC3233 for Tasman District Council. https://www.landcareresearch.co.nz/__data/assets/pdf_file/0007/170935/hydric-soils-fieldguide.pdf

Part 4: Recommendations for further work

Recommendation 15:

Undertake urgent work to fill the identified knowledge gaps which currently constrain our ability to effectively manage fresh water and the health of freshwater ecosystems.

Discussion

We have identified a series of topics that urgently require additional work. While all these areas of work are important, we are particularly concerned that the current framework for freshwater management has important gaps relating to:

- **Ecological flows (variability and minimum flows) for rivers and levels for lakes, wetlands and groundwater**. These factors have an influence over all other ecological health metrics and attributes.

- **Guidelines for the management of recreational waters.** There is an urgent need to review and update the 2003 Microbiological guidelines to bring them in to line with current science, monitoring and modelling approaches, and management practices. The STAG does not consider itself qualified to comment on this aspect of the science, particularly the direct measurement of human pathogens (as opposed to indicator bacteria) and the relationships between pathogens and human health. The STAG understands there is a proposal to include tables in the NPS-FM relating to *E coli* levels in designated swimming spots. The STAG has not been invited to review or comment upon them and notes that national consistency in this area will be important.

- **Toxic cyanobacteria in rivers, monitoring methods, tools for and evaluating risks, and thresholds for management action**. There is an urgent need to update the 2009 guidelines for cyanobacteria in recreational waters following the review in 2018.[8] There is increasing concern in several regions over the proliferation of toxic cyanobacteria in rivers that experience low flow conditions that may be associated with water allocation and may intensify with climate change in some areas. These bacterial growths are a hazard to dogs and potentially to bathers, especially children.

- **Understanding and protecting groundwater quality, which is a need that goes well beyond simply preventing nitrate-nitrogen elevation in spring-fed streams and rivers.** Groundwater aquifers host their own important, if poorly understood, groundwater dependent ecosystems. Groundwater is also highly utilised in ways that affect human health, either directly as drinking water or indirectly through food production. The development of protective measures for groundwater quality is urgently needed, as demonstrated by the increasing exposure of rural residents in many regions of New Zealand to higher nitrate concentrations and the presence of pathogens in their groundwater drinking water supplies.

[8] Wood S, Puddick J, Thomson-Laing G, Hawes I, Safi K, McBride G, Hamilton D 2018. Review of the 'New Zealand Guidelines for Cyanobacteria in recreational Fresh Waters'. Prepared for the New Zealand Ministry for the Environment. Cawthron Report No. 3233

National guidance and direction on limits for groundwater extraction also needs to be further developed and implemented.

- **Nationally consistent methods for monitoring compulsory values, guidance on the design of systems for data generation and analysis** (including system design, data collection, storage and analysis, and reporting protocols), **and applied science to describe what is required to lift ecosystem health to meet community objectives and support adaptive management.**

Other topic areas we have identified as requiring urgent work, in no particular order, are:

- New and emerging contaminants; including the effects on human and ecosystem health of micro-plastics and chemicals (e.g. PFAS), infectious diseases and microbial resistance to antibiotics, copper, zinc and other urban contaminants in stormwater networks, and heavy metals and trace elements in food production systems.

- Ecosystem metabolism - where more data is required to adequately define bottom lines and to link to environmental drivers.

- Lake mid-hypolimnion; where more work is required to adequately interpret and understand the national characteristics of lake thermal profiles to assist with appropriate sampling of water masses – particularly for medium sized lakes (10-50 m deep) – gain insight into how their oxygen regimes may have been under historic conditions.

- Wetland hydrology, mapping (delineation and condition) and attribute break points at different scales (property, freshwater management unit, catchment, region, nation).

- ‘Source to sea’ understanding of sediment transport, the downstream impacts of sediment on lakes, estuaries and wetlands, and the relationship between in-stream sediment limits and downstream values (at what levels do the former need to be set to preserve the latter?)

- Threatened indigenous aquatic species, which are not currently included in the NPSFM. Much greater effort needs to be placed on integrating and addressing the gaps between national instruments, and national direction on native biodiversity needs to place greater emphasis on aquatic species.

- Invasive species, which have an overwhelmingly significant effect on ecosystem health and water quality and are not addressed by the NPS-FM; there needs to be much greater alignment between programmes for managing biosecurity and a significant increase in monitoring and management effort.

- Physical habitat (geomorphology) including the application of existing tools for characterising and identifying changes to physical habitats at the national scale, potentially incorporating these tools into national direction.

- Fish passage, including amending national direction to incorporate existing tools for identifying and characterising the effects of barriers to fish passage, clarifying the roles and responsibilities of agencies and tiers of government, and providing guidance on how to balance the benefit of removing barriers to indigenous fish passage with the possible drawback of creating pathways for invasive exotic species.

- Sediment-bound phosphorus and its role in controlling periphyton/macrophyte growth.
- Biotic indicators of ecosystem health, especially in lake environments.

Appendix 1: Terms of reference[9]

The purpose of the STAG is to support officials with science and technical advice on the Water Taskforce work programme, as requested by the Water Taskforce officials, throughout 2018 - 2020. The Group will have a role in ensuring the interpretation of the science for policy development is accurate and help improve protocols to better manage incorporating science into the policy process.

The STAG membership includes respected individuals with expertise in data, science and technical matters related to freshwater and estuarine water quality and processes. Members are selected to represent a breadth of expertise across freshwater disciplines and from a range of organisations. Members serve in the group in a personal capacity and are not representatives of their organisation.

The STAG members for 2018- 2020 (the Members) are:

- Ken Taylor (Chair)
- Dr Adam Canning
- Dr Bev Clarkson
- Dr Bryce Cooper
- Dr Clive Howard-Williams
- Dr Chris Daughney
- Dr Dan Hikuroa
- Graham Sevicke-Jones
- Prof. Ian Hawes
- Prof. Jenny Webster-Brown
- Dr Joanne Clapcott
- Dr Jon Roygard
- Dr Marc Schallenberg (joint member with Freshwater Leaders Group)
- Dr Mike Joy
- Rawiri Smith
- Prof. Russell Death

Kahui Wai Māori members who are also on the Science and Technical Advisory Group are:

- Dr Tanira Kingi
- Dr James Ataria
- Mahina-a-rangi Baker

The STAG will:

- Have a solid understanding of the fundamental purpose of the National Policy Statement for Freshwater Management (NPSFM) and the guiding principles of attribute development
- Advise on scientific evidence for freshwater policy development by:
    - reviewing science that underpins Freshwater NPSFM National Objectives Framework (NOF) attributes and other freshwater policy options
    - identifying any gaps in the science
    - improving the NOF attribute development process
    - improving protocols to better manage incorporating science into the policy process
    - providing overarching scientific advice and guidance as it relates to freshwater policy development

[9] Terms of Reference available at: https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/STAG%20TOR%20Nov%202018.pdf

- contributing to science and technical related guidance for councils to implement the NPSFM
- providing science advice on issues raised in public submissions on proposed Appendix 2 attributes and wider freshwater policy.

Final decisions on policy advice, working with Ministers, management and provision of funding, budgets and financial aspects of the programme and the management of procurement processes remain the sole responsibility of the Ministries and not the STAG.

The STAG is not expected to reach consensus, and it is important that any disagreements are noted when advice is communicated to Ministers.

The STAG will advise on science-based issues. Economic considerations are not to be taken into account. Minister Parker has asked the STAG to leave the wider economic decisions to him. The STAG’s role is providing science advice rather than designing policy.

There may be a role for other disciplines that are not yet included in the group; other members can be co-opted in as required. The group can identify knowledge gaps where necessary.

The scope of the group is focussed on biophysical science but is also being informed by kaupapa Māori approaches.

Appendix 2: Summary of key concerns with the requirement to 'maintain or improve overall water quality'

- **Limited ability to link changes in water quality to causes**: We have a limited ability to explain changes in water quality. Simply assessing performance in terms of water quality at points A and B will not provide enough information to attribute that to a cause or a particular source and determine whether the plan was effective (or whether something else like climate was at play). There is a large amount of uncertainty here that needs to be communicated, and more information is needed to tell the full story.

- **Confusion over whether compliance with this requirement means all attributes must be maintained or improved**: Are all attributes important all of the time, or are some more important than others in some circumstances and, if so, which attributes and which circumstances?

- **Inputs are important too**: A narrow focus on water quality outcomes is unnecessarily limiting – inputs (e.g. changes in land use) can also provide useful information and tell a fuller story.

- **Taking a bottom-up approach is preferable**: It's more practical to think about maintaining water quality by starting at the individual site level and building up a picture of the catchment from there (as opposed to starting at the catchment level and somehow deriving what needs to happen at the site level).

- **The number of monitoring sites is insufficient in many cases to reliably establish compliance:**

- **Load to come**: It is not clear how unavoidable or predicted declines due to past management activities are accounted for within this framework.

- **Implications for allocation and trading**: How requirements to maintain water quality are expressed (e.g. as maintaining current concentrations of a contaminant at every site) has implications for allocation systems and trade-ability of discharge rights.

- **The NOF is incomplete**: We are considering what 'maintaining' water quality means without a 'complete' set of attributes that need to be managed.
    - Other measures may be complex or have peculiarities that mean whatever approach we take is not appropriate (e.g. requiring specific monitoring periods/approaches, have complex relationships with other attributes, etc.).
    - Having adequate measures of water quality is critical to knowing whether you are maintaining in a meaningful way (i.e. how ecosystems are actually doing).

Appendix 3: Deposited fine sediment classification system

Table 1 - Deposited fine sediment classification system (left); suspended sediment classification (right)

Class (grouping)	Ref (deposited fine sediment)	% River Net.	CTG Classes	Class (grouping)	Ref (turbidity - NTU)	% River Net.	CTG Classes
1	0.79	1.88	WD_Low_VA; WD_Low_Al	1	1.6	7.05	WW_Low_VA; CW_Low_VA
5	0.74	3.05	WD_Low_SS	12	2.2	22.37	CW_Mount_HS; CW_Hill_SS
9	0.43	0.36	WD_Low_HS	2	4.9	1.42	WD_Low_Al
8	0.13	0.14	WW_Lake_Any	5	5.9	10.81	WW_Low_SS; WD_Low_SS
11	0.69	0.45	WW_Low_Al	8	3.6	3.61	CD_Low_SS
6	0.22	13.32	WW_Low_VA; WW_Low_HS; CD_Low_VA; CD_Hill_Al; CD_Low_HS	6	3.8	2.84	WW_Low_HS
12	0.20	19.73	CW_Hill_VA; CW_Low_VA; CW_Low_SS; CD_Hill_HS	3	1.1	2.72	CD_Low_HS
3	0.33	4.68	CW_Lake_Any; CW_Low_Al; CD_Hill_SS	4	2.7	6.01	CW_Low_SS
7	0.34	15.51	WW_Low_SS; CD_Low_SS; CD_Low_Al	7	2	10.92	CD_Low_Al; CW_Hill_VA
10	0.09	36.41	WW_Hill_VA; CW_Hill_HS; CW_Low_HS; CW_Mount_HS; CW_Hill_SS; CW_Hill_Al; CD_Mount_HS; CW_Mount_Al	10	0.9	1.63	CW_Lake_Any
2	0.04	1.46	WW_Hill_HS; CW_Mount_VA	11	0.9	2.03	CW_Low_HS
4	0.07	1.95	CW_Mount_SS	9	1.0	17.12	CW_Hill_HS; CD_Hill_HS; CW_Low_Al

Appendix 4: Overview of method for deriving numeric attribute states for DIN and DRP

The STAG aimed to develop nationally applicable attribute criteria for nitrogen and phosphorus in rivers as it is a key pillar of ecosystem health – see biophysical framework above. Nutrients are a core component of water quality (i.e., ecosystems include biotic and abiotic components, nutrients being abiotic), and nutrients influence biotic life and ecological processing.

Inspired by Death et al (2018), nutrient criteria were derived using multiple lines of evidence (MLoE). Each line of evidence represents a regression between a national dataset of an ecosystem health metric and nutrient concentrations. The ecosystem health metrics, number of sites and the statistical relationship are in Table A4-1, and the bands that were used for each metric are the same as those proposed in this report (except for cotton decay, which was based on 25th, 50th and 75th percentiles), these are in Table A4-2. Metrics were first averaged to derive bands for each trophic level and ecosystem processing, these were then averaged (i.e., weighted equally) to produce the final score (Table A4-3).

Table A4-1. The ecosystem health metrics using the in MLoE derivation of nutrient criteria, the number of sites and the relationship used.

Ecosystem health metric	Number of sites	Relationship
Chlorophyll *a* (Matheson et al, 2016)	981	Quantile regression
Chlorophyll *a* (Biggs, 2000)	30	Log regression
Macroinvertebrate community index (MCI)	390	Piecewise regression
Quantitative macroinvertebrate community index (QMCI)	390	Piecewise regression
Macroinvertebrate average score per metric (ASPM)	390	Piecewise regression
Fish index of biotic integrity (F-IBI)	2923	Quantile regression
Ecosystem respiration	84	Log-log regression
Gross primary production	84	Log-log regression
Cotton decay	84	Log-log regression

Table A4-2. The bands used for each ecological metric used in nutrient band derivation.

Band	Chlorophyll a	MCI	QMCI	ASPM	IBI	GPP	ER	Cotton K dd
A	50	130	6.5	0.6	34	3.5	5.8	0.0009
B	120	110	5.5	0.4	28	5	7	0.0019
C	200	90	4.5	0.3	18	7	9.5	0.00395

Table A4-3. Nutrient criteria for each trophic group and the overall average (mg/L).

Nutrient	Band	Periphyton	Invertebrates	Fish	Ecosystem processes	**Average**
DIN	A	0.11	0.01	0.50	0.35	**0.24**
	B	0.53	0.33	0.63	0.50	**0.50**
	C	1.00	1.47	0.76	0.77	**1.00**
DRP	A	0.004	0.001	0.013	0.008	**0.006**
	B	0.009	0.009	0.016	0.009	**0.010**
	C	0.016	0.028	0.019	0.010	**0.018**

Statistical regressions were preferred given the complex and difficult nature of deriving deterministic models for each (if even possible at national scale). Ecosystems, by their very nature, exhibit relatively high uncertainty that should not be ignored on the basis that humans cannot model them deterministically with high accuracy (i.e., we recommend the precautionary principle apply).

As a result, it is inevitable that there will be site-specific variation (e.g., as shown for MCI relationships with DIN and DRP in Figure 1 below). However, the multiple lines of evidence approach adds substantial strength to the criteria and some ecological objectives may still require more criteria to be applied locally. Furthermore, it is highly likely that even if some components of the ecosystem do not measurably respond to a reduction in nutrients, other components will.

The STAG had substantial conversations and investigations throughout DIN and DRP attribute development and suggested the following principles:

- Multiple lines of evidence are used.
- Recognition in narratives that nationally correlative relationships do not always translate to site-specific thresholds.
- Nutrient relationships are derived by correlating national datasets of nutrients against metrics of ecosystem health (rather than percentiles). Where possible, use observed rather than modelled data and only nationally consistent calculations. In the case of MCI, for example, use national scoring for MCI rather than regional-specific variants.
- Relationships for each trophic level and ecosystem processes are weighted equally.
- The bands derived for derived nutrient criteria are harmonised, so they align with the existing and proposed bands for other metrics of ecosystem health.
- A single set of criteria apply nationally, and more stringent criteria derived locally if required.
- The nutrient species are in dissolved rather than total form, as this is the biologically available form. Furthermore, dissolved inorganic nitrogen (DIN) is preferred to nitrate-nitrogen as it includes ammoniacal-nitrogen and nitrite-nitrogen.
- Medians and 95th percentiles are provided. The 95^{th} percentiles were derived from the LAWA dataset by correlating medians with standard deviations (2SD giving the 95^{th} percentile).
- Piecewise regressions are used for macroinvertebrate relationships to remove the unduly weight arising from a very small portion of sites that have extremely high nutrient concentrations and are outside the discriminative range of the MCI.

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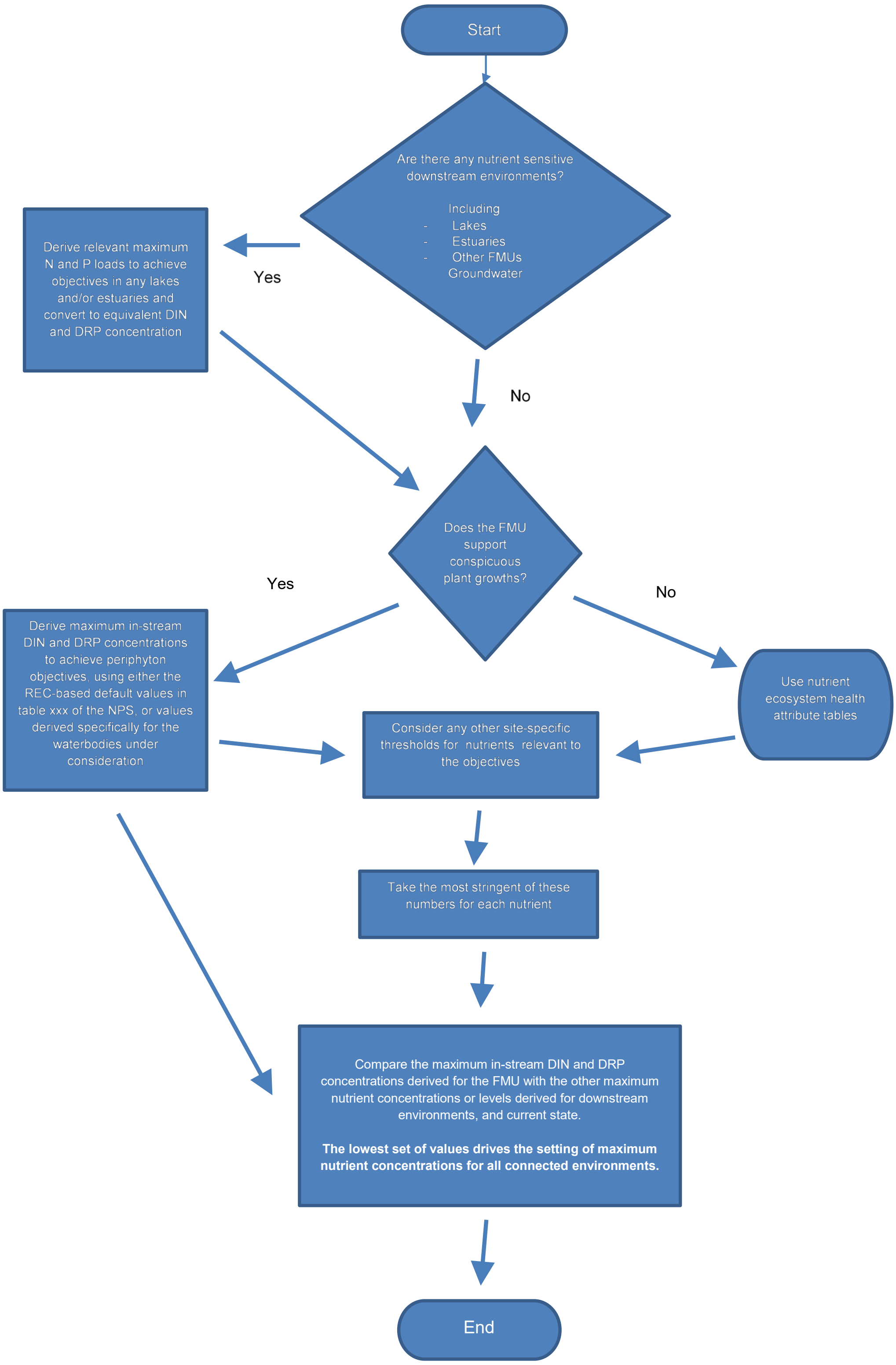
Appendix 5: Flow chart of the process to determine maximum in-stream nutrient concentrations in a Freshwater Management Unit to support the periphyton and ecosystem health objectives



Appendix 6: Response to a review of the proposed nutrient attributes by Professor David Hamilton

Professor David Hamilton (Griffith University, Brisbane) conducted an independent review of the STAG's proposed nutrient attribute tables (Proposed nutrient attributes 6 May JWB ver (2).doc) and associated documents outlining the statsitical analysis undertaken to develop the attribute tables. In his review, Professor Hamilton concluded

> *'My opinion is that the numerical values of nutrient concentrations derived for supporting thresholds for different Attribute States (i.e., A/B, B/C and C/D) given in the Death et al. (and/or Canning) reports match reasonably well with my own interpretation of whereabouts the concentrations would 'fall out'. There is strong evidence for additional attributes besides periphyton and nutrient toxicity to manage stream ecosystem health'* (DH review MfE stream nutrients (002).pdf)

Professor Hamilton made seven recommendations that he thought, if addressed, could provide a stronger evidence base for nutrient attributes. The STAG amended the nutrient attributes based on Professor Hamilton's review and responses to his recommendations are given below.

Recommendation 1*: Clarification could be sought that if nutrient attributes are introduced to manage eutrophication for ecosystem health purposes, then nutrient toxicity attributes would no longer be required.*

The STAG clarifies that if nutrient attributes are introduced to manage for ecosystem health purposes, then nutrient toxicity attributes would no longer be required.

Recommendation 2: *There should be clear justification for using dissolved inorganic nutrients versus total nutrients as an attribute. Assessments using dissolved inorganic nutrients may need to consider the temporal and spatial variability of dissolved inorganic nutrients, for example associated with stream discharge.*

The NPSFM uses total nitrogen and total phosphorus to assess ecosystem health of lakes because these constituents are generally strongly correlated with phytoplankton chlorophyll a. In rivers, dissolved nutrients are more readily correlated with periphyton than totals and for this reason the STAG considered dissolved nutrient guidelines. Stream discharge is addressed, in part, by the use of annual medians in exploring relationships with ecoystem health response variables.

Recommendation 3: *If dissolved inorganic nutrients are to be used in the attribute table, then consideration should be given to use of concentrations of dissolved inorganic nitrogen (DIN = NO_3-N + NH_4-N) as a nitrogen attribute in preference to NO_3-N, to reflect the nitrogen supply available to aquatic primary producers.*

The STAG recommends use of dissolved inorganic nitrogen (DIN).

Recommendation 4: *Consideration could be given whether it is valid to use different metrics of the same (or similar) indicator group to build weight-of-evidence for nutrient concentration thresholds.*

The STAG proceeded with a multiple lines of evidence approach (as opposed to a weight of evidence approach) whereby each level of the food web as well as ecological processes were afforded equal weight in informing the nutrient thresholds.

Recommendation 5: *Consideration could be given to setting an acceptable (statistical) cut off for including an indicator to provide weight-of-evidence for establishing nutrient concentration thresholds. Levels of significance (p values) are irrelevant for many of the large data sets used for the weight-of-evidence approach.*

The STAG explored how the inclusion or exclusion of models based on model strength could inform the nutrient attribute levels and concluded that there would be little effect on final values and therefore included all lines of evidence.

Recommendation 6*: Alignment of data sets used by scientists needs to be carried out urgently so that there is greater consistency of statistical information and analysis provided to the STAG. At the very least, a common example data set should be used to show that different statistical analyses are broadly in agreement.*

The STAG conducted additional statistical analysis using consistent datasets including observed and modelled nutrients as well as regional and national calculations of ecosystem health metrics. This was done to reconcile the differences between initial independent analyses undertaken by Drs Snelder and Canning. The STAG incorporated consistent results into the multiple lines of evidence.

Recommendation 7: *Work by McDowell et al. (2013) and recently by Abell et al. (also with McDowell) should be re-examined by the STAG for the purpose of deriving spatial variations in stream reference nutrient concentrations across New Zealand.*

The STAG explored reference site data and concluded that spatial variation of DIN was minimal (in terms of the effect on ecosystem health) and for DRP there was a ‘north-south’ deviation that could be effectively accounted for by a ‘natural exceedances’ exclusions attribute note.