Established 1968

# New Zealand Freshwater Sciences Society

31 October 2019

**Hon David Parker**

**Ministry for the Environment**

**PO Box 10362**

**Wellington 6143**

**NZFSS submission on Action for Healthy Waterways**

Dear Minister Parker,

The New Zealand Freshwater Sciences Society (NZFSS) was established in 1968 as the New Zealand Limnological Society. It is a constituent body of Te Apārangi, the Royal Society of New Zealand and has some 500 members. The Society's membership spans the breadth of the field of freshwater, from academics and researchers to NGOs and resource managers. We have a strong Te Wai Māori rōpū comprised of Society members who work in tangata whenua resource management and Māori freshwater science/mātauranga. The NZFSS is the key professional society for practitioners in freshwater science and management in Aotearoa New Zealand. The Society aims to "*establish effective liaison between all persons interested in any aspect of fresh or brackish water research in New Zealand, and to encourage and promote these interests*".

As a constituent body of Te Apārangi, the Royal Society, the Society has responsibilities[1] "*To take reasonable steps to prevent their activities leading to significant avoidable or unjustified degradation of the environment, and where appropriate, to contribute to improved conservation, protection and sustainability.*"

The NZFSS has provided detailed submissions and feedback on various iterations of freshwater reform over many years and remains concerned about the widespread decline and degraded state of ecosystem health and water quality in Aotearoa New Zealand. A large proportion of the Society's membership is directly involved in resource management as experts on behalf of local government and iwi authorities, through the Environment Court and in providing advice to central government. A number of members are accredited as independent hearings commissioners through the 'Making Good Decisions' programme. As such, the Society holds a wealth of science and resource management expertise to contribute to the freshwater reform process. This submission has

[1] https://royalsociety.org.nz/who-we-are/our-rules-and-codes/code-of-professional-standards-and-ethics/code-of-professional-standards-and-ethics-in-science-technology-and-the-humanities/

provided an opportunity for the Society, across wide-ranging expertise and experience in freshwater management, to collectively review the proposed package of freshwater reforms. We have also collated feedback from members after our direct engagement with MfE officials on the package at two science focussed NZFSS/MfE workshops in early October.

We have found the direct engagement with Ministry officials very useful during this round of reforms; we wish to maintain this level of engagement and we are happy to provide any further advice into the process as needed. We thank you for the opportunity to review the Action for Healthy Waterways package and to provide feedback in our attached submission for your consideration in progressing freshwater management reform in Aotearoa New Zealand.

Sincerely,

Kate McArthur

**President – On behalf of the New Zealand Freshwater Sciences Society**

PO Box 8602

Riccarton

Christchurch 8440

**NZFSS submission – action for healthy waterways package**

The New Zealand Freshwater Sciences Society (NZFSS) support the intention of the draft National Policy Statement for Freshwater Management (NPS FM), the proposed NES Freshwater and the draft s360 Stock Exclusion Regulations to improve the management of freshwater to support critical freshwater values.

Our submission provides the collective view and advice of Society members on the following aspects of the three policy instruments:

**Summary of key issues:**

1. Support the overarching management of freshwater under Te Mana o te Wai and the hierarchy for the waterbody first, then the essential needs of people and then other uses.
2. That the term water body includes surface water bodies and ground water bodies.
3. Support the requirement for environmental outcomes to be clearly stated in regional plans
4. Strongly support the inclusion of threatened species habitats, mahinga kai and tangata whenua values as national compulsory values
5. Strongly support the broadening and addition of attributes and bottom lines for ecosystem health as national attributes
6. Support the inclusion of macroinvertebrates as national attributes
7. Support the inclusion of fish as national attributes
8. Support the inclusion of sediment as national attributes
9. Support the inclusion of dissolved nutrients (DIN and DRP) as national attributes
10. Support the broader national attributes for dissolved oxygen
11. Support the new lake attributes for dissolved oxygen and macrophytes
12. Support the inclusion of ecosystem metabolism as a critical component of ecosystem health (e.g., ecological processes) and consider development of a robust national bottom line (NBL) would be more useful than a trend
13. Improvement in water quality for Human health and primary contact are supported, although further work is needed to holistically manage water bodies for primary contact
14. Consider that benthic cyanobacteria and periphyton cover attributes for rivers should be included as national attributes
15. Consider that action plans should be required to be part of regional plans and limits to achieve an environmental outcome or target attribute state must sit within the objectives, policies and rules of a regional plan
16. Consider that the water quantity directions should be clarified and redrafted
17. Consider that the wording of the draft NPS FM is overly focussed on trend (e.g., deterioration) in preference to addressing degraded state and that the importance of state and trend need to be more clearly expressed noting concern with the current state baseline of 2020 locking in existing degradation

18. Consider the framework for components of ecosystem health (Clapcott et al. 2018) is a useful addition to the NPS FM, noting concern over reporting a single number
19. Support the intention to halt the loss and deterioration of wetlands, noting that small wetlands on private land which are difficult to identify and map are most at threat
20. Consider that the Wetland Condition Index and Wetland Extent attributes need to be included as national attributes
21. Support the intention to halt the loss of streams from reclamation, noting that net loss of stream length and habitat quantum should also be addressed
22. Support the intention to improve fish passage
23. Consider that īnanga spawning habitats and the spawning habitats of other indigenous fish (including access to them) should be protected in the same manner as wetlands
24. Do not support a blanket exclusion of large hydro schemes from national bottom lines (NBL)
25. Support national requirements for farm environment plans (FEPs), noting that these need to be based on science and evidence that links environmental outcomes effectively to FEPs
26. Support stock exclusion from waterbodies and setbacks, noting that streams less than 1m wide and headwaters are extremely important in the management of water quality and ecosystem health
27. Support the intention to manage intensive land use and winter grazing
28. Consider the linkages between lakes, rivers, groundwater and estuaries are not strong enough in the draft NPS FM
29. Consider that our knowledge is incomplete with respect to the effectiveness of land management practices to improve water quality at the catchment scale which needs urgent prioritisation and funded
30. Support the urgent need to better manage freshwater for ecosystem health and water quality but highlight that there may not be sufficient technical capacity to support rapid plan making by 2025
31. Consider there is an urgent need to build capacity nationally for farm environment planners and auditors to be appropriately skilled or qualified in freshwater science, ecology and sustainable land management practices
32. Consider there is an urgent need to build capacity nationally for skilled and qualified people to measure and monitor the environment to support regional councils and communities
33. Consider that the language, terminology and structure of the draft NPS FM and proposed NES freshwater require significant further work to enable clear and consistent implementation

We have provided a more detailed discussion and where possible scientific evidence to support our views for each of the key themes below. Additional matters with respect to definitions and recommended changes to some of the wording are also included below, following the discussion of these key themes.

## Management of freshwater under Te Mana o te Wai

1. The Society supports Te Mana o te Wai as a fundamental concept for the management of freshwater and also supports the hierarchy of obligations to the water first. Te Mana o te Wai reflects the critical need to protect the ecosystems and life of the water, and to determine limits to do this, before allocating to human uses. We note that the expression of Te Mana o te Wai requires fundamental changes in how we value water as a nation. We hope that the Government continues to support the changes needed to fully and meaningfully embed Te Mana o te Wai into freshwater management for the benefit of future generations.

## Environmental outcomes

2. The Society generally supports requirements for councils to set environmental outcomes for waterbodies in regional plans as this will provide clear direction and more integrated management across multiple areas of freshwater resources that are within council functions. The minimum requirements for environmental outcomes should be better defined in the draft NPS FM.

## National compulsory values

3. The Society supports all of the proposed options for inclusion of new compulsory values. We note that the NPS FM should require regional councils to spatially define all values in regional plans so that management actions (including FEPs) can be targeted to the values in a catchment, waterbody or site. Schedules of values (for surface waters and ground waters) and where they apply should be explicitly required in regional plan by the NPS FM. However, we note that to update such schedules requires a plan change and this can be time consuming and costly if schedules require updating frequently; a plan process to ease updates to schedules would highly beneficial. This is of importance to the threatened species compulsory value where threat rankings are conducted every five years and the updated rankings will need to be added to regional plan schedules following reranking of species.

### Threatened species habitats

4. We strongly support the addition of threatened species habitat as a compulsory value and note that there are more opportunities for policies and requirements to refer directly to this value to provide broader protection within the NPS FM, including but not limited to policies 2, 4 and 11. We note, however, that the approach may only apply to waterbodies where these taxa are known to still occur and as such may be a 'hold the line' approach that maintains current habitats and populations of threatened species, rather than restoring and improving habitats and populations under threat with a view to improving their national threat status over time.

5. We consider that there should also be a requirement for councils to consider the habitats of at risk and declining species. Although we note that the habitats of species with this threat class are widespread, populations are declining nationally, and enhancement and restoration of their habitats is needed which also considers the risks posed by climate change. We are concerned that if the habitats of at risk species in national decline are not better protected through regional plans there will be more species elevated to threatened status in future. The NPS FM and NES should seek to avoid this occurring.

6. The present intention to restrict the threatened species value to those in the categories *Nationally critical, endangered and vulnerable* limits this compulsory value to 21 fish taxa.

However, we note that often when threatened fish are discuss it includes all the *At Risk* taxa too (e.g., 74% of NZ freshwater fish are threatened). Of the 21 threatened fish; ten occur only in Otago, one in Otago and Canterbury, a further three in Canterbury, one in Otago and Southland and another two just in Southland, a single taxa in Marlborough/Tasman, West Coast, one in Northland, and just two occur more widely in Aotearoa New Zealand. Therefore, while this compulsory value is supported, we note that in its current form, it will have little impact on freshwater fish management and protection of their habitat across the majority of Aotearoa New Zealand. If the value is extended to cover the *At Risk* threat categories, this compulsory value would be more effective at arresting the declining of freshwater fish and associated values (e.g., ecosystem health and mahinga kai).

7. Īnanga (*Galaxias maculatus*) spawning habitat is an example where targeted protection of an at risk species habitat could significantly contribute to halting the decline and facilitating the restoration of īnanga populations. Īnanga spawn in spatially discrete areas at the interface between fresh and coastal waters on high spring tides in riparian vegetation. Regional councils should be required to identify potential īnanga spawning habitats and protect them for inappropriate subdivision, use and development, with similar rules as those for wetlands in the NES. A national model to identify potential spawning habitats (similar to the model of Greer et al. (2015) applied in the Canterbury Land and Water Plan), based on existing information could be easily and quickly developed to apply as a default, nationally, unless councils have better information for their regions. Potential habitats could also be delineated with a buffer, to recognise the threat of climate change to īnanga spawning habitats resulting from a shift inland of the saltwater wedge as a result of predicted sea level rise. Further work to protect the spawning habitat of other indigenous fish through application of a model of predicted spawning habitat nationally should also follow.

8. We also note that the threat ranking process works with described *taxa* i.e. species and undescribed taxa or indeterminate taxa, i.e. populations that are thought to be distinct species but that have not been formally described. For instance, the current freshwater fish threat rankings (Dunn et al. 2018) has twelve taxonomically indeterminate taxa. Also, many invertebrate taxa in surface waters and ground waters are undescribed. If the NPS FM used *threatened species* as a compulsory value, it is possible that indeterminate taxa would not be included within the bounds of the NPS-FM and the compulsory value would be restricted to described species, or only nine, rather than 21, freshwater fish taxa. We would recommend that the term 'threatened taxa' is used in place of 'threatened species' to avoid confusion.

9. The threat ranking process also includes a data deficient category for taxa with insufficient data to undertake a threat ranking process. No freshwater fish fit this category, but 168 freshwater invertebrates are listed as data deficient by Grainger et al. (2018). Many of these taxa would likely be categorised as threatened if sufficient data were available and including the data deficient category in the compulsory value would also encourage research and management effort to acquire sufficient data to allow a more complete threat ranking to be conducted.

10. There is a very limited pool of taxonomists and the issue of indeterminate species is not easily resolved when there are few if any new taxonomist being trained and few agencies and research organisations include taxonomic specialists amongst their staff. An example of this is that there are no trained and well-resourced freshwater fish taxonomists in Aotearoa New Zealand since Dr Bob McDowall passed away in 2011. Therefore, despite attempts to progress freshwater fish

taxonomy (e.g., Bowie 2014), this has stalled in recent years. This creates a further limitation on the threatened species (taxa) value.

11. We note that standard regional council monitoring may not identify other threatened taxa habitats, particularly for plants, algae and invertebrates. Further direction is needed for the habitats of these taxa groups.

12. All provisions in the draft NPS FM and NES Freshwater that affect indigenous fish habitat should also be cross referenced to the appropriate Conservation Act and amendment legislation for the protection of indigenous fish habitats to ensure legislative consistency and implementation (e.g., management of activities) through RMA instruments and regional plans.

### Other options for compulsory values

13. The Society's Te Wai Māori rōpū supports the inclusion of a compulsory tangata whenua value. All waterbodies across Aotearoa are connected to one or more hapū or iwi, and therefore have tangata whenua values attached. Such a value should align with Te Mana o te Wai and relate to matters able to be managed under the RMA. Te Wai Māori considers that the proposed mahinga kai value predominantly meets these criteria but needs to be slightly reworded. For example, it is not the role of councils to ensure transfer of knowledge is occurring, however it is their role to ensure that waterbodies are healthy enough to support cultural practices to continue, and therefore knowledge of those practices to be transferred. In addition, the compulsory tangata whenua value should, like Ecosystem Health and Human Health, have attributes associated with it in Appendices 2A and 2B. Many of these will be the same as for Ecosystem Health and Human Health, but some will relate solely to the tangata whenua value.

## Additional attributes for ecosystem health

14. The Society supports using the framework for ecosystem health developed by Clapcott et al. (2018) with five components: aquatic life, water quantity, water quality, habitat and ecological processes. We support the addition of additional national attributes into the NPS FM to provide more holistically for ecosystem health across these five components. In particular, we support including additional attributes for aquatic life (macroinvertebrates, fish and macrophytes), habitat (sediment) and ecological processes (dissolved oxygen and ecosystem metabolism) in the draft NPS FM. We acknowledge that some of these attributes are in their infancy in applied resource management, however they are critical to the management of healthy ecosystems.

15. We note that the NPS-FM does not specifically include any groundwater policies (in section 2.2 of the draft NPS FM) and the Society submits that these are freshwater ecosystems in their own right that harbour taxa and ecosystems dependent on freshwater and are therefore highly relevant to the NPS FM. By extension this lack of groundwater policy is reflected in the lack of proposed NBL for groundwaters. We acknowledge that the ability to set such NBL for groundwater is problematic but submit that even non-numeric targets or a limit on the range of change in relevant attributes can be provided.

16. Development of further habitat attributes and acknowledgement of groundwater ecosystems at a national level are needed for future iterations of the NPS FM to meaningfully support ecosystem health. The Society would like to engage directly with MfE on the forward work programme for future attribute development across the full range of values.

## Attribute guidance

17. There are inconsistencies in the degree of sampling and statistical specifications provided across the 23 attribute tables that need to be rectified (e.g., Tables 1, 3 and 4 do not specify a monitoring frequency or the timeframe over which to assess attribute state and Table 18 (deposited fine sediment) does not specify a statistic). Some medians are specified as *annual* medians while others are *rolling* medians, and some sampling requirements are presented as recommendations while others are more directive. Other than for Table 11, it is not clear when there is more than one numerical attribute state (e.g., Table 18), how to assign an overall attribute band. One option to resolve this, which would also provide a place for further explanation of methods and streamline the updating of these over time (e.g., via the ongoing development of National Environmental Monitoring Standards), would be to remove details on sampling requirements and reproduce these in a stand-alone revised attribute guidance document that could be cross-referenced under each attribute table.

## Macroinvertebrates

18. The Society has consistently advocated for and strongly supports the inclusion of macroinvertebrates as national attributes and NBLs for macroinvertebrate community health. Macroinvertebrates are the most commonly used biological indicator for freshwater in Aotearoa New Zealand and their use in biomonitoring of aquatic ecosystems is regularly used to inform water resource management globally.

## Fish

19. The Society supports the inclusion of fish as a national attribute. Fish are critical components of healthy freshwater ecosystems and often provide a proxy indicator of habitat quality and barriers to fish passage. The health of indigenous fish communities is an important addition to macroinvertebrate attributes for ecosystem health. Fish and macroinvertebrates provide different, but complementary information about the health of freshwater ecosystems. The indigenous fish communities of Aotearoa New Zealand are unique as a result of our remote island biogeography. However, the proportion of indigenous fish species that are threatened or at risk of extinction has risen over the last decade and is higher than the global average (Joy et al. 2018). Whilst some of the increase in the number of species with an assigned threat status has been as a result of changes in taxonomic resolution or better data over the years, many species of indigenous fish populations have continued to decline and their habitats are directly at threat from activities which can be controlled under the RMA. We consider the inclusion of fish and threatened taxa as a specific focus of the Action for Healthy Waterways is scientifically justified and long overdue.

20. The exclusion proposed for large hydro-electric schemes will mean even when migratory fish passage is blocked, and the fish community is impaired these cases will be excluded. For regions such as Southland (the Waiau catchment), Otago (the Clutha catchment), Canterbury (the Waitaki catchment) and the Waikato (the Waikato catchment) this will limit the value of the Fish IBI in these catchments and exclusions should be considered on a case by case basis as discussed further below.

21. The requirement to use fish survey protocols from Joy et al. (2013) may result in substantial commitment of resources as undertaking the methods is labour and time intensive. While this is appropriate and supported in lowland waterways with diverse fish communities, this effort may be considered excessive in high country areas with few if any fish species. However, guidance

on balancing effort and number of survey sites could be provide with protocols to cover less area where fish communities are restricted to one or two species.

22. Reach and catchment (including downstream) scale habitat information also needs to be collected alongside fish surveys to enable effective interpretation of reach-scale fish IBI scores. And, the Society recommends further development of fish community indicators for non-wadable rivers, lakes and wetlands.

## Sediment

23. Elevated sediment is one of the most pervasive impacts on freshwater in Aotearoa New Zealand. Deposited and suspended fine sediment can have adverse aesthetic, cultural and recreational effects; it is also of considerable ecological interest.

24. When suspended sediment loads become too high to stay in suspension or flow velocity reduces, sediment settles on the substrate and in interstitial spaces (small spaces between stones and gravels) of the streambed. Sediment that falls out of suspension fills interstitial spaces and reduces the amount of habitat available for fish and invertebrates. Grazing invertebrates need low (healthy) levels of periphyton to be able to feed. Deposited fine sediment, however, can smother periphyton, preventing invertebrates from grazing. Even low levels of deposited and suspended sediment in the water column can reduce the feeding efficiency of aquatic invertebrates (Broekhuizen et al. 2001). Invertebrate production (particularly in the lower gradient sections of the stream) is likely to be negatively affected by large volumes of fine sediment smothering the underlying substrate. Direct effects on fish and invertebrates can occur when sediment clogs or abrades the gills of these taxa.

25. Indigenous fish, salmonids and macroinvertebrates need access to hyporheic habitat, which is the zone beneath the bed of rivers where shallow groundwater flows. The hyporheic zone provides refuge to indigenous fish during droughts and floods and spawning habitat for many fish species (both indigenous taxa and salmonids). Fish have been found to burrow deep into the gravels of riverbeds (McEwan and Joy 2011; McEwan and Joy 2013a, b and c), receiving essential dissolved oxygen flowing through gravels at the surface. Deposited fine sediment reduces fish access to the hyporheic zone and blocks flow from the surface.

26. Numerous studies in New Zealand streams have clearly shown the impacts of excess sediment on stream habitat and ultimately fish and invertebrate species, their relative abundances and community structure (e.g. Ryan, 1991; Rowe et al. 1999, Richardson & Jowett 2002, Rowe et al. 2002).

27. The Society strongly supports the inclusion of sediment as a key component of ecosystem health with respect to aquatic habitat and supports the need for both suspended and deposited sediment national attributes. Both suspended and deposited sediment should operate as limits. We note, however, that not all REC geology classes are included in the tables in Appendix 2C, for example, in Nelson there is a monitoring site with CD_low_VA REC classes which does not fit into the suspended sediment classification. Additional guidance on REC classes or a default protocol where the classifications do not cover monitoring sites is needed in Tables 1 and 2 of Appendix 2C or a reference to the tool developed to inform regional councils and communities.

28. The Society also notes that the deposited sediment attribute bands and bottom lines are not as stringent as previous national guidance (Clapcott et al. 2011), particularly in naturally hard-bottomed rivers. We are concerned that the attribute may not provide a high level of protection for ecosystem health in these systems and more stringent thresholds already contained in regional plans (e.g., Canterbury and others) may be undermined by the bottom lines in the draft NPS FM.

29. Additionally, we note that many councils include limits for water clarity for safe contact recreation. An attribute state for recreational water clarity should be included in the primary contact provisions along with a threshold for periphyton cover for recreation (discussed below).

### Dissolved nutrients (DRP and DIN)

30. Dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) are nutrients which can enrich freshwater ecosystems and at elevated levels result in poorer outcomes for ecosystem health in groundwater, rivers and lakes and receiving environments such as estuaries and the coast. The Society supports the inclusion of DIN and DRP national attributes for ecosystem health in rivers and the inclusion of NBLs for these contaminants, noting that where natural processes exceed the attribute states this can be managed through the draft NPS FM provisions at 3.23. Limiting resource use to halt and reverse the uncontrolled discharge of nutrients into water is important to ensure that resource use is sustainable into the future and freshwater ecosystems and connected waterbodies are healthy. More work is urgently needed to identify nutrient limits for groundwater ecosystem health.

### Dissolved oxygen

31. The Society supports the extension of dissolved oxygen as national attributes for rivers and lakes. The decision to limit dissolved oxygen as an attribute only for rivers downstream of point source discharges in the NPS FM (2014) was not supported by the Society and was contrary to the recommended thresholds developed to support a dissolved oxygen attribute for the NOF for all rivers (Davies-Colley et al. 2013).

32. Dissolved oxygen is critical for aquatic life. Aquatic species can suffer hypoxic stress, will actively avoid low oxygen waterbodies and can be lethally affected and become locally extinct when dissolved oxygen concentrations are below critical levels, particularly during warm summer periods when thermal stress also contributes to lowering of the saturation of dissolved oxygen. Furthermore, unnatural anoxic conditions at the bottom of lakes can cause irreversible changes in the biogeochemistry that must be avoided.

33. We strongly recommend removing the focus on point source discharges and replacing Table 9 in Appendix 2A of the draft NPS FM with Table 19 from Appendix 2B so that dissolved oxygen applies as a limit for all rivers. The Society also supports the dissolved oxygen attributes and the STAG recommendations for dissolved oxygen at the bottom of lakes and for seasonally stratified lakes a mid-hypolimnetic dissolved oxygen attribute to protect for aquatic life directly and prevent the episodic release of nutrients from lake beds that occurs in anoxic conditions.

### Ammonia toxicity

34. The ammonia toxicity attribute in the NPS FM 2014 applied to both rivers and lakes. The draft NPS FM Table 7 only applies this attribute to rivers. This appears to be a transcription error in the drafting as there is no supporting technical justification for the removal of lakes from the ammonia toxicity attribute. This error requires correction.

## Periphyton biomass

35. Nuisance periphyton growth affects ecological, recreational and cultural values and is commonly reported to detract from freshwater values by the public, particularly at the 120 and 200 mg/$m^2$ band thresholds. We note that the bands below the A band threshold of 50mg/$m^2$ are not strongly correlated with ecological outcomes; rather they were more related to fishery and recreational values as per Biggs (2000). Although Matheson et al. (2016) using more recent data found there was some discrimination between chlorophyll *a* and macroinvertebrate indices, the greatest differences occurred between 1 and 50 mg/$m^2$.

36. We note that monitoring records show that for many months in a year there is very little periphyton biomass in many rivers as flow is the overriding control on periphyton growth during wetter periods in unregulated rivers. Exceedances of a band threshold or bottom line are more likely to occur over the summer period when flows are usually more stable (although high periphyton biomass is also commonly observed in late autumn and early winter). Allowing periphyton to exceed the national bottom line for six months of a three-year period (17% exceedance) by an unspecified amount (e.g., no maximum allowable biomass limit applies to the exceedance of the bottom line) does not protect ecosystem health or freshwater values.

37. Few rivers in Aotearoa New Zealand exceed the periphyton bottom line when the 17% exceedance criteria are applied, and 8% exceedance is also relatively uncommon. This means the current application of the bottom line does not effectively control nuisance periphyton growth or protect values and is so rare that it is meaningless. We question the effectiveness of any exceedance criteria for periphyton biomass as there is no scientific justification for exceedance criteria and their application does not manage periphyton to protect freshwater values. We support the STAG recommendation to remove the productive class (17%) exceedance criterion. We request that the 8% exceedance criterion is also removed as the draft NPS FM at 3.23 already provides an exception for naturally occurring processes and the exceedance criteria are therefore redundant in cases where regional councils can show clear evidence that periphyton biomass naturally exceeds the band thresholds.

38. If the 8% exceedance is not removed, we recommend revisiting this using the larger national dataset that has been collected over recent years.

## Other attributes

### *Periphyton cover*

39. We recommend the inclusion of periphyton weighted composite cover (and concurrent measures of benthic cyanobacteria cover) are included as complementary periphyton attributes for rivers as there are significant advantages to measuring and monitoring periphyton cover over biomass (chlorophyll *a*), enabling more sites to be monitored in a cost-effectively. The work of Matheson et al. (2012) provides attribute states with respect to ecological condition and a threshold for recreational values (Table 1) that can easily be adopted as national attributes complementary to the periphyton biomass attribute (in a similar way to the complementary attributes for macroinvertebrates) and will provide better protection across a broader range of freshwater values (e.g., ecological, cultural and recreational values).

40. The work of Matheson et al. (2012 and 2016) was undertaken at the national level through MBIE Envirolink Tools funding in three phases work to support councils in setting periphyton outcomes in regional plans for various values as an update to Biggs (2000). The advantages and

disadvantages of each attribute are discussed further below. Although measures of periphyton biomass and cover do not always correlate, the attributes complement each other and provide for more thorough measures of the state of periphyton across multiple freshwater values and both should be included for the reasons set out below.

**Table 1.** Matheson et al. (2012) provisional guidelines for periphyton weighted composite cover percentage (periWCC) for classes of ecological condition.

| PeriWCC | Ecological condition |
|---|---|
| <20% | Excellent |
| 20 – 39% | Good |
| 30% | Recreation threshold |
| 40 – 55% | Fair |
| >55% | Poor |

41. Chlorophyll *a* biomass has been used in many studies (both in New Zealand and internationally) to determine the effects of periphyton on ecological communities. The disadvantages of measuring periphyton biomass include: the potential for bias in the collection of stones for substrate scrapings (although there are standard protocols to address this); it can be time consuming to collect in the field; samples need to be shipped to a laboratory on ice or frozen; laboratory testing adds costs to monitoring; and the return time for results can be weeks or months (although laboratory processing can be completed within two days if it is urgently required).

42. Periphyton percent cover is measured by in-stream visual observation in the field across measured transects, using standard protocols (Biggs and Kilroy 2000; Kilroy et al. 2008). There is some potential for between-observer bias, particularly if observers are not well trained. However, this bias has been shown to be much lower than expected (Kilroy et al. 2013) and periphyton cover is a scientifically supported, and recommended alternative or complimentary method to periphyton biomass sampling, that is readily available to councils. The advantages of periphyton cover include: it is easily collected in the field; observations of periphyton cover can be efficiently measured at the same time as fine deposited sediment and benthic cyanobacteria cover; there are no transport logistics for samples; there are no laboratory costs; if appropriate training is provided it can be used by tangata whenua and the community to monitor their own rivers; and the results are almost instantaneous. Additionally, because the costs are significantly less than biomass monitoring, councils can include more sites in periphyton assessment programmes.

43. We recommend including periphyton cover (with concurrent measurement of potentially toxic benthic cyanobacteria) as a complementary national attribute, using the methods and thresholds developed nationally by Matheson et al. (2012) and (2016) to better reflect the influences of varying amounts of periphyton on ecological condition. There is also a draft National Environmental Monitoring Standard (NEMS) in progress that includes periphyton cover.

### *Benthic cyanobacteria*

44. We have has consistently advocated for the inclusion of a benthic cyanobacteria national attribute for rivers (since the 2014 NPS FM submission). There are significant human health, mauri, aesthetic and recreation effects from potentially toxic benthic cyanobacteria (e.g.,

*Phormidium autumnale,* now known as *Microcoleus autumnalis*) and our knowledge of these organisms has improved greatly over recent years commensurate with the rise in prevalence of rivers affected by benthic cyanobacteria. The STAG report highlights the need for an urgent update of the MoH/MfE (2009) guidelines to support a national attribute. We support the need for this to occur and note the NPS FM should include as a minimum a requirement for councils to monitor and report benthic cyanobacteria and frequency of activation of the alert status from the 2009 guidelines with a view to gathering the necessary data and inclusion of benthic cyanobacteria in future NPS FM iterations. We note that benthic cyanobacteria information can be collected by councils within the monitoring protocols for periphyton cover with no additional monitoring effort required. Moreover, some councils already actively monitor cyanobacteria cover, particularly at primary contact sites.

### *Metals, metalloids and toxicants*

45. We consider further national attributes associated with key toxicants and metals (notably copper and zinc, two metals commonly found in stormwater) are needed and development of bands for these attributes should be initiated as soon as possible.

## Human health and primary contact

46. We support the more holistic management of primary contact sites for the six "matters" outlined in Appendix 1A and recommend adding litter/rubbish to the list. Collectively, these seven "matters" are consistent with many of those identified in national and international research as influencing the way people assess the suitability of water bodies for primary contact (Milne et al. 2017, Valois et al. in press). Given the importance of these matters, particularly benthic cyanobacteria which can pose a potential human health risk and visual water clarity which affects both recreational safety (e.g. submerged hazards are obscured in cloudy water) and aesthetics, we suggest that they should be both monitored and reported on. Further, the availability of national guidelines and standard measurement methods for some of these matters (e.g. visual water clarity, nuisance periphyton), suggests they could be included as measurable attributes for which objectives are set and water quality managed. Inclusion of a wider suite of attributes will better align with how tangata whenua and communities assess suitability for primary contact and acknowledges that many components of ecosystem health, human health and primary contact are interlinked.

47. In terms of microbial water quality, we acknowledge the urgent need to complete a national Quantitative Microbial Risk Assessment (QMRA) so that the thresholds associated with the *E. coli* attribute can be updated. In the interim, we support initiatives to improve water quality at primary contact sites through the inclusion of Table 23. However, we suggest that the flexibility offered in Appendix 5 of the current NPS-FM for regional councils to sample over a date range(s) and flow conditions applicable to each site is a more appropriate approach than the blanket requirements stated on page 19 (draft NPS FM 3.18) for weekly sampling over November to March inclusive.

48. While most regional councils already undertake some form of summer surveillance monitoring for primary contact, this varies across regions because seasonal use is limited at many sites (e.g. in the lower South Island), and a number of sites pose a very low health risk (e.g. 'pristine' sites in or near forest parks or reserves), reducing the need for extensive monitoring. The 2003 national microbiological water quality guidelines explicitly accommodate reduced monitoring under these situations, enabling resources to be re-directed to sites where increased monitoring

and intervention are required. Consideration should be given as to how Table 23 might be better linked with Table 11 and Appendix 3 (national target for primary contact sites).

49. Regional plans (or action plans) targeted at specific sources of faecal contamination will require establishing the sources of contamination under different environmental conditions and an understanding of the risk posed by different viral or bacterial sources given concentrations of indicator bacteria (*E. coli*). The proposed Quantitative Microbial Risk Assessment of recreational freshwater will collect data on the different sources of contamination (e.g. urban land, birds, dairy, forests) and the concentrations of *E. coli* or other indicators, and pathogens which affect humans. This will help determine if there is a differential in risk posed from different sources, given the concentration of indicator bacteria.

50. It would be helpful to directly reference the value (and component) in Table 11 of the draft NPS FM and link this to the Appendix 3 target to have an overall improvement in swimmability of freshwater across Aotearoa New Zealand (signalling the intention for long term improvement across all waterbodies). It would also be helpful to direct regulatory agencies to use Table 23 for surveillance management of primary contact sites. Tables 11 and 23 and their implementation will need to be reconsidered following the proposed QMRA of recreational freshwater.

51. The phrase "predicted average risk of infection" in Table 11 can be interpreted differently. There is a need to clarify what it means and a reference as to how it was derived. The draft NPS FM for primary contact sites (3.18) should refer the reader to the MoH Guidelines, as the text differs from the guidelines and doesn't include the full details of actions to take if concentrations of *E. coli* are exceeded, e.g. sanitary survey. Referring the reader to the source document ensures that the advice is current and consistently undertaken by councils.

## Action plans

52. The Society considers that either action plans should be required to be part of regional plans and limits, rules and methods to achieve an environmental outcome or that target attribute states must sit within the objectives, policies and rules of a regional plan. If action plans sit outside of regional plans there is no mechanism for public input and review of any science supporting an action plan. Where there is a clear evidential and science-based link between outcomes for freshwater values and limits on resource use or methods (or both) these should be included as regulatory provisions in a regional plan. Action plans may encompass actions that are non-regulatory in nature, but they should be transparent, able to be tested (through public review and scientific analysis) and councils should be accountable for implementing them. It is the Society's view that this would be more likely to occur if action plans are within regional plans.

## Water quantity

53. There is a lack of clarity across the provisions addressing water quantity (Policy 7, clauses 3.11, 3.12 and 3.19). This would be remedied if the provisions sat together within the draft NPS FM and significant redrafting is needed for clarity. It is ecologically relevant to consider minimum flows and allocation limits together as the size of the allocation limit directly influences the duration, frequency and severity of minimum flows in rivers. This relationship needs to be explicit within the NPS FM, currently it is not.

54. Environmental flows is a new term in the NPS FM that is not defined in the policy statement. A definition of environmental flows is needed in the NPS FM. We assume, and recommend, that

the definition of an environmental flow is consistent with the proposed NES on flows and water levels (2008) that was not made operative. The proposed NES defines environmental flows and water levels as "*the flows and water levels required in a water body to provide for a given set of values which are established through a regional plan or other statutory process. Environmental flows and water levels may provide for ecological, tangata whenua, cultural, amenity, recreational, landscape, natural character and other values associated with water*."

55. The draft NPS FM specifies that environmental flows and levels must be expressed in terms of the water level, flow rate, and variability of flow (as appropriate to the waterbody). The variability of flows is inherently linked to the allocation limit, this linkage needs to be made clear in the NPS FM.

56. Clause 3.11 requires every regional council to set environmental flows and levels for each FMU and *may* set them for individual waterbodies or parts of waterbodies in an FMU. The FMU scale may not be the appropriate spatial scale to set environmental flows and may not provide adequate protection of flow in small rivers if the scale is too large. Councils may default to only setting environmental flows at the FMU scale, where minimum flows in regional plans are generally set at a much finer resolution, the NPS FM should not encourage a coarser approach to flow and level limits. We recommend provisions are included in the NPS FM to ensure environmental flows are set at the waterbody scale, within FMUs. It is also not clear from the draft NPS FM whether consideration of permitted takes authorised by plans should also be considered in setting environmental flows; this also requires clarification through redrafting.

57. Environmental flows and levels must be developed based on the environmental outcomes identified under clause 3.7 of the draft NPS FM and be done with consideration of the requirements under 3.9(6). Whilst we generally support the need for environmental flows to be set with regard to environmental outcomes and the 3.9(6) (a – e) considerations, resetting all minimum flows across the country in plans by 2025, following the identification of desired environmental outcomes, will be a challenging and contentious task, requiring significant science input, resourcing and capacity. When this issue is matched with the potential to set minimum flows at a broader spatial scale (i.e., the FMU) this may result in less protection of critical flows for aquatic life at the necessary scale for small waterbodies. The Society's Te Wai Māori considers that setting environmental flows at an FMU level may also impact negatively on cultural values at a local level, including mahinga kai and mauri.

58. Further work from MfE on environmental flows and allocation limits has been signalled for the coming years; without expediting that further guidance it will be difficult for councils to embark on a process to reset all minimum flows in regional plans by 2025. We note that most minimum flows in plans do not currently consider tangata whenua values.

59. It is not clear whether take limits (3.12) should also include consideration of permitted takes authorised under regional plans. In some sub-catchments the estimated permitted take may exceed the allocation limit depending on what types of takes are permitted and the size of the waterbodies. For example, some councils permit takes for root-stock watering in dry years, in some regions with a number of small rivers there is over-allocation as a result of permitted takes for domestic or stock drinking uses (e.g., Nelson). Clarity is needed about the role of permitted takes in assessing allocation limits and over-allocation under the NPS FM. As noted for

environmental flows, tangata whenua values will need to be further considered in any changes to allocation limits in regional plans.

## Trend vs state

60. The Society considers that the wording of the draft NPS FM is overly focussed on trend (e.g., deterioration) in preference to addressing degraded state and that both state and trend need to be more clearly expressed throughout the draft NPS FM wording as they are both of critical relevance to ecosystem health, mauri and other freshwater values. In many cases ecosystem health or attributes of water quality may be in a degraded state but not exhibiting a deteriorating trend. They may have 'bottomed out' to an extremely poor, stable but degraded state. Long-term trends (i.e., at least ten years) are needed to confidently detect trends, and even then, confidence in trends and their cause and effect linkages is often low or unknown respectively. If action is not taken until a trend is detected, significant degradation could have already occurred, and more expensive and difficult remediation will be needed. The NPS FM must direct councils to address degraded state and deteriorating trends. Examples of this and recommended wording include:
    a. Policy 3: The condition of waterbodies and freshwater ecosystems is systematically monitored over time, and action is taken to reverse deteriorating trends. We note that action should be taken with reference to improve degraded state as well as reversing deteriorating trends.
    b. 3.5(1) Overview of the national objectives framework: … takes steps if deterioration is detected – should read "… take steps if a degraded state or deterioration are detected".
    c. 3.14 What to do if deterioration detected – this whole section needs to be reframed to include requirements when a degraded state is detected, for the reasons outlined above. All reference to deterioration should instead read: "degraded state or deterioration".
    d. Table 22 Ecosystem metabolism: Councils are to monitor and develop an action plan to respond to deteriorating trends – this should also refer to "degraded state and deteriorating trends".

61. The draft NPS FM would also benefit from clear definitions of "maintain" and "improve" and a method for the detection of an ecologically significant trend. We suggest that, at a minimum, for an attribute to be considered as maintained, then the Trend Direction Assessment (TDA) procedure defined in McBride (2019) be used over a minimum of the most recent 10 years (longer where records allow) and yield at least a 66% likelihood of not degrading.

62. Degradation also needs to consider waterbodies that are below community expectations, not just with reference to national bottom lines. The Society is also concerned that defining current state as at the operative date of the NPS FM may 'lock in' recent degradation. Furthermore, some newer attributes will require two to five years of monitoring before current state can be determined. This could result in the 'maintain' component of 'maintain and improve' degrading from the 2011 baseline of the first NPS FM, to a baseline set in 2025 – with the potential for a far worse baseline for current state. The Society's Te Wai Māori considers that this would negatively impact on the mauri of the waterbody and on tangata whenua values for those waters.

63. Councils will require guidance on the representativeness of monitoring sites to report and evaluate state and trend. Many regional council monitoring networks were established to detect and measure impacts and are not necessarily representative of an FMU. For example, the Waikato Regional Council has a site network for ecological monitoring that is representative of the region's waterbodies (using a randomised probabilistic network design), this network may not necessarily be representative of FMUs (e.g., Waikato and Waipā catchments) and it is not linked to the council's SOE water quality monitoring network.

64. Further guidance is required on the setting of FMUs and representative monitoring sites for lakes and wetlands.

## Reporting on ecosystem health

65. Assessing and reporting requires councils to at 3.21(4)(b) "*provide a single ecosystem health score (by reference to the 5 components of Ecosystem Health) for each FMU in the region*." The Society is concerned that a single ecosystem health score (e.g., one number or grade) will not be adequate to transparently report the state of ecosystem health and may be easily misused politically or misunderstood by the public. The requirement should instead clearly state an ecosystem health score for all five components of ecosystem health and clearly demonstrate or account for deficiencies and uncertainties in the data. This requirement should instead state: "provide an ecosystem health score for each of the five components of ecosystem health" and the recent work of Clapcott et al. (2019) to develop a national ecosystem health score card should be progressed to assist councils with this.

## Monitoring primary contact sites

66. We suggest that, consistent with the commentary provided in the 2017 regional sector discussion paper on recreational water quality monitoring and reporting (Milne et al. 2017), the human contact value should be evaluated in a much more holistic manner, drawing on a wider range of human health and other relevant components (e.g., benthic cyanobacteria, visual water clarity, nuisance periphyton growth). Inclusion of a wider suite of components will better align with how tangata whenua and communities assess suitability for primary contact and acknowledges that many components of ecosystem health and human contact are interlinked. At the very least, regional councils should be directed to monitor and report on a wider suite of primary contact components. A report card approach could be adopted, complementing that which is proposed for ecosystem health.

## Monitoring cultural health

67. The Society's Te Wai Māori submits that, in line with the proposed compulsory tangata whenua value, the NPS should require reporting on cultural health like that required for the Ecosystem Health and Human Contact values under Section 3.21. However, the reporting should be flexible enough to use a range of locally appropriate cultural health monitoring tools across the country, rather than prescribing a national tool.

## Effects management hierarchy and biodiversity offsetting

68. The use of offsets in resource management is usually applied to biodiversity offsetting, for which best-practice guidance and principles have been developed by and for regional councils (Maseyk et al. 2018). Offsets are a values-based approach whereby there is a need to generate a gain in

values that are adequate to fully balance the losses in that same value. According to Maseyk et al. (2018) the principles[2] of biodiversity off-setting are:

a. Limits to offsetting,
b. No-net-loss and preferably a net-gain,
c. Landscape context,
d. Additionality,
e. Permanence,
f. Ecological equivalence,
g. Adherence to the mitigation hierarchy,
h. Stakeholder participation,
i. Transparency,
j. Science and traditional knowledge, and
k. Equity.

69. All provisions in the draft NPS FM and NES Freshwater relating to the use of biodiversity offsetting should directly reference the best-practice document of Maseyk et al. (2018) and include the key principles of offsetting.

## Wetlands

70. We strongly support the intention to halt the loss, degradation and deterioration of wetlands, noting that small and ephemeral wetlands on private land which are difficult to identify and map, are most at threat and may not be adequately protected in the requirements to identify and map wetlands. Instead a schedule of wetland types (based on Johnson and Gerbeaux 2004) should be included in regional plans so that wetlands not identified and mapped are also subject to the NPS FM and NES Freshwater provisions and objectives, policies and rules in regional plans. An example of this approach can be found in the objectives, policies and rules and Schedule F of the Manawatū-Whanganui Region's One Plan.

71. We note that restoration of wetlands should be a goal of the NPS FM and NES, not just halting loss and deterioration. Exclusions for activities for national infrastructure should be tightened as they are too broad and may undermine the goal of halting the loss of wetlands without more control.
72. The approach in the draft NPS FM and proposed NES Freshwater should be broadened to include all wetlands regardless of size and wetlands that can't be easily identified and mapped, based on wetland type (via the recommended requirement for a schedule of wetland types discussed above). Wetlands constructed for the purposes of conservation or biodiversity offsets or compensation should be included in the definition of inland/natural wetlands in the NPS FM and NES Freshwater respectively. These wetlands should be treated the same as inland wetlands because if they are not as good or equal to natural wetlands, they are not achieving conservation or biodiversity outcomes and are not an offset. A key principle in biodiversity offsetting is that the offset be permanent and therefore should also be subject to Policy 8 and subservient provisions in the NPS.

73. We also support the STAG recommendation to include attribute states for wetlands associated with wetland extent and condition.

[2] Based on the international BBOP principles: Business and Biodiversity Offsets Programme (BBOP) 2012. Standard on Biodiversity Offsets. BBOP, Washington D.C http://bbop.forest-trends.org/

## Streams

74. We strongly supports the intention to halt the loss of streams from infilling and reclamation, noting that loss of stream length and habitat quantum should also be considered through including 'realignment' alongside reclamation (we note 'infilling' is not a commonly used term with respect to permanent diversion of streams and 'reclamation' is the most appropriate term). There should be no net loss of stream length included in the NES Freshwater proposals as a minimum, to control the loss of stream habitat quantum via a death by a thousand cuts.

75. We note the interplay between the draft NPS FM, and proposed NES Freshwater provisions is not clear, particularly with respect to no net loss. Because regional plans will take time to develop and be implemented, we recommend that all provisions relating to no net loss are included in the NES Freshwater so they can be implemented with urgency.

76. We are concerned with the broad range of exclusions from the stream provisions in the NES Freshwater and we do not support blanket exclusions for activities or organisations. These should instead be considered on a case by case basis.

## Fish passage

77. The Society strongly support the intention to improve fish passage in the draft NPS FM and NEW Freshwater. The loss or reduction of habitat caused by barriers to fish is a key factor in the causes of declining fish populations and depleted fish communities in Aotearoa New Zealand. The Freshwater Fisheries Regulations (1983) require that culverts and fords shall not impede passage without approval from the Department of Conservation (DOC) (and this is no matter what age the structure is) and any proposals for dams and diversion should apply to DOC to determine if a fish facility is required (this only applies to structures built after 1983). Many existing structures were either not built originally for fish passage or have not been maintained, and as such have become fish barriers.

78. We support the program to assess and remediate fish passage barriers. However, we note some remediation methods will require ongoing maintenance, e.g., mussel spat ropes need regular replacement due to breakage and downstream water level controls can be eroded. Providing fish passage for the foreseeable life of the structure is critical and should be included in the NES Freshwater conditions.

79. We support and adopt the submission of the New Zealand Fish Passage Advisory Group with additional advice included below. Furthermore, the Society would also support a target to ensure that at least 90% of river reaches have unhindered connectivity with the coast, using the prioritisation tool from Franklin et al. (2018) to ensure the most problematic barriers are addressed first. We note that the straightening and realignment of streams, along with reclamation reduces the length, extent and available habitat of a stream (and thus it's ecosystem health). We recommend including provisions in the NPS FM and NES Freshwater which specifically control loss of stream length and thereby habitat quantum. For example, no net loss of stream length would provide useful and clear controls in the provisions.

80. Section (3)(b) of the NES Freshwater is problematic as it says, "the extent to which the structure does not cause a greater impediment to fish movements than in adjacent stream reaches". There are many existing barriers, and this should not be taken to mean we should allow for additional barriers commensurate with the extent of barriers in adjacent streams. The Society

recommends this refers to existing natural features which challenge fish passage or the clause should be removed. Monitoring should provide for fish surveys before and after the barrier is removed/remediated.

## Culverts

81. At present it is unknown how many culverts there are in Aotearoa New Zealand, but a conservative estimate is that over 300,000 exist. The cumulative effects of these culverts on fish passage and the loss of stream length is unknown. We note that data collection will assess the current state of culverts, however, this can be temporary as floods can damage culverts and scour the downstream reaches creating new fish passage barriers. Maintenance and monitoring over time will need to continue for the life of the structure.

82. The definition of a culvert in the NES Freshwater is problematic and unclear and the definitions in the draft NPS FM and NES are too permissive. The NES Freshwater does not specifically note that a culvert is for access nor does it differentiate a culvert (which is the minimum size needed for access) from a reclamation (e.g. piped flows under fill). Also, it is unclear whether the definition of a culvert in a wetland is a culvert (for access) or is a pipe in a wetland associated with earth disturbance for drainage. Building a culvert in a wetland results in reclamation of that section of wetland so this definition should specifically exclude all structures through wetlands. We recommend clear definitions of culverts and pipes are included in the NES Freshwater to avoid this.

83. The Auckland Unitary Plan (AUP) defines a culvert as "*A structure with an inlet from and an outlet to a lake, river, stream or the coastal marine area, designed to enable access across a river, such as a road or stock crossing.*" And also stipulates that "*the structure is designed to be the minimum size necessary for its purpose to minimise the modification to the bed of a lake, river, stream or wetland."* (at E3.3(7)(b) of the AUP).

84. A useful definition across both the NPS FM and NES Freshwater could read: "A culvert means:
    a. A pipe or box structure with an inlet and outlet to a lake, river, stream or coastal marine area, designed to enable access across a river/lake/CMA, such as a road or stock crossing, which has been designed to be the minimum size necessary to achieve this purpose; and
    b. Specifically excludes structures in wetlands; and
    c. Does not include stormwater pipes or reclamations."

85. A useful definition across the NPS FM and NES Freshwater could read: "A pipe means:
    a. A pipe or box structure that conveys stormwater flow; or
    b. The entire structure used to channel a natural waterbody and pipe flow under fill."

86. We also note that the NES Freshwater seemingly requires the monitoring of a reclaimed (infilled) stream. This will be impossible as there will be no ecosystem to monitor once the stream is reclaimed/infilled. This requires clarification on what the scale of monitoring encompasses.

87. The Society expects that documenting and monitoring structures will be difficult as culverts are currently a permitted activity in many regions and remain so in the NES Freshwater. This could be altered so that culverts are a controlled activity if they provide for fish passage and discretionary if not. This would assist councils to track and monitor the by far most common type of structure in streams. We suggest culverts should be a Controlled activity rather than a permitted activity at minimum so that councils can have oversight on how many and the types of

culverts being built and to actually ensure they are providing for fish passage. Currently, activities such as progressive encasement and the cumulative effects of culverting streams is nearly impossible to keep track of and ensuring that these are built to provide for fish passage and comply with the permitted activity standards is very difficult. Leaving culverts as a permitted activity will make it very costly and difficult for councils to comply with their requirements under the new rules. If culverts were a controlled activity, it would ensure that people will be granted consents to construct them while also providing the necessary oversight and ability to quantify effects such as progressive encasement.

88. The fish passage structure information for discretionary culverts (and other structures in the NES Freshwater) which do not provide for fish passage could be better assessed and conditioned through a resource consent process. It is not appropriate to defer the assessment to after the consent has been granted. All other permitted activity structures (weirs, passive flap gates & dams/fords/non-passive flap gates) will be difficult to implement, monitor and enforce.

## Other habitats for protection

89. Migratory galaxiid fish (i.e., banded kōkopu, giant kōkopu, shortjaw kōkopu, kōaro and īnanga) spawn within riparian vegetation when it is inundated by spring tides (in the case of īnanga and at times banded kōkopu) or autumnal freshes (in river and lake margins used for spawning by kōkopu and kōaro). Eggs develop within the humid conditions of the riparian vegetation and hatched larvae are washed into rivers and streams on subsequent tides/freshes.

90. The Society considers that īnanga spawning habitats and the spawning habitats of other indigenous fish should be protected in the same manner as wetlands in the NES Freshwater and that the application of threatened species habitats could be broadened across the NPS FM and NES. The habitats of at risk and declining species is a gap in the draft NPS FM and NES Freshwater which needs to be filled if these habitats are to be managed in a way that promotes their improvement and restoration and avoids at risk species becoming more threatened in the future.

## Groundwater ecosystems

91. Research over the last two decades in Aotearoa New Zealand and over a longer period globally has established that microbial and invertebrate biodiversity is ubiquitous in groundwater. Aquifers containing groundwater underlie 26% of New Zealand's land surface, making groundwater ecosystems (GEs) our largest freshwater body and freshwater ecosystem. A recent Envirolink report summarised much of the available information on GEs for regional councils (https://www.envirolink.govt.nz/assets/Envirolink/Reports/1838-HZLC143-Groundwater-Ecosystems-Functions-values-impacts-and-management.pdf).

92. Groundwater biodiversity and the functioning GEs deliver services fundamental to sustaining groundwater resources. Microbes in biofilms accumulate and metabolise contaminants carried into groundwater from the land surface and surface waters. Invertebrates browse these microbial biofilms, stimulating their activity and removing biomass. In the process, they reduce clogging by biofilms to maintain water flows through the aquifer. This minimises anoxia and adverse biochemical processes that develop in deoxygenated groundwaters. Thus, GEs remediate water quality and sustain groundwater flows, including the water flows for extraction by humans and the water quality effects of groundwater on surface waterbodies.

93. To date, very few regional plans even acknowledge GEs. Wellington Regional Council has started along the path and Tasman Council is coming to terms with some aspects via the application for a Water Conservation Order to protect Te Waikoropupū Springs and its contributing aquifers.

94. The Society recommends national methods are developed so that regional councils be required to monitor microbes, invertebrates and water quality across their groundwater ecosystems. The data collected should then be used to develop any relevant attributes for inclusion in the next iteration of the NPS FM.

## Exclusion of large hydro schemes

95. We do not support the blanket exclusion of large hydro schemes from national bottom lines in the draft NPS FM at 3.22. Whilst we appreciate that renewable energy and the flexibility and generation capacity of the six largest hydro-electric schemes is of national importance, they constitute approximately 60% of the total surface waters of Aotearoa New Zealand and as such, excluding these schemes from national bottom lines will have a major impact on the effectiveness of the NPS FM in these catchments.

96. No specific evidence has been provided to support which bottom lines cannot be met by each of the schemes in these large catchments. We propose that they need to be assessed on a case by case basis with clear evidence of which bottom lines may impose restrictions on their generation capacity and flexibility and how catchments will be managed to improve waterbodies and ecosystems in the absence of bottom lines for some attributes. It is also unclear from the draft NPS FM how catchment-wide effects and impacts will be considered or managed if bottom lines are exempted in these catchments.

97. Furthermore, the Society's Te Wai Māori considers that a blanket exclusion of large hydro schemes is inconsistent with s6(e) of the RMA, will impact on the ability of tangata whenua to exercise kaitiakitanga (as under s7(a)), and will have adverse effects on cultural values.

## Stock exclusion and setbacks from water

### Definitions

98. The definitions of a riverbed, setback, bankfull discharge and bankfull width may not be adequate across all river types in Aotearoa New Zealand. Small spring-fed streams have very different 'edge' characteristics than braided rivers for example. Definitions related to the range of river types nationally will be useful in measuring where the regulations for stock exclusion and setbacks will apply and compliance with the regulations.

99. Braided rivers are globally rare. In Aotearoa New Zealand, braided rivers have very high cultural, ecological, recreational and amenity (e.g. tourism) values. These values are under threat from inappropriate encroachment and loss of the areal extent of the braidplain (Gray et al. 2017).

100. The RMA definition of river bed (" . . . the space of land which the waters of the river cover at its fullest flow without overtopping its banks") is difficult to apply in braided rivers because of a general absence of banks and the fact that the active bed of the river moves about within a wider area known as the braidplain (Gray et al. 2017). The braidplain is the area that has been (and might in future be) occupied by the active channels of the river. To protect the ecological and natural character of braided rivers the unit of management must be the entire braidplain (Grove et al. 2015).

101. We recommend an alternative definition to provide for the natural character of braided rivers within the regulations, based on work in Canterbury: "The lateral extent of a braided river is either the area that the active bed of the river could conceivably occupy based on geomorphology adjusted for impact of river protection and other structures or the area that has been covered by active channels in historical imagery adjusted for impact of river protection and other structures."

## Stock exclusion and setbacks

102. We generally support the intent to exclude stock from waterways and to have setbacks from waterbodies. We note however, that small streams and headwaters are critical to the success of fencing and setbacks in achieving water quality and ecological outcomes. The Society does not support allowing stock to access waterways less than one metre wide.

103. Small streams contribute 77% of the national contaminant load of nitrogen and phosphorus (McDowell et al. 2017) as well as faecal contaminants and sediment. Small headwater streams are also important for ecosystem health (Greenwood et al. 2012). Management of small streams to reduce contaminant transport is therefore a critical consideration for the effectiveness of stock exclusion regulations. We have consistently advised government in previous iterations of the stock exclusion regulations that the science does not support allowing stock to access these waterbodies.

104. We are concerned that the stock crossing allowances may not be stringent enough to avoid the destruction of stream habitat and should be tightened. Stock crossings in smaller waterways may be particularly detrimental.

105. Whilst we support requirements for setbacks from waterways, we note that in some cases the proposed five metre buffer will only be effective at reducing large particulate sediment; wider buffers are needed to control fine sediment and some dissolved nutrients. Five metres may also not be effective at controlling microbial pathogens from entering water. While stock exclusion is clearly important with respect to improving water quality, it must be effective and supported by empirical evidence to ensure that anticipated water quality outcomes are realised. For example, Holmes et al. (2016) estimated that, to reduce fine sediment cover of the bed to <20% for a spring-fed stream in a dairying catchment, an average fenced width of at least 5 m (on both banks of the stream) over at least 300 m upstream would be required.

106. We do not support setback widths averaged at the farm scale. This should refer to an average at the waterbody scale to ensure effects are adequately managed for each waterbody and 'trading off' between waterbodies at the farm scale cannot occur.

107. International literature expands on the New Zealand evidence (McDowell et al. 2017) on the benefits of exclusions and riparian buffers to improve nitrate removal. The role of wetlands and riparian buffers adjacent to springs and first order streams in nitrogen removal has long been recognised internationally (Peterson et al. 2001). A high-profile strategy for global management of the nitrogen cycle recommends that one of five key solutions focus on "wetland and riparian restoration," noting also that engineered restoration may be more effective than natural environments in removing nitrogen (Houlton et al. 2019). However, a review of well-cited literature on hot spots of nitrate mobilisation and removal (Bernhardt et al. 2017) suggests a lack of efficiency resulting from the establishment of riparian buffers of uniform width, e.g., the

proposal of 5 meters. Instead, the review suggests that targeted "control points" for contaminant management can be identified in a manner that would be consistent with rules in regional or catchment plans and implemented through Farm Environment Plans.

108. Setback distances from water bodies and (preferably well vegetated) riparian buffers are needed that provide effective reductions in the risk of contaminants reaching water, not just from the direct effects of stock in waterways, but also through providing effective buffers between farmland, earthworks, cultivated land and water to reduce overland flow of contaminants and erosion from de-vegetated, cultivated or stock-trampled river banks.

109. Riparian management (including stock exclusion, vegetated buffers and setbacks) has multiple benefits for water quality, including preventing bank erosion, nutrient and contaminant interception and processing, shading, input of wood and leaves to stream ecosystems, and enhanced fish and invertebrate habitat (Parkyn 2004; McKergow et al. 2016). Stock access and cultivation in riparian margins are two activities that can have adverse effects on freshwater values and water quality.

110. Overland flow is the greatest source of diffuse microbial pollutants to New Zealand's rural waterways that can be practically mitigated. In rural areas diffuse pollutants which reach rivers via overland flow are either associated with sediment mobilised by land disturbance or under intensively grazed systems and manure from livestock.

111. Diffuse sources of pollutants can be manged via different mitigations including correctly designed riparian buffers. Key design aspects for effective riparian buffers include slope – steeper land requires wider buffers (Liu et al. 2008), climate (particularly rainfall), soil characteristics, the potential load and source of key pollutants and the hydrology of the waterway in relation to the scale and frequency of flood events.

112. Careful selection of riparian plant species, in conjunction with correct setback distances in consideration of the slope, has a significant influence on the effectiveness of buffers. For example, research has shown that root extracts of manuka and kanuka (*Leptospermum scoparium* and *Kunzea ericoides)* reduce survival rates of *E. coli* and other pathogens. Furthermore, current research indicates that mānuka and kānuka can significantly alter the nitrogen cycle and improve soil infiltration rate, reducing surface water ponding (Gutierrez Gines et al. 2017). These findings illustrate the potential of specifically identified plant species to improve the function of riparian buffers to reduce the rate of pathogens and nitrates from entering waterways both via leaching processes and overland flow.

113. Cultivation of land adjacent to waterways exacerbates and accelerates the transport of sediment and phosphorus to water (Basher et al. 1997). Microbial contaminants can also be problematic if cultivated land adjacent to waterbodies is used for grazing of forage crops. Setback distances and vegetated riparian margins can alleviate many of the effects of cultivation on water quality and should be consistent with stock exclusion setbacks and buffers.

114. Parkyn (2004) reviewed the New Zealand and international literature on the effectiveness of riparian buffer zones, reporting that in studies of perennial ryegrass filter strips the first five metres were critical for particulate sediment removal and that 20 metre filter strips were able to remove 90% of sediment along with sediment-bound and particulate nutrients due to increased

infiltration within the wider buffer. Liu et al. (2008) reported an optimal buffer width of ten metres for sediment removal and that sediment removal did not appreciably increase beyond ten metre wide filter strips, although consideration of clogging by fine sediment over time was needed for a ten metre strip, and wider strips (>10 metres) remove more nutrients (Parkyn 2004).

115. Smith (1989) in a New Zealand study, found removal of more than 80% of suspended sediment and particulate nutrients for vegetated filter strips of ten to thirteen metres, with dissolved nutrient removal of 67% (N) and 55% (P). Parkyn (2004) notes that improving the infiltration capacity of vegetated buffers will improve their removal of dissolved nutrients. Infiltration capacity is improved through root structures of vegetation in buffer zones. Planting of large trees on the edge of grass filter strips increases the effective width contributing to nutrient removal via the root structure of large trees extending beyond the retired buffer width.

116. Parkyn's (2004) review also reported sediment and total phosphorus removal rates increase (between 53% and 98%) with increasing buffer width (4.6 metres to 27 metres). Most larger sediment particles will be removed within five metres of grass buffer, although ten metres was needed to remove finer particles. Ten to 30-metre-wide buffers can be effective at removing large amounts of soluble nitrate, particularly if forested.

117. Importantly, Parkyn (2004) also notes that optimising the filtration effectiveness of riparian buffers also requires improved land use practices over the broader landscape, to reduce nutrient and sediment influx to the riparian zone. For this reason, we support the intensive winter grazing and other farming provisions in the NES Freshwater. Farm environment planners will need to be cognisant of the literature to assist farmers in developing plans that are effective and evidence-based.

118. Another key issue with respect to stock exclusion, beyond the obvious and well-documented adverse effects on water quality, is the impact stock grazing and trampling can have on the potential for indigenous fish to spawn successfully in riparian margins. This occurs through two mechanisms: trampling of riparian spawning habitat, eggs and larvae and vegetation removal via grazing. Where riparian areas are known or predicted to be utilised for galaxiid spawning, stock exclusion, larger setbacks (for both stock and cultivation) and preferably riparian restoration should be required, regardless of stream size or flow permanence (i.e., intermittent or ephemeral/headwater streams).

119. As summarised above, increasing riparian setback distance significantly influences the effectiveness of the riparian zone to intercept pollutants and provide habitat for threatened indigenous wildlife. However, to be effective stock exclusion and setback distance should be managed in relation to the slope at the site, potential pollutant loads and flood dynamics. Importantly, incentivising landowners to increase setbacks and undertake riparian planting in conjunction with provision of technical support to improve riparian function will be critical to the success of the proposed stock exclusion rules.

120. The table below presents the results from a large meta-analysis (combines the findings from multiple studies around the globe) by Zhang et al. (2010). With a five metre buffer, on average, around 80% of sediment and 50% of nutrient flowing over the buffer (does not include groundwater flows) into the stream are captured. However, the effectiveness of

riparian buffers to remove nutrients is highly variable and depends on the type of plants, the density of stems, soil type, plant nutrient uptake rates, flow velocity, slope, sub-surface flow depth. Typically, above a slope of 10% (5-6 degrees) buffers lose their capture efficiency reduces. Furthermore, Daigneault et al. (2017) found that in some cases monetary benefits of riparian buffers can outweigh the costs by more than 20:1.

**Table 2.** The average mitigation effectiveness (%) of vegetated buffers at various widths (Zhang et al. 2010).

| Buffer width (m) | Sediment | Nitrogen | Phosphorus | Pesticides |
|---|---|---|---|---|
| **1** | 33 | 14 | 13 | 18 |
| **3** | 67 | 35 | 34 | 45 |
| **5** | 81 | 51 | 49 | 62 |
| **10** | 90 | 73 | 71 | 83 |
| **15** | 91 | 84 | 81 | 90 |
| **20** | 91 | 88 | 86 | 92 |

## Farm Environment Plans

121. We generally support the national requirements for farm environment plans (FEPs), noting that these need to be based on science and evidence (included above) that links environmental outcomes, target attribute states and compulsory national values (and other values determined at the council level) effectively to FEP actions.

122. Under the proposed package, FEPs are the key mechanism to ensure environmental outcomes and freshwater values are provided for in rivers less than one metre wide (unless these are included in the 360 regulations as recommended) the importance of these systems needs to be clear and directive in FEPs. Headwater and small streams are critical ecosystems and key sources of diffuse contaminants entering water. They must be managed coherently and effectively at the national scale if improvements in water quality, ecosystem health and mauri are to be realised. The science supports the views that many water quality benefits could be achieved if the focus of stock exclusion from small streams is prioritised.

123. We note that significant upskilling of farm environment planners will be needed to ensure they are able to identify and remediate (used evidence-based mitigations or practices) critical impacts of various activities on farm, particularly with respect to effects on ecological and biodiversity values. For example, a farm environment planner may need to be able to identify critical source areas, ephemeral waterbodies, wetlands, threatened taxa habitats and other potential impacts on aquatic life and water quality. Farm environment planners will also need to be able to interpret environmental outcomes and target attribute states in regional plans at the farm scale.

124. The current skill level and capacity of providers to effectively implement FEPs needs to significantly increase nationally. Farm environment planners are likely to need qualifications in freshwater sciences, ecology and sustainable land management practices and will require considerable regional council support to ensure they can interpret and articulate the environment outcomes and target attributes states for a particular waterbody and what farm practices may need to change to implement plans and improve ecosystem health, mauri and water quality in the freshwater module of a farm plan.

125. We recommend that the certification requirements for farm environment planners specifically include environmental management experience. This is essential to ensure farm environment planners have the right skillset to achieve the desired environmental outcome. FEPs are primarily designed for environmental outcomes and are different from general farm operation plans (which the current proposed experience is tailored towards). The Society suggests the following wording:
*"*3 years' experience in environmental management or ecology. Management of pastoral, horticultural, or arable farm systems may also be considered*".*

## Intensive farming and winter grazing

126. We generally support the provisions controlling intensive farming and winter grazing. The majority of water quality issues in Aotearoa New Zealand result from diffuse inputs of contaminants to water from land and in particular agricultural land use. Controlling and reducing the flux of contaminants from land is critical to implementing improvements in water quality. We note however that many lake and ICOLL catchments with significant nitrogen issues are not included in the proposed nitrogen cap catchment in Schedule 1 of the NES Freshwater. For example, Arawhata Stream, a tributary of Lake Horowhenua, has some of the highest nitrogen concentrations in the country (with a total oxidised nitrogen 5-year median concentration of 10.5 mg/L[3]), yet this catchment is excluded from Schedule 1. Lake and ICOLL catchments should must also be included in Schedule 1 and a reassessment of the criteria for inclusion in Schedule 1 may be needed.

## Measuring, monitoring and reporting

### National standards and consistency

127. We support the increased level of measuring, monitoring and reporting, particularly the requirement to monitor and report at a site level, rather than the FMU scale as in the previous NPS FM, however, we note that monitoring must also be cost-effective. The change in monitoring scale removes previous uncertainties about 'under and overs' between attributes and sites and prevents some of the ability for 'gaming' between these to establish whether water quality is maintained or improved. We note, however, that there are still outstanding issues of national consistency in measuring and monitoring freshwater. The NEMS programme to address this remains incomplete and unresolved. We urge central government to prioritise increased support for the completion of this critical work.

### Science and technical capacity

128. We support the urgent need to better manage freshwater for ecosystem health, mauri and water quality. However, we note that there are significant capacity issues with respect to the availability of freshwater scientists and qualified technicians to support councils, tangata

[3] https://www.lawa.org.nz/explore-data/manawat%C5%AB-whanganui-region/river-quality/lake-horowhenua/arawhata-at-hokio-beach-road/

whenua and the community for rapid plan making by 2025. If a water commission is established there will be a need for an independent multi-disciplinary panel of scientists and technicians to provide technical support.

129. We consider there is an urgent need to build capacity nationally for skilled and qualified people to measure and monitor the freshwater environment and there is a lack of appropriate training courses to bring new technicians rapidly into the field. We note that training can only achieve part of the increase in capacity required and skills developed over years are important for tasks such as aquatic ecosystem monitoring and farm environment planning. Therefore, mentoring and on the job guidance by skilled staff will be required to ensure that initial work under the NPS FM is not limited by limited experience. This will reduce the risk that changes observed in aquatic ecosystem condition are real changes and not due to the gradual upskilling of staff that are more effective at the assessments after several years on the job.

130. Capacity needs to be urgently addressed if rapid plan making and implementation are to be successful. We note there is a good example of collaboration on freshwater monitoring in the Manawatū-Whanganui Region between the council and Ngāti Rangi. Tangata whenua collaboration models should be encouraged and supported, along with considerations of the capacity benefits of citizen science to contribute.

131. We have considered these capacity issues and recommend that a national approach is taken to provide support in three critical areas:

a. A national panel of independent multidisciplinary experts (e.g., freshwater, groundwater, coastal, land management, soil sciences) available to councils, tangata whenua and the community to provide land and water expertise for the development of plans and testing and review of the science by 2025, and
b. A national pool of qualified and experienced monitoring technicians across the freshwater and land spaces, and
c. A national pool of farm environment planners and auditors with skills in freshwater sciences, environmental management and ecology.

## Ecosystem linkages

132. The Society considers that the linkages between lakes, rivers, wetlands, groundwater (including recharge zones) and estuaries are not strong enough in the draft NPS FM. All these aquatic systems are linked by connected flow and maintaining the quality and quantity of water in individual systems is required to manage the downstream effects. Ground water inputs to some surface aquatic ecosystems are large and maintaining high ground water quality and appropriate ground water levels is important for the protection of downstream surface water bodies.

133. The Society recommends that in setting limits for nutrients and sediment in rivers, that regional councils must first assess and determine the load requirements of sediment and nutrients for downstream estuaries, coasts, lakes and wetlands, and then ensure river limits provide for the health of downstream environments.

## Knowledge gaps

134. We consider that there are significant gaps in our knowledge with respect to current and changing land use, intensification within land use types and land management practices

(including access to OVERSEER files or key information in these files) and long-term testing and support of science in 'demonstration' catchments. This makes it difficult to evidentially link specific land use and land management practices to changes in water quality, particularly at the catchment or sub-catchment level and to measure correlated changes over time. This knowledge gap urgently needs to be addressed through science priorities, measurement and monitoring and multi-disciplinary funding.

135. The Society also supports all the recommendations of the STAG group for topics for urgent additional science and work to support ecosystem health and freshwater values on page 47 of their report, noting that there is an additional urgent need for taxonomy specialists to identify and enable better management of data poor taxa, e.g., indigenous fish.

### Emerging contaminants

136. The Society recommends that the future work programme includes requirements to collect national information to develop management approaches to emerging contaminants, including anti-microbial resistant bacteria, antidepressants, hormones, pesticides and heavy metals.

## Structure of the proposed package

137. The Society notes there are significant difficulties associated with the terminology, language and structure of the draft NPS FM and NES freshwater. In our view the proposals require redrafting to enable clear and consistent implementation, using known and current freshwater terminology. We support a redraft of the proposals by experienced and qualified freshwater resource management professionals.

## References

Basher LR, Hicks DM, Ross CW, Handyside B 1997. Erosion and sediment transport from the market gardening lands at Pukekoe, Auckland, New Zealand. Journal of Hydrology (NZ) 36:73–95.

Bernhardt ES, Blaszczak JR, Ficken CD, Fork ML, Kaiser KE, Seybold EC 2017. Control Points in Ecosystems: Moving Beyond the Hot Spot Hot Moment Concept. Ecosystems 20(4): 665-682.

Biggs BJF 2000. New Zealand Periphyton Guideline: Detecting, monitoring and managing enrichment of streams. Prepared for the Ministry for the Environment. NIWA, Christchurch.

Bowie S, Pham L, Dunn N, Allibone R, Crow S (Eds) 2014. Freshwater fish taxonomic workshop – focussing on New Zealand non-migratory galaxias taxonomic issues. Proceedings of a workshop, Dunedin 14 May 2013. Unpublished DOC publication Christchurch.

Broekhuizen N, Parkyn S, Miller D 2001. Fine sediment effects on feeding and growth in the invertebrate grazers Potamopyrgus antipodarum (Gastropoda, Hydrobiidae) and Deleatidium sp. (Ephemeroptera, Leptophlebiidae). Hydrobiologia 457:125-132.

Clapcott JE, Young RG, Harding JS, Matthaei CD, Quinn JM, Death RG 2011. Sediment Assessment Methods: Protocols and guidelines for assessing the effects of deposited fine sediment on in-stream values. Cawthron Institute, Nelson, New Zealand.

Clapcott J, Young R, Sinner J, Wilcox M, Storey R, Quinn J, Daughney C, Canning A, 2018. Freshwater biophysical ecosystem health framework. Prepared for Ministry for the Environment. Cawthron Report No. 3194. 89 p. plus appendices.

Daigneault AJ, Eppink FV, Lee WG 2017. A national riparian restoration programme in New Zealand: Is it value for money?. *Journal of environmental management*, *187*, 166-177.

Davies-Colley R, Franklin P, Wilcock B, Clearwater S, Hickey C 2013. National Objectives Framework - Temperature, Dissolved Oxygen & pH. Proposed thresholds for discussion. NIWA report prepared for Ministry for the Environment.

Dunn NR, Allibone RM, Closs GP, Crow SK, David BO, Goodman JM, Griffiths M, Jack DC, Ling N, Waters JM, Rolfe JR 2018. Conservation status of New Zealand freshwater fishes, 2017. New Zealand Threat Classification Series 24. Department of Conservation, Wellington. 11 p.

Grainger N, Harding J, Drinan T, Collier K, Smith B, Death R, Makan T, Rolfe J 2018. Conservation status of New Zealand freshwater invertebrates, 2018. Zealand Threat Classification Series 28. Department of Conservation, Wellington. 25 p.

Gray DP, Harding JS. 2007. Braided River Ecology: a Literature Review of Physical Habitats and Aquatic Invertebrate Communities. Vol. 279. Science for Conservation. Wellington.

Gray DP, Grove P, Surman M, Keeling C 2017. "Braided Rivers: Natural Characteristics, Threats and Approaches to More Effective Management". Environment Canterbury Technical Report R17/13. Christchurch, New Zealand: Canterbury Regional Council.

Greenwood MJ, Harding JS, Niyogi DK, McIntosh AR 2012. Improving the effectiveness of riparian management for aquatic invertebrates in a degraded agricultural landscape: stream size and land-use legacies. Journal of Applied Ecology 49, 213–222.

Greer M, Gray D, Duff K, Sykes J 2015. Predicting inanga/whitebait spawning habitat in Canterbury. 10.13140/RG.2.1.5143.1922.

Grove, PM, Parker, DP, Gray, and F Behrens. 2015. "Land Use Change on the Margins of Lowland Canterbury Braided Rivers, 1990-2012". Environment Canterbury Technical Report R15/49. Christchurch, New Zealand: Canterbury Regional Council.

Gutierrez Gines M, Robinson B, Prosse J, Esperschuetz J, Mishra M, Horswell J 2017. Manuka planting for water quality. Water NZ Environment November/December 2017

Holmes R, Hayes J, Matthaei C, Closs G, Williams M, Goodwin E 2016. Riparian management affects instream habitat condition in a dairy stream catchment. New Zealand Journal of Marine and Freshwater Research 50, 581–599.

Houlton BZ, Almaraz M, Aneja V, Austin AT, Bai E, Cassman KG, Compton JE, Davidson EA, Erisman JW, Galloway JN and others 2019. A world of co-benefits: Solving the global nitrogen challenge. Earths Future 7: 1-8.

Johnson P, Gerbeaux P 2008. Wetland types of New Zealand. Department of Conservation, & Ministry for the Environment,

Joy M, David B, Lake M 2013. New Zealand freshwater fish sampling protocols (Part 1): Wadeable rivers and streams. Palmerston North, New Zealand, Massey University.

Joy MK, Foote KJ, McNie P, Piria M, 2018. Decline in New Zealand's freshwater fish fauna: effect of land use. Marine and Freshwater Research https://doi.org/10.1071/MF18028. CSIRO Publishing.

Liu X, Zhang X, Zhang M 2008. Major factors influencing the efficacy of vegetated buffers on sediment trapping: A review and analysis. Journal of Environmental Quality 37: 1667–1674. https://pdfs.semanticscholar.org/fce1/11cd3961cb3ca9eb8cae35600333553a119e.pdf

Maseyk F, Ussher G, Kessels G, Christensen M, Brown M 2018. Biodiversity Offsetting under the resource management Act: A guidance document. Prepared for the Biodiversity Working Group on behalf of the BioManagers Group. https://www.lgnz.co.nz/our-work/our-policy-priorities/3-environment/biodiversity/

Matheson F, Quinn J, Hickey C 2012. Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision making framework: Phases 1 and 2 final report. Prepared for the Ministry of Science & Innovation Envirolink Fund. NIWA Client Report No: HAM2012-081.

Matheson F, Quinn JM, Unwin M 2016. Instream plant and nutrient guidelines. Review and development of an extended decision-making framework Phase 3, HAM2015-064: 118.

McBride G B 2019. Has water quality improved or been maintained? A quantitative assessment procedure. Journal of Environmental Quality, 48(2), 412-420.

McDowell RW, Cox N, Snelder TH 2017. Assessing the Yield and Load of Contaminants with Stream Order: Would Policy Requiring Livestock to Be Fenced Out of High-Order Streams Decrease Catchment Contaminant Loads? Journal of Environmental Quality 46:1038–1047 (2017) doi:10.2134/jeq2017.05.0212.

McEwan A, Joy M 2011 Monitoring a New Zealand freshwater fish community using passive integrated transponder (PIT) technology; lessons learned and recommendations for future use. Conference Proceedings

McEwan AJ, Joy MK 2013a. Responses of three PIT-tagged native fish species to floods in a small, upland stream in New Zealand. New Zealand Journal of Marine and Freshwater Research 47: 225-234;

McEwan AJ, Joy MK 2013b. Habitat use of redfin bullies (Gobiomorphus huttoni) in a small upland stream in Manawatu, New Zealand. Environmental Biology of Fishes 97: 121-132;

McEwan AJ, Joy MK 2013c. Diel habitat use of two sympatric galaxiid stream fishes at two spatial scales a small upland stream in Manawatu, New Zealand. Environmental Biology of Fishes 97: 897-907.

McKergow LA, Matheson FE, Quinn JM 2016. Riparian management: A restoration tool for New Zealand streams. Ecological Management and Restoration 17(3) 218-227

Milne JR, Madarasz-Smith A, Davies T 2017. Recreational water quality monitoring and reporting in New Zealand: A discussion paper for Regional and Unitary Councils. NIWA Science and Technology Series Report No. 82.

Parkyn, S 2004 Review of Riparian Buffer Zone Effectiveness. No. 2004/05, Ministry of Agriculture and Forestry, Wellington, New Zealand.

Peterson BJ, Wollheim WM, Mulholland PJ, Webster JR, Meyer JL, Tank JL, Martí E, Bowden WB, Valett HM, Hershey AE and others 2001. Control of Nitrogen Export from Watersheds by Headwater Streams. Science 292(5514): 86-90.

Richardson J, Jowett IG 2002. Effects of sediment on fish communities in East Cape streams. North Island, New Zealand. New Zealand Journal of Marine and Freshwater Research 36: 431-442.

Rowe DK, Chisnall BL, Dean TL, Richardson J 1999. Effects of land use on native fish communities in east coast streams of the North Island of New Zealand. New Zealand Journal of Marine and Freshwater Research 33: 141-151.

Rowe DK, Smith J, Quinn J, Boothroyd I 2002. Effects of logging with and without riparian buffer strips on fish species abundance, mean size, and the structure of native fish assemblages in Coromandel, New Zealand streams. New Zealand Journal of Marine and Freshwater Research 36: 67-79.

Ryan PA 1991. Environmental effects of sediment on New Zealand Streams: a review. New Zealand Journal of Marine and Freshwater Research 25: 207-221.

Smith CM 1989. Riparian pasture retirement effects on sediment, phosphorus and nitrogen in channelised surface run-off from pastures. New Zealand Journal of Marine and Freshwater Research 23: 139-146.

Valois AE, Milne JR, Heath MW, Davies-Colley RJ, Martin E and Stott R, In press. Community volunteer assessment of recreational water quality in the Hutt River, Wellington. New Zealand Journal of Marine and Freshwater Research.

Zhang X, Liu X, Zhang M, Dahlgren RA, Eitzel M 2010. A review of vegetated buffers and a meta-analysis of their mitigation efficacy in reducing nonpoint source pollution. *Journal of environmental quality*, *39*(1), 76-84.