Otago Regional Council

LWRP Nitrogen and Phosphorus Reduction Scenarios

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Executive Summary

Many of New Zealand's freshwater environments are under pressure from land use intensification resulting in deteriorating water quality and ecosystem health. As a result, limits must be set on resource use to achieve receiving environment water quality objectives such as the health of rivers, lakes, and estuaries. To aid communities in determination of desired level of ecosystem health, a model is needed which can fill the knowledge gap on required emission reductions to achieve target attribute states and whether different mitigation suites (GMP and GMP+) may achieve the desired reductions. By undertaking an analysis, we can determine 1. the percent of river segments and likelihood that reaches may comply with the selected target attribute state or better, 2. the likelihood a given receiving environment complies with the target attribute state under different emission reduction/mitigation scenarios and 3. visualize compliance with the target attribute state spatially. The results of this model aim to inform the relative change possible through different relatable land use practice scenarios to inform decision making about limits on resource use and target attribute state for receiving environments.

Given the uncertainty and limitations present, our findings are best interpreted as indicating the magnitude of instream and on-land change likely to occur under these scenarios. Comparisons of reductions in nitrogen and phosphorus achieved through the GMP and GMP+ packages indicate that while large "on-land" reductions can be achieved in some areas (>20%), these reductions generally do not result in multi-band changes in receiving environments. Instead, these scenarios are likely to result in within band improvement. Therefore, where the target attribute is set at, or near, baseline state, the mitigation scenarios are likely to result in compliance. Where the target attribute is set above the baseline state band, reductions beyond GMP+ may be required to comply.

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Introduction

Freshwater environments in many parts of New Zealand are under pressure from land use intensification resulting in deteriorating water quality and ecosystem health. To halt and reverse declines in freshwater ecosystem health, an amended National Policy Statement for Freshwater Management was released in 2020. This policy statement, and its previous versions, provide ecosystem health bottom line conditions for a suite of attributes and requires that ecosystem health be maintained, or improved, above these bottom lines. To do so, limits on resource use must be set which provide for ecosystem health of rivers and their downstream receiving environments (Ministry for the Environment 2020).

High nutrient loads can affect aquatic ecosystems in two ways. High nitrogen concentrations can have toxic effects on aquatic species, inhibiting growth and reproduction (Camargo and Alonso 2006). At lower levels, nitrogen and phosphorus may still lead to undesirable algal biomass (Biggs et al. 2008; MFE 2022; Snelder et al. 2022). When not limited by other factors, algal growth, in the form of periphyton in rivers, phytoplankton in lakes, and macro-algae in estuaries, can increase to nuisance levels, commonly referred to as a bloom. Blooms are aesthetically unacceptable, can be a human health risk, lead to lower oxygen levels, smother habitat for macroinvertebrates and lead to shifts from oligotrophic to eutrophic states. Therefore, anthropogenic emissions loads must be managed.

In Otago, anthropogenic sources of nutrient enrichment include contaminant loss to water (here termed emissions) from urban environments and agricultural land uses. Changes to land use practice in both environments can lead to a reduction in emissions. In urban environments these reductions can be achieved through improvement of storm water management, water treatment, and management of “point source” discharges. For agricultural landscapes, emissions are generally diffuse and can be improved through practices such as stock exclusion, effluent management, variable rate fertilizer application, improved irrigation practice and others (McDowell et al. 2020; Monaghan et al. 2021; Sise et al. 2022).

To aid in understanding whether suites of limits relating to improved on-farm practice can achieve potential instream ecosystem health target attribute states, a model is needed which links on-land practices to the required emission reductions which provide for the desired target attribute states. This model would provide an estimate of the magnitude of change in land use practice needed to reach the desired targets. Here we focus on diffuse pollution sources from agriculture and describe the modelling approach used to relate land use practice changes (i.e., mitigation measures) to potential river, lake, and estuary target attribute states (receiving environment). In this report we focus on nitrogen, phosphorus, and algal growth. Sediment and bacterial contaminants are also important and, while not considered in this report, the required reductions associated with these contaminants are reported in the respective references.

Methods

Scenarios

To provide context on the magnitude of change needed to achieve different target attribute states, three scenarios were developed. These scenarios comprise a range of hypothetical land use or behavioural scenarios intended to reduce the impacts of land use on water quality. Efforts that aim to improve water quality within a given land use activity are referred to as mitigations– i.e., they mitigate the potential detrimental effect of a given land use activity on water quality. Examples of individual mitigations are fencing off streams to exclude stock or applying fertilizer with more precision. To provide a relatable context for communities, the three scenarios were based on current practice, good management practice (GMP) and good management practice plus (GMP+). The mitigations included in the GMP and GMP+ scenarios were slight alterations of two papers from the Our Land and Water national science challenge (Mcdowell et al. 2020; Monaghan et al. 2021; Sise et al. 2022). For additional details on the development of the GMP and GMP+ scenarios in an Otago context, see Mackey (2022).

GMP

The good management practice (GMP) scenario is outlined in Monaghan et al., (2021) and represents a suite of known mitigations, many of which have variable uptake around the region already, though the extent of uptake of individual practices is uncertain. The GMP scenario is unlikely to have been fully implemented throughout Otago and thus some improvement is expected under this scenario.

Table 1: Actions associated with the assumed GMP scenario under Monaghan et al., 2021 (here termed historic) and McDowell et al., 2021 (here termed future). Also noted is whether the mitigation targets nitrogen and/or phosphorus and its applicability to dairy and dry stock

Management Area	Description	Paper	N Loss	P Loss	Dairy	Dry stock
Riparian management	Stock exclusion	Historic	Yes	Yes	Yes	Yes
Fertiliser management	Optimum Olsen P	Historic		Yes	Yes	Yes
	Low soluble P fertiliser	Historic		Yes	Yes	
	Avoiding at risk Months	Historic	Yes	Yes	Yes	Yes
	Reduced N inputs stage 1	Historic	Yes		Yes	
Effluent Management	Land application of FDE	Historic	Yes		Yes	
	Enlarged FDE area	Historic	Yes		Yes	

Management Area	Description	Paper	N Loss	P Loss	Dairy	Dry stock
	Limiting fertiliser to effluent area	Historic	Yes		Yes	
	Deferred and low rate FDE	Historic	Yes		Yes	
Wintering	Catch crop	Future	Yes		Yes	
Irrigation management	Reduced flood irrigation out wash	Historic	Yes	Yes	Yes	Yes
Overland Flow	Strategic grazing of crop in CSA	Future		Yes	Yes	
	Constructed or facilitated natural wetlands	Future	Yes	Yes	Yes	Yes
	Sediment traps etc.	Future		Yes	Yes	

GMP+

The good management practice plus (GMP+) scenario describes the effects of a suite of developing or potential mitigation actions (Mcdowell et al. 2020). These are, in most cases, mitigation practices that have been identified as holding promise but have yet to be widely tested or implemented. These mitigations are listed in Table 2 below taken from McDowell et al. (2020). Five mitigations from McDowell et al., are not included as they were determined to be unsuitable in Otago and two additional mitigations added to represent the GMP+ scenario in this report. This scenario is analogous to the GMP++ scenario in Sise et al. (2022) and its effects were assumed to be additive to the GMP scenario described above (assuming the GMP mitigations are fully implemented).

Table 2: Actions associated with the assumed GMP+ scenario under Monaghan et al., 2021 here termed historic and McDowell et al., 2021 here termed future. Also noted is whether the mitigation targets nitrogen and/or phosphorus and its applicability to dairy and dry stock. The scenario is cumulative on top of the GMP scenario.

Management Area	Description	Paper	N Loss	P Loss	Dairy	Dry stock
Fertilizer management	Reduced N inputs stage 2	Future	Yes		Yes	
	Controlled release P fert	Future		Yes	Yes	Yes
	Variable rate fertiliser	Future		Yes	Yes	Yes

Management Area	Description	Paper	N Loss	P Loss	Dairy	Dry stock
Wintering	Wintering in barn or standoff	Historic	Yes		Yes	
	On-off grazing in autumn/winter	Future	Yes	Yes	Yes	
Irrigation management	Variable rate irrigation and fertigation	Future		Yes	Yes	
Land retirement	Stock exclusion/planting trees	Historic		Yes		Yes
	Increasing plantation forestry area	Future	Yes	Yes		Yes
Overland flow	Strategic grazing of pasture in CSA	Future		Yes	Yes	
	Edge of field attenuation	Future	Yes	Yes	Yes	
	Plantain	Sise et al., 2022	Yes		Yes	

To determine the reductions possible under the GMP and GMP+ scenario Sise et al., (2022) developed a series of representative Overseer models which can be used to characterise the majority of farming systems found within the Otago Region. These models were then used to assess the reductions achieved through the GMP and GMP+ scenarios on N and P. Broadly, the GMP scenario results in a 9% reduction in N and a 6% reduction in P whereas the GMP+ scenario could double reductions to 20% for N and 11% for P. For more information on determining the on-land reductions achieved through the GMP and GMP+ scenarios, see Sise et al., (2022).

Potential target attribute states

Modelled scenario attributes

The current environment, and reductions achieved through GMP and GMP+, are assessed against different potential receiving environment outcomes. For rivers, these outcomes correspond to the nitrate toxicity and periphyton A, B, and C band target attribute states in the NPSFM, 2020. For lakes, potential outcomes are determined based on the phytoplankton biomass A, B, and C band target attribute states in the NPSFM 2020. Estuary potential outcomes are modeled as the A, B, and C ecological quality rating (EQR) band target attribute states (Plew et al., 2021). The set of different potential outcomes is modeled to inform selection of desired target attribute states and potential interim target attribute states in a staged approach to plan implementation.

Nitrate Toxicity- Rivers

Natural concentrations of nitrates usually do not have a direct effect on aquatic insects or fish. However, excess levels of nitrates in water can create conditions that make it difficult for aquatic insects or fish to survive. The national bottom line for nitrate, set at the bottom of the B-band, is set to protect 95% of species with some growth effects on up to 5% of species. Nitrate concentrations in excess of the bottom line, are more likely to result in growth effects, particularly in sensitive species, such as some species of fish. The A-band is unlikely to have effects even on sensitive species.

Periphyton- Rivers

Periphyton, or algae, plays an important role in aquatic ecosystems providing food for many macroinvertebrates. Large blooms of periphyton can smother habitat, are aesthetically unacceptable, and are not favourable for swimming (Biggs 2000). Many factors influence periphyton growth including nutrient availability, flow, substrate, and sunlight. Periods of long, stable flows with ample sunlight in nutrient rich waters provide the potential for periphyton blooms. Sites which fall in the A-band, reflect rare blooms with negligible nutrient enrichment and/or alteration of the flow regime or habitat. Sites in the B-band have occasional algal blooms reflecting low nutrient enrichment and/or flow alteration. C-band sites have periodic short-duration nuisance blooms which may reflect moderate alteration of natural flow regimes/habit and/or moderate levels of nutrient enrichment. Sites which fall below the national bottom line are likely to have extended nuisance blooms which reflect high levels of nutrient enrichment and significant alteration of natural flow regimes or habitats (Ministry for the Environment 2020).

Phytoplankton- Lakes

Phytoplankton form the base of the food web in lakes. However, much like periphyton blooms in rivers, large phytoplankton/cyanobacterial blooms are aesthetically unpleasant, can be toxic, are unfavourable for swimming, and may lead to low dissolved oxygen levels in the lake. Factors influencing phytoplankton growth include light availability and nutrient concentrations. Sites which fall in the A-band for phytoplankton are likely to have rare blooms which reflect low nutrient enrichment levels. Sites in the B-band are likely to have occasional phytoplankton blooms reflecting some nutrient enrichment while sites in the C-band are likely have periodic short-duration nuisance blooms reflecting moderate nutrient enrichment. Sites which fall below the national bottom line may have regular blooms with the potential for extended durations (Ministry for the Environment 2020).

Macro-algae (EQR)- Estuaries

The opportunistic macroalgal blooming tool produces an ecological quality rating (EQR) that is used to indicate the extent of nuisance macroalgal blooms in intertidal estuaries (see Plew et al., 2021). Nuisance blooms of macroalgae are an indicator of eutrophication in estuaries and blooms are strongly linked to total nitrogen (TN) loads and the final concentration of nitrogen in the estuary. As a result, basic modelling can be used to predict the TN concentration in an estuary and assess the potential susceptibility of the estuary to macroalgal blooms. Total phosphorus is generally not considered a key driver of eutrophication in estuaries as it is usually freely available in sea water. Factors that influence macro-algae growth include nutrient levels (particularly nitrogen), light availability, substrate, and hydraulics including flushing time. However, the macroalgae susceptibility modelling only considers the response of nuisance macroalgae to nutrients and does not account for other factors that may limit macroalgal growth.

An A-band indicates the estuary has low macroalgal cover potential (<5% across the available intertidal habitat), low biomass, and no significant growth of algae in underlying sediment, in general these estuaries are healthy, resilient and are not expressing signs of eutrophication. A B-band indicates the estuary has some localised areas of nuisance macroalgal growths (5-20% cover across the available intertidal habitat) with moderate biomass and no significant growth of algae in the underlying sediment, in areas affected by nuisance macroalgae ecological communities are slightly impacted. For a C-band, nuisance macroalgae is more widespread with areas of moderate to high macroalgal cover (25-50% across the available intertidal habitat), high biomass and evidence of persistent beds of macroalgae (i.e., macroalgae growing in the underlying sediments). A C-band indicates nutrients are elevated, the estuary is showing signs of eutrophication and ecological communities are likely to be moderately to strongly impacted by nuisance macroalgal blooms. There is no national bottom line for nuisance macroalgal blooms in estuaries. Estuaries that fall below the C-band have persistent, very high cover and high biomass nuisance blooms that are strongly impacting ecological communities.

Management Class Framework

Water quality, ecological communities, hydrology, and other characteristics naturally vary from headwaters to lower elevation reaches. To encompass these variations the River Environment Classification (REC; (Snelder and Biggs 2007)) has been used to classify river segments in Otago in to one of five management classes using the second (source of flow) level (T. Snelder and Fraser 2023)[1]. This classification system reduces the number of management classes from the original REC allowing for justifiable and specific plan provisions which incorporate natural river heterogeneity while maintaining a manageable, understandable, level of detail. Results are presented for each freshwater management unit (FMU) and Rohe in Otago.

[1] Modifications to the original REC Source-of-flow categories were made. First, the ‘Glacial Mountain’ and ‘Mountain’ Source-of-flow categories were combined and called ‘Mountain’ (M), the Lake-fed Source-of-flow category was subdivided into upper lakes (Lk Upper) and lower lakes (Lk Lower). The other two river management classes were defined by the Hill (H) and Lowland (L) Source-of-flow categories.

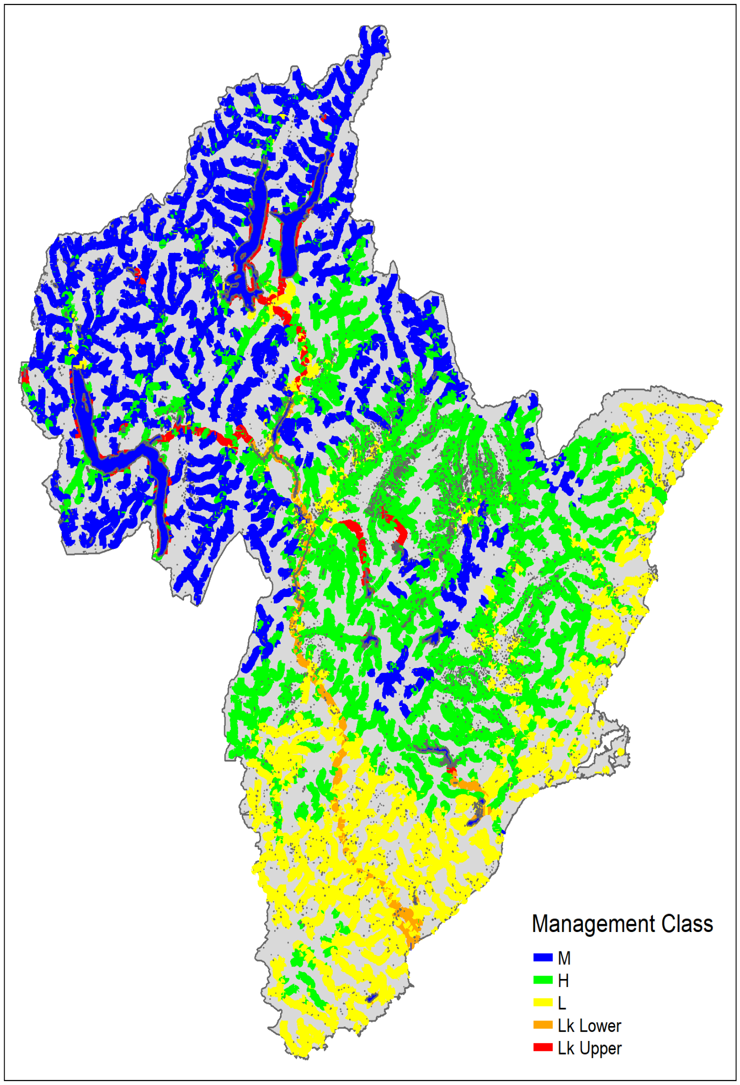

Figure 1: Management class distribution across the Otago Region

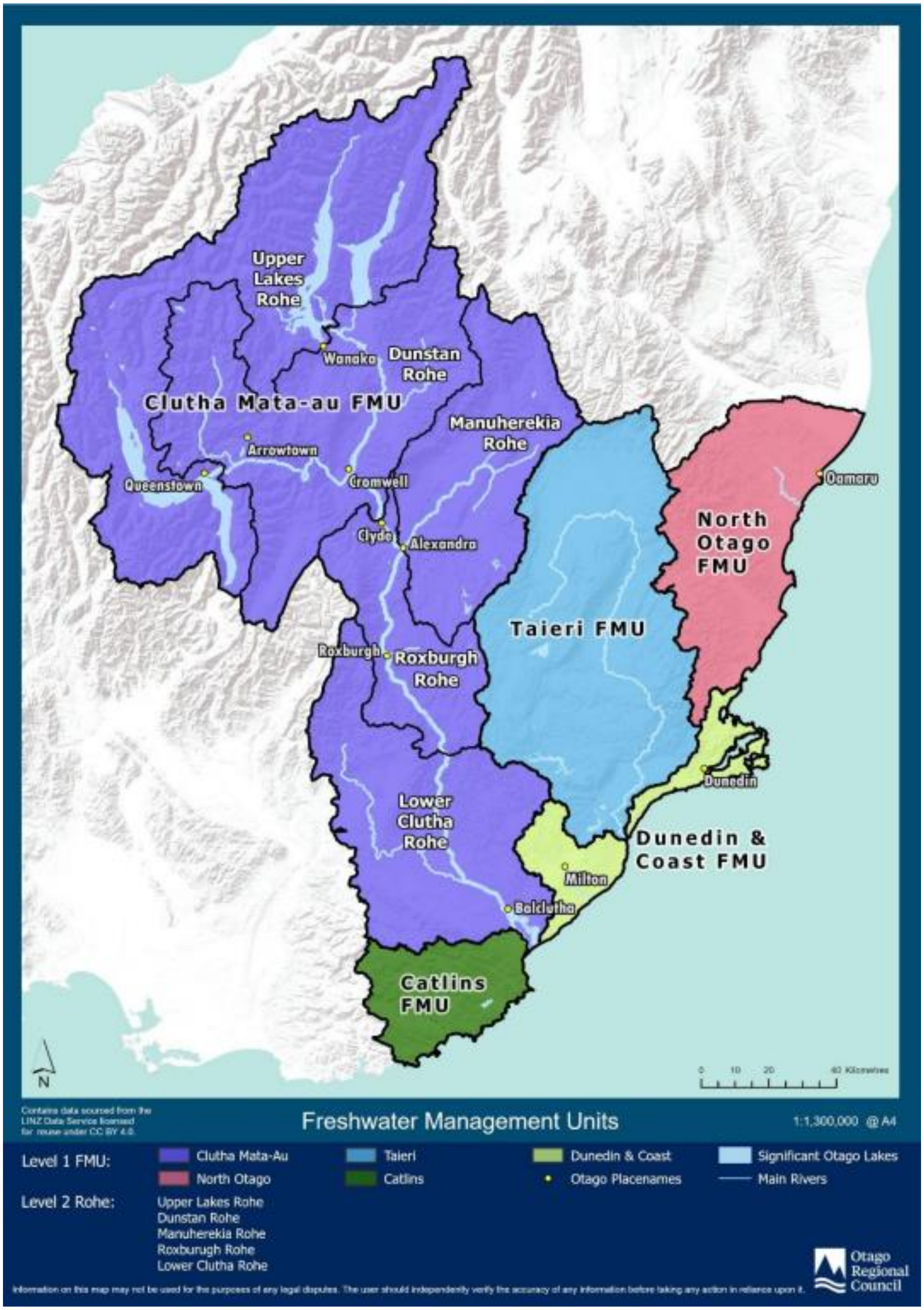

Figure 2: Otago's FMUs and Rohe

Modelling

NNN toxicity, Periphyton (N and P), Phytoplankton (N and P), and Macro-algae (N and P)

Component models

Our approach for linking potential receiving environment outcomes for NNN toxicity, periphyton, phytoplankton and EQR, to land use practice change is to calculate the emission reduction achieved through GMP and GMP+ mitigation measures on a land parcel and link this to required reductions to comply with the potential receiving environment target attribute states. To link land use practice changes to potential receiving environment objectives, our model builds on, and links, four existing models:

Model 1: The first model determines the required concentration of total nitrogen and total phosphorus (termed nutrient criteria) to achieve the desired target attribute state. Periphyton biomass-nutrient modelling was provided in a national guidance report (MFE 2022) whereas lake (T. Snelder and Fraser 2023) and estuary modelling (Plew 2021) were conducted for Otago.

To use the periphyton biomass-nutrient criteria, the user must select a level of under protection risk (UPR). The UPR is the proportion of sites which are likely to exceed the biomass target attribute state despite being compliant with the associated nutrient criteria. Therefore, if all segments achieve the nutrient criteria, a 20% UPR would result in 80% of segments achieving the biomass objective. Lower UPRs are associated with lower, and therefore more stringent, nutrient criteria. For this modelling exercise a 20% UPR was selected[2]. As such, if the nutrient criteria are complied with in all segments, 80% of the river network would be expected to achieve associated biomass band.

Model 2: The second model determines the in-stream nutrient load reduction required to comply with the target attribute nutrient criteria from model 1 (Snelder and Fraser, 2023). This model also provides a current load estimate for every river segment, lake and estuary.

Model 3: The third model uses model farms to calculate potential nutrient emission reductions resulting from mitigations (GMP and GMP+). Model farms were developed with the GMP and GMP+ mitigations suites applied. The full development of these model farms and mitigation application is outlined in Sise et al., 2022.

Model 4: The fourth model provides predicted source loss for Otago's land uses and is outlined in Couldrey (2022). This model relies on an alteration to Srinivasan et al. (2021) to provide estimated baseline emissions of nitrogen and phosphorus losses to water for various land uses (e.g. conservation, dairy, sheep and beef, urban, etc.) on physiographic types defined by combinations of categories for climate, irrigation, slope, and soil drainage (Appendix 1). As a result, every land parcel in Otago has an estimated current emission coefficient for nitrogen and phosphorus expressed as kilograms per hectare per year (kg/ha/yr). While individual farm emissions are likely to vary due to different management practices and characteristics, this approach provides a best estimate of the

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[2] De Pelsemaeker, T., 2024. Selecting Under-protection Risk. Otago Regional Council Memo.

current mean nutrient emission rates across the region. Further, predicted nutrient emissions are consistent with un-mitigated model farm emission predictions from model 3 (Sise et al. 2022).

The combination of models described above provide the nutrient concentration required to achieve different potential target attribute state bands (model 1), required load reduction to achieve these bands (model 2), current predicted load (model 3) and reductions achieved for different land use typology combinations (model 4). The linking of the models is described in Figure 2.

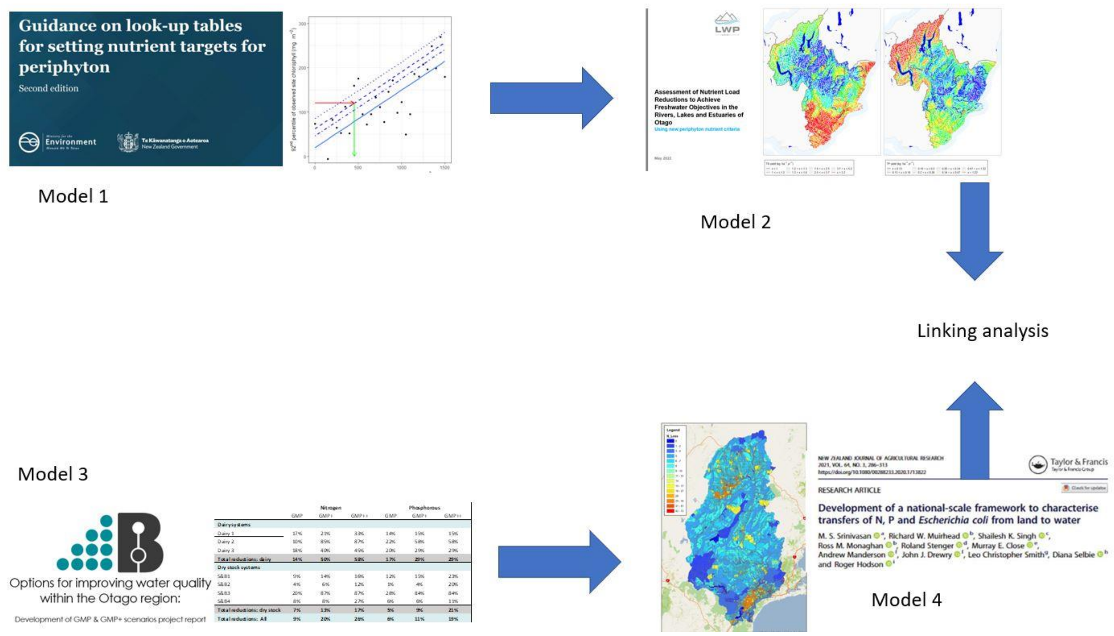

Figure 3: Schematic diagram of model chain (or linked models) to estimate the outcomes for receiving environments resulting from application of the GMP and GMP+ mitigations. Model 1, the receiving environment target attribute model, provides input to model 2. Model 2 determines current nutrient loads for all river segments and estimates the load reductions required to achieve the concentrations determined by model 1. Model 3 determines the reductions that can be achieved by application of GMP and GMP+ for different land use typology combinations. Model 4 estimates current source loss for all land use typology combinations in Otago. Model 3's mitigation reductions are applied to Model 4 to provide estimates of reductions in all receiving environments across the region. An analysis to link the land reduction to required segment reductions is then needed and is outlined below.

Linking analysis

To link the models and assess receiving environment outcomes under the mitigation scenarios, the reductions achieved through the mitigation scenarios are summed in catchments upstream of all receiving environments (each river segment, lake, or estuary). A GIS-based drainage network (the River Environment Classification (REC)), and the associated watersheds, enables the catchment upstream of an individual river segment to be identified. The total load reduction for a given receiving environment is calculated by summing the new load achieved under the GMP and GMP+ scenarios across all land parcels and dividing by the original unmitigated load for the upstream area of every segment in the drainage network. The reduction is expressed as a proportion of the estimated source loss (%) on each receiving environment. As all receiving environments have upstream reductions achieved, and the required reductions to achieve the potential target attribute state, the results of the analysis can be reported at any spatial scale from individual river segment, lake, or estuary to FMU or the entire region. Due to the limitations of monitoring data input into model two, and for computational ease, outcome assessments were limited to 3rd order streams and above.

In comparing the GMP and GMP+ reductions achieved to the required receiving environment reductions (model 2) a "1:1" reduction is assumed (e.g., a 25% reduction achieved across the upstream land parcels would correspond to a 25% reduction in the current load at receiving environment). The assumption of the "1:1" reduction is a simplification because the processes involved in the transport of contaminants (such as N or P) from a land parcel source to a receiving environment is complex, with multiple possible pathways, time frames and biophysical processes at play. Contaminants can be reduced between a land parcel and receiving environment (attenuated) by processes such as de-nitrification. The attenuation or reduction of contaminant loads as they are transported from the land parcel through to downstream receiving environments is an area of active research, and there is limited data to quantify this process. The uncertainty present in the relationship is currently unquantifiable. Alongside a "1:1" reduction, implementation of the GMP and GMP+ mitigations are assumed to be 100% and all reductions are realized immediately and not subject to staged uptake by land users or lags.

Incorporation of uncertainty

A Monte Carlo approach was used in model 2 to estimate the uncertainty of the load reduction required for each receiving environment. This allows the outcomes resulting from application of the GMP and GMP+ mitigations to be expressed probabilistically.

The outcomes are expressed, for any FMU, as the mean (i.e., best estimate) and 90% confidence interval (i.e., 5-95 levels of confidence) of "percent receiving environments complying with target attribute band". This process was carried out across all potential target attribute states and spatial units. To account for heterogeneity within different types of streams the results are presented by management class.

A variation on the above approach was used for the individual receiving environments (i.e., individual river segments, lakes, and estuaries). Instead of calculating a "percent of receiving environments complying with a target attribute band", the "probability of target attribute state compliance" for each river segment (with Strahler order >3), lake, and estuary were determined. The total upstream reduction was calculated as above but, each river segment, lake, and estuary were then assessed to determine the probability that they comply with a target attribute state. For lakes and estuaries, a corresponding Bernoulli 90% confidence interval was then calculated.

Result presentation

To simplify communication of results, a terminology set is used (Table 3). For river network results where the percentage of segments achieving a target-band was calculated, the terms "few", "some", "about half", "most" and "nearly all" are used to discuss percentage ranges of 0-20%, 20-40%, 40-

60%, 60-80% and 80-100% respectively. Results for individual receiving environment results are expressed probabilistically and therefore use the terms, “very unlikely”, “unlikely”, “as likely as not”, “likely”, and “very likely” to express probabilities of 0-20%, 20-40%, 40-60%, 60-80%, 80-100% respectively.

Table 3: Terminology used to discuss segment probability of achieving the potential target attribute state and percent of segments achieving the potential target attribute state.

Probability	Terminology	Percentage	Terminology
0-0.20	Very unlikely	0-20%	Few
0.20-0.40	Unlikely	20-40%	Some
0.40-0.60	As likely as not	40-60%	About half
0.60-0.80	Likely	60-80%	Most
0.80-1.0	Very likely	80-100%	Nearly all[3]

To simplify communication of confidence interval results for river outcomes, four categories were considered:

- First, if both confidence intervals and the mean approach 100% (e.g., 99%; 100-100), there is high confidence *no reduction is required* to comply.
- Where the upper confidence overlaps 100%, the lower confidence interval does not, and the mean percent of segments comply is high (e.g., 95%; 43-100), a reduction *may be required* to comply.
- Similarly, where the upper confidence interval overlaps 100%, the lower does not, and the mean is low, a *reduction is likely required* (75%; 20-100).
- When neither confidence interval overlaps 100%, there is high confidence *a reduction is required* to comply (50%; 40-80).

To aid in interpretation, results are presented as four different map sets:

1. The first map set aggregates the land uses classes from Model 4 based on the table in Appendix 2 to simplify the graphic representation of land uses within the FMU.

2. The second map set displays average yield for each segment. This map divides the total load for each segment by the upstream catchment area for the current, GMP and GMP+ scenarios to provide the average kilograms of nutrient per hectare per year (kg/Ha/yr) This map demonstrates how reductions influence average yield across the catchment and does not compare to receiving

[3] Termed as *all* when 100% of segments comply.

environment outcomes. This map therefore links only models three and four. Underlaying river lines is a heat map of on-land yield (kg/Ha/yr) representing the current source loss from model 4 and source loss with the mitigations from model 3 applied.

3. The third map set links on-land reductions to the required receiving environment reductions for different target attribute states by displaying the probability that individual river segments achieve the potential target attribute state bands. For this map suite, the probability that individual segments achieve the target attribute state is quantified as a percent. Probabilities are provided for each target attribute state for current scenario and after the GMP and GMP+ reductions are applied. As a result, there are three maps (current state, GMP and GMP+) for each target-band (A,B,C; a total of 9 maps for each nutrient). These maps do not describe the outcome as "predicted target attribute band". Instead, these maps show the probability of complying with a given target attribute state varies under the different mitigation scenarios.

4. The last map set displays the "potential state" under the current, GMP and GMP+ scenarios. For this map set, the percent reduction achieved for each segment is compared to the mean required reduction. The most stringent target attribute state complied with is determined and assigned to the receiving environment to show its potential "state" under the different scenarios. To keep this spatial visualization simple, we have not incorporated uncertainty estimates within this map. As a result, the potential state map solely conveys a potential "outcome state" of the target attributes and not the associated uncertainty.

Results

North Otago FMU

Land use characteristics

Land use in the North Otago FMU (Table 4; Figure 4) is comprised primarily of sheep and beef (45%), dairy (12%), exotic forestry (7%), mixed stock (6%), and conservation estate (6%). In this FMU, the GMP and GMP+ mitigations packages can be applied to approximately 75% of the FMU based on land use.

Table 4: Land use statistics for the North Otago FMU.

Land Use	Area (Ha)	Percent
Arable	4,455.23	1.50%
Beef	14,203.16	4.79%
Commercial Use	35.55	0.01%
Conservation	16,489.61	5.56%
Dairy	36,367.34	12.27%
Dairy Support	704.83	0.24%

Land Use	Area (Ha)	Percent
Exotic Forestry	20,810.20	7.02%
Horticulture	558.78	0.19%
Industrial Use	1,211.95	0.41%
Lakes & Rivers	1,592.88	0.54%
Lifestyle Block	2,495.35	0.84%
Livestock Support	4,767.53	1.61%
Majority Deer with Mixed Livestock	6,863.66	2.32%
Mixed Livestock	17,473.88	5.90%
Nurseries & Orchards	65.42	0.02%
Other Animals	493.16	0.17%
Pig Farming	478.06	0.16%
Poultry	510.24	0.17%
Public Use	46.40	0.02%
Residential Use	1,021.37	0.34%
Road & Rail	4,246.16	1.43%
Sheep	7,302.20	2.46%
Sheep & Beef	134,528.09	45.40%
Small Land Holding	1,922.08	0.65%
Specialist Deer	1,566.19	0.53%
Tourism & Recreational Use	190.89	0.06%
Unknown Land Use	8,281.47	2.79%
Unknown Land Use - Indigenous Cover	1,175.28	0.40%
Unknown Land Use - Non-agricultural	141.22	0.05%
Unknown Land Use - Pastoral Cover	6,314.69	2.13%

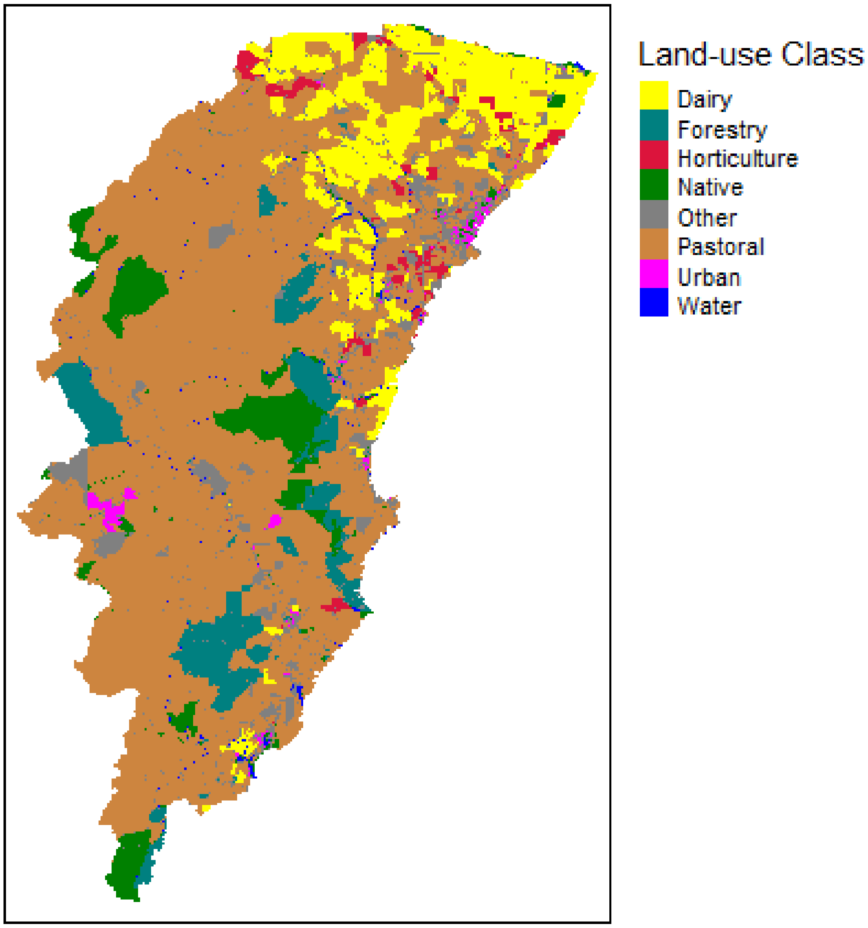

Figure 4: Land-use within the North Otago FMU. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

The GMP scenario in the North Otago *FMU* results in approximately a 7% reduction in nitrogen emissions and 9% reduction in phosphorus emissions whereas the GMP+ scenario results in a 38% reduction in nitrogen emissions and 21% reduction in phosphorus emissions (Table 5). These reductions result in the FMUs overall average yield decreasing from 12.86 kg/ha/yr of nitrogen under the current scenario to 11.93 kg/ha/yr and 7.99 kg/ha/yr under the GMP and GMP+ scenarios respectively (Table 6). The average phosphorus yield decreases from 0.49 kg/ha/yr under the current scenario to 0.45 kg/ha/yr and 0.39 kg/ha/yr under the GMP and GMP+ scenarios, respectively.

Table 5: Total on-land nitrogen and phosphorus load reductions achieved through GMP and GMP+ scenarios for the North Otago FMU

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	7.18%	273,401.40	37.84%	1,441,627.07
P	9.33%	13,621.02	21.38%	31,218.31

Table 6: Average yield of nitrogen and phosphorus under current, GMP and GMP+ scenarios for the North Otago FMU

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	12.86	11.93	7.99
P	0.49	0.45	0.39

Rivers

The highest yield areas of North Otago for both nitrogen and phosphorus occur on the Waitaki plain, north of the Kakanui River and in the Waiareka Creek catchment (Figure 5; Figure 6). Under the GMP and GMP+ scenarios, average upstream yields of both nitrogen and phosphorus are decreased in these areas. The southern portion of the FMU tends to have lower average upstream yields with decreases under the GMP and GMP+ scenarios, particularly for phosphorus.

Yields

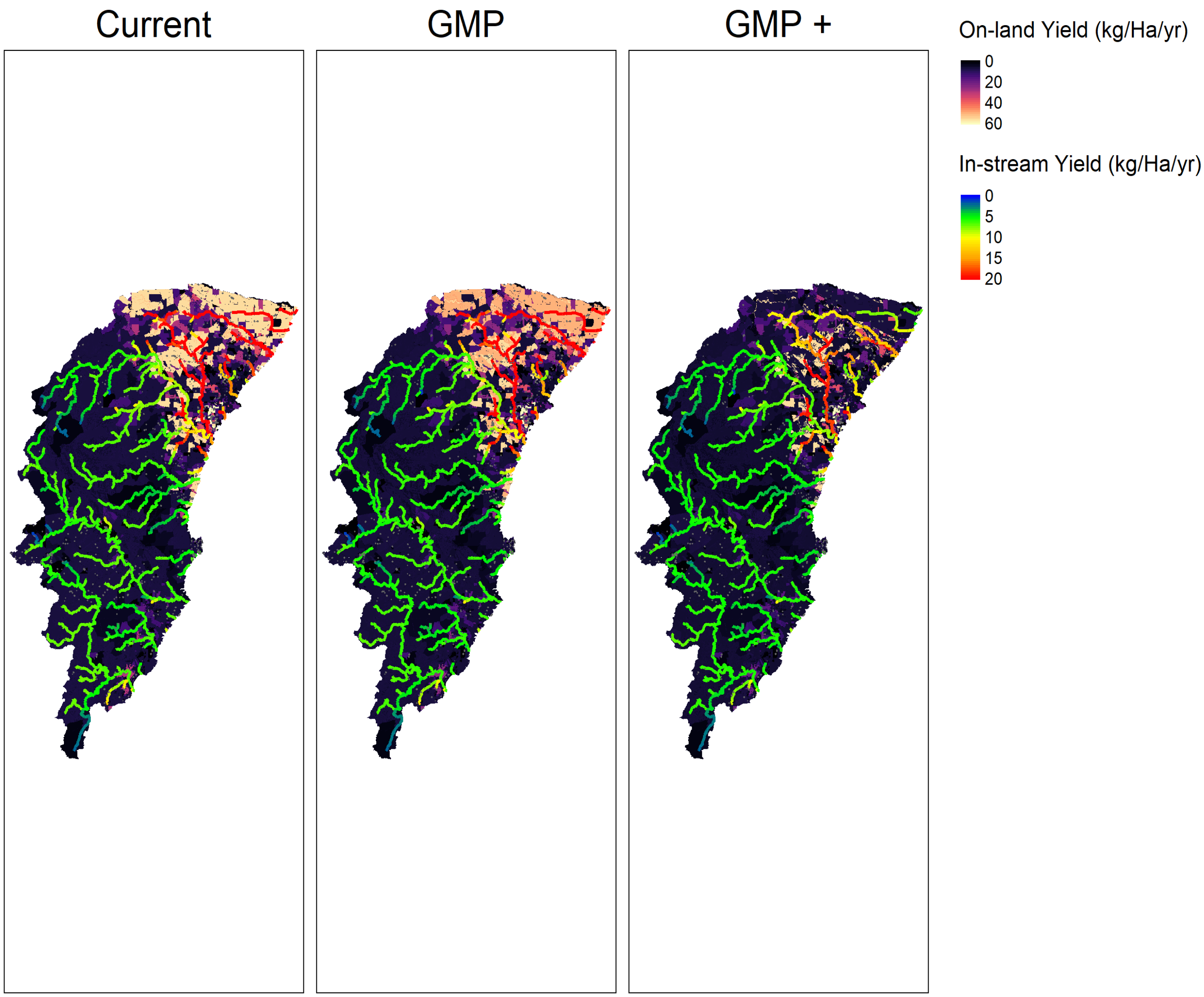

Figure 5: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for current, GMP and GMP+ scenarios for the North Otago FMU

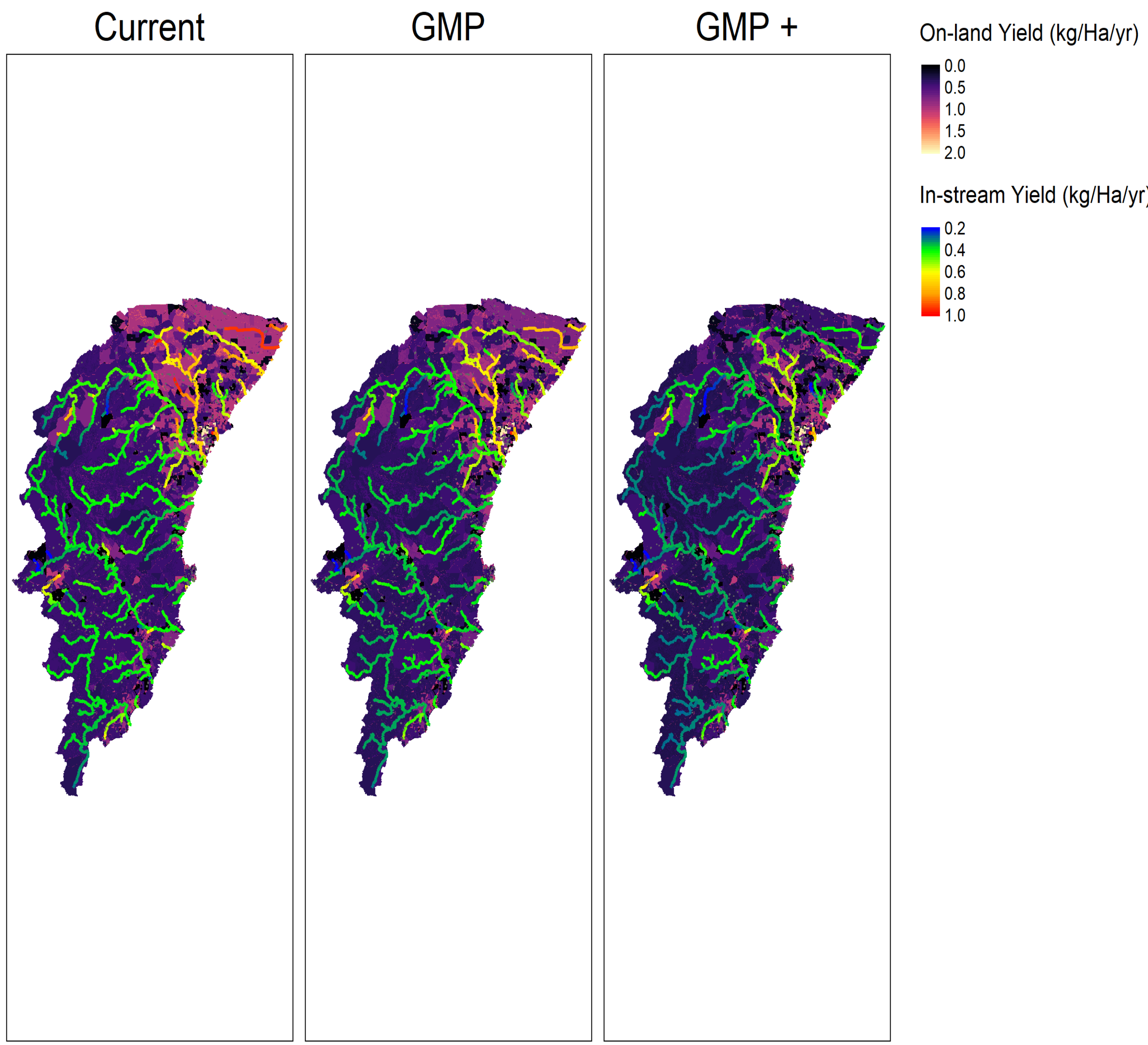

Figure 6: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for current, GMP and GMP+ scenarios for the North Otago FMU

Nitrate Toxicity

For the nitrate toxicity attribute (Table 7), *all* of the North Otago FMU complies with the B-band target attribute state currently therefore *no reduction is required* to comply with the B-band. For the A-band target attribute state, under the current scenario *nearly all* segments comply. However, *reductions may be* required for all segment to comply. Under the GMP and GMP+ scenarios the proportion of segments expected to comply improves.

When split by management class (Table 8), *all* segments comply with the nitrate toxicity A-band in the mountain and hill classes currently *requiring no reductions*. The lowland class has the lowest compliance within the FMU with *nearly all* segments complying under the current scenario. Reductions *may be required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves. However, further reductions *may still be required* for all segments to comply. The lower confidence interval shows particularly large increases under the GMP+ scenario indicating greater confidence a larger portion of segments is likely to comply under this scenario compared with the current and GMP scenarios.

Table 7: Percent of river segments in the North Otago FMU complying with potential nitrate toxicity target attribute states with 90 percent confidence intervals for current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	98 (93 - 100)	99 (94 - 100)	99 (98 - 100)	1,599
B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,599
C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,599

Table 8: Percent of river segments in the North Otago FMU complying with potential nitrate toxicity target attribute states, split by management class, with 90 percent confidence intervals for current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity					
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
M	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	51
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	51
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	51
H	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	806

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	806
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	806
L	A	96 (84 - 100)	97 (86 - 100)	99 (96 - 100)	254
L	B	100 (99 - 100)	100 (100 - 100)	100 (100 - 100)	254
L	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	254

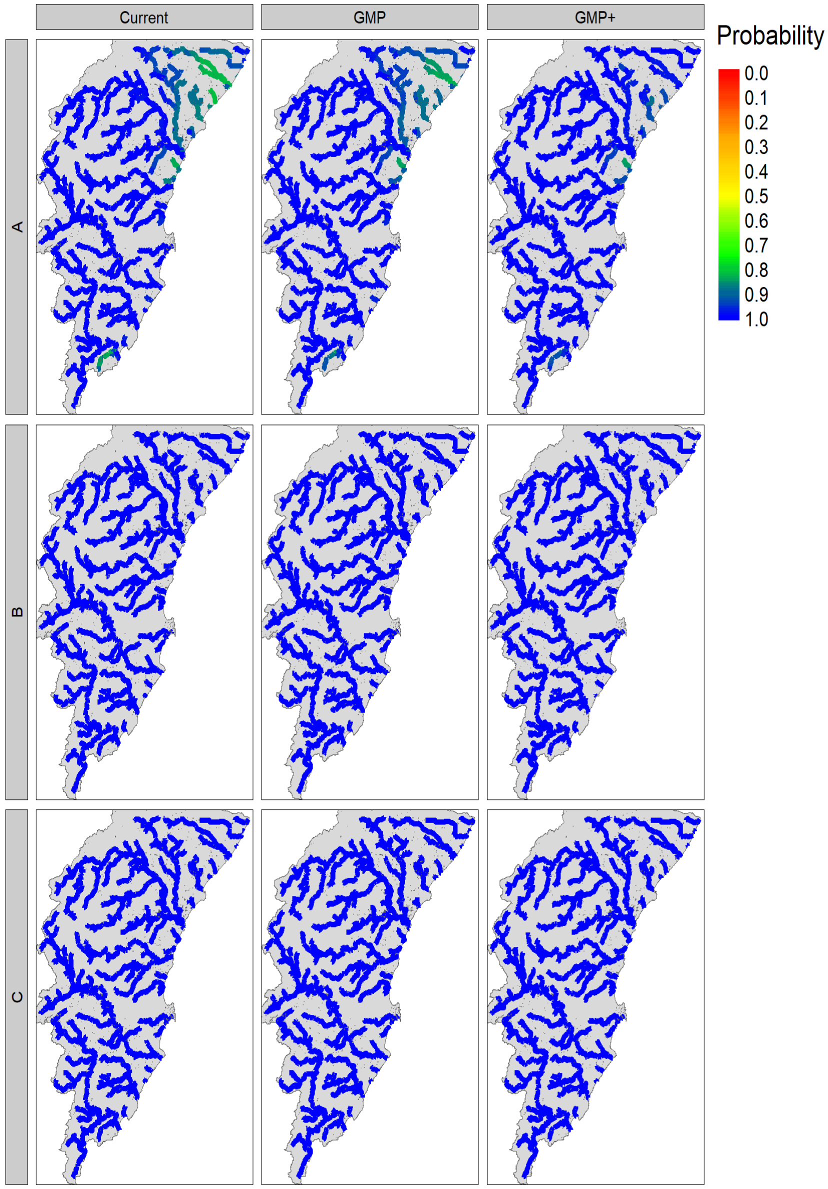

Figure 7: Individual segment probability of complying with the A, B, and C nitrate toxicity target attribute bands under the current, GMP and GMP+ scenarios for the North Otago FMU.

Spatially, all of the North Otago FMU is *very likely* to comply with the B-band nitrate toxicity target attribute state thus complying with the national bottom line (Figure 7). Southern areas of the FMU are also *very likely* to achieve the A-band nitrate toxicity target attribute state whereas northern areas on the Waitaki plain and Waiareka Creek catchment are *likely* to *very likely* to achieve the A-band target attribute state. The GMP scenario increases the probability of these areas complying with the A-band target attribute state with further increases under the GMP+ scenario resulting in all segments being *very likely* to achieve the A-band target attribute state.

Periphyton

For total nitrogen in relation to the periphyton biomass nutrient criteria (Table 9), *nearly all* of the North Otago complies with the C-band criteria under the current scenario. However, confidence intervals indicate a reduction *is required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly with upper confidence intervals overlapping 100%. The mean estimate and lower confidence interval indicate reductions beyond GMP+ *may be* required for all segments comply with the C-band criteria. *About half* of North Otago's segments comply with the B-band periphyton total nitrogen criteria under the current, GMP and GMP) scenarios. Further reductions beyond GMP+ *are required* for all segments to comply with the B-band criteria.

For total phosphorus in relation to the periphyton biomass nutrient criteria (Table 9), *nearly all* segments comply with the C-band criteria under the current scenario. While the upper confidence interval overlaps 100%, indicating that a less than 95% confidence reduction is required, the mean and lower confidence interval fail to overlap 100% indicating a reduction *may be* required. Under the GMP and GMP+ scenarios the proportion of segments expected to comply improves. *Few* segments comply with the B-band criteria under the current, GMP and GMP+ scenarios. Reductions beyond GMP+ *are required* for all segments to comply with the B-band criteria.

Few segments in any class comply with the A-band criteria for both total nitrogen and total phosphorus. This indicates the A-band nutrient criteria would not naturally be expected to be complied with in 80% of segments.

When split by management class, for the total nitrogen C-band criteria (Table 10), *all* mountain and hill segments in the North Otago FMU comply under all scenarios requiring *no reduction*. *Nearly all* lowland segments comply with the C-band nitrogen criteria under the current scenario however reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios the proportion of segments expect to comply improves. However, the upper confidence interval for the lowland class fails to overlap 100% indicating with 95% confidence a reduction beyond GMP+ *is required*. For lowland segments to comply, reductions in upstream classes (i.e., hill/mountain) may need to occur despite the upstream class complying with its respective nutrient criteria.

In relation to the total nitrogen B-band criteria (Table 10), when split by management class, *all* mountain segments comply (under all scenarios indicating no reductions are required). *Most* hill segments comply with the B-band nitrogen criteria currently. A reduction is required for all segments to comply as the upper confidence interval fails to overlap 100%. The proportion of segments expected to comply improves slightly under the GMP and GMP+ scenarios. However, reductions beyond GMP+ are required for all segments to comply. *Few* lowland segments comply with the B-band criteria under any scenario. Reductions beyond GMP+ would be required for this class to comply.

When split by management class, for the total phosphorus C-band criteria (Table 10), *all* mountain segments comply under all scenarios indicating *no reductions* are required for this management class to comply. *Nearly all* hill-fed segments comply with the C-band total phosphorus criteria under the current scenario. As the mean does not overlap 100%, reductions *may be* required for all segments to comply. Under the GMP and GMP+ scenarios, slight improvement occurs. However, the mean does not overlap 100% indicating reductions beyond GMP+ *may be* required for all segments to comply. In the lowland class, *nearly all* segments comply with the C-band criteria currently. However, a reduction *is required* for all segments to comply. The proportion of segments expected to comply improves under the GMP and GMP+ scenarios. Under the GMP+ scenario, the confidence interval overlaps 100% indicating less than 95% confidence a reduction beyond GMP+ is required. However, the mean fails to overlap 100% indicating further reductions *may be* required.

When split by management class, for the total phosphorus B-band criteria (Table 10), *nearly all* mountain segments comply currently. However, a reduction *may be* required for all segments to comply. Under the GMP and GMP+ scenarios, there is a slight improvement in the proportion of segments expected to comply. *Few* hill and lowland class segments comply with the B-band total phosphorus criteria under any scenario. For hill and lowland classes to comply with the B-band total phosphorus criteria, there is 95% confidence reductions beyond GMP+ *are required*.

Table 9: Percent of river segments in the North Otago FMU complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria with 90 percent confidence intervals for current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			Total Phosphorus				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	4 (0 - 18)	5 (0 - 18)	6 (0 - 20)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	1,111
B	52 (33 - 71)	54 (35 - 73)	56 (37 - 74)	12 (4 - 31)	13 (4 - 38)	15 (4 - 40)	0	1,111
C	96 (93 - 99)	96 (93 - 99)	97 (94 - 100)	95 (84 - 100)	96 (88 - 100)	97 (90 - 100)	0	1,111

Table 10: Percent of river segments in the North Otago FMU complying with Snelder et al., 2023 20% under protection risk periphyton nutrient criteria, split by management class, with 90 percent confidence intervals for current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	A	21 (0 - 88)	23 (0 - 92)	25 (0 - 92)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	51
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	93 (76 - 100)	94 (76 - 100)	95 (78 - 100)	0	51

		Total Nitrogen			Total Phosphorus				
Management Class	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+	Periphyton exempt	Total segments
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	51
H	A	4 (0 - 19)	5 (0 - 19)	6 (0 - 22)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	806
H	B	65 (39 - 91)	68 (42 - 95)	71 (45 - 95)	10 (0 - 32)	11 (0 - 42)	14 (0 - 44)	0	806
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	96 (84 - 100)	97 (88 - 100)	98 (90 - 100)	0	806
L	A	1 (0 - 6)	1 (0 - 6)	1 (0 - 7)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	254
L	B	1 (0 - 5)	1 (0 - 6)	1 (0 - 6)	3 (0 - 13)	4 (0 - 17)	4 (0 - 19)	0	254
L	C	82 (68 - 96)	85 (70 - 97)	87 (73 - 98)	90 (77 - 99)	91 (79 - 99)	92 (81 - 100)	0	254

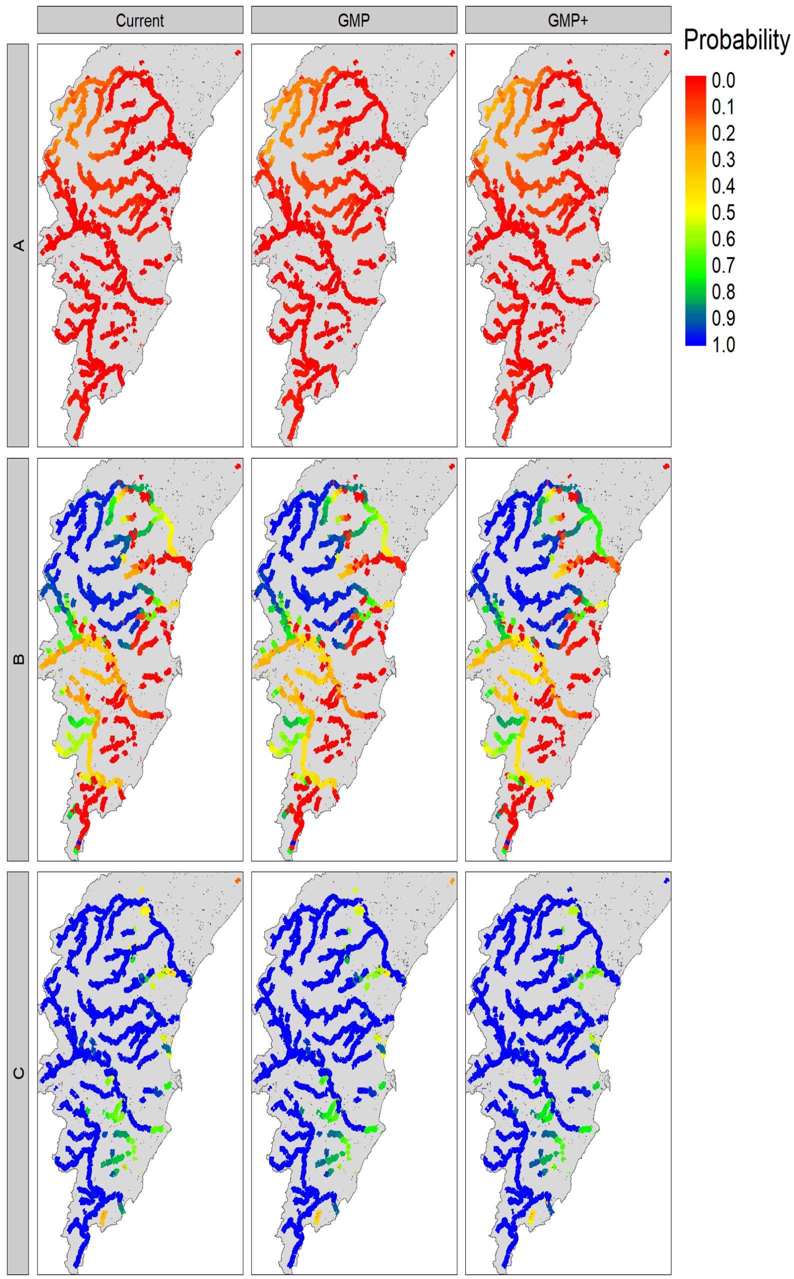

Figure 8: Individual segment probability of complying with the total nitrogen A, B, and C periphyton nutrient criteria under the current, GMP and GMP+ scenarios for the North Otago FMU.

Spatially (Figure 8), for the C-band total nitrogen criteria, the majority of the FMU is *very likely* to comply under all scenarios. Lower areas in the catchments range from *likely* to *very likely* to comply with some segments in the Kakanui catchment *as likely as not*. Under the GMP and GMP+ scenarios, probabilities of compliance with the C-band criteria improve. Compliance with the B-band criteria is higher in upper catchments ranging from *as likely as not* to *very likely*. Lower catchment areas are *very unlikely* to comply under all modelled scenarios. Under the GMP and GMP+ scenarios, probability improvements are most noticeable in mid-catchment areas. All segments are *very unlikely* to comply with the A-band nitrogen criteria under any modelled scenario.

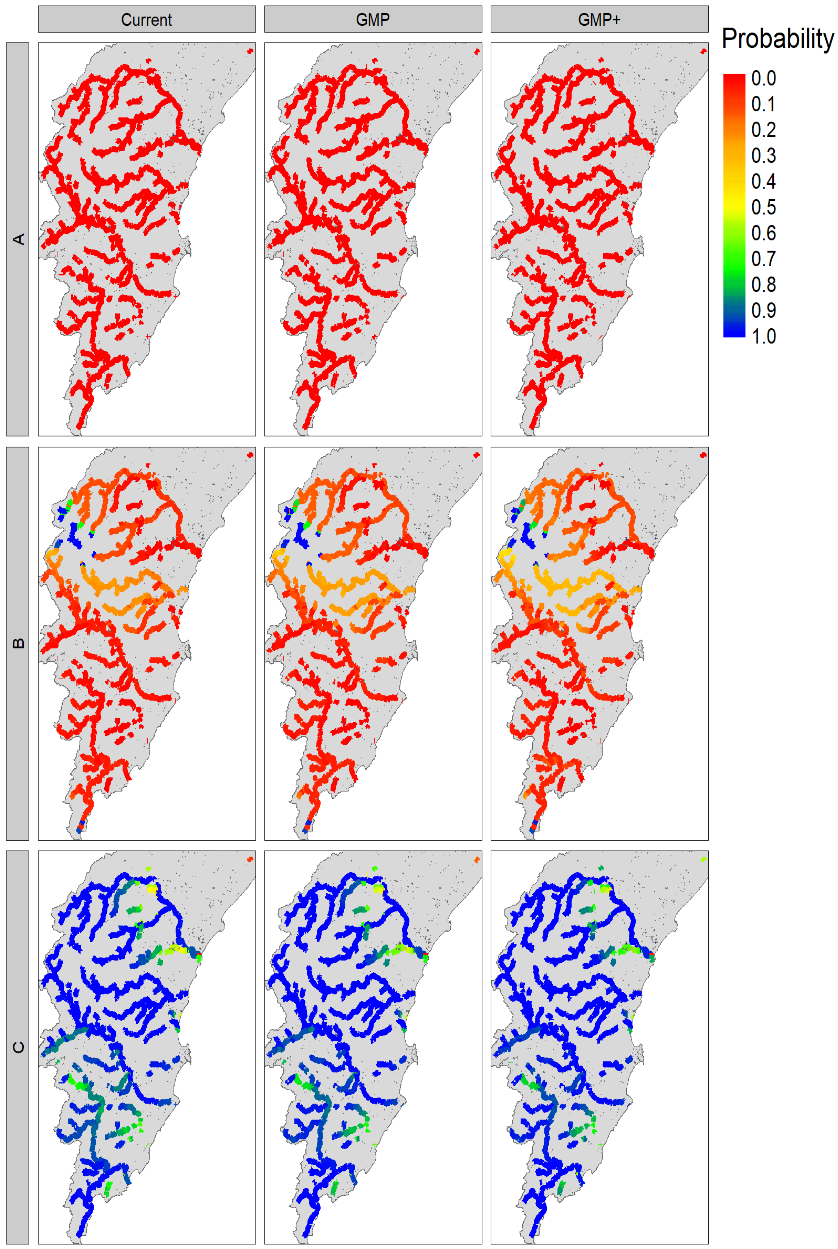

Figure 9: Individual segment probability of complying with the total phosphorus A, B, and C periphyton nutrient criteria under the current, GMP and GMP+ scenarios for the North Otago FMU.

The majority of the North Otago FMU is *very likely* to comply with the C-band total phosphorus criteria under all modelled scenarios (Figure 9). For the B- and A-band criteria the majority of segments in the FMU are *very unlikely* to comply under all scenarios.

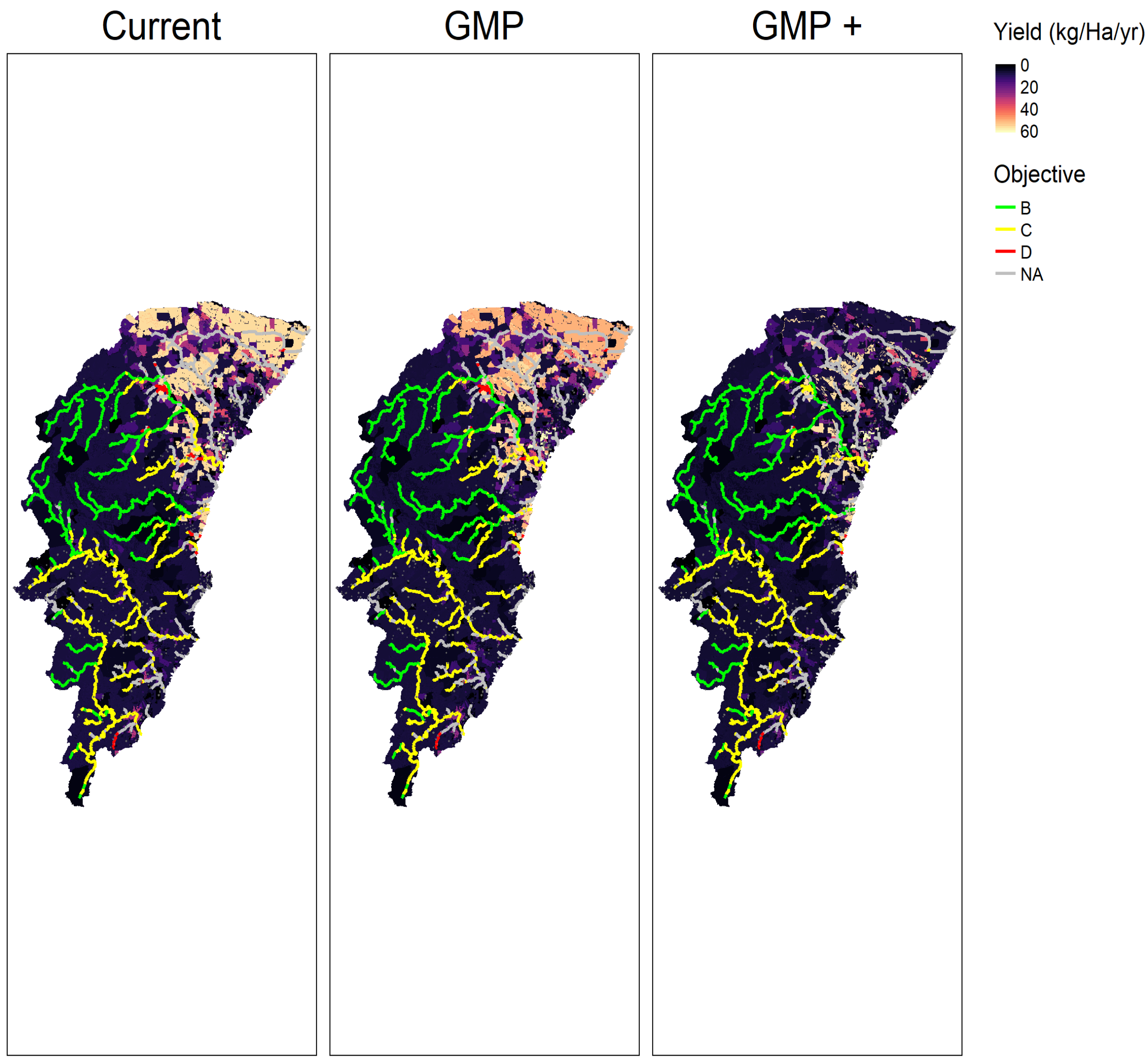

Figure 10: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization total nitrogen periphyton target attribute band outcome for each river segment under the current, GMP, and GMP+ scenarios in the North Otago FMU.

Mean realization nitrogen comparisons for the North Otago FMU result in the majority of mid to upper catchment segments complying with the B-band total nitrogen criteria and lower catchment complying with the C-band criteria (Figure 10). Band changes occur under the GMP and GMP+ scenario in mid-reaches of the Kakanui river. However, the overall patterns present in the FMU remains the same under these reduction scenarios.

Mean realization phosphorus comparisons result in the majority of segments in the North Otago FMU complying with the C-band criteria (Figure 11). Under the GMP and GMP+ scenarios, few band changes occur between the three scenarios considered.

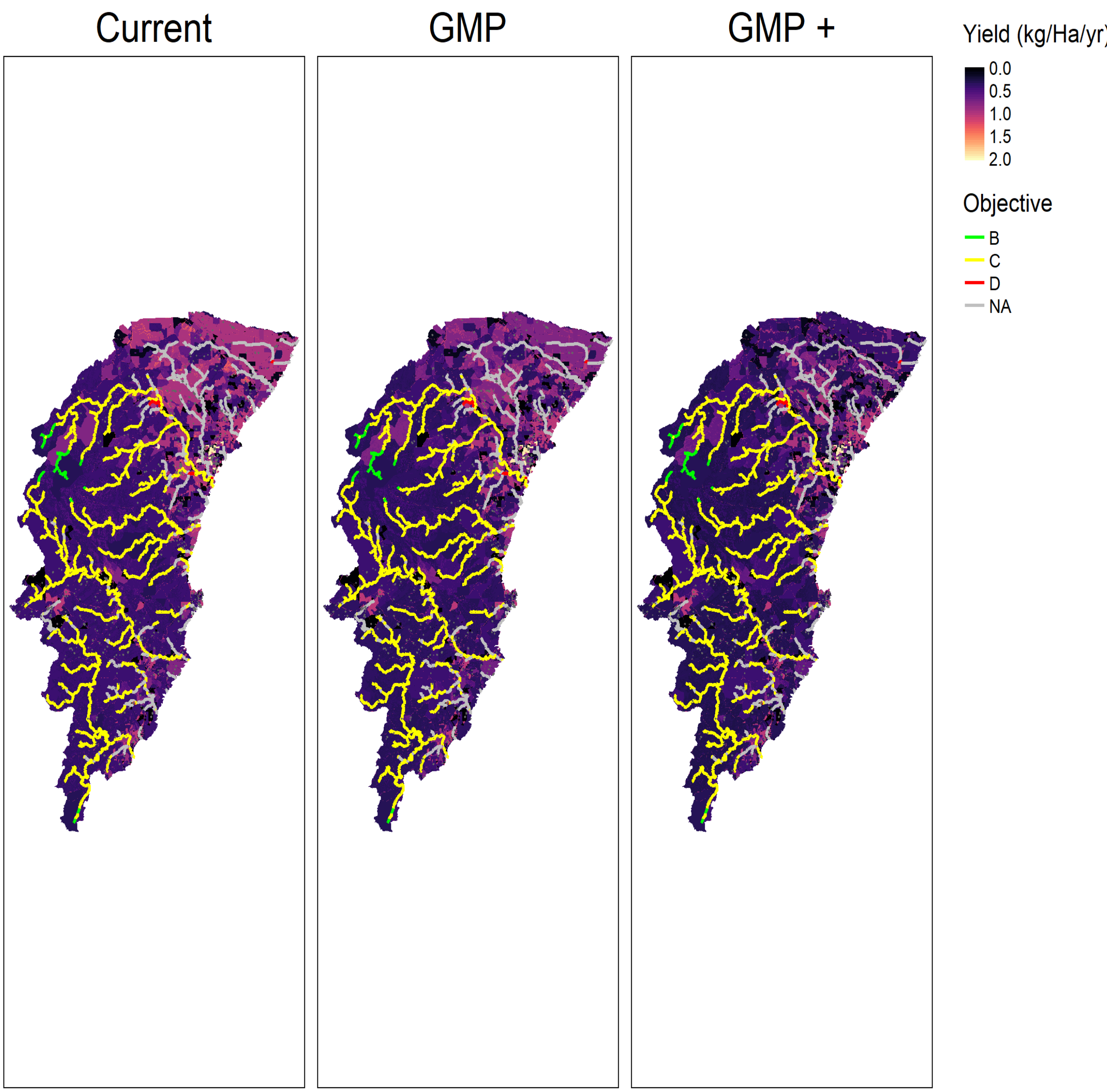

Figure 11: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute band outcome for each river segment under the current, GMP, and GMP+ scenarios in the North Otago FMU.

Estuaries

Nitrogen

The North Otago FMU contains six estuaries where modelling results are available (Table 11). For total nitrogen, under the current and GMP scenarios, the Kakanui and Orore Creek estuaries are *very* *unlikely* to comply with the C-band target attribute state. The Kakanui improves under the GMP and GMP+ scenarios whereas the Orore Creek estuary does not.

The Pleasant River Estuary is currently *likely* to comply with the C-band target attribute state, *unlikely* to comply with the B-band, and *very unlikely* to comply with the A-band. The probability of complying with the C-band and B-band target attribute states improves a small amount under the GMP and GMP+ scenarios. Probability of A-band compliance does not improve under any scenario.

The Shag River Estuary is currently *very likely* to comply with the C-band target attribute state, *likely* to comply with the B-band and *unlikely* to comply with the A-band. Under the GMP and GMP+ scenarios, the probabilities of complying with the C-band and B-band target attribute state improve. Very small improvements in the probability of complying with the A-band target attribute state under occur under the GMP+ scenario.

Stony Creek Estuary is *very unlikely* to comply with the C, B, or A-band target attribute state under any scenario.

The Waikouaiti River Estuary is currently *likely* to comply with the C-band target attribute state, *unlikely* to comply with the B-band, and *very unlikely* to comply with the A-band target attribute state. Probability of complying with the C- and B-bands improve under the GMP and GMP+ scenarios.

Phosphorus

Three estuaries have phosphorus results available as it may be a limiting nutrient under estuary mouth closure scenarios (Table 11). The Kakanui is *very unlikely* to comply with the C-band target attribute state under the current scenario with improvement under the GMP, and GMP+ scenarios. For the B-band target attribute state, the Kakanui is *very unlikely* to comply under current scenario with improvement under the GMP, and GMP+ scenarios. The A-band target attribute state is also *very unlikely* under the current and mitigation scenarios.

Under the current scenario, the Orore Creek is *unlikely* to comply with the C-band target attribute state and *very unlikely* to comply with the B and A-band target attribute states. The probability of complying with the C-band target attribute state increases under the GMP and GMP+ scenarios while the B-band increases only under the GMP+ scenario. The A-band probability does not increase under any scenario.

Stony Creek Estuary is currently *likely* to comply with the C-band target attribute state, *unlikely* to comply with the B-band and *very unlikely* to comply with the A-band. The probability of Stony creek estuary complying with the C-band target attribute state increases under the GMP and GMP+ scenarios. The B- and A-band probabilities also increase under the GMP and GMP+ scenarios.

Table 11: Probability of compliance of estuaries in the North Otago FMU with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval. Where phosphorus probabilities are blank, phosphorus is not considered to be a key nutrient for estuary health.

		Total Nitrogen			**Total Phosphorus**		
Estuary	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Kakanui River	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	2 (1 - 6)	4 (2 - 9)	5 (2 - 10)
Kakanui River	B	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	6 (3 - 11)	6 (3 - 11)	9 (5 - 15)
Kakanui River	C	4 (2 - 9)	7 (4 - 12)	15 (10 - 22)	6 (3 - 11)	10 (6 - 16)	12 (8 - 18)
Orore Creek	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Orore Creek	B	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	4 (2 - 9)	4 (2 - 9)	6 (3 - 11)
Orore Creek	C	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	28 (21 - 36)	28 (21 - 36)	29 (22 - 37)
Pleasant River	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)			
Pleasant River	B	27 (20 - 35)	28 (21 - 36)	31 (24 - 39)			
Pleasant River	C	60 (52 - 68)	64 (56 - 71)	68 (60 - 75)			
Shag River	A	0 (0 - 3)	0 (0 - 3)	1 (0 - 4)			

		Total Nitrogen			Total Phosphorus		
Estuary	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+
Shag River	B	71 (63 - 78)	74 (66 - 81)	75 (67 - 81)			
Shag River	C	94 (89 - 97)	95 (90 - 98)	95 (90 - 98)			
Stony Creek	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	4 (2 - 9)	6 (3 - 11)	7 (4 - 12)
Stony Creek	B	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	21 (15 - 28)	26 (19 - 34)	31 (24 - 39)
Stony Creek	C	1 (0 - 4)	1 (0 - 4)	1 (0 - 4)	66 (58 - 73)	69 (61 - 76)	77 (69 - 83)
Waikouaiti River	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)			
Waikouaiti River	B	33 (26 - 41)	35 (28 - 43)	42 (34 - 50)			
Waikouaiti River	C	67 (59 - 74)	75 (67 - 81)	77 (69 - 83)			

Dunedin Coast FMU

Land use characteristics

Land use in the Dunedin Coast FMU (Table 12; Figure 12) is comprised primarily of exotic forestry (29%), sheep and beef (19%), dairy (8%), and sheep (8%). There is also a large residential (3%) and road and rail component (3%) relative to other FMUs. In this FMU, the GMP and GMP+ mitigations packages can be applied to approximately 50% of the FMU based on land use.

The GMP and GMP+ mitigations will not apply to the Dunedin urban area. Urban areas are likely to have point source discharges and other factors not covered here as the focus is diffuse source mitigations. As a result, additional reductions could be achieved through alternative mitigation measures in urban areas.

Table 12: Land use statistics for the Dunedin Coast FMU.

Land Use	Area (Ha)	Percent
Arable	227.03	0.21%
Beef	4,929.68	4.64%
Commercial Use	121.58	0.11%
Conservation	3,912.41	3.68%
Dairy	8,881.58	8.35%
Dairy Support	543.00	0.51%
Exotic Forestry	31,222.33	29.36%
Horticulture	35.14	0.03%
Industrial Use	293.46	0.28%
Lakes & Rivers	444.32	0.42%
Lifestyle Block	3,961.80	3.73%
Livestock Support	940.29	0.88%
Majority Deer with Mixed Livestock	159.22	0.15%
Mixed Livestock	4,784.33	4.50%
Nurseries & Orchards	17.08	0.02%
Other Animals	273.89	0.26%

Land Use	Area (Ha)	Percent
Pig Farming	38.40	0.04%
Poultry	22.21	0.02%
Public Use	313.60	0.29%
Residential Use	2,936.50	2.76%
Road & Rail	2,852.93	2.68%
Sheep	8,686.77	8.17%
Sheep & Beef	20,083.81	18.89%
Small Land Holding	2,612.75	2.46%
Specialist Deer	198.77	0.19%
Tourism & Recreational Use	769.77	0.72%
Unknown Land Use	3,311.45	3.11%
Unknown Land Use - Indigenous Cover	2,029.06	1.91%
Unknown Land Use - Non-agricultural	788.54	0.74%
Unknown Land Use - Pastoral Cover	955.56	0.90%

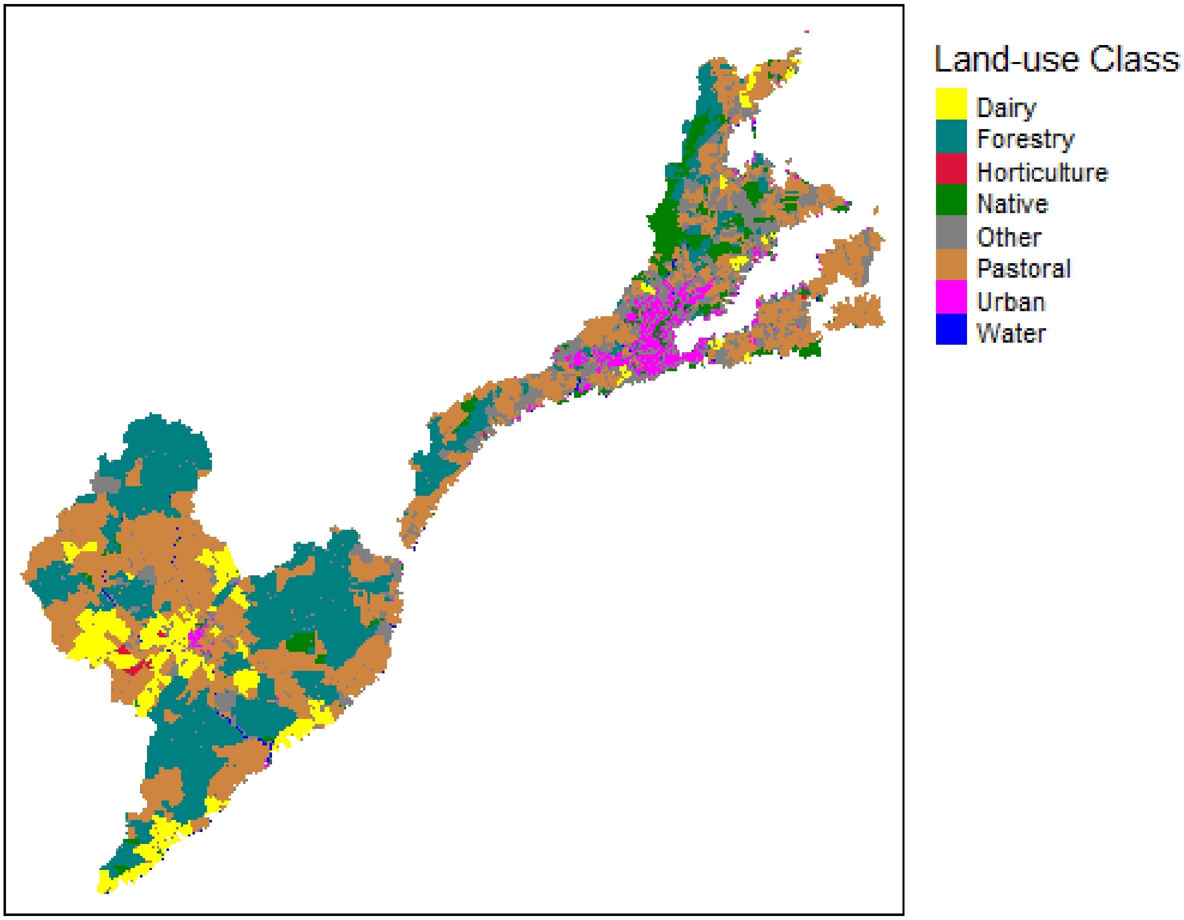

Figure 12: Land-use within the Dunedin Coast FMU. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

In the Dunedin Coast FMU, the GMP scenario results in approximately a 6% reduction in nitrogen and 3% reduction phosphorus emissions whereas the GMP+ scenario results in an 11% reduction of nitrogen and a 5% reduction in phosphorus emissions (Table 13). These reductions result in the FMUs overall average yield decreasing from 7.69 kg/ha/yr of nitrogen under the current scenario to 7.25 kg/ha/yr and 6.81 kg/ha/yr under the GMP and GMP+ scenarios respectively (Table 14). The average phosphorus yield decreases from 0.51 kg/ha/yr under the current scenario to 0.49 kg/ha/yr and 0.48 kg/ha/yr under the GMP and GMP+ scenarios, respectively.

Table 13: Total on-land nitrogen and phosphorus load reductions achieved through GMP and GMP+ scenarios in the Dunedin Coast FMU.

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	5.72%	46,748.16	11.38%	93,038.04
P	3.18%	1,710.60	4.97%	2,674.18

Table 14: Average yield of nitrogen and phosphorus under current, GMP, and GMP+ scenarios in the Dunedin Coast FMU.

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	7.69	7.25	6.81
P	0.51	0.49	0.48

Rivers

Yields

Spatially, the highest yield areas for nitrogen (Figure 13) in the Dunedin Coast FMU occur in the Tokomairiro catchment whereas the highest phosphorus (Figure 14) yields occurs near Dunedin City. Under the GMP and GMP+ scenarios, average upstream yields of nitrogen decreased. The yields surrounding Dunedin City do not decrease as mitigations were not applicable to these land use types in this analysis.

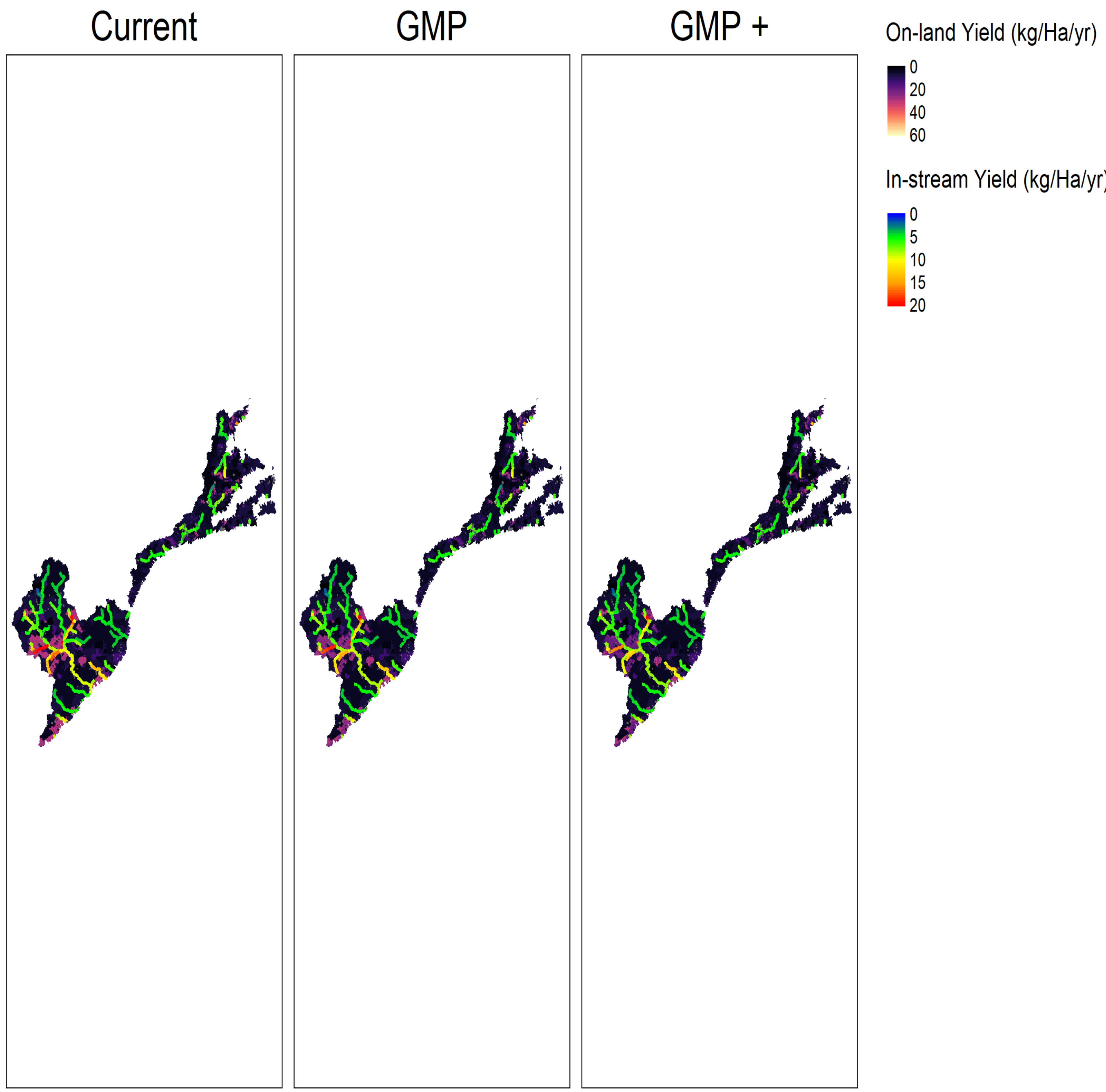

Figure 13: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for the current, GMP, and GMP+ scenarios in the Dunedin Coast FMU

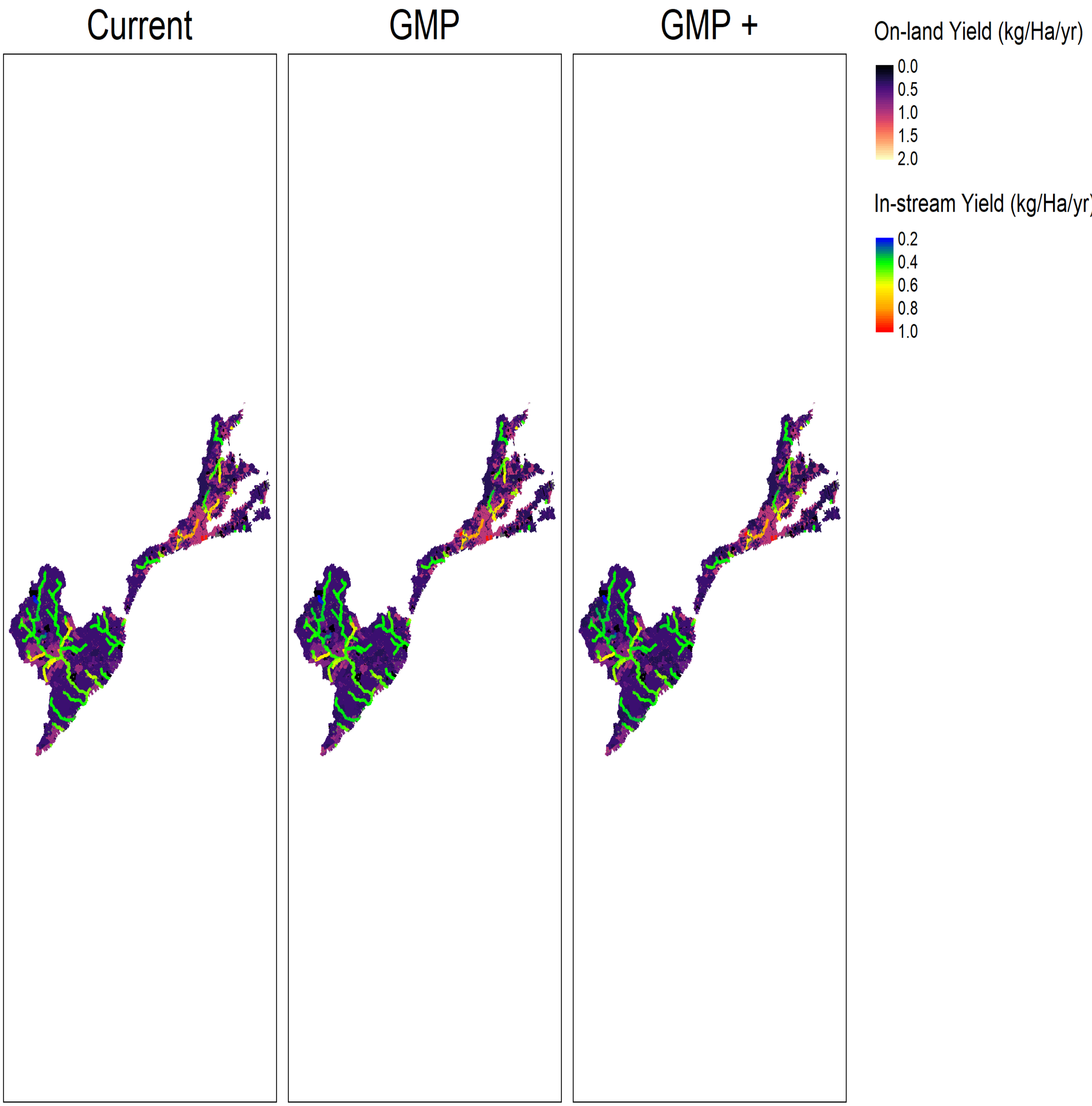

Figure 14: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for the current, GMP, and GMP+ scenarios in the Dunedin Coast FMU.

Nitrate Toxicity

All segments in the Dunedin Coast FMU comply with the B-band nitrate toxicity target attribute state (Table 15) under all scenarios thus *no reductions are required* to comply with the national bottom line in this FMU. *Nearly all* segments in the Dunedin Coast FMU comply with the A-band nitrate toxicity target attribute state under the current scenario. However, the mean estimate fails to overlap 100% indicating reductions *may be required*. Under the GMP and GMP+ scenarios the proportion of segments expected to comply improves slightly but still fails to overlap 100% indicating reductions beyond GMP+ *may be required* for all segments to comply.

When split by management class (Table 16), *all* hill segments comply with the A band nitrate toxicity target attribute state across all scenarios *requiring no reductions*. The lowland class has the lowest compliance within the FMU with *nearly all* segments complying currently. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly. However, the mean percentage of segments complying fails to overlap 100% indicating reductions beyond GMP+ *may be required*.

Table 15: Percent of river segments complying with potential nitrate toxicity target attribute states in the Dunedin & Coast FMU with 90 percent confidence intervals for current, GMP, and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	95 (72 - 100)	96 (77 - 100)	97 (84 - 100)	476
B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	476
C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	476

Table 16: Percent of river segments complying with potential nitrate toxicity target attribute states in the Dunedin & Coast FMU, split by management class, with 90 percent confidence intervals for current, GMP, and GMP+ scenarios. The national bottomline is the B-band.

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	29
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	29
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	29
L	A	95 (70 - 100)	95 (76 - 100)	96 (83 - 100)	322
L	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	322
L	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	322

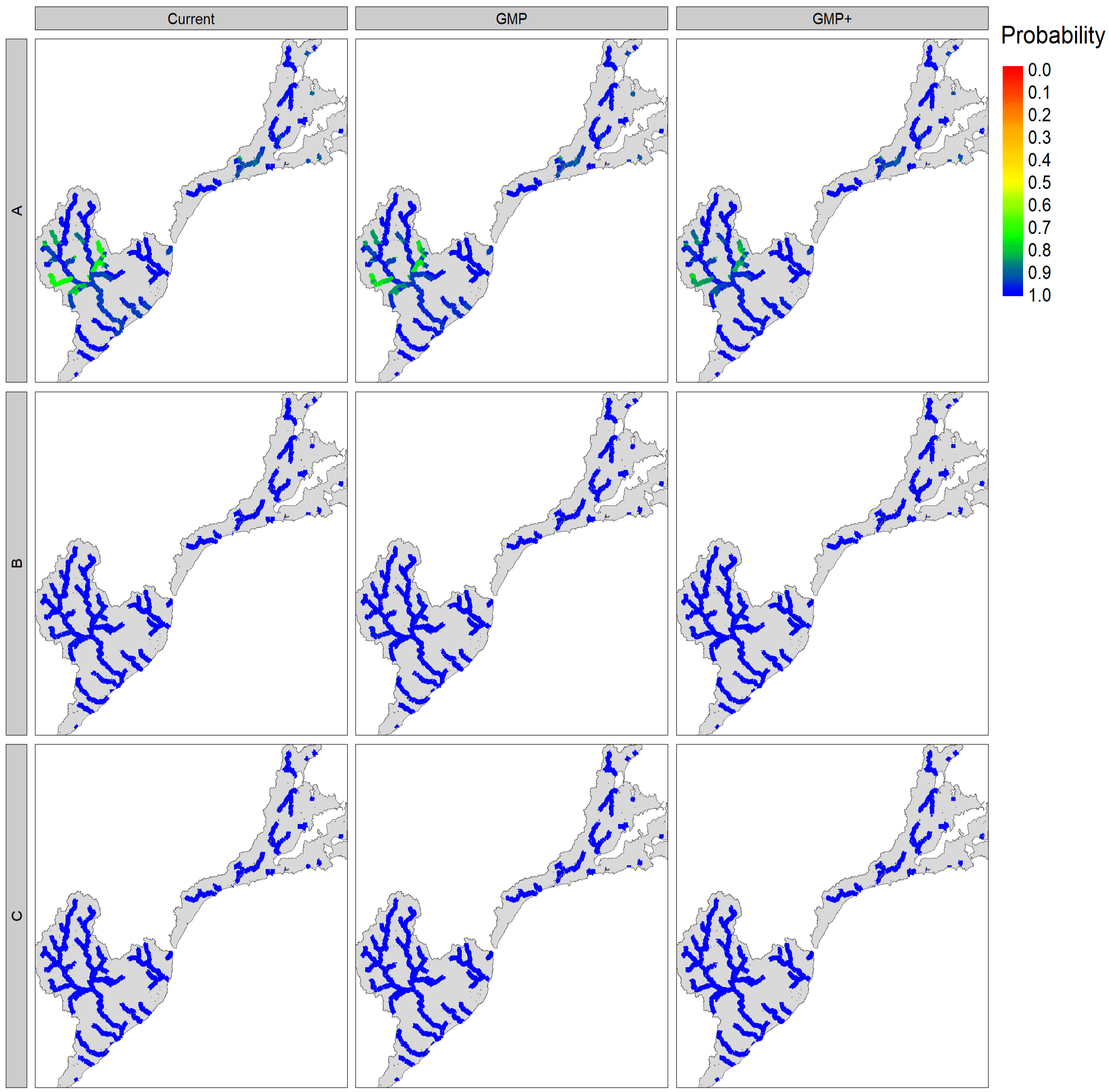

Figure 15: Individual segment probability of complying with the A, B, and C nitrate toxicity target attribute states under current, GMP, and GMP+ scenarios in the Dunedin & Coast FMU.

All of the Dunedin & Coast FMU is *very likely* to comply with the B-band nitrate toxicity target attribute state (Figure 15), thus complying with the national bottom line. Southern areas of the FMU are all *likely* to *very likely* to achieve the A band nitrate toxicity target attribute state under the current scenario improving to *very likely* under the GMP and GMP+ scenarios. Northern areas of the FMU are all *very likely* to comply with the A-band nitrate toxicity target attribute state under all scenarios.

Periphyton

For total nitrogen in relation to the periphyton biomass nutrient criteria (Table 17), *about half* of segments in the Dunedin Coast FMU comply with the C-band criteria under the current scenario indicating reductions *are required*. Under the GMP and GMP+ scenarios *most* segments are expected to comply. However, the upper confidence interval fails to overlap 100% indicating reductions beyond GMP+ *are required* for all segments to comply. *Few* segments comply with the B-band total nitrogen criteria under any modelled scenario. This indicates reductions beyond GMP+ *are required* to comply.

For total phosphorus in relation to the periphyton biomass nutrient criteria (Table 18), *most* segments in the Dunedin Coast FMU currently comply with the C-band criteria indicating reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply increases slightly. However, confidence intervals fail to overlap 100% indicating reductions beyond GMP+ *are required* for all segments to comply with the C-band criteria. *Few* segments comply with the B-band total phosphorus criteria under any modelled scenario. To comply with the B-band criteria, reductions beyond GMP+ *are required*.

Few segments in any class comply with the A-band criteria for both total nitrogen and phosphorus. This indicates the A-band nutrient criteria would not be expected to be complied with in 80% of segments and is unlikely to be a reasonable target.

When split by management class (Table 18), for the total nitrogen C-band criteria, *all* hill-fed segments comply under the current scenario indicating *no reduction is required* for this class. In lowland segments, *about half* of segments comply with the C-band total nitrogen criteria currently with confidence intervals indicating reductions *are required*. Under the GMP and GMP+ scenarios the proportion of segments expected to comply improves, but the upper confidence interval fails to overlap 100%. This indicates reductions beyond GMP+ *are required* for all segments to comply. This may need reductions in upstream hill segments despite meeting their respective criteria.

When split by management class, for the total nitrogen B-band criteria (Table 18), *most* hill segments comply with the B-band nitrogen criteria currently (62%; 3-100). Confidence intervals are wide indicating uncertainty in the reduction required to comply with the criteria. Under the GMP+ scenario the mean proportion expected to comply improves by 1% with no change to the confidence interval (63%; 3-100). As the upper confidence interval overlaps 100% but the mean and lower confidence interval do not approach 100%, reductions *are likely* required. Few lowland segments comply with the B-band under all three scenarios indicating reductions beyond GMP+ *are required* for all lowland segments to comply with the B-band criteria.

When split by management class, for the total phosphorus C-band criteria (Table 18), *nearly all* hill-fed segments currently comply with the C-band criteria. No reduction *is required* as the lower confidence interval overlaps 100%. In lowland segments, *most* comply with the C-band total phosphorus currently. However, as the upper confidence interval fails to overlap 100%, reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios the proportion of segments expected to comply improves slightly. However, the confidence interval still fails to overlap with 100% indicating reductions beyond GMP+ *are required* for all segments to comply.

When split by management class, for the total phosphorus B-band criteria (Table 18), *few* hill-fed and lowland (3%; 0-7) segments comply with B-band criteria under all three scenarios. This indicates reductions beyond GMP+ *are required* for all segments in these classes to comply with the B-band criteria.

Table 17: Percent of river segments in the Dunedin Coast FMU complying with Snelder et al., 2023 20% under protection risk periphyton nutrient criteria with 90 percent confidence intervals for the current, GMP, and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			Total Phosphorus				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	351
B	7 (1 - 11)	7 (1 - 11)	7 (1 - 11)	4 (1 - 10)	4 (1 - 10)	5 (1 - 10)	0	351
C	58 (38 - 88)	61 (39 - 88)	63 (40 - 91)	67 (43 - 94)	68 (44 - 95)	69 (45 - 95)	0	351

Table 18: Percent of river segments complying in the Dunedin Coast FMU with Snelder et al., 2023 20% under protection risk periphyton nutrient criteria, split by management class, with 90 percent confidence intervals for the current, GMP, and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
H	A	1 (0 - 0)	1 (0 - 0)	1 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	29
H	B	72 (10 - 100)	72 (10 - 100)	73 (10 - 100)	16 (7 - 97)	16 (7 - 97)	16 (7 - 97)	0	29
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	97 (100 - 100)	97 (100 - 100)	97 (100 - 100)	0	29
L	A	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	322

		Total Nitrogen			Total Phosphorus				
Management Class	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+	Periphyton exempt	Total segments
L	B	1 (0 - 3)	1 (0 - 3)	1 (0 - 4)	3 (0 - 7)	3 (0 - 7)	3 (0 - 7)	0	322
L	C	54 (32 - 87)	57 (34 - 87)	59 (35 - 90)	64 (39 - 93)	66 (40 - 94)	67 (41 - 95)	0	322

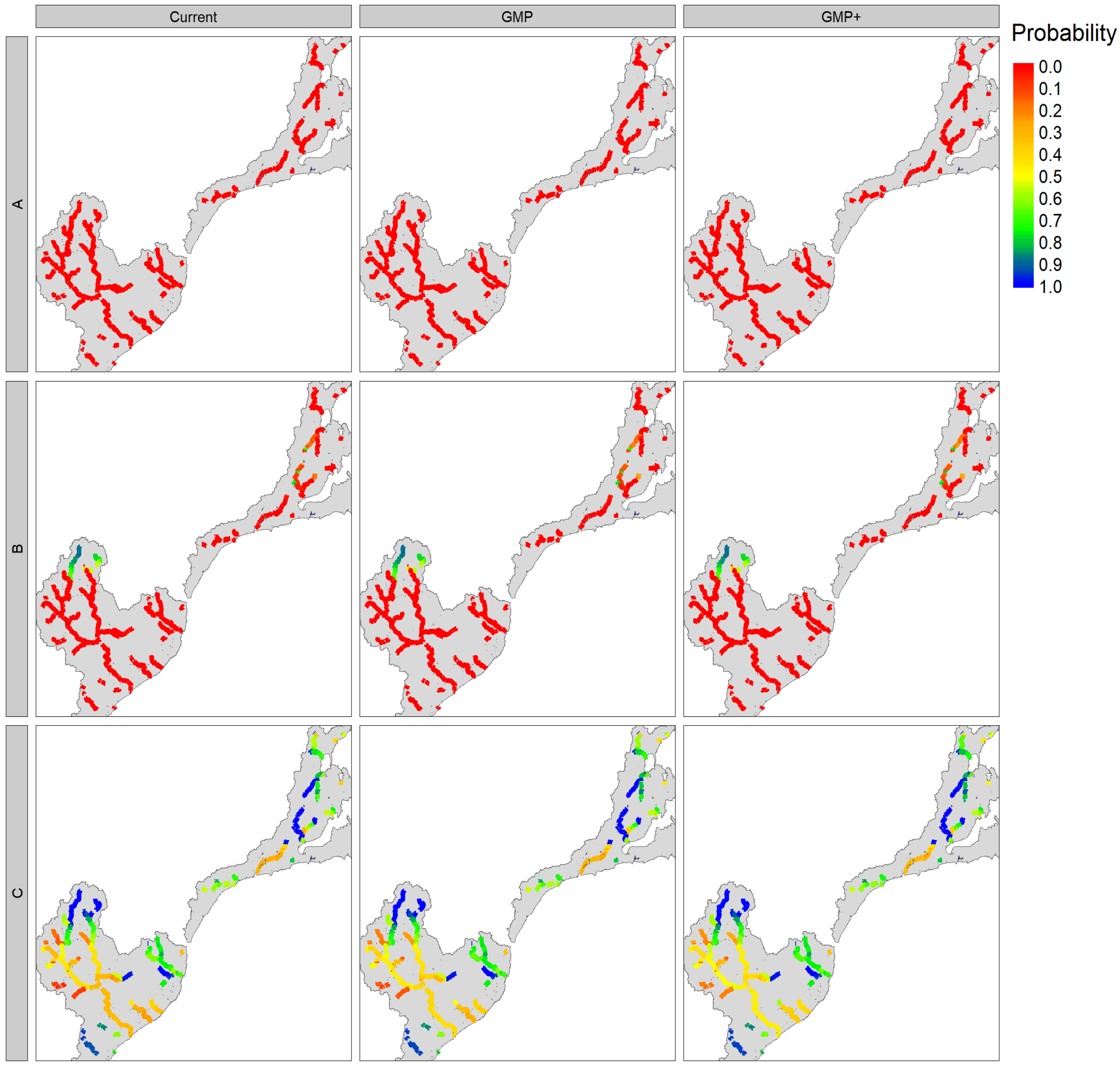

Figure 16: Individual segment probability of complying with the total nitrogen A, B and C periphyton criteria under current, GMP and GMP+ scenarios in the Dunedin Coast FMU.

For the C-band total nitrogen criteria, many segments are *about as likely as not* to comply with a range from *very unlikely* to *very likely* across the FMU (Figure 16). For the B-band and A-band criteria, all segments are *very unlikely* to comply with the exception of the upper Tokomairiro.

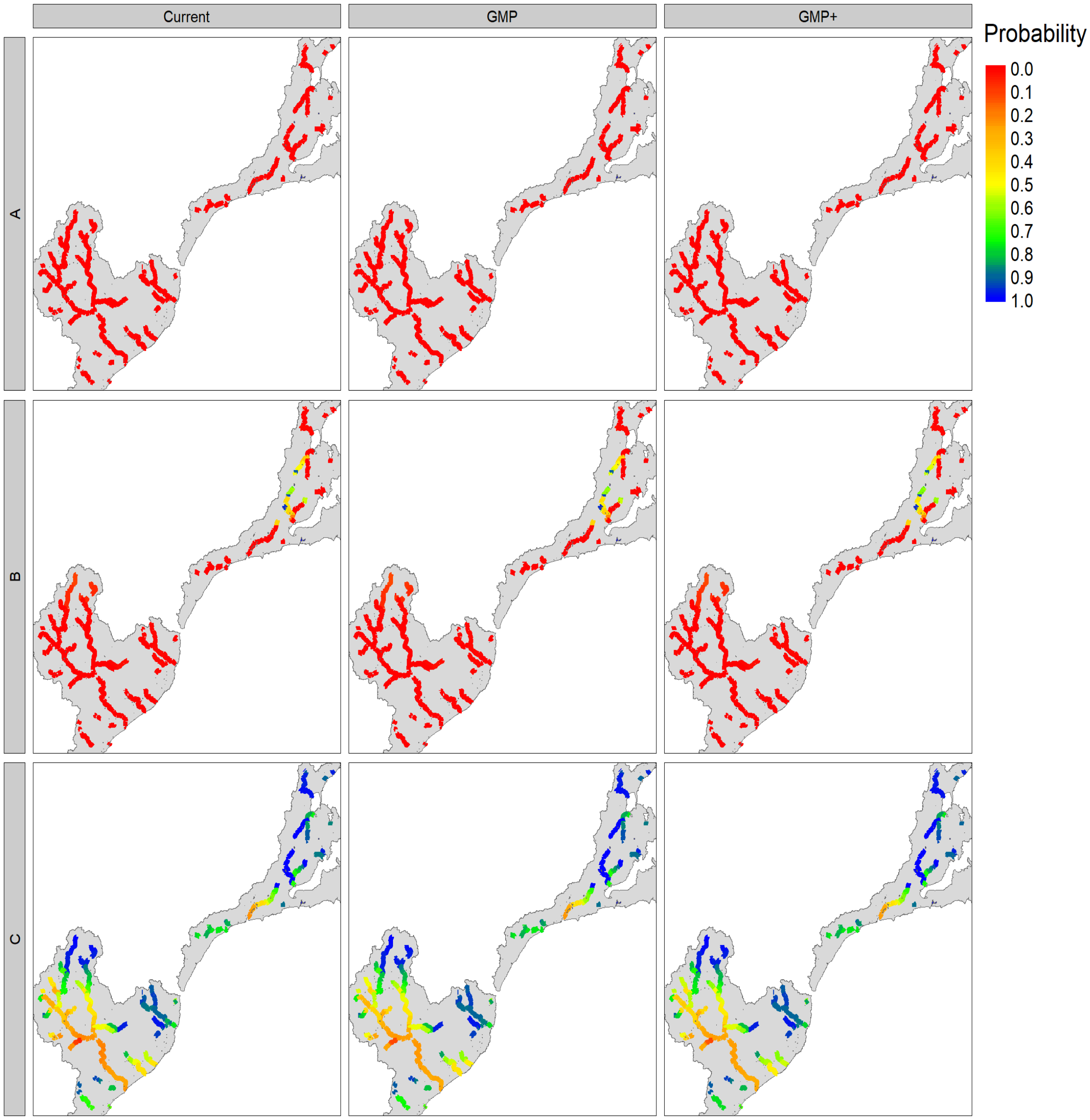

Figure 17: Individual segment probability of complying with the total phosphorus A, B and C periphyton criteria under current, GMP and GMP+ scenarios in the Dunedin Coast FMU.

For the C-band phosphorus criteria, many segments are *very likely* to comply with a range from *very unlikely* to *very likely* across the FMU (Figure 17). For the B-band and A-band criteria, segments are *very unlikely* to comply.

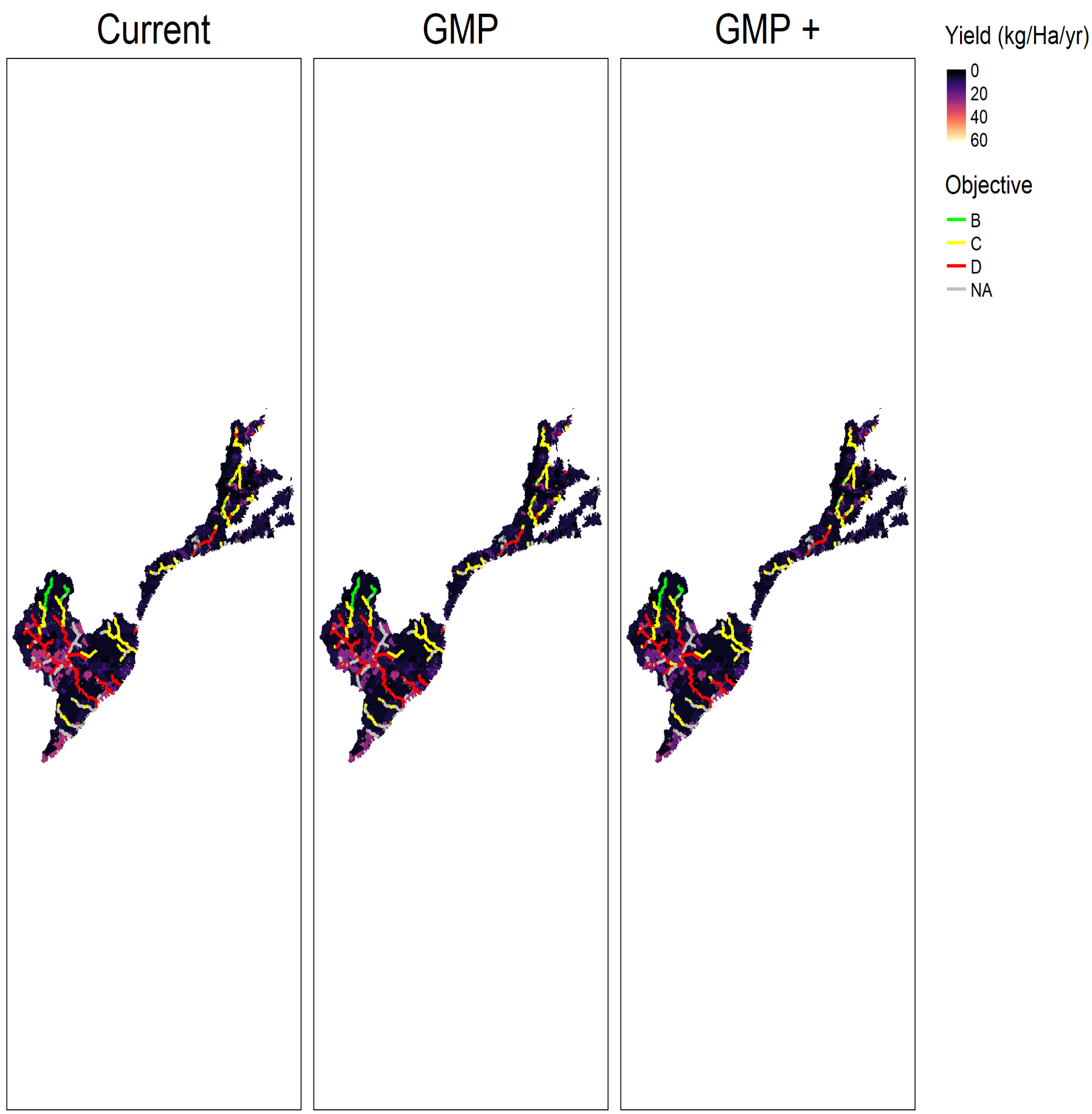

Figure 18: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization total nitrogen periphyton target attribute state outcome for each river segment under the current, GMP, and GMP+ scenarios in the Dunedin Coast FMU.

Based on the mean realization comparison, many segments in the Dunedin Coast FMU fail to comply with the C-band nitrogen criteria under all scenarios (Figure 18). Similarly, many segments fail comply with the C-band phosphorus criteria when compared to the mean realization under all three scenarios (Figure 19).

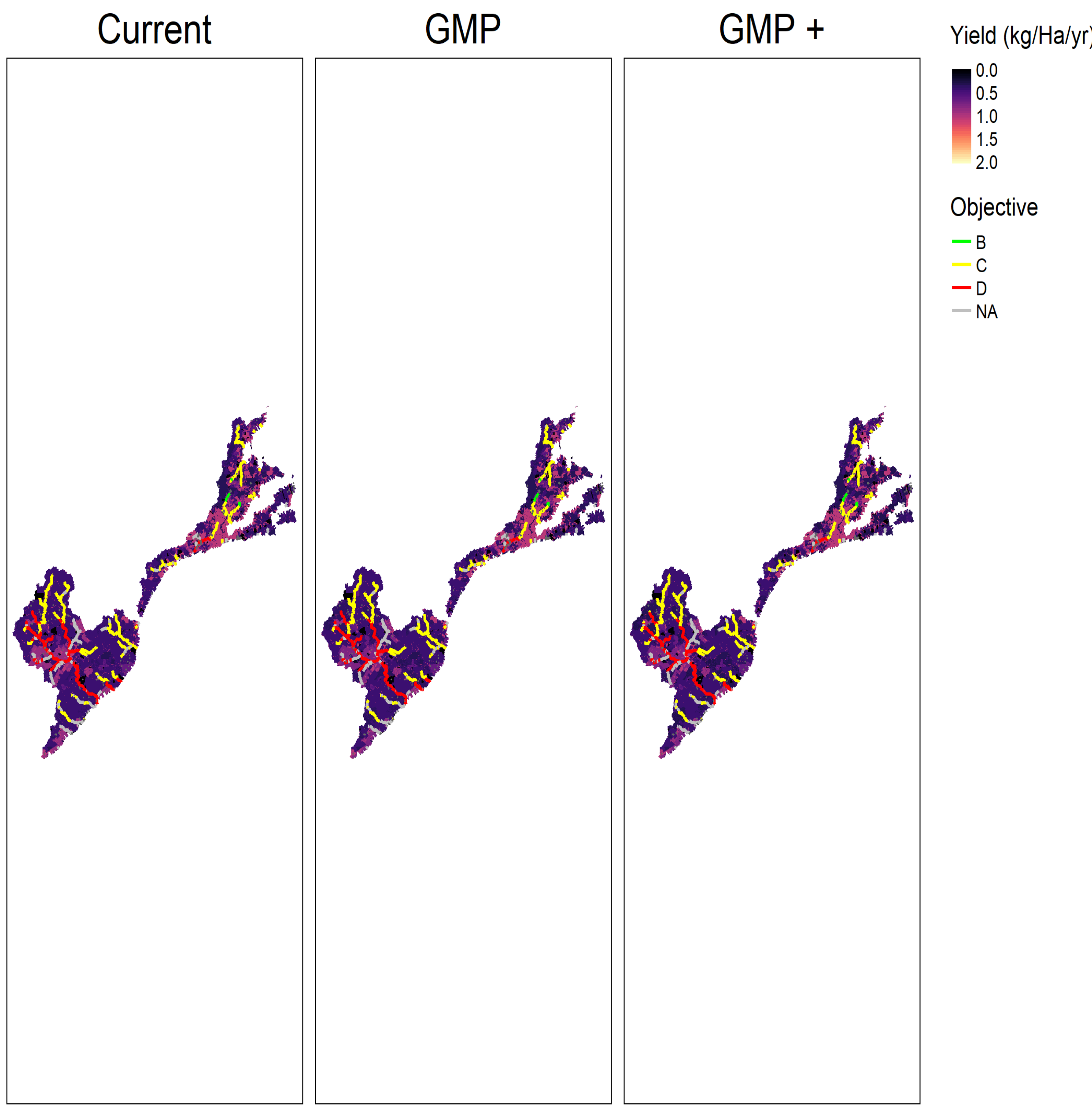

Figure 19: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute state outcome for each river segment under the current, GMP, and GMP+ scenarios in the Dunedin Coast FMU.

Estuaries

The Dunedin Coast FMU contains seven estuaries for which required reductions are available (Table 19). Akatore Creek Estuary is *as likely as not* to comply with the C-band target attribute state under the current and GMP with slight improvement under the GMP+ scenario. The B- and A-band target attribute state are *very unlikely* to be complied with under all scenarios.

Blueskin Bay is *very likely* to comply with the C-band under all three scenarios. The B-band target attribute state is *likely* to be complied with under the current scenario with slight improvement under the GMP and GMP+ scenarios. Compliance with the A-band target attribute state is *very unlikely* under all scenarios.

The Kaikorai Estuary is *very unlikely* to comply with the C-band target attribute state under all three scenarios. And *very unlikely* to comply with the B or A-band target attribute states.

The Otago Harbor is *very likely* to comply with the A-band target attribute state under all three scenarios.

Papanui Inlet is *very likely* to comply with the B- and C-band target attribute states under all three scenarios. Compliance with the A-band target attribute state is *very likely* under the current scenario and improves under the GMP scenario and GMP+ scenarios.

Purakaunui Inlet is *very likely* to comply with the C- and B-band target attribute states under all scenarios. Compliance with the A-band target attribute state is *very unlikely* under the current scenario with slight improvement under the GMP and GMP+ scenarios.

The Tokomairiro River Estuary is *very unlikely* to comply with the C, B, or A-band target attribute states under any scenario. The probability of complying with the C-band improves slightly under the GMP and GMP+ scenarios.

Table 19: Probability of compliance of estuaries in the Dunedin Coast FMU with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval. Where phosphorus probabilities are blank, phosphorus is not considered to be a key nutrient for estuary health.

		Nitrogen			Phosphorus		
Estuary	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Akatore Creek	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)			
Akatore Creek	B	4 (2 - 9)	4 (2 - 9)	4 (2 - 9)			
Akatore Creek	C	30 (23 - 38)	30 (23 - 38)	31 (24 - 39)			
Blueskin Bay	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)			
Blueskin Bay	B	75 (67 - 81)	78 (70 - 84)	79 (72 - 85)			
Blueskin Bay	C	99 (96 - 100)	100 (97 - 100)	100 (97 - 100)			
Kaikorai Stream	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Kaikorai Stream	B	1 (0 - 4)	1 (0 - 4)	1 (0 - 4)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Kaikorai Stream	C	6 (3 - 11)	6 (3 - 11)	6 (3 - 11)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Otago Harbour	A	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Otago Harbour	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Otago Harbour	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Papanui Inlet	A	84 (77 - 89)	85 (78 - 90)	88 (82 - 92)			

		Nitrogen			Phosphorus		
Estuary	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Papanui Inlet	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)			
Papanui Inlet	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)			
Purakaunui Inlet	A	2 (1 - 6)	4 (2 - 9)	4 (2 - 9)			
Purakaunui Inlet	B	95 (90 - 98)	95 (90 - 98)	96 (91 - 98)			
Purakaunui Inlet	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)			
Tokomairiro River	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)			
Tokomairiro River	B	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)			
Tokomairiro River	C	1 (0 - 4)	2 (1 - 6)	3 (1 - 7)			

Taieri FMU

Land use characteristics

Land use in the Taieri FMU (Table 20; Figure 20) is comprised primarily of sheep and beef (57%), conservation (10%), mixed stock (8%), sheep (5%), exotic forestry (5%) and dairy (4%). The GMP and GMP+ mitigations packages can be applied to approximately 77% of the FMU based on land use.

Table 20: Land use statistics for the Taieri FMU

Land Use	Area (Ha)	Percent
Arable	253.95	0.04%
Beef	9,578.55	1.68%
Commercial Use	26.87	0.00%
Conservation	54,792.56	9.60%

Land Use	Area (Ha)	Percent
Dairy	23,434.99	4.11%
Dairy Support	1,267.43	0.22%
Exotic Forestry	30,162.54	5.29%
Horticulture	88.42	0.02%
Industrial Use	157.82	0.03%
Lakes & Rivers	6,850.87	1.20%
Lifestyle Block	2,502.77	0.44%
Livestock Support	2,126.22	0.37%
Majority Deer with Mixed Livestock	472.45	0.08%
Mixed Livestock	43,436.12	7.61%
Nurseries & Orchards	75.88	0.01%
Other Animals	370.78	0.06%
Poultry	22.72	0.00%
Public Use	37.15	0.01%
Residential Use	909.03	0.16%
Road & Rail	6,982.56	1.22%
Sheep	34,135.56	5.98%
Sheep & Beef	324,394.20	56.86%
Small Land Holding	2,438.30	0.43%
Specialist Deer	444.12	0.08%
Tourism & Recreational Use	2,086.97	0.37%
Unknown Land Use	12,156.04	2.13%
Unknown Land Use - Indigenous Cover	2,877.17	0.50%
Unknown Land Use - Non-agricultural	3,009.15	0.53%
Unknown Land Use - Pastoral Cover	5,450.52	0.96%

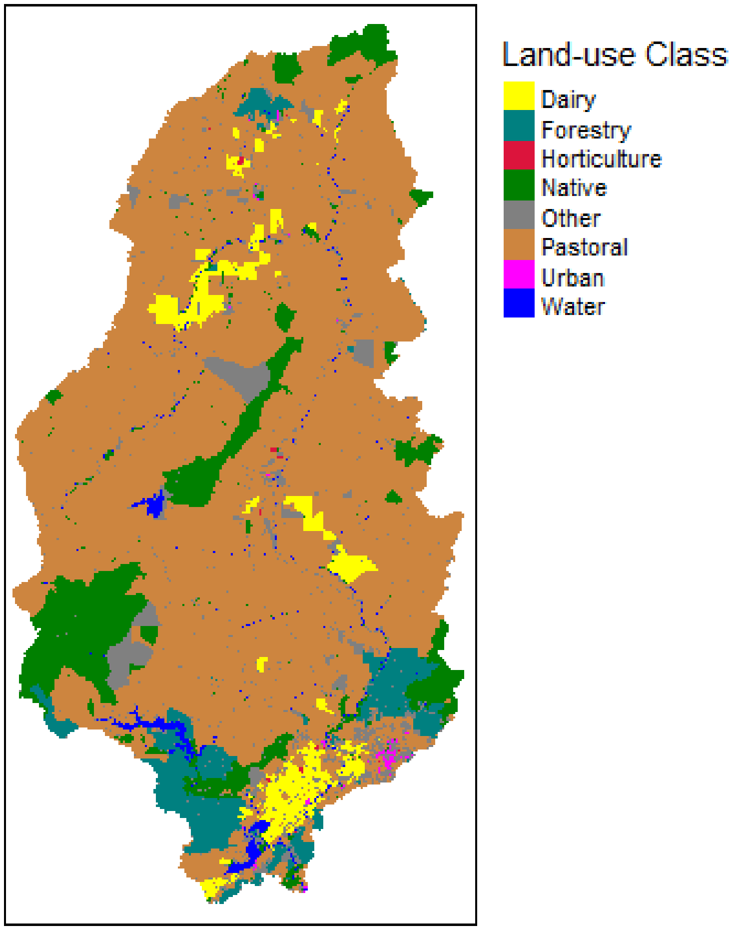

Figure 20: Land-use within the Taieri FMU. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

In the Taieri FMU, the GMP scenario results in approximately an 8% reduction in nitrogen and 9% reduction phosphorus emissions whereas the GMP+ scenario results in an 22% reduction of nitrogen and 17% reduction in phosphorus emissions (Table 21). These reductions result in the FMUs overall average yield decreasing from 7.54 kg/ha/yr of nitrogen under the current scenario to 6.92 kg/ha/yr and 5.92 kg/ha/yr under the GMP and GMP+ scenarios respectively (Table 22). The average phosphorus yield decreases from 0.41 kg/ha/yr under the current scenario to 0.38 kg/ha/yr and 0.35 kg/ha/yr under the GMP and GMP+ scenarios, respectively.

Table 21: Total on-land nitrogen and phosphorus load reductions achieved through GMP and GMP+ scenarios for the Taieri FMU.

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	8.31%	357,821.36	21.55%	927,478.66
P	8.72%	20,649.38	16.57%	39,227.84

Table 22: Average yield of nitrogen and phosphorus under current, GMP and GMP+ scenarios for the Taieri FMU.

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	7.54	6.92	5.92
P	0.41	0.38	0.35

Rivers

Yields

Spatially, the highest yield areas for both nitrogen and phosphorus in the Taieri FMU occur in the upper Taieri, near Waipiata, and on the lower Taieri plain near Dunedin (Figure 21;Figure 22). Under the GMP and GMP+ scenarios, average upstream yields of nitrogen decreased with larger decreases occurring in these areas. Phosphorus yields decreased in the upper catchment. Higher yields of phosphorus remain on the lower Taieri plain under both the GMP and GMP+ scenarios.

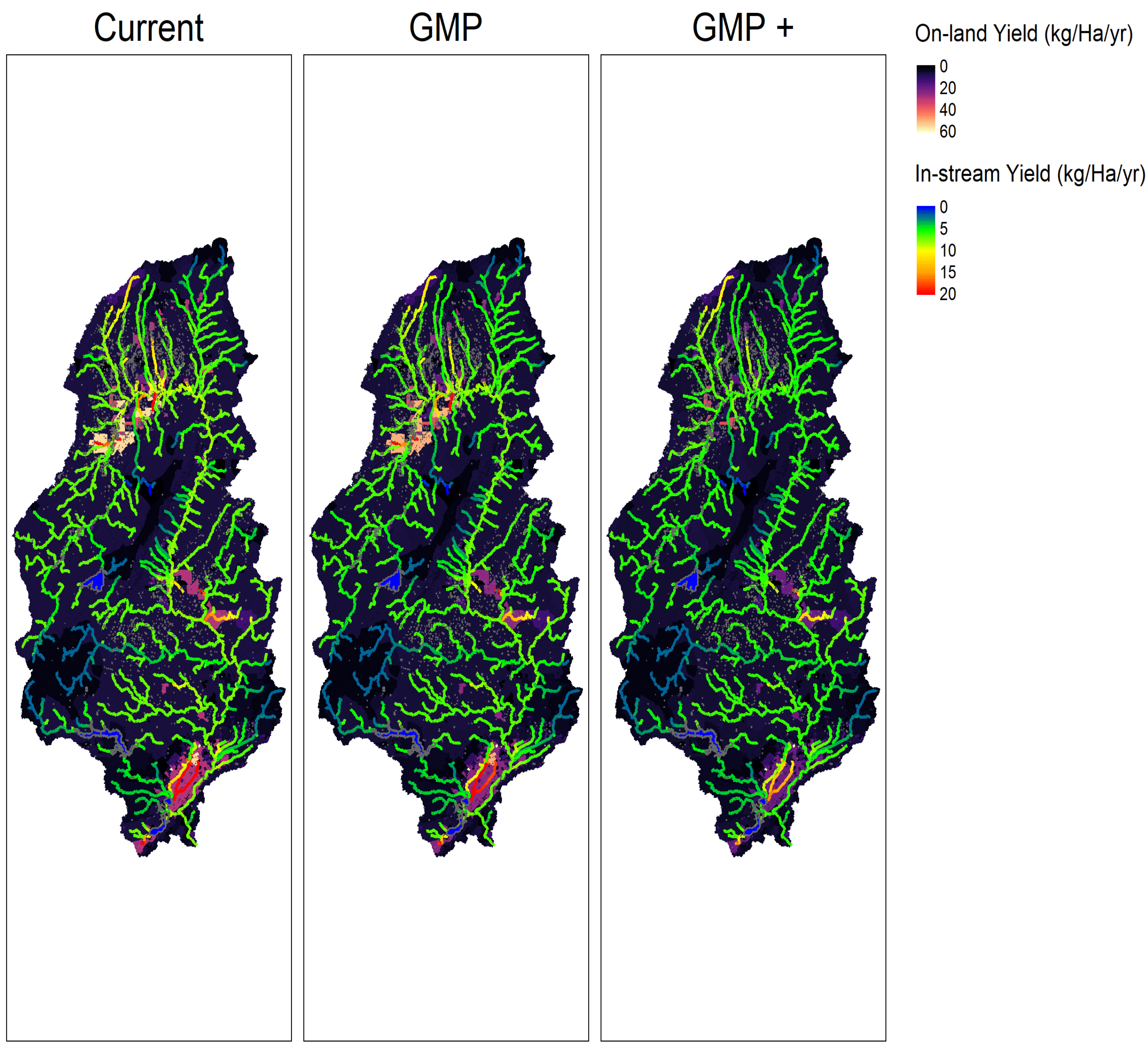

Figure 21: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for current, GMP, and GMP+ scenarios in the Taieri FMU.

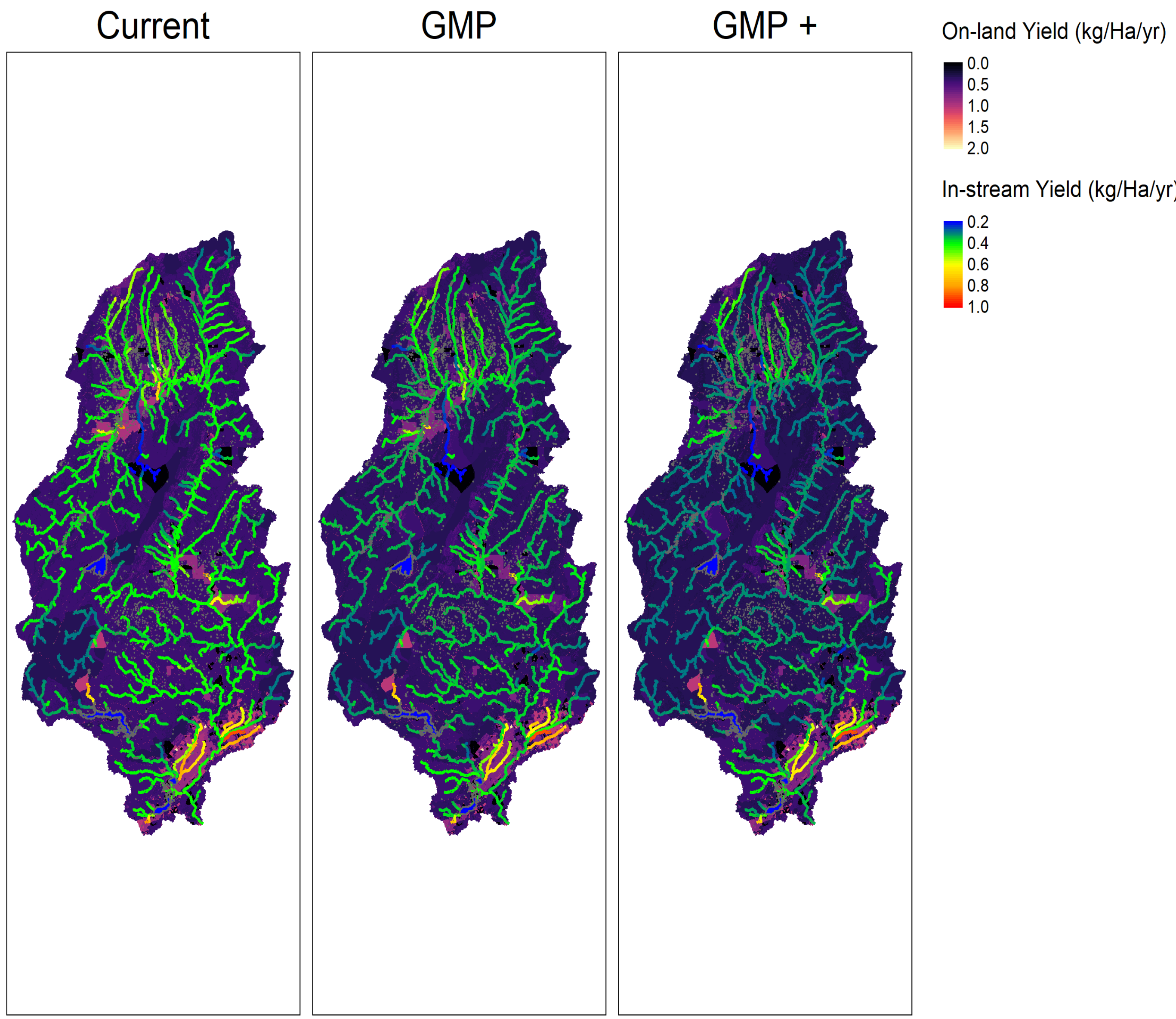

Figure 22: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for current, GMP, and GMP+ scenarios in the Taieri FMU.

Nitrate Toxicity

Nearly all segments in all classes comply with the nitrate toxicity B-band target attribute state; Table 23; Table 24). *No reduction is required* to comply with the national bottom line. *Nearly all* of the Taieri FMU also complies with the A-band nitrate toxicity target attribute state under all scenarios meaning *no reduction is required* to comply.

When split by management class (Table 24), *nearly all* mountain and hill-fed segments comply with the A-band nitrate toxicity target attribute state. *No reduction is required* in these classes. *Nearly all* lowland class segments comply with the A-band target attribute state currently. In this class, a *reduction may be required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly. In the lower lake class, *nearly all* segments, comply under the current scenario. For all segments to comply, a *reduction may be required*. Under the GMP and GMP+ scenarios the proportion of segments expected to comply improves.

Table 23: Percent of river segments complying with potential nitrate toxicity target attribute states in the Taieri FMU with 90 percent confidence intervals for current, GMP, and GMP+ scenarios. The national bottom line is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	99 (97 - 100)	100 (97 - 100)	100 (98 - 100)	3,265
B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,265
C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,265

Table 24: Percent of river segments complying with potential nitrate toxicity target attribute states in the Taieri FMU, split by management class, with 90 percent confidence intervals for current, GMP, and GMP+ scenarios. The national bottom line is the B-band.

	Nitrate Toxicity				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
M	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	352
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	352
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	352

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	2,076
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	2,076
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	2,076
L	A	96 (78 - 100)	97 (79 - 100)	98 (85 - 100)	241
L	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	241
L	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	241
Lk Lower	A	96 (85 - 100)	97 (88 - 100)	97 (88 - 100)	36
Lk Lower	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	36
Lk Lower	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	36

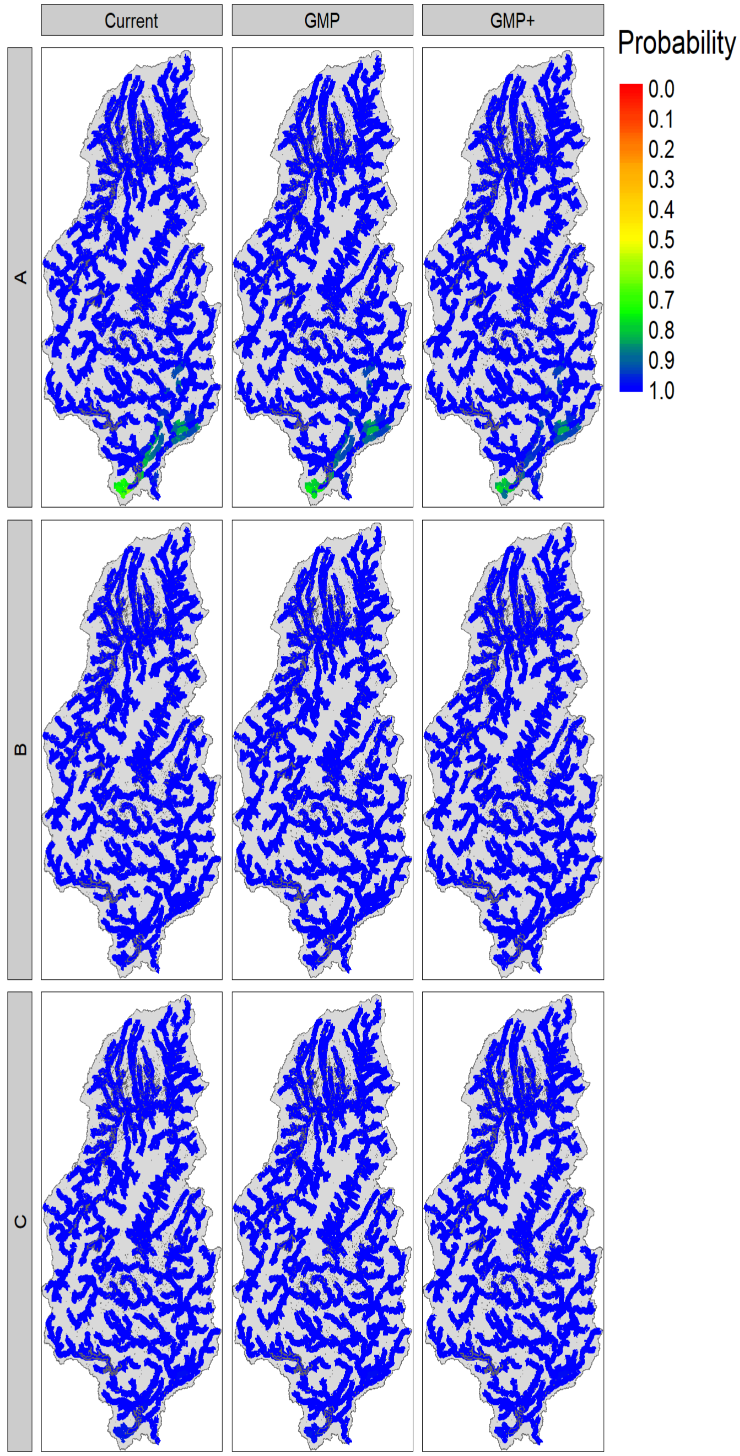

Figure 23: Individual segment probability of complying with the A, B, and C nitrate toxicity target attribute states under current, GMP, and GMP+ scenarios in the Taieri FMU.

All of the Taieri FMU is *very likely* to comply with the B-band nitrate toxicity target attribute state, thus complying with the national bottom line (Figure 23). The majority of the FMU is also *very likely* to comply with the A band nitrate toxicity target attribute state under all scenarios. Areas on the lower Taieri plain range from *likely* to *very likely* to comply with the A-band target attribute state under the current scenario and improve to *very likely* under the GMP and GMP+ scenarios.

Periphyton

For total nitrogen in relation to the periphyton biomass nutrient criteria (Table 25), *nearly all* segments in the Taieri FMU comply with the C-band criteria under the current scenario. Reductions *may be* required for all segments to comply. Under the GMP scenario, the proportion of segments expected to comply improves slightly with no further improvements under GMP+. *Most* segments comply with the B-band total nitrogen criteria under the current scenario with improvement under the GMP and GMP+ scenarios. However, the confidence interval fails to overlap 100% indicating 95% confidence a reduction beyond GMP+ *is required* for all segments to comply.

For total phosphorus in relation to the periphyton biomass nutrient criteria (Table 25), *nearly all* segments in the Taieri FMU comply with the C-band criteria under the current scenario. A reduction *is required* for all segments to comply with the C-band as the upper confidence interval fails to overlap 100%. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves. Reductions beyond GMP+ *may be* required for all segments to comply. *Few* segments comply with the B-band criteria under the current scenario which improves to *some* under the GMP and GMP+ scenarios. A reduction beyond GMP+ *is required* for all segments to comply with the B-band criteria.

Few segments in any class comply with the A-band criteria for both total nitrogen and phosphorus. This indicates the A-band nutrient criteria would not naturally be expected to be complied with in 80% of segments.

When split by management class, for the total nitrogen C-band criteria (Table 26), *nearly all* mountain, hill, and lowland lake segments comply under all modelled scenarios. *No reduction is required* to comply in these classes. *Most,* lowland segments comply with the C-band total nitrogen criteria under the current scenario. Under the GMP and GMP+ scenarios, the proportion expected to comply improves. However, a reduction beyond GMP+ *may be* required for all segments to comply. This may require reductions in upstream mountain and hill segments despite those classes meeting their respective criteria.

When split by management class, for the total nitrogen B-band criteria (Table 26), *all* mountain and lowland lake segments currently comply. Confidence intervals indicate *no reduction is required* for all segments to comply in the mountain class whereas a reduction *may be* required for all segments to comply in the lower lake class. In the hill management class, *most* segments comply with the B-band total nitrogen criteria under the current scenario with improvement under both the GMP and GMP+ scenarios. Reductions beyond the GMP+ scenario *may be* required for all segments to comply. Under all three scenarios, the confidence intervals are wide indicating uncertainty in the load reduction required to comply with the criteria. *Few* lowland segments comply with the B-band (1%; 0-1) total nitrogen criteria under any of the three scenarios modelled. A reduction beyond GMP+ *is required* for all segments to comply. The upper lake management class comprises a small portion of the FMU (i.e., only 5 segments present) and thus has been removed from these analyses.

When split by management class, for the total phosphorus C-band criteria (Table 26), *all* mountain segments comply currently indicating *no reduction is required*. For hill-fed segments *nearly all* segments comply with the C-band total phosphorus criteria under the current scenario. Confidence intervals indicate a reduction *may be* required for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly. Reductions beyond GMP+ *may be* required for all segments to comply. In the lowland management class *most,* segments comply with the C-band criteria under the current scenario. Confidence intervals indicate reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion expected to comply improves slightly. However, confidence intervals indicate a reduction beyond GMP+ *is required* for all segments to comply. *Nearly all* lowland lake segments comply with C-band criteria under the current scenario with improvement under the GMP and GMP+ scenarios. Confidence intervals indicate a reduction beyond GMP+ *may be* required for all segments to comply.

When split by management class, for the total phosphorus B-band criteria (Table 26), *most* mountain segments comply under the current and GMP scenarios. Under the GMP+ scenario, *nearly all* segments comply. However, the confidence interval indicates reductions beyond GMP+ *may be* required for all segments to comply. *Few* hill, lowland, and lower lake class segments comply with the B-band criteria under any scenario. Reductions beyond GMP+ *are required* for all segments in the hill and lowland classes to comply. Reductions beyond GMP+ *may be* required in the lower lake class for all segments to comply.

Table 25: Percent of river segments in the Taieri FMU complying with Snelder et al., 2023 20% under protection risk periphyton nutrient criteria, with 90 percent confidence intervals for the current, GMP, and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			**Total Phosphorus**				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	3 (0 - 17)	3 (0 - 21)	4 (0 - 28)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	2,710
B	61 (25 - 91)	65 (31 - 91)	68 (34 - 91)	18 (13 - 41)	20 (14 - 48)	21 (14 - 53)	0	2,710
C	98 (93 - 100)	98 (94 - 100)	98 (94 - 100)	85 (46 - 99)	88 (52 - 100)	90 (57 - 100)	0	2,710

Table 26: Percent of river segments in the Taieri FMU complying with Snelder et al., 2023 20% under protection risk periphyton nutrient criteria, split by management class, with 90 percent confidence intervals for the current, GMP, and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			**Total Phosphorus**				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	A	8 (0 - 79)	9 (0 - 93)	9 (0 - 95)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	352
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	76 (56 - 100)	79 (58 - 100)	82 (59 - 100)	0	352

		Total Nitrogen			Total Phosphorus				
Management Class	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+	Periphyton exempt	Total segments
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	352
H	A	2 (0 - 9)	2 (0 - 12)	3 (0 - 20)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	2,076
H	B	61 (15 - 100)	66 (22 - 100)	70 (25 - 100)	11 (7 - 33)	12 (8 - 42)	13 (8 - 49)	0	2,076
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	85 (38 - 100)	88 (46 - 100)	90 (52 - 100)	0	2,076
L	A	1 (0 - 1)	1 (0 - 1)	1 (0 - 3)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	241
L	B	1 (0 - 1)	1 (0 - 1)	1 (0 - 4)	2 (0 - 15)	3 (0 - 15)	3 (0 - 16)	0	241
L	C	74 (25 - 100)	77 (29 - 100)	80 (34 - 100)	70 (27 - 94)	73 (29 - 95)	76 (32 - 95)	0	241
Lk Lower	A	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	36
Lk Lower	B	95 (81 - 100)	96 (83 - 100)	98 (83 - 100)	8 (0 - 81)	9 (0 - 81)	10 (0 - 81)	0	36
Lk Lower	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	96 (81 - 100)	97 (81 - 100)	97 (83 - 100)	0	36

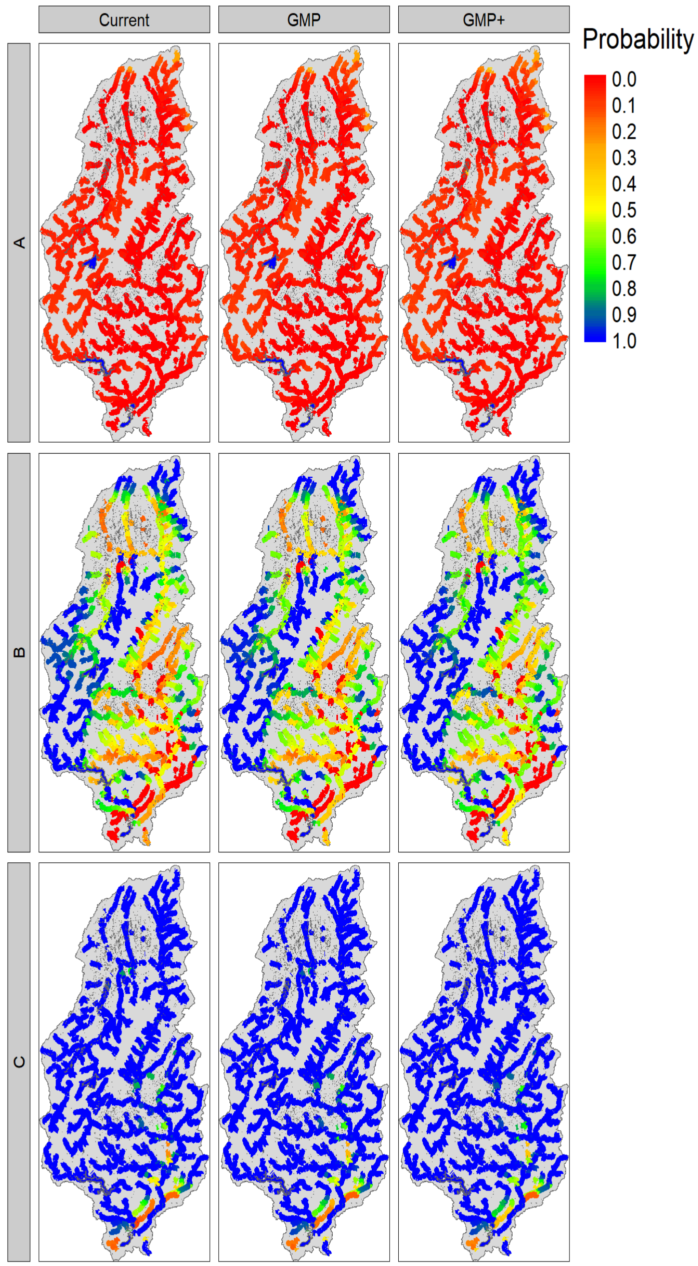

Figure 24: Individual segment probability of complying with the total nitrogen A, B, and C periphyton criteria under the current, GMP, and GMP+ scenarios in the Taieri FMU.

Spatially, for total nitrogen (Figure 24), the majority of the Taieri FMU is *very likely* to comply with the C-band criteria. Compliance with the B-band criteria varies ranging from *very likely* to comply in higher elevation tributaries to *as likely as not* or *unlikely* to comply in areas of the lower catchment. All segments are *very unlikely* to comply with the A-band total nitrogen criteria under any modelled scenario.

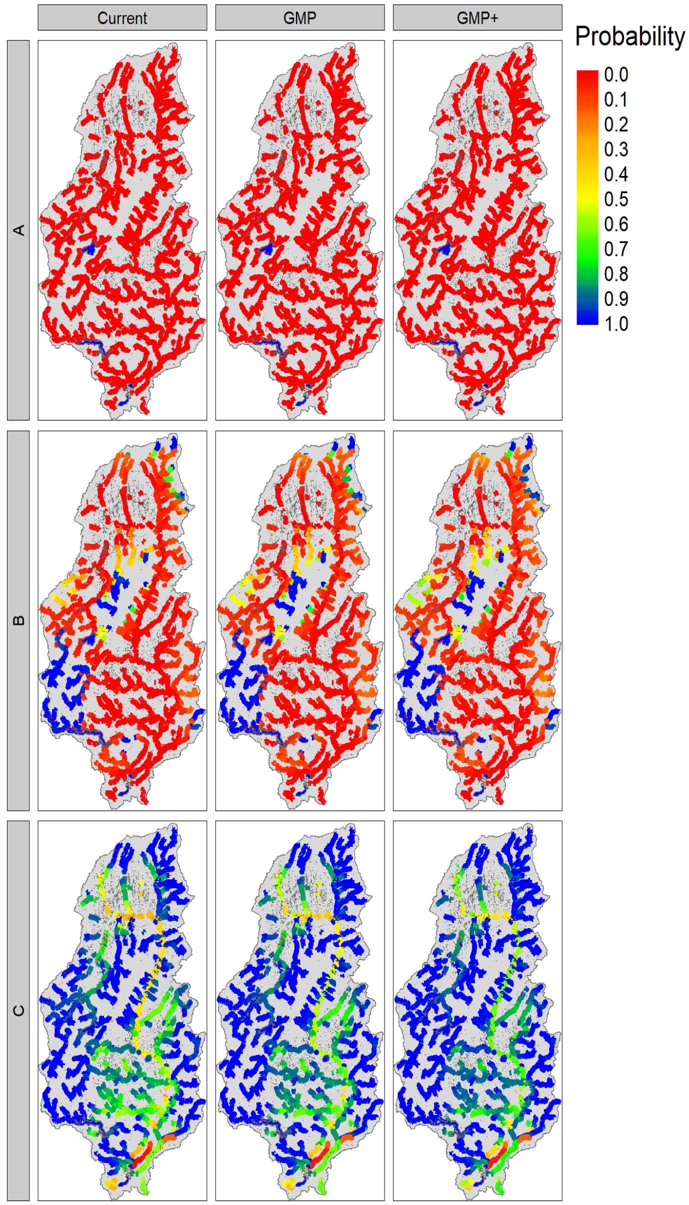

Figure 25: Individual segment probability of complying with the total phosphorus A, B, and C periphyton criteria under the current, GMP, and GMP+ scenarios in the Taieri FMU.

Spatially, for total phosphorus (Figure 25), the majority of the Taieri FMU is *likely* to *very likely* to comply with the C-band criteria under all scenarios. The mainstem of the Taieri improves from *unlikely* to *as likely as not* to comply under the current scenario to *likely* to comply under the GMP+ scenario for most of its length. The majority of the catchment is *very unlikely* to comply with the B-band criteria under all scenarios modelled. The exception are high elevation tributaries of the upper catchment which range from un*likely* to *very likely* to comply with the B-band criteria under all scenarios. All segments are *very unlikely* to comply with the A-band criteria under any modelled scenario.

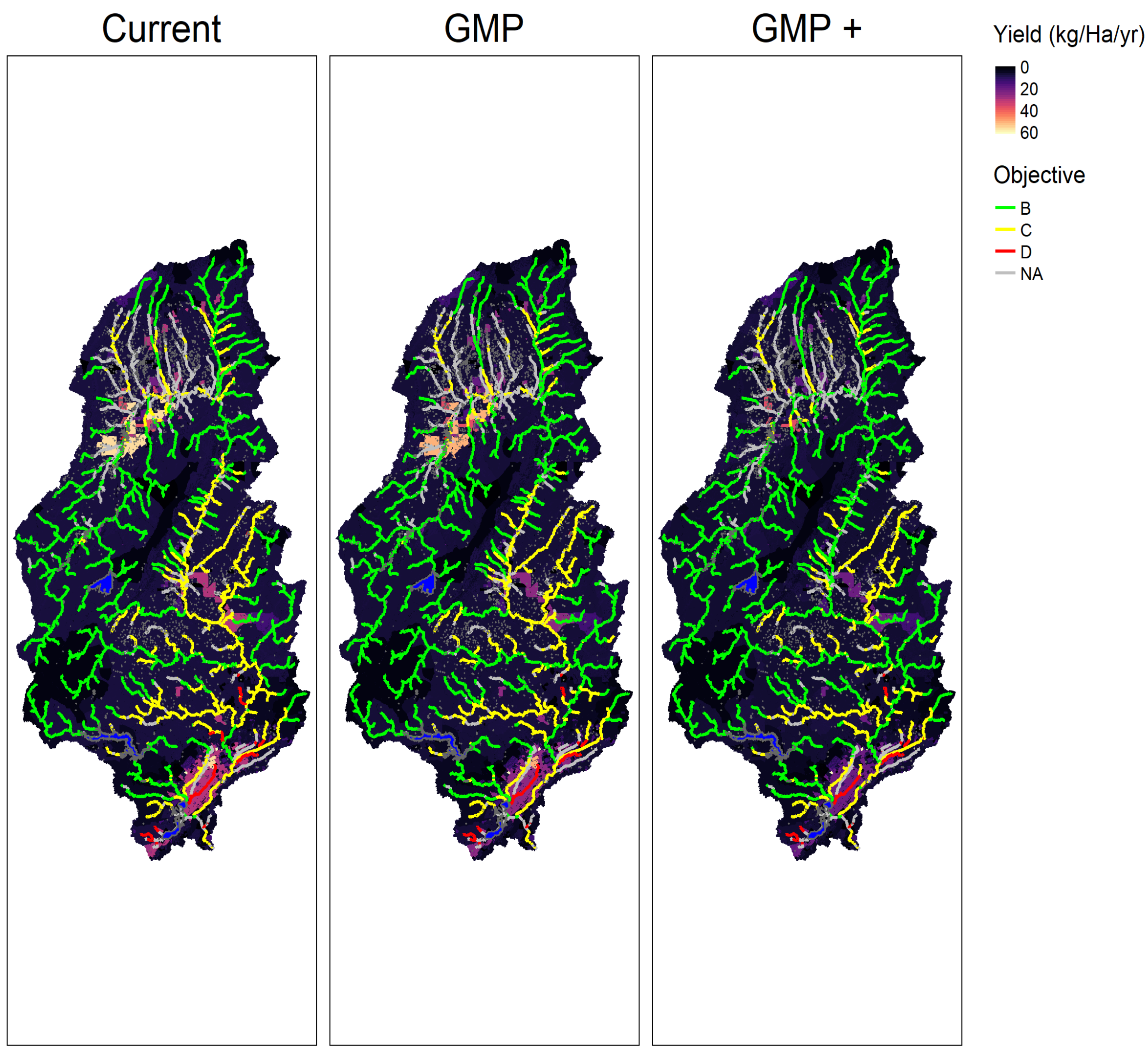

Figure 26: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization total nitrogen periphyton target attribute state outcome for each river segment under the current, GMP, and GMP+ scenarios in the Taieri FMU.

The mean realization nitrogen comparison (Figure 26) results in the majority of the catchment complying with the B-band criteria with the exception of the Taieri mainstem and few major tributaries which comply with the C-band criteria under the current scenario. Under the GMP and

GMP+ scenarios segments on the mainstem change from complying with the C band criteria to also complying with the B-band criteria.

The mean phosphorus realization comparison (Figure 27) results in the majority of the catchment complying with the C-band criteria. However, the mainstem fails to comply with the C-band criteria. However, under the GMP and GMP+ scenarios, the mainstem compliance improves in mid to lower reaches of the catchment but still fails near Waipiata and the Kyeburn confluence. Some upper catchment tributaries comply with the B-band criteria under all scenarios.

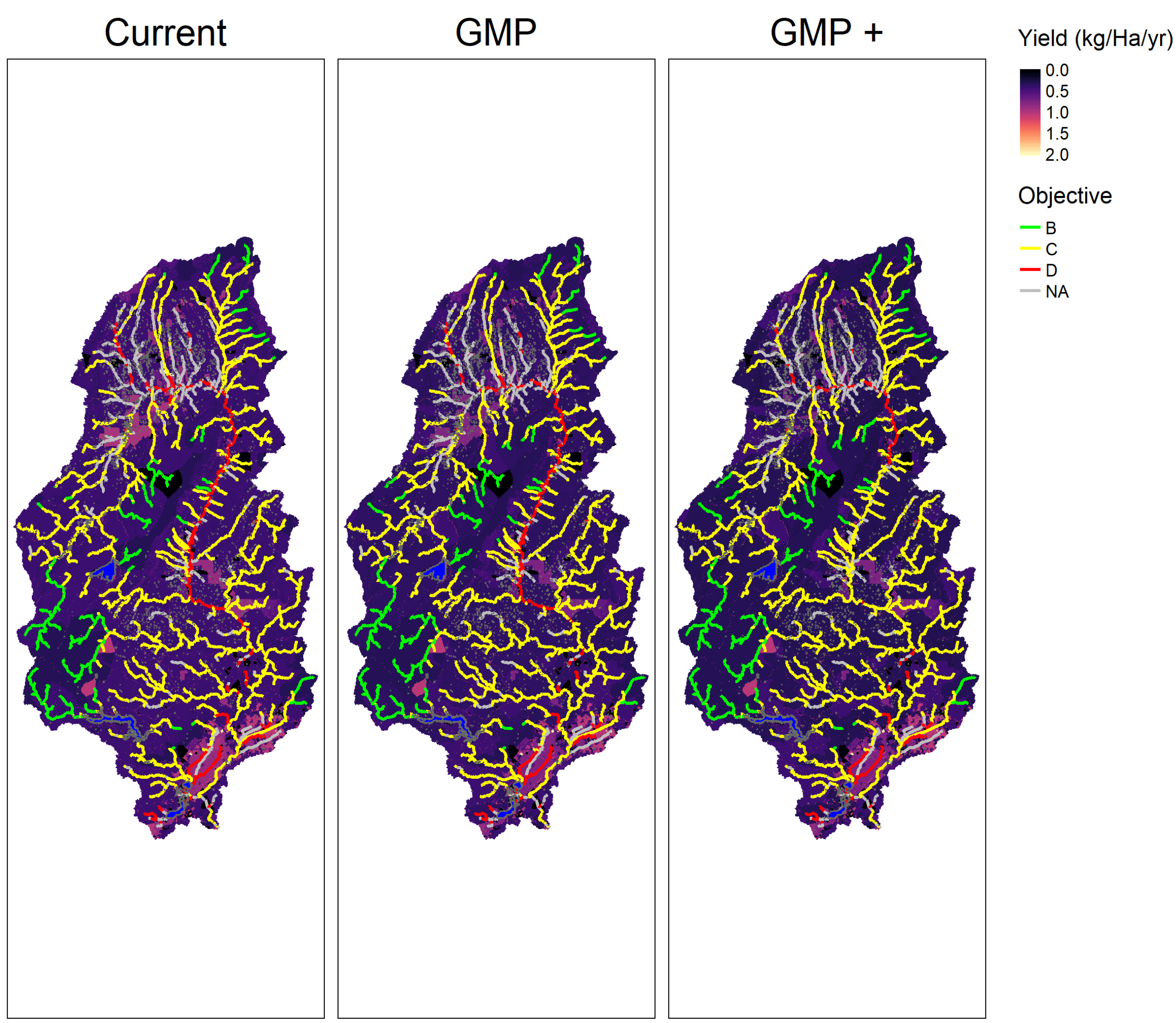

Figure 27: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute state outcome for each river segment under current, GMP, and GMP+ scenarios in the Taieri FMU.

Lakes

Nitrogen

The Taieri FMU has five named lakes with modelling results available (Table 27), the West Eweburn Dam, Lake Waihola, Lake Waipori, Lake Mahinerangi, and Logan Burn. For total nitrogen, lakes Waihola and Waipori are *very unlikely* to comply with the C, B, and A-band total nitrogen target attribute state under all scenarios. Probabilities of compliance in Waihola improve under the GMP+ scenario.

The West Eweburn Dam is *very likely* to comply with the C-band under all scenarios and therefore requires no reduction to comply with this band. For the B-band target attribute state West Eweburn Dam is *very likely* to comply the under the current scenario with improved probabilities under GMP and GMP+. Compliance with the A-band target attribute state is very unlikely under all scenarios but improves under the GMP and GMP+ scenarios.

Lake Mahinerangi is *very likely* to comply with the B- and C-band target attribute state under all scenarios. Probabilities of complying with the B-band increase under the GMP scenario with no further increase under GMP+. The A-band target attribute state is *very unlikely* to be complied with under any scenario with improvement under GMP.

Logan Burn is currently *very likely* to comply with the C and B-band target attribute states. Therefore, no reductions are required to comply with these bands. Compliance with the A-band is *as likely as not* under the current scenario. Under the GMP scenario this improves to *likely* with further improvement under GMP+.

Phosphorus

For total phosphorus, all lakes are *very unlikely* to comply with the A-band target attribute state under all scenarios (Table 27).

The West Eweburn Dam is *very likely* to comply with the C-band target attribute state under the current, GMP and GMP+ scenarios and *very unlikely* to comply with the B-band target attribute state. Probabilities of complying improve under the GMP scenario with further improvement under GMP+.

Lake Waihola is *unlikel*y to comply with the C-band target attribute state and is *very unlikely* to comply with the B-band under all scenarios. Probability of complying does improve under both GMP and GMP+.

Under the current, GMP, and GMP+ scenarios Lake Waipori is *as likely as not* to comply with the C-band target attribute state and *very unlikely* to comply with B-band. Probability of complying improves under GMP with no further improvement under GMP+.

Mahinerangi is *very likely* to comply with the C-band target attribute state all scenarios with no change in probability. Compliance with the B-band target attribute state is *unlikely* under the current scenario with improvement under GMP. Under GMP+, compliance improves to *as likely as not*.

Logan Burn is *very likely* to comply with the C-band target attribute state under all scenarios. Compliance with the B-band target attribute state is *likely* under the current scenario and improves to *very likely* under the GMP scenario. Under the GMP+ scenario, probability of compliance increases further.

Table 27: Probability of compliance of lakes with potential target attribute states in the Taieri FMU across the Monte Carlo realisations with a Bernouilli 90% confidence interval.

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
West Eweburn Dam	A	4 (2 - 9)	6 (3 - 11)	9 (5 - 15)	0 (0 - 3)	0 (0 - 3)	1 (0 - 4)
West Eweburn Dam	B	84 (77 - 89)	86 (79 - 91)	87 (80 - 92)	12 (8 - 18)	17 (12 - 24)	20 (14 - 27)
West Eweburn Dam	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	86 (79 - 91)	90 (84 - 94)	93 (88 - 96)
Lake Waihola	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Lake Waihola	B	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Lake Waihola	C	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	27 (20 - 35)	33 (26 - 41)	34 (27 - 42)
Lake Waipori	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Lake Waipori	B	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	1 (0 - 4)	1 (0 - 4)	1 (0 - 4)
Lake Waipori	C	1 (0 - 4)	1 (0 - 4)	5 (2 - 10)	51 (43 - 59)	53 (45 - 61)	53 (45 - 61)
Lake Mahinerangi	A	4 (2 - 9)	6 (3 - 11)	6 (3 - 11)	7 (4 - 12)	7 (4 - 12)	7 (4 - 12)
Lake Mahinerangi	B	86 (79 - 91)	87 (80 - 92)	87 (80 - 92)	35 (28 - 43)	37 (29 - 45)	40 (32 - 48)

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Lake Mahinerangi	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	98 (94 - 99)	98 (94 - 99)	98 (94 - 99)
Logan Burn	A	59 (51 - 67)	63 (55 - 71)	66 (58 - 73)	10 (6 - 16)	10 (6 - 16)	10 (6 - 16)
Logan Burn	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	77 (69 - 83)	82 (75 - 87)	84 (77 - 89)
Logan Burn	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)

Estuaries

The Taieri River Estuary is a deep, river dominated, estuary (Table 28). Currently, the Taieri Estuary is *very unlikely* to comply with the C, B and A-band target attribute states. Under the GMP and GMP+ scenarios the probabilities of complying with the C band improve.

Table 28: Probability of compliance of estuaries in the Taieri FMU with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval. Where phosphorus probabilities are blank, phosphorus is not considered to be a key nutrient.

		Total Nitrogen			Total Phosphorus		
Estuary	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Taieri River	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)			
Taieri River	B	1 (0 - 4)	1 (0 - 4)	1 (0 - 4)			
Taieri River	C	9 (5 - 15)	12 (8 - 18)	22 (16 - 30)			

Clutha FMU

Due to its size, the Clutha FMU is split into five Rohe: Upper Lakes, Dunstan, Manuherekia, Roxburgh, and Lower Clutha. Results for each individual Rohe and the whole of the FMU are presented. Rohe reductions here are non-cumulative; the Clutha mainstem reductions achieved within each Rohe's results are the sum of the reductions achieved within that Rohe. The mainstem results from the whole of FMU are presented in the Whole of Clutha Mata-Au section and are cumulative within the mainstem.

Upper Lakes Rohe

Land use characteristics

Land use in the Upper Lakes Rohe (Table 29; Figure 28) is comprised primarily of conservation (45%), sheep and beef (20%), mixed livestock (12%), rivers and lakes (11%), and other indigenous cover. In this Rohe, the GMP and GMP+ mitigations packages can be applied to approximately 37% of the FMU based on current land use. Given the large portion of the FMU in conservation estate, intervention tools are somewhat limited in this Rohe and large reductions in total Rohe load through mitigation measures are unlikely.

Table 29: Land use statistics for the Upper Lakes Rohe

Land Use	Area (Ha)	Percent
Arable	1.36	0.00%
Beef	2,623.17	0.38%
Commercial Use	67.41	0.01%
Conservation	312,933.33	44.77%
Exotic Forestry	775.20	0.11%
Industrial Use	16.89	0.00%
Lakes & Rivers	74,533.46	10.66%
Lifestyle Block	1,021.01	0.15%
Livestock Support	79.47	0.01%
Mixed Livestock	84,051.28	12.03%
Nurseries & Orchards	80.12	0.01%
Other Animals	72.55	0.01%
Public Use	28.20	0.00%
Residential Use	1,386.14	0.20%
Road & Rail	1,367.99	0.20%
Sheep	2,195.69	0.31%
Sheep & Beef	165,376.84	23.66%
Small Land Holding	327.00	0.05%
Specialist Deer	64.22	0.01%
Tourism & Recreational Use	3,919.05	0.56%
Unknown Land Use	1,790.41	0.26%
Unknown Land Use - Indigenous Cover	44,593.94	6.38%
Unknown Land Use - Non-agricultural	27.99	0.00%
Unknown Land Use - Pastoral Cover	1,615.49	0.23%

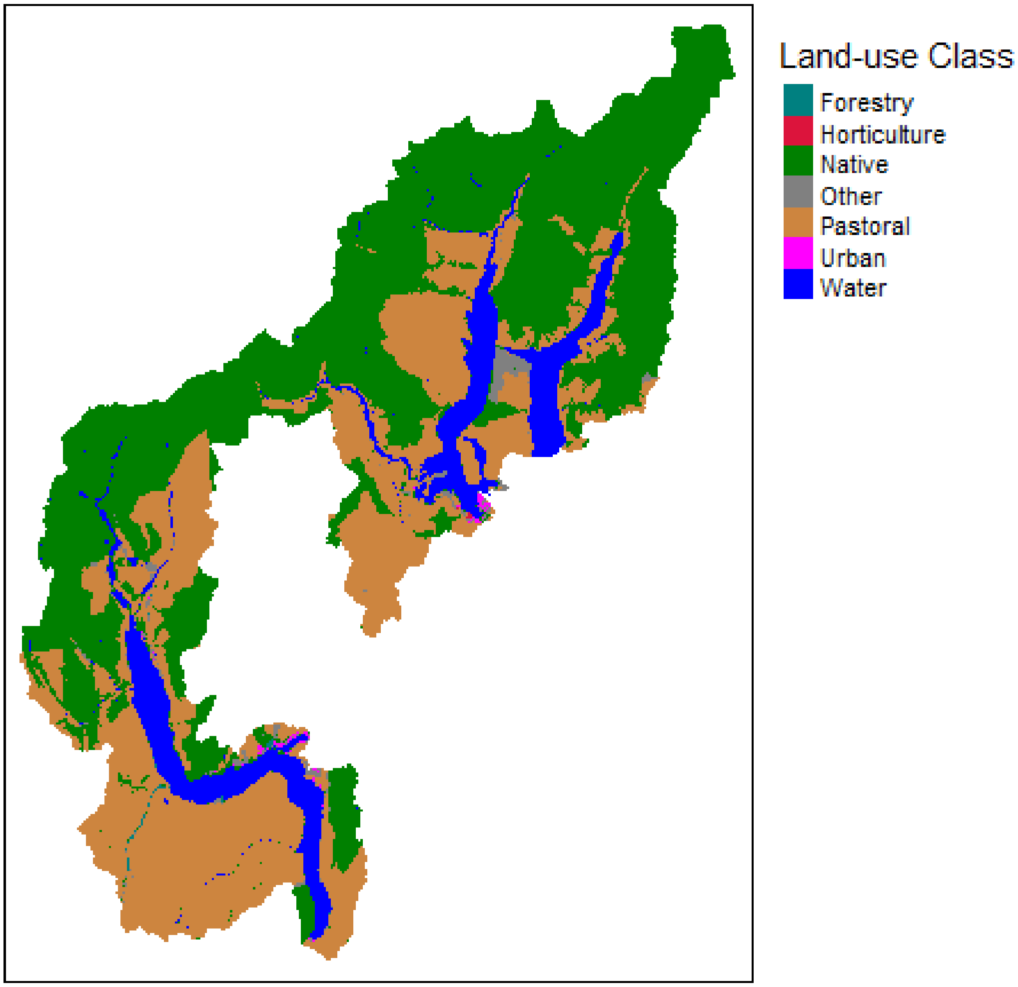

Figure 28: Land-use within the Upper Lakes Rohe. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

In the Upper Lakes Rohe, the GMP scenario results in approximately a 1% reduction in nitrogen and 0.6% reduction phosphorus whereas the GMP+ scenario results in a 3% reduction of nitrogen emissions and 4% reduction in phosphorus emissions *(*Table 30*)*. These reductions result in the FMUs overall average yield decreasing from 4.90 kg/ha/yr of nitrogen under the current scenario to 4.85 kg/ha/yr and 4.78 kg/ha/yr under the GMP and GMP+ scenarios respectively *(*Table 31*)*. The average phosphorus yield decreases from 0.48 kg/ha/yr under the current and GMP scenarios to 0.46 kg/ha/yr under the GMP+ scenario.

Table 30: Total on-land nitrogen and phosphorus load reductions achieved through GMP and GMP+ scenarios in the Upper Lakes Rohe.

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	1.05%	35,862.65	2.52%	86,377.71
P	0.61%	2,055.35	3.86%	12,971.14

Table 31: Average yield of nitrogen and phosphorus under current, GMP and GMP+ scenarios in the Upper Lakes Rohe.

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	4.90	4.85	4.78
P	0.48	0.48	0.46

Rivers

Yields

Spatially, the highest yield areas for both nitrogen and phosphorus occur in the southwest corner of the Rohe and on the western side of Lake Wanaka. Under the GMP and GMP+ scenarios, average upstream yield decreases are generally minor.

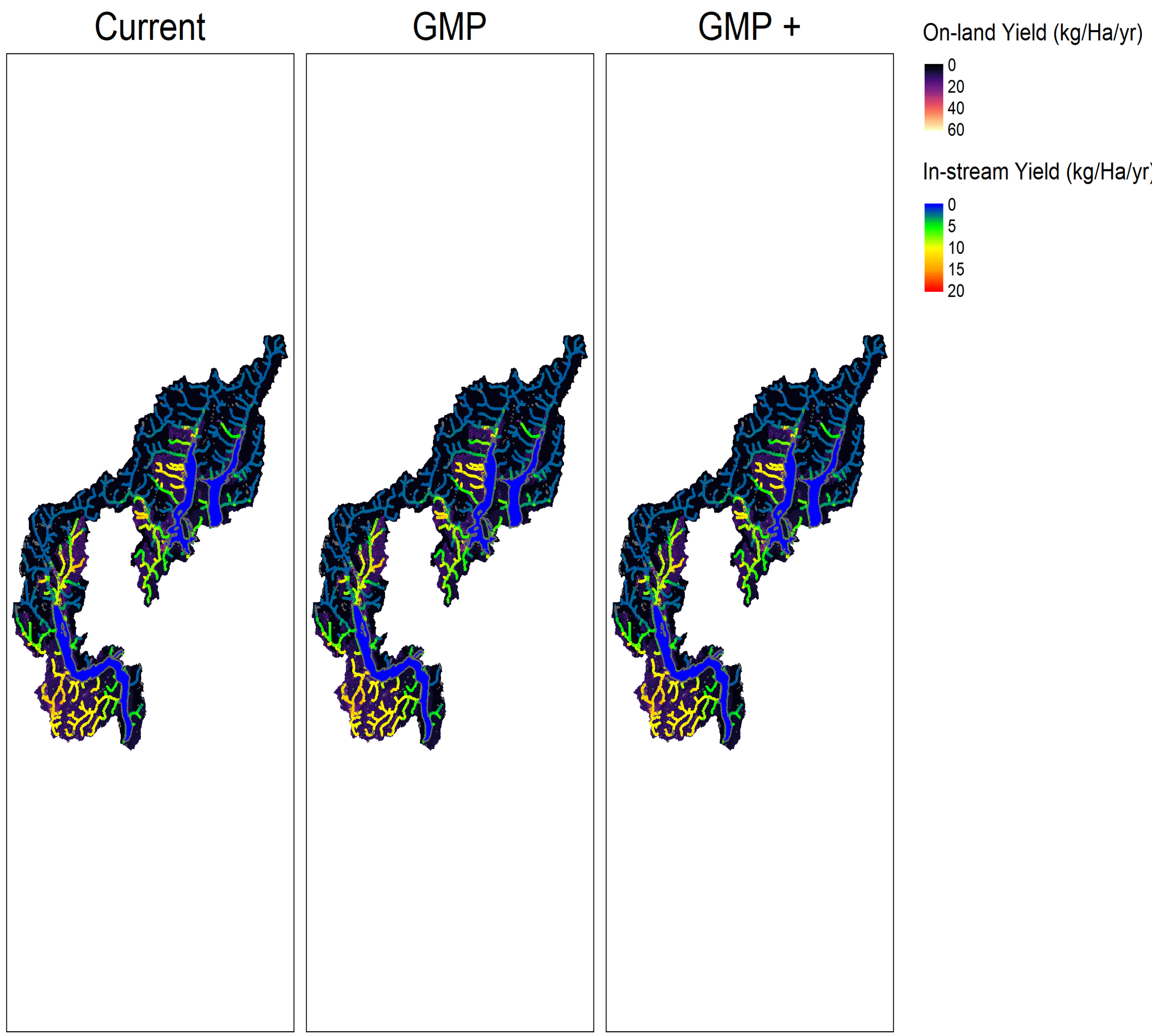

Figure 29: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios in the Upper Lakes Rohe.

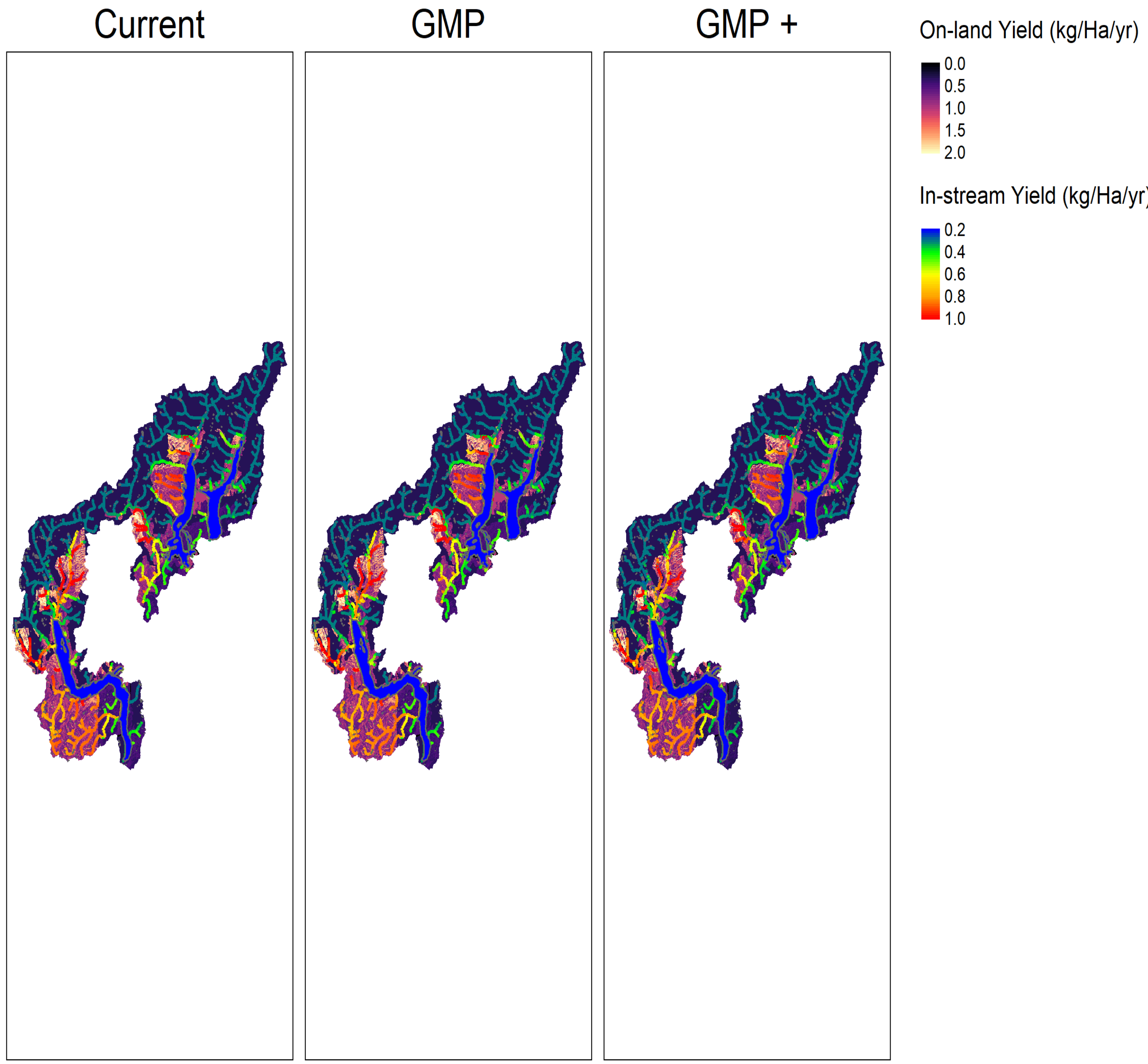

Figure 30: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios in the Upper Lakes Rohe.

Nitrate Toxicity

All segments in the Upper Lakes Rohe comply with the A-band nitrate toxicity target attribute state (Table 32) under all modelled scenarios. *No reduction is required* as the lower confidence interval overlaps 100%. This is also true for all management classes (Table 33). All segments in the FMU are also *very likely* to comply with the A-band nitrate toxicity criteria (Figure 31).

Table 32: Percent of river segments in the Upper Lakes Rohe complying with potential nitrate toxicity target attribute states with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	4,386
B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	4,386
C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	4,386

Table 33: Percent of river segments in the Upper Lakes Rohe complying with potential nitrate toxicity target attribute states, split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

	Nitrate Toxicity				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
M	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,399
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,399
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,399
H	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	581

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	581
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	581
L	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	18
L	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	18
L	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	18
Lk Upper	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	167
Lk Upper	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	167
Lk Upper	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	167

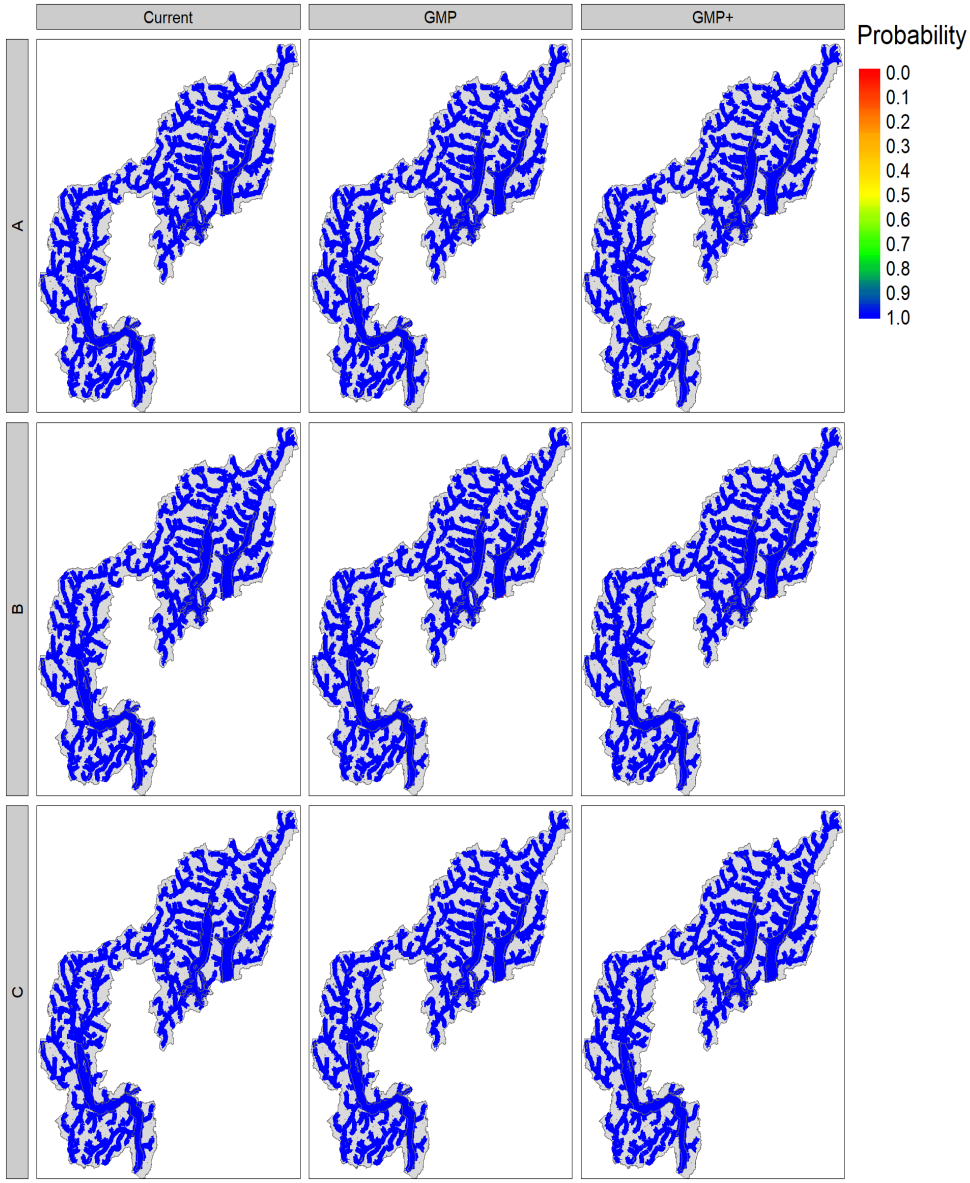

Figure 31: Individual segment probability of complying with the A, B and C nitrate toxicity target attribute states under the current, GMP and GMP+ scenarios in the Upper Lakes Rohe.

Periphyton

For total nitrogen in relation to the periphyton biomass nutrient criteria (Table 34), *all* segments in the Upper Lakes Rohe comply with the C-band criteria under all scenarios. *No reduction is required* to comply with the C-band criteria. *Nearly all* segments also comply with the B-band criteria current scenario. Confidence intervals indicate *no reductions are required* to comply the B-band criteria.

For total phosphorus in relation to the periphyton biomass nutrient criteria (Table 34), *all* segments in the Upper Lakes Rohe comply with the C-band criteria under all modelled scenarios. Confidence intervals indicate *no reduction is required* for all segments to comply with the C-band criteria. N*early all* segments comply with the B-band criteria under the current scenario. However, confidence intervals reductions *may be* required for all segments to comply. Under the GMP, and GMP+ scenarios, the proportion expected to comply does not change. This is likely to the limited area where mitigations measures are applied in this Rohe.

About half of the mountain class and *some* hill segments comply with the A-band criteria for total nitrogen. However, confidence intervals are wide, and no segments comply with the total phosphorus criteria. This indicates the A-band nutrient criteria would not be expected to be complied with in 80% of segments even under natural conditions.

When split by management class, for the total nitrogen C-band criteria (Table 35), *all* mountain, hill, lowland, and upper lake segments in the Upper Lakes Rohe comply with the C-band criteria for all modelled scenarios. As the lower confidence interval in the mountain, hill and lake classes overlaps 100% *no reduction is required* to comply. In the lowland class, the upper confidence interval overlaps 100% indicating less than 95% confidence a reduction is required.

When split by management class, for the total nitrogen B-band criteria (Table 35), *all* mountain and upper lake segments comply with the B-band criteria under all scenarios. As the mean proportion of segments comply and confidence interval overlaps 100% in both classes, *no reduction is required*. *Nearly all* hill segments, comply with the B-band criteria currently. The mean estimate indicates a reduction *may be* required for all hill segments to comply. Under the GMP and GMP+ scenario the lower confidence interval increases slightly indicating increased confidence in the proportion of segments that comply with the criteria. However, the mean does not overlap 100% indicating further reductions *may be* required. *About half* of lowland segments comply with the B- band criteria under the current scenario indicating a reduction *is required* for all segments to comply. Under the GMP+ scenarios the mean proportion of segments complying increases by 1%. However, confidence intervals fail to overlap 100% indicating that further reductions beyond GMP+ *are required* to comply with the B-band criterion. The limited change under the GMP and GMP+ scenarios is likely due to the limited land area on which mitigations can be implement.

When split by management class, for the total phosphorus C-band criteria (Table 35), *nearly all* mountain, hill, lowland, and upper lake segments comply with the C-band criteria under all scenarios. For all but the lowland class, *no reduction is required* to comply. In the lowland class, reductions *may be required*. However, under the GMP and GMP+ scenarios the proportion of segments expected to comply does not change.

When split by management class, for the total phosphorus B-band criteria (Table 35), *nearly all* mountain, hill, and upper lake segments comply with the B-band criteria under all scenarios. As the mean proportion of segments comply and confidence interval overlaps 100% in the mountain class, *no reduction is required* to comply. In the hill and upper lake classes, reductions *are required* for all segments to comply. However, under the GMP and GMP+ scenarios, the expected proportion of segments complying does not change. This is likely due to the limited land area where mitigations are applied in this Rohe. *About half* of lowland segments comply with the B- band criteria under the current scenario *requiring a reduction* for all segments to comply. Under the GMP and GMP+ scenario, the proportion of segments expected to comply does not increase.

Table 34: Percent of river segments in the Upper Lakes Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			Total Phosphorus				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	44 (0 - 96)	44 (0 - 97)	45 (0 - 97)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	4,165
B	100 (99 - 100)	100 (99 - 100)	100 (99 - 100)	97 (96 - 99)	97 (96 - 99)	97 (96 - 99)	0	4,165
C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	4,165

Table 35: Percent of river segments in the Upper Lakes Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	A	47 (0 - 100)	47 (0 - 100)	48 (0 - 100)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	3,399
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	3,399
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	3,399
H	A	30 (0 - 85)	31 (0 - 85)	31 (0 - 85)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	581
H	B	98 (92 - 100)	98 (93 - 100)	98 (94 - 100)	86 (83 - 94)	87 (83 - 94)	87 (84 - 94)	0	581
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (99 - 100)	100 (99 - 100)	100 (100 - 100)	0	581
L	A	24 (0 - 61)	24 (0 - 61)	24 (0 - 61)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	18

		Total Nitrogen			Total Phosphorus				
Management Class	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+	Periphyton exempt	Total segments
L	B	58 (50 - 84)	58 (50 - 84)	59 (50 - 84)	51 (17 - 78)	51 (17 - 78)	54 (17 - 78)	0	18
L	C	97 (89 - 100)	97 (89 - 100)	97 (89 - 100)	99 (89 - 100)	99 (89 - 100)	99 (89 - 100)	0	18
Lk Upper	A	27 (0 - 75)	28 (0 - 75)	28 (0 - 75)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	167
Lk Upper	B	100 (99 - 100)	100 (99 - 100)	100 (99 - 100)	81 (62 - 99)	81 (62 - 99)	81 (62 - 99)	0	167
Lk Upper	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	167

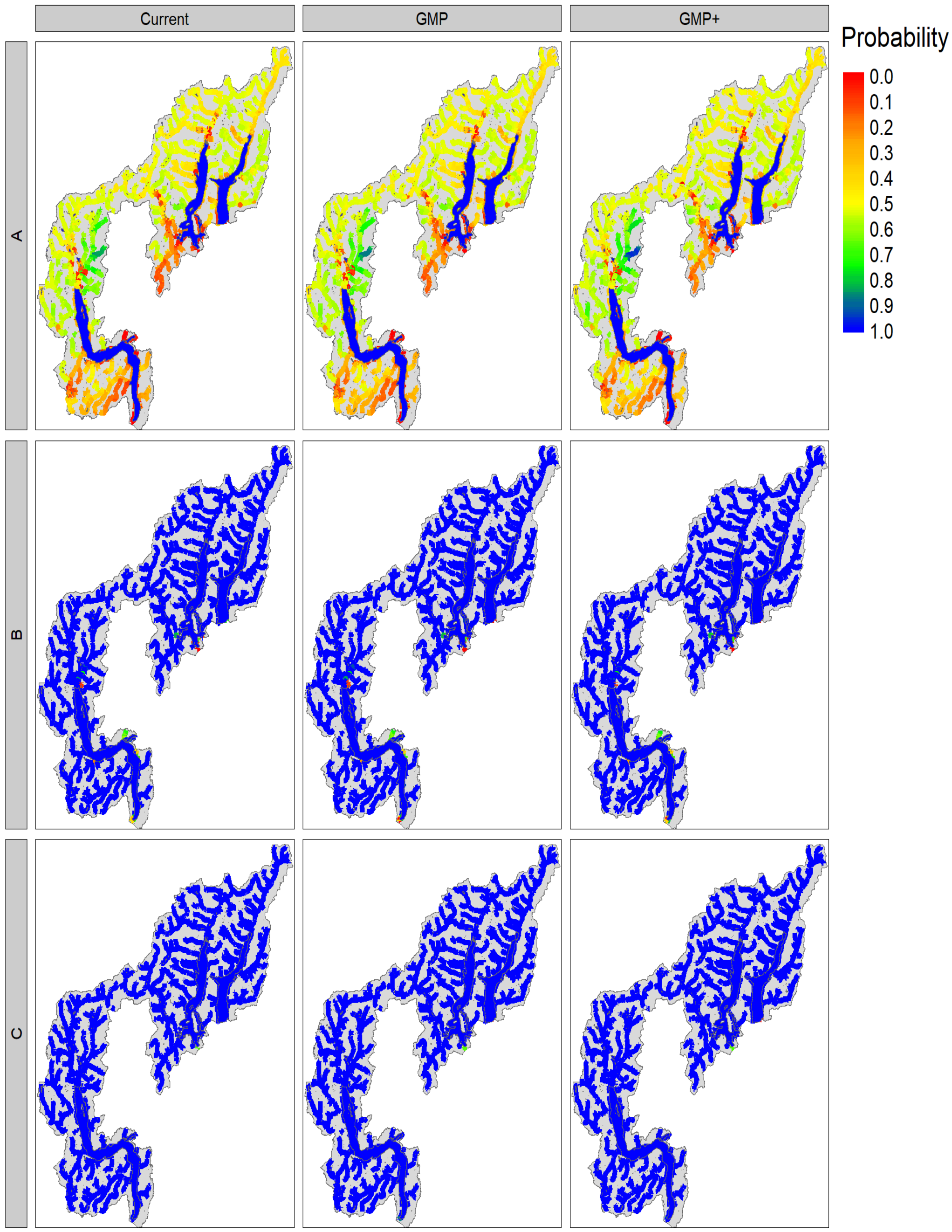

Figure 32: Individual segment probability of complying with the total nitrogen A, B and C periphyton criteria under the current, GMP and GMP+ scenarios in the Upper Lakes Rohe.

Spatially, for total nitrogen, the majority of the Upper Lakes Rohe is *very likely* to comply with the C- and B-band criteria under all scenarios. Isolated segments, particularly near urban areas, are *very* *unlikely* to comply the B-band criteria under all scenarios. This is expected as the modelled mitigations do not apply to urban areas. For the A-band criteria, upper catchment tributaries are *as likely as not* to *likely* to comply whereas lower catchments are *unlikely* to *very unlikely to comply.*

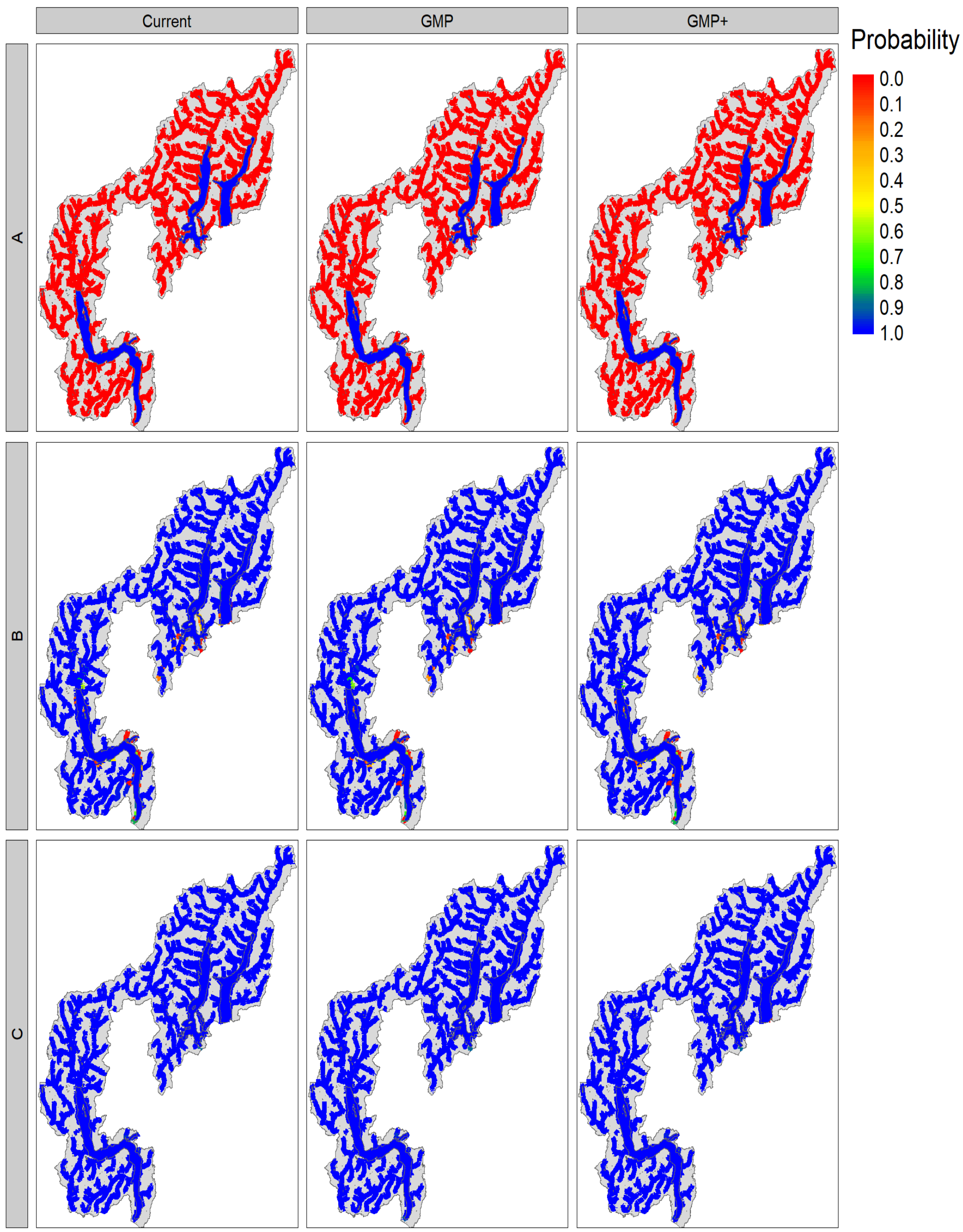

Figure 33: Individual segment probability of complying with the total phosphorus A, B and C band periphyton criteria under the current, GMP and GMP+ scenarios in the Upper Lakes Rohe.

Spatially, for total phosphorus, the majority of the Upper Lakes Rohe is *very likely* to comply with the C- and B-band criteria under all scenarios. Under all scenarios modelled, all segments are *very unlikely* to comply with the A-band criteria.

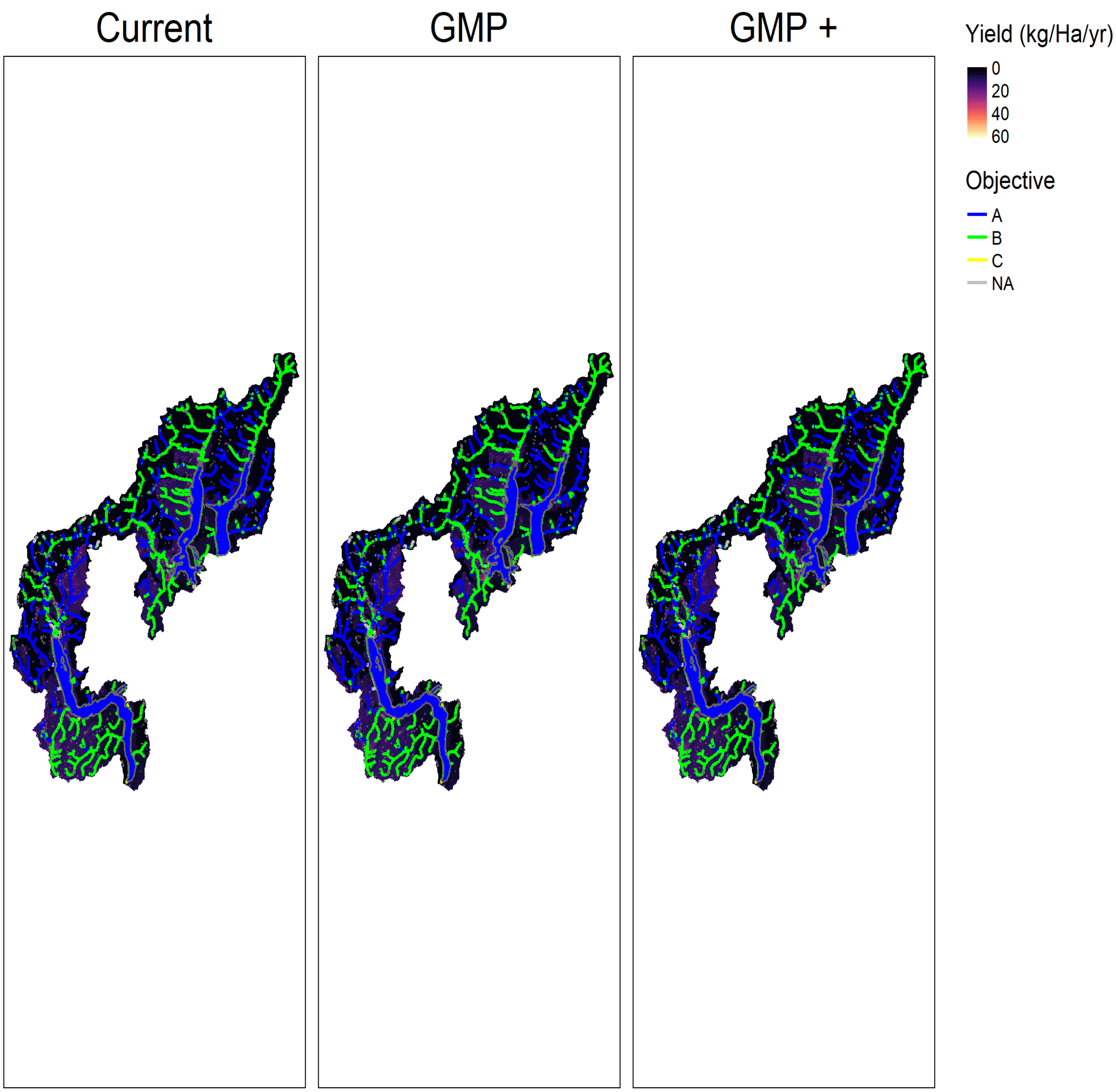

Figure 34: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization total nitrogen periphyton target attribute state outcome for each river segment under current, GMP and GMP+ scenarios in the Upper Lakes Rohe.

The mean realization total nitrogen comparison results in the majority of the Rohe complying with the B-band criteria. Upper catchments in conservation estates have some segments complying with the A-band. Few to no band changes occur under the GMP and GMP+ scenarios. The mean total phosphorus realization results in the majority of the catchment complying with the B-band criteria.

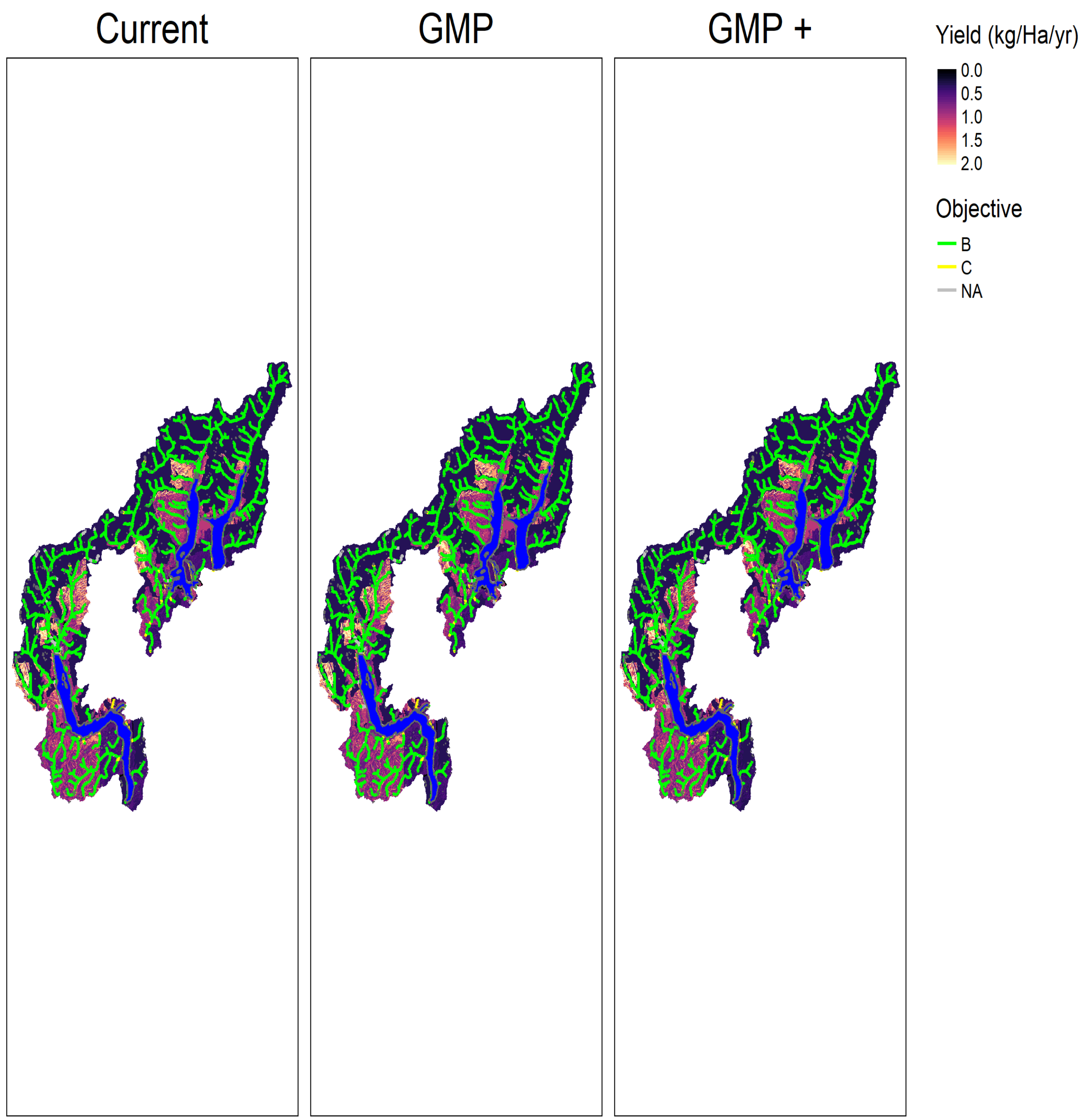

Figure 35: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute state outcome for each river segment under current, GMP and GMP+ scenarios in the Upper Lakes Rohe.

Lakes

There are 10 named lakes in the Upper Clutha FMU with results available (Table 36). Lakes Lucidus, Nigel, Ned, McKellar, and Sylvan do not change under the GMP and GMP+ scenarios as result of catchments primarily or entirely lying within the conservation estate where mitigations measures are unnecessary or do not apply.

Nitrogen

All lakes are *very likely* to comply with the C-band (100%; 97-100) and therefore require no reduction to comply with the national bottom line.

For the lakes with no anthropogenic inputs, Lake Lucidus is *very likely* to comply with the total nitrogen A-band currently. Lakes Nigel is *very likely* to comply with the B-band currently and *as likely as not* to comply with the A-band. Lake McKellar and Lake Ned are *very likely* to comply with the B-band and *unlikely* to comply with the A-band currently. Lake Sylvan is very likely to comply with the B-band currently and *unlikely* to comply with the A-band.

For the lakes with higher anthropocentric inputs, Diamond Lake is *very likely* to comply with the B-band and A-band under all scenarios. Lake Reid is *likely* to comply with the A-band and *very likely* to comply with the B-band criteria under all scenarios. Lakes Hawea, Wanaka and Wakatipu are *very likely* to comply with the A-band criteria under all scenarios.

Phosphorus

For total phosphorus in the lakes with minimal upstream anthropogenic inputs, Lake Lucidus, Nigel, Ned, McKellar, and Sylvan are all *very unlikely* to comply with the A-band. For the B-band, all of these lakes are also *very unlikely* to comply except for Sylvan (*unlikely*) and McKellar (*as likely as not*). Lakes Lucidus, McKellar, and Sylvan are *very likely* to comply with the C-band target attribute state whereas lakes Ned and Nigel are *likely* to comply with the C-band target attribute state. While these lakes do not comply with the A-band, this outcome is not reflective of mitigation effectiveness. Instead, this likely reflects the natural phosphorus loads of these lakes.

For total phosphorus in the lakes with higher anthropocentric inputs, Diamond Lake is *very likely* to comply with the C--band criteria and *very unlikely* to comply the B- and A-band target attribute state under all scenarios. Lake Reid is *likely* to comply with the C- band target attribute state and very *unlikely* to comply with the B-and A-band target attribute state. Lakes Wanaka, Wakatipu and Hawea are all *very likely* to comply with the A-band target attribute state under all scenarios.

Table 36: Probability of compliance of lakes in the Upper Lakes Rohe with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval.

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Lucidus Lake	A	96 (91 - 98)	96 (91 - 98)	96 (91 - 98)	2 (1 - 6)	2 (1 - 6)	2 (1 - 6)
Lucidus Lake	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	7 (4 - 12)	7 (4 - 12)	7 (4 - 12)
Lucidus Lake	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	87 (80 - 92)	87 (80 - 92)	87 (80 - 92)
Lake Nigel	A	45 (37 - 53)	45 (37 - 53)	47 (39 - 55)	2 (1 - 6)	2 (1 - 6)	2 (1 - 6)
Lake Nigel	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	1 (0 - 4)	1 (0 - 4)	1 (0 - 4)
Lake Nigel	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	75 (67 - 81)	75 (67 - 81)	75 (67 - 81)
Lake Ned	A	37 (29 - 45)	38 (30 - 46)	38 (30 - 46)	1 (0 - 4)	1 (0 - 4)	1 (0 - 4)
Lake Ned	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Lake Ned	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	75 (67 - 81)	75 (67 - 81)	75 (67 - 81)
Lake Wakatipu	A	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Lake Wakatipu	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lake Wakatipu	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lake Mckellar	A	86 (79 - 91)	86 (79 - 91)	86 (79 - 91)	8 (5 - 14)	8 (5 - 14)	8 (5 - 14)
Lake Mckellar	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	52 (44 - 60)	52 (44 - 60)	52 (44 - 60)
Lake Mckellar	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	99 (96 - 100)	99 (96 - 100)	99 (96 - 100)
Diamond Lake	A	93 (88 - 96)	93 (88 - 96)	94 (89 - 97)	1 (0 - 4)	2 (1 - 6)	2 (1 - 6)
Diamond Lake	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	5 (2 - 10)	5 (2 - 10)	7 (4 - 12)
Diamond Lake	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	84 (77 - 89)	84 (77 - 89)	87 (80 - 92)
Lake Reid	A	76 (68 - 82)	76 (68 - 82)	79 (72 - 85)	2 (1 - 6)	2 (1 - 6)	2 (1 - 6)
Lake Reid	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	2 (1 - 6)	2 (1 - 6)	3 (1 - 7)

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Lake Reid	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	78 (70 - 84)	78 (70 - 84)	81 (74 - 87)
Lake Sylvan	A	31 (24 - 39)	31 (24 - 39)	31 (24 - 39)	3 (1 - 7)	3 (1 - 7)	3 (1 - 7)
Lake Sylvan	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	28 (21 - 36)	28 (21 - 36)	28 (21 - 36)
Lake Sylvan	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	94 (89 - 97)	94 (89 - 97)	94 (89 - 97)
Lake Wanaka	A	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lake Wanaka	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lake Wanaka	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lake Hawea	A	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lake Hawea	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lake Hawea	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)

Dunstan Rohe

Land use characteristics

Land use in the Dunstan Rohe (Table 37; Figure 36) is comprised primarily of sheep and beef (45%), conservation (23%), and mixed livestock (15%). In this Rohe, the GMP and GMP+ mitigations packages can be applied to approximately 68% of the FMU based on land use.

Table 37: Land use statistics for the Dunstan Rohe

Land Use	Area (Ha)	Percent
Arable	900.55	0.18%
Beef	7,080.51	1.39%
Commercial Use	157.78	0.03%
Conservation	115,164.22	22.65%
Dairy	5,351.28	1.05%
Exotic Forestry	875.59	0.17%
Horticulture	1,783.86	0.35%
Industrial Use	393.47	0.08%
Lakes & Rivers	7,328.96	1.44%
Lifestyle Block	7,911.13	1.56%
Livestock Support	997.60	0.20%
Majority Deer with Mixed Livestock	2,649.50	0.52%
Mixed Livestock	74,011.89	14.55%
Nurseries & Orchards	4,071.91	0.80%
Other Animals	205.73	0.04%
Public Use	34.63	0.01%
Residential Use	2,970.84	0.58%
Road & Rail	3,071.87	0.60%
Sheep	24,587.99	4.84%
Sheep & Beef	227,325.23	44.70%

Land Use	Area (Ha)	Percent
Small Land Holding	2,602.90	0.51%
Specialist Deer	1,784.04	0.35%
Tourism & Recreational Use	2,165.03	0.43%
Unknown Land Use	8,442.84	1.66%
Unknown Land Use - Indigenous Cover	3,572.93	0.70%
Unknown Land Use - Non-agricultural	200.92	0.04%
Unknown Land Use - Pastoral Cover	2,890.73	0.57%

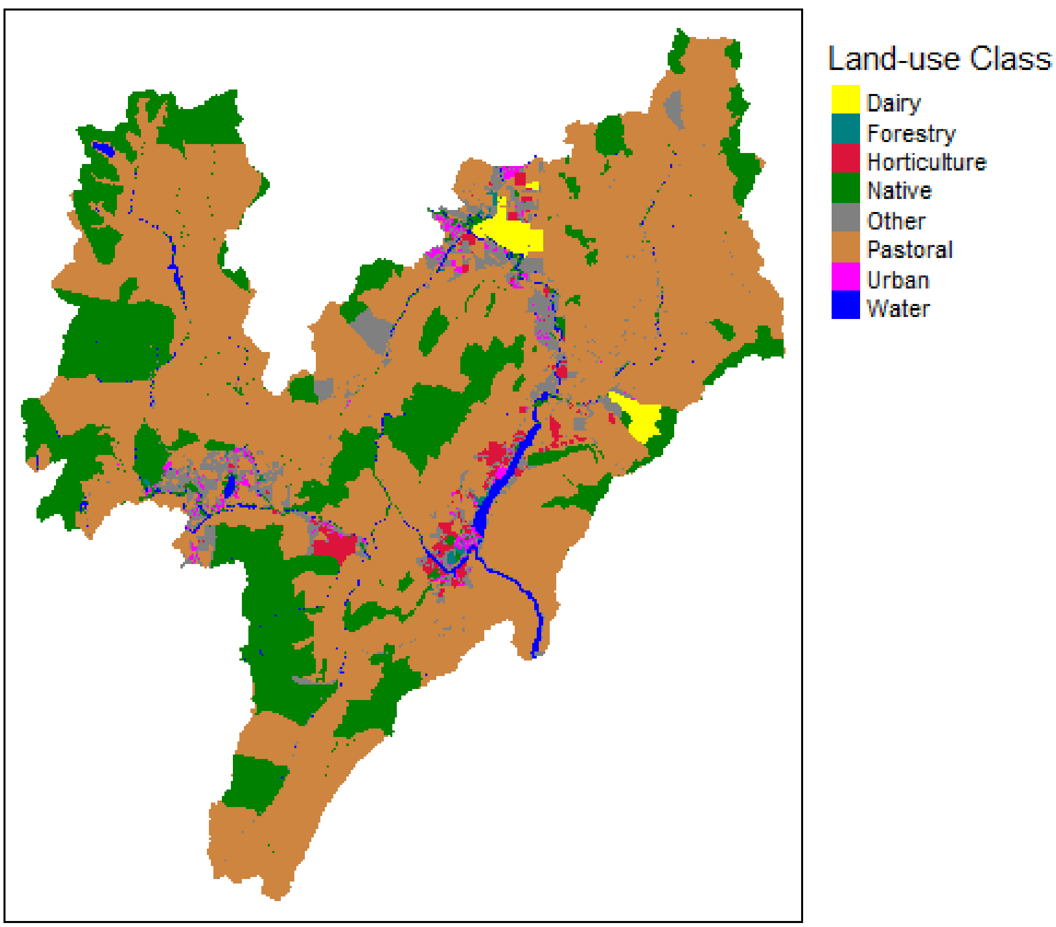

Figure 36: Land-use within the Dunstan Rohe. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

In the Dunstan Rohe, the GMP scenario results in approximately a 4% reduction in nitrogen and 2% reduction phosphorus emissions whereas the GMP+ scenario results in a 13% reduction of nitrogen and 12% reduction in phosphorus emissions *(*Table 38*)*. These reductions result in the FMUs overall average yield decreasing from 7.19 kg/ha/yr of nitrogen under the current scenario to 6.94 kg/ha/yr and 6.26 kg/ha/yr under the GMP and GMP+ scenarios respectively *(*Table 39*)*. The average phosphorus yield decreases from 0.49 kg/ha/yr under current, under 0.48 kg/ha/yr GMP and 0.43 kg/ha/yr under the GMP+ scenario.

Table 38: Total on-land nitrogen and phosphorus load reductions achieved through the GMP and GMP+ scenarios in the Dunstan Rohe.

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	3.51%	128,388.96	12.93%	472,968.64
P	1.66%	4,136.87	12.29%	30,603.64

Table 39: Average yield of nitrogen and phosphorus under the current, GMP and GMP+ scenarios in the Dunstan Rohe.

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	7.19	6.94	6.26
P	0.49	0.48	0.43

Rivers

Yields

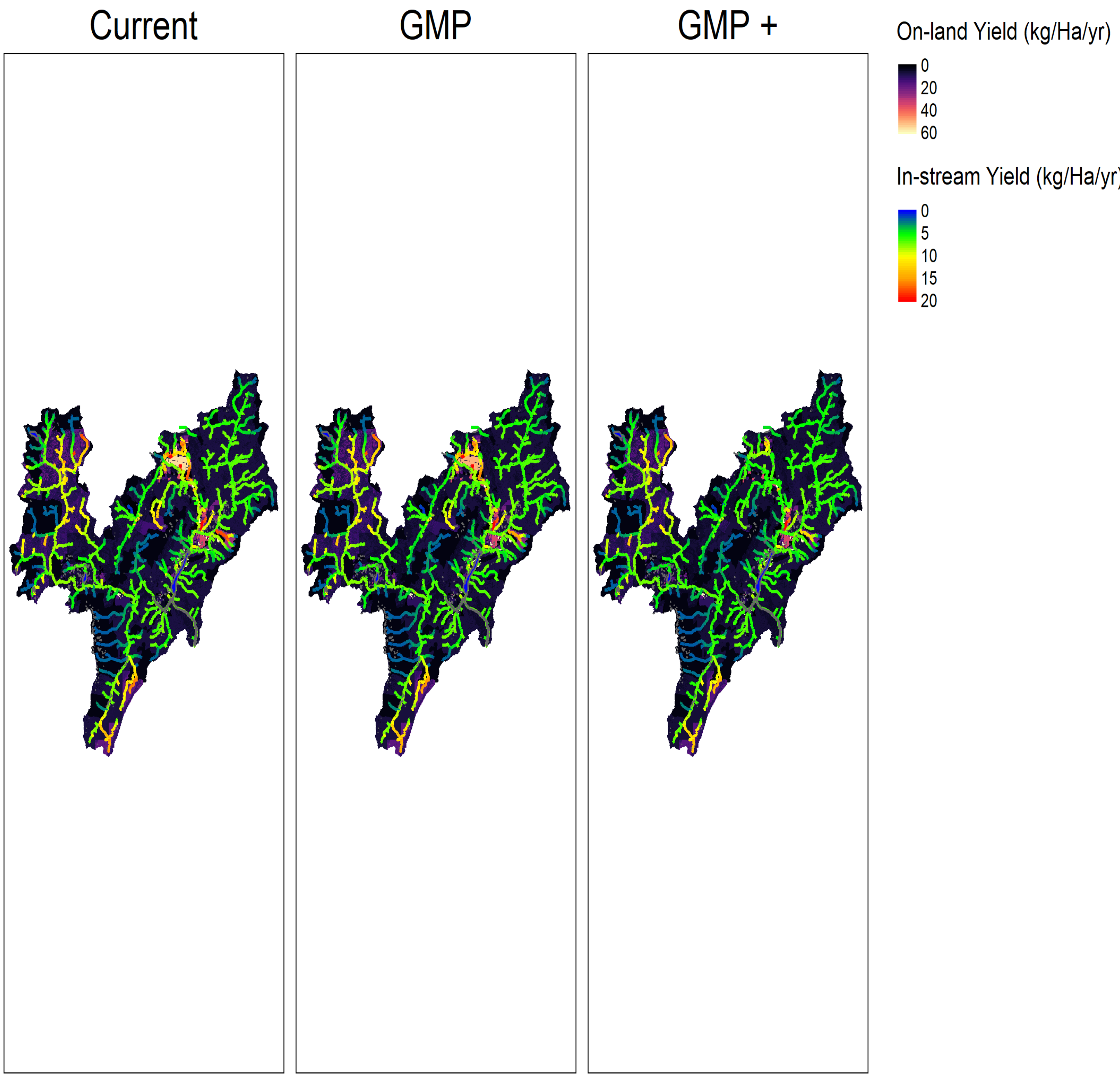

Figure 37: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios for the Dunstan Rohe.

Spatially, the highest nitrogen yield areas (Figure 37) for occur in tributaries near the confluences of the Cardrona and Hawea rivers with the Clutha mainstem. Higher yield segments also occur in the upper Nevis, tributaries of the lower Lindis, and the upper Shotover catchments. Under the GMP and GMP+ scenarios many of these segments have reduced upstream average yields.

Phosphorus yields (Figure 38) are highest in the upper Shotover catchment, and the area near the confluences of the Cardrona and Hawea rivers with the Clutha mainstem. Under the GMP and GMP+ scenario average upstream yields in these segments show reductions.

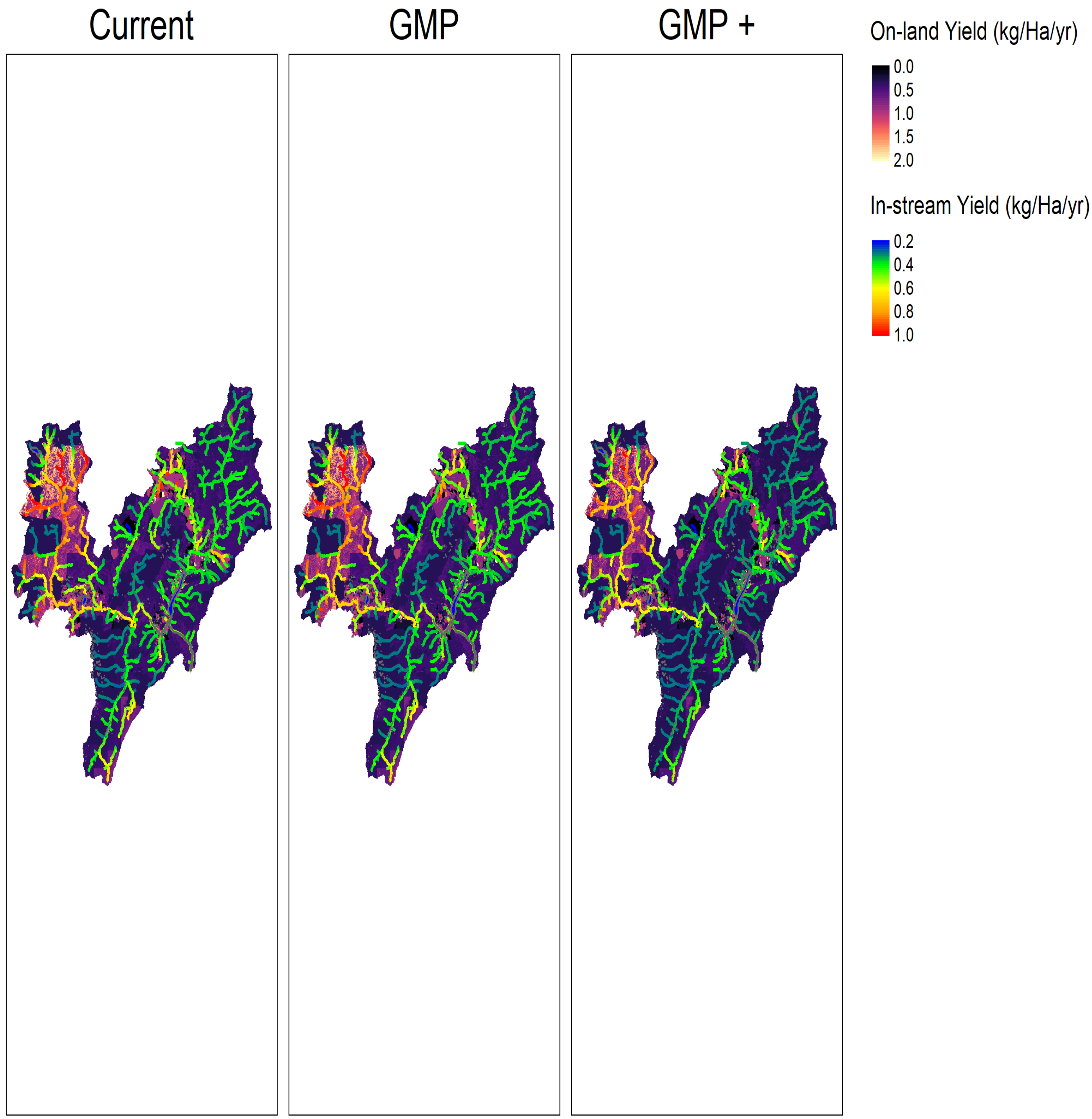

Figure 38: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios for the Dunstan Rohe.

Nitrate Toxicity

All segments in the Dunstan Rohe comply with the A-band nitrate toxicity target attribute state (Table 40) under all modelled scenarios. *No reduction is required* to comply with the A-band as the lower confidence interval overlaps 100%. This is also true for all management classes (Table 41). All segments in the FMU are also *very likely* to comply with the A-band nitrate toxicity target attribute state (Figure 39).

Table 40: Percent of river segments in the Dunstan Rohe complying with potential nitrate toxicity target attribute states with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,147
B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,147
C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,147

Table 41: Percent of river segments in the Dunstan Rohe complying with potential nitrate toxicity target attribute states, split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity					
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
M	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,827
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,827
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,827

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	869
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	869
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	869
L	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	25
L	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	25
L	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	25
Lk Lower	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	32
Lk Lower	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	32
Lk Lower	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	32
Lk Upper	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	167
Lk Upper	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	167
Lk Upper	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	167

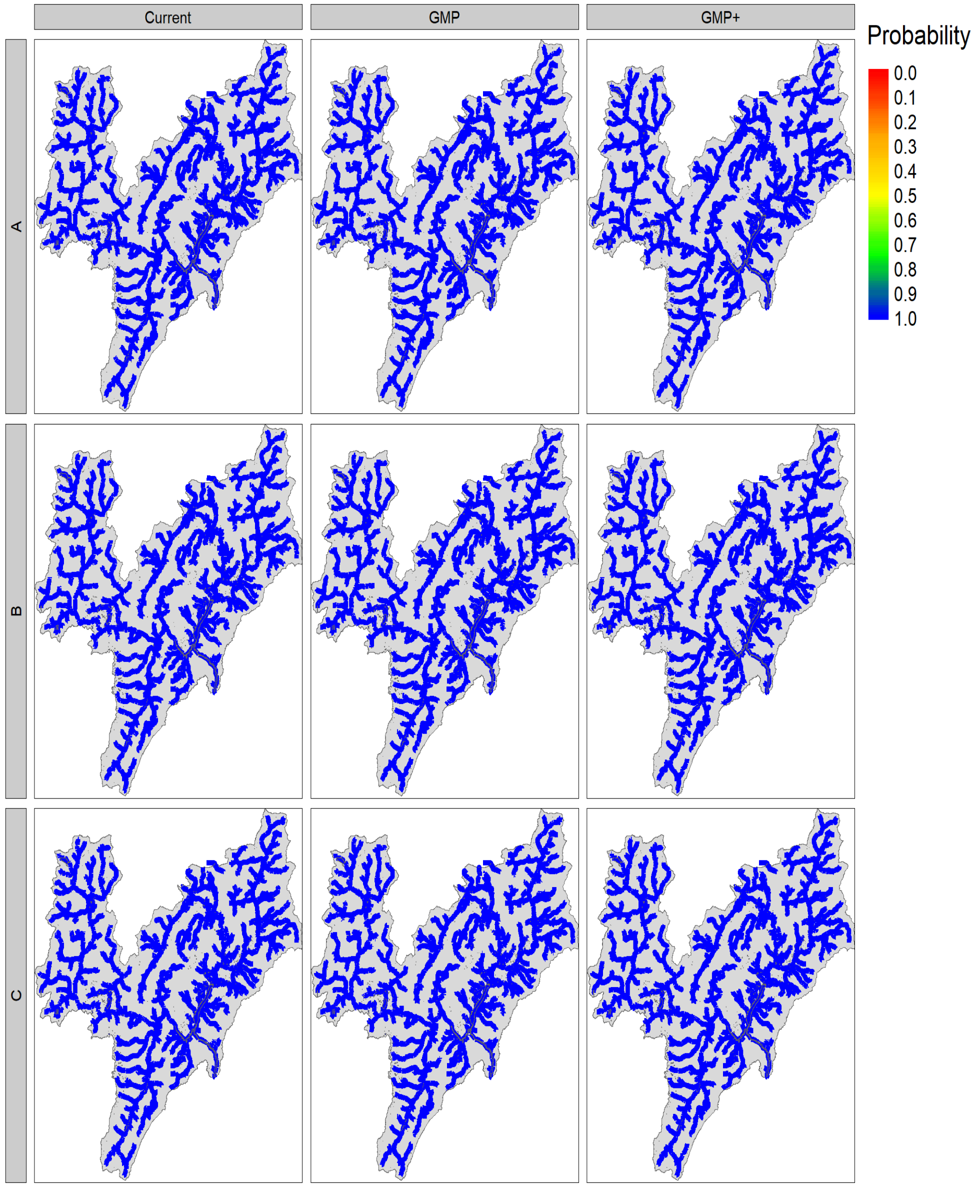

Figure 39: Individual segment probability of complying with the A, B and C nitrate toxicity target attribute states under the current, GMP and GMP+ scenarios for the Dunstan Rohe.

Periphyton

For total nitrogen in relation to the periphyton biomass nutrient criteria (Table 42), *all* of the Dunstan Rohe complies with the C-band criteria under all three scenarios *requiring no reduction*. *Nearly all* segments also comply with the B-band total nitrogen criteria under the current scenario. However, the confidence interval indicates reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply with B-band criteria increases slightly but still fails to overlap 100% indicating reductions beyond GMP+ *are required* for all segments to comply.

For total phosphorus in relation to the periphyton biomass nutrient criteria (Table 42), *nearly all* segments in the Dunstan Rohe comply with the C-band criteria under all scenarios. As the mean, upper and lower confidence interval sit within 97-100% of segments, *no reductions are likely required* to comply with the C-band criteria. *Most* segments comply with the B-band criteria under the current scenario. However, confidence intervals indicate *reductions are required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly. However, the upper confidence interval still fails to overlap 100% indicating reductions beyond GMP+ *are required* for all segments to comply with the B-band total phosphorus criteria.

Few to *some* segments in any class comply with the A-band criteria for both total nitrogen and phosphorus. This indicates the A-band nutrient criteria would not be expected to be complied with in 80% of segments even under natural conditions. In the case that *some* segments do comply, confidence intervals are wide indicating high uncertainty.

When split by management class, for the total nitrogen C-band criteria (Table 43), *all* mountain, hill, lowland lake, and upper lake segments comply *requiring no reduction*. Lowland segments comprise a small portion of the FMU, represented by only 25 segments (<1% of total segments). *Nearly all*, lowland segments comply with the C-band total nitrogen criteria under the current scenario. As the mean does not overlap 100%, a reduction *may be* required for all lowland segments to comply with the C-band criteria. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly. However, the mean still does not overlap 100% indicating reductions beyond GMP+ *may be* required for all segment to comply.

When split by management class, for the total nitrogen B-band criteria (Table 43), *all* mountain, lowland lake, and upper lake segments currently comply *requiring no reduction*. In the hill management class, *nearly all* segments comply under the current scenario. However, the mean estimate indicates reductions *may be* required for all segments to comply. Under the GMP (and GMP+ scenarios the proportion of segments expected to comply with the B-band criteria increases slightly. However, the mean still fails to overlap 100% indicating reductions beyond GMP+ *may be* required for all segments to comply. *Few* lowland segments comply with the B-band criteria under any scenario indicating reductions beyond GMP+ *are required* for all lowland segments to comply with the B-band criteria.

When split by management class, for the total phosphorus C-band criteria (Table 43), *all* mountain, lowland lake, and upper lake segments comply under the current scenario *requiring no reductions*. *Nearly all* hill and lowland also currently comply with the C-band criteria. In both classes, the confidence interval and means indicate reductions *may be* required for all segments to comply. Under the GMP and GMP+ scenarios the proportion of hill and lowland segments expected to comply improves slightly. However, further reductions *may still be* required for all segments to comply.

When split by management class, for the total phosphorus B-band criteria (Table 43), *nearly all* mountain, lower lake, and upper lake segments currently comply. In the upper lakes class, the lower and confidence interval and mean approach 100% indicating a reduction *is required*. Under the GMP scenario, no change is seen while the proportion expected to comply increases under the GMP+ scenario. However, the upper confidence interval fails to overlap 100% indicating reductions beyond GMP+ are required for all segments to comply. In the lower lake and mountain classes, the mean and confidence interval indicate reductions *may be* required for all segments to comply. Under the GMP and GMP+ scenario the proportion expected to comply improves. The mean and confidence interval indicate further reductions *may be* required for all segments to comply. In hill and lowland segments, *few* segments currently comply with the B-band total phosphorus criteria. As the upper confidence interval does not overlap 100%, *reductions are required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves, but still fails to overlap 100% indicating, with 95% confidence, reductions beyond GMP+ *are required* for all segments in these classes to comply with the B-band criteria.

Table 42: Percent of river segments in the Dunstan Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			Total Phosphorus				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	21 (0 - 66)	22 (0 - 71)	25 (0 - 78)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	2,920
B	95 (85 - 99)	96 (86 - 99)	96 (89 - 99)	69 (58 - 79)	69 (59 - 79)	71 (60 - 87)	0	2,920
C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	99 (97 - 100)	100 (97 - 100)	100 (98 - 100)	0	2,920

Table 43: Percent of river segments in the Dunstan Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria, split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	A	29 (0 - 88)	30 (0 - 91)	33 (0 - 96)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	1,827

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	94 (83 - 100)	94 (84 - 100)	95 (87 - 100)	0	1,827
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	1,827
H	A	7 (0 - 30)	8 (0 - 38)	10 (0 - 47)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	869
H	B	87 (54 - 100)	88 (57 - 100)	90 (67 - 100)	13 (9 - 33)	13 (9 - 33)	16 (9 - 61)	0	869
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	99 (92 - 100)	99 (93 - 100)	99 (95 - 100)	0	869
L	A	1 (0 - 0)	1 (0 - 4)	3 (0 - 8)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	25
L	B	3 (0 - 40)	3 (0 - 40)	4 (0 - 40)	1 (0 - 0)	1 (0 - 0)	1 (0 - 0)	0	25
L	C	89 (64 - 100)	90 (64 - 100)	93 (72 - 100)	91 (48 - 100)	92 (52 - 100)	93 (60 - 100)	0	25
Lk Lower	A	3 (0 - 0)	3 (0 - 0)	6 (0 - 50)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	32
Lk Lower	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	86 (0 - 100)	86 (0 - 100)	89 (0 - 100)	0	32
Lk Lower	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	32

		Total Nitrogen			Total Phosphorus				
Management Class	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+	Periphyton exempt	Total segments
Lk Upper	A	10 (0 - 23)	11 (0 - 49)	19 (0 - 57)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	167
Lk Upper	B	100 (99 - 100)	100 (99 - 100)	100 (99 - 100)	88 (57 - 99)	88 (57 - 99)	91 (57 - 99)	0	167
Lk Upper	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (99 - 100)	100 (99 - 100)	100 (99 - 100)	0	167

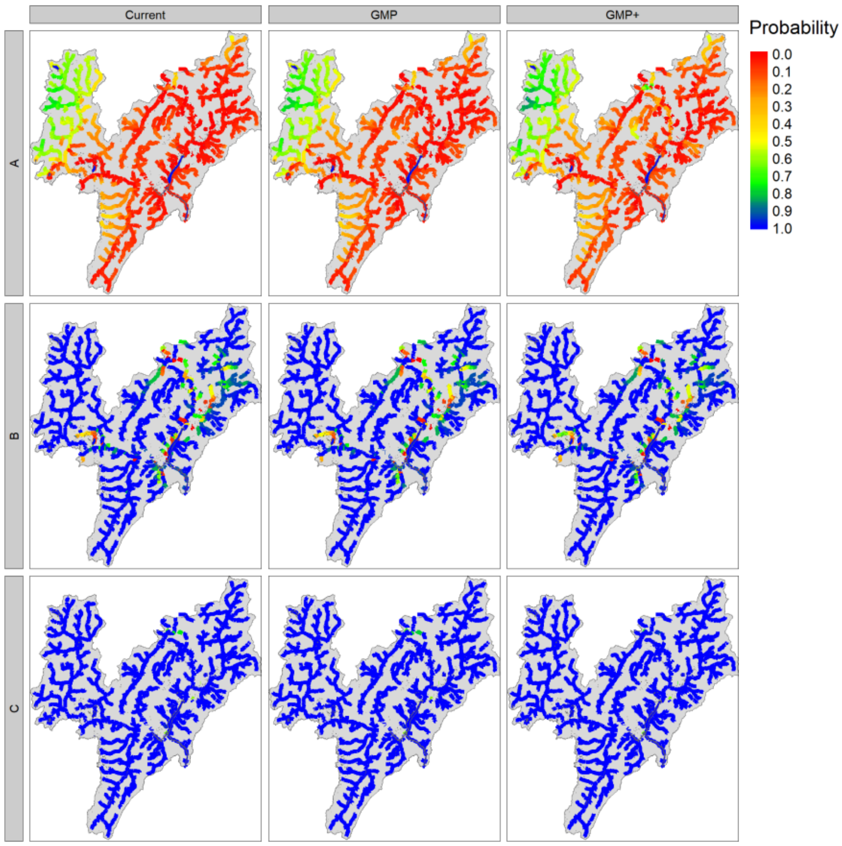

Figure 40: Individual segment probability of complying with the total nitrogen A, B and C periphyton criteria under the current, GMP and GMP+ scenarios for the Dunstan Rohe.

Spatially, for total nitrogen, the majority of the Dunstan Rohe is *very likely* to comply with the C and B-band criteria under all scenarios (Figure 40). Tributaries range from *very unlikely* to *very likely* to comply with the B-band criteria. Compliance with the A-band ranges from *very unlikely* to *likely* to comply. Headwater segments in mountain class rivers have higher probabilities of compliance with the A-band criteria.

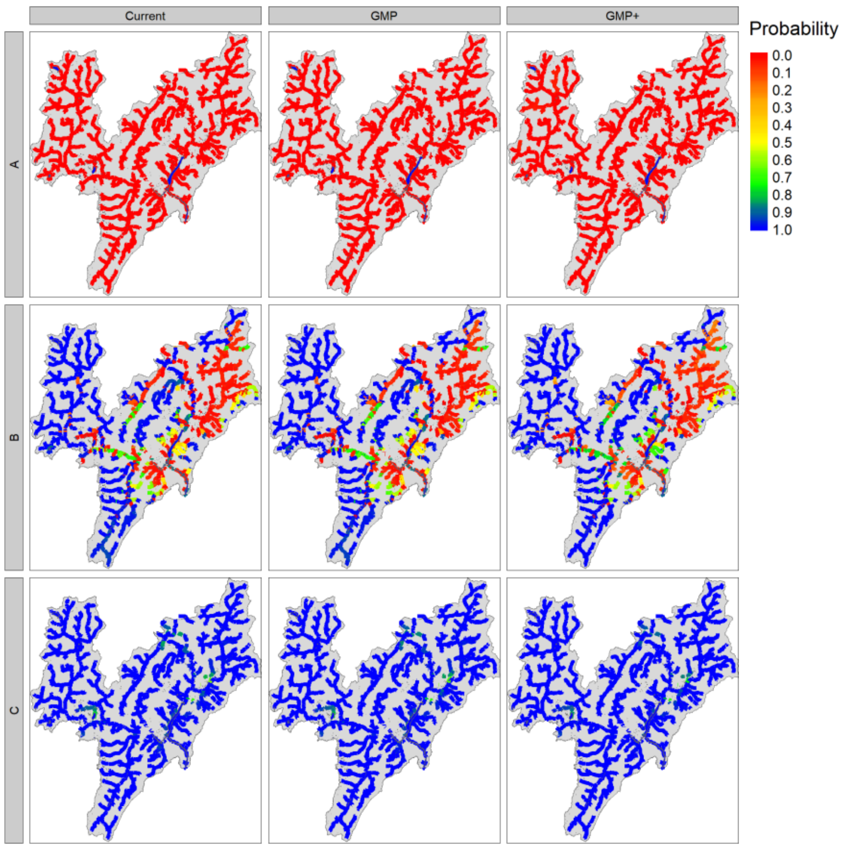

Figure 41: Individual segment probability of complying with the total phosphorus A, B and C periphyton criteria under the current, GMP and GMP+ scenarios for the Dunstan Rohe.

Spatially, for total phosphorus, the majority of the Dunstan Rohe is *very likely* to comply with the C-band criteria under all scenarios (Figure 41). For the B-band criteria, a large portion of the Rohe is *very* likely to comply. The Lindis and Cardrona rivers, as well as other smaller tributaries, are *very* unlikely to comply with the B-band criteria under all scenarios. All segments are *very unlikely* to comply with the A-band criteria under any scenario modelled.

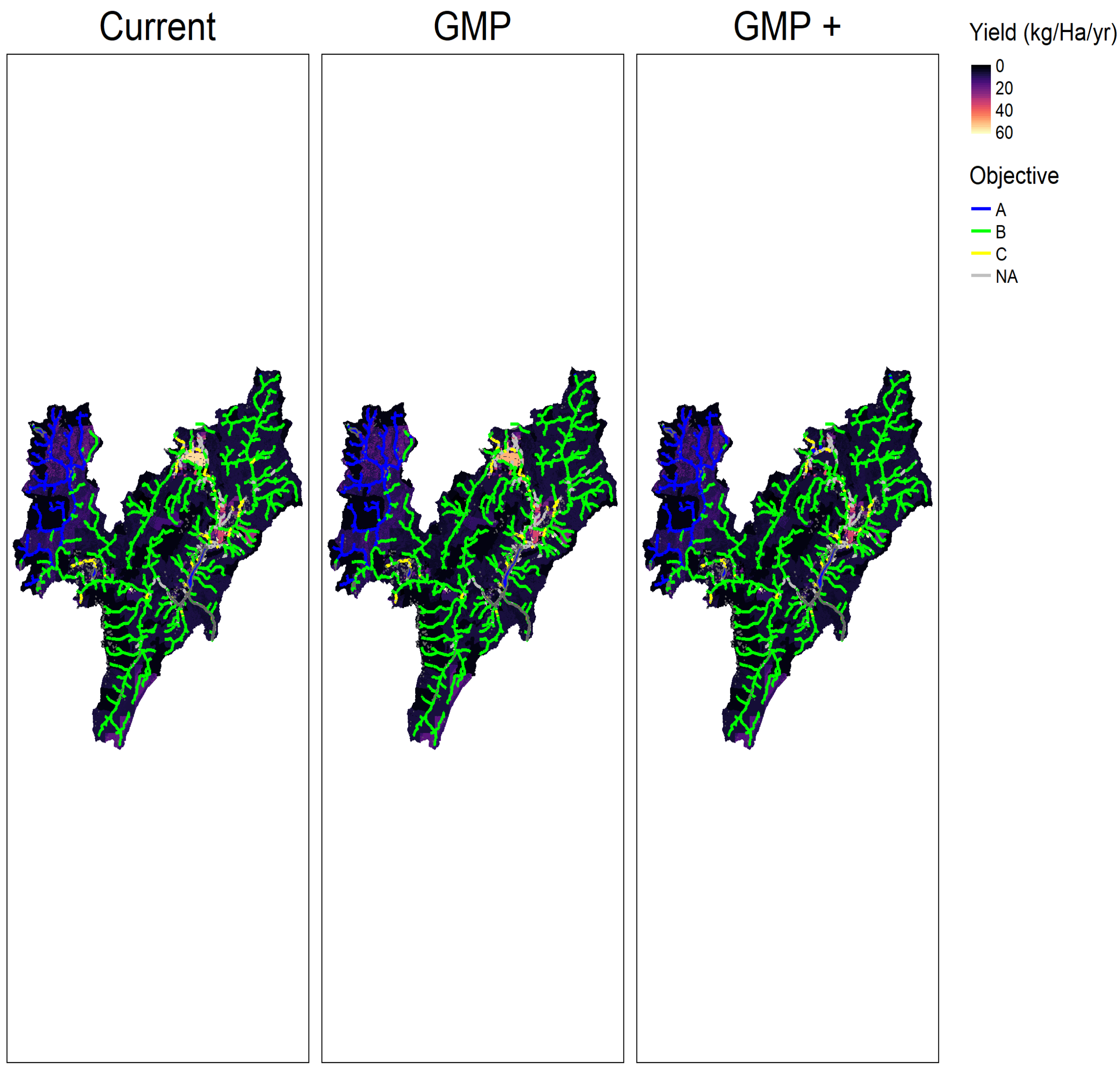

Figure 42: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization nitrogen periphyton target attribute band outcome for each river segment under current, GMP and GMP+ scenarios in the Dunstan Rohe.

When compared against the mean realization, the majority of segments comply with the B-band total nitrogen criteria with headwater segments in the Shotover catchment complying with the A-band criteria (Figure 42). While yields reduce under the GMP and GMP+ scenario band changes are uncommon indicating within band improvement.

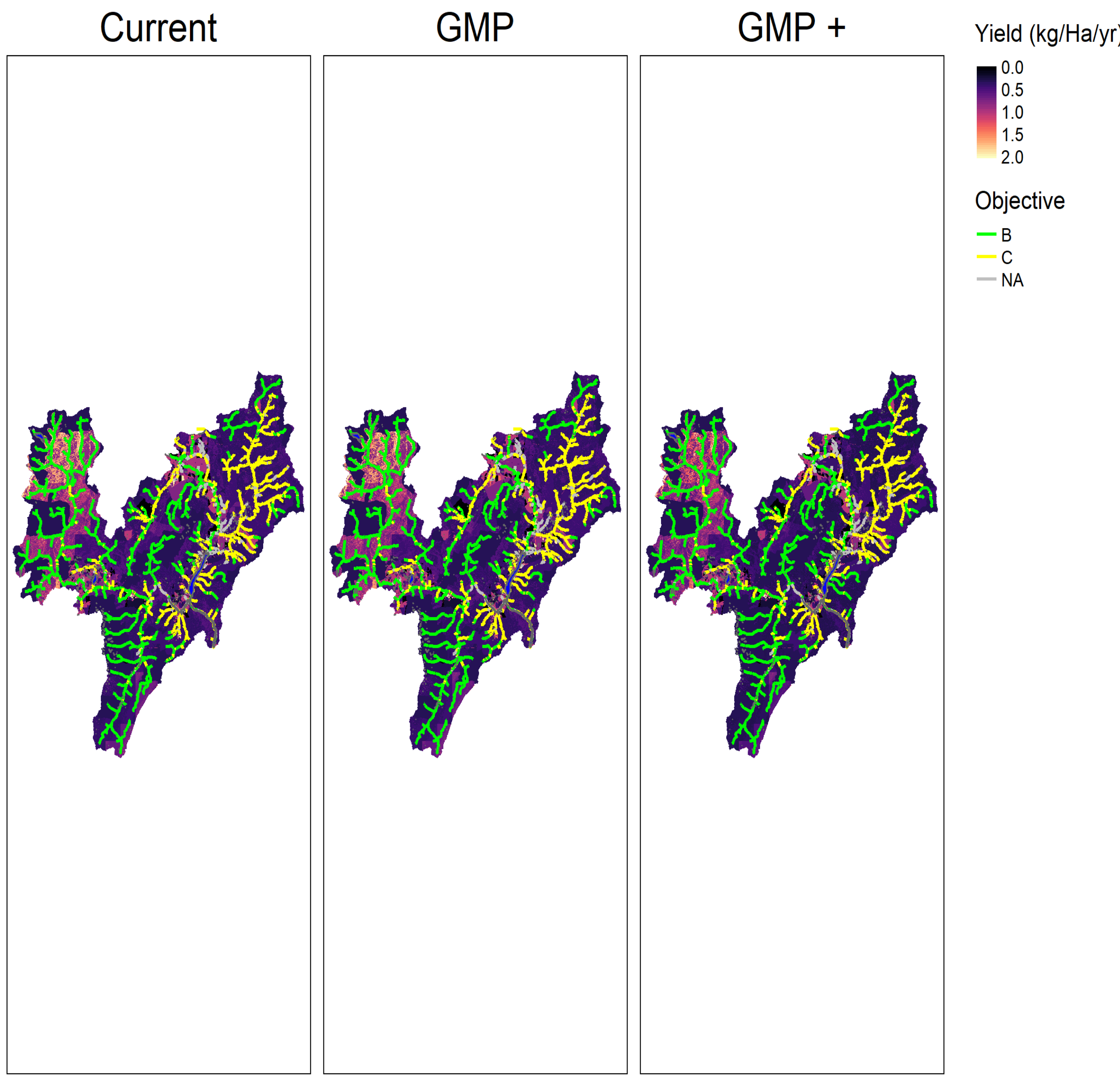

Figure 43: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios in the Dunstan Rohe.

When compared against the mean realization, the western catchments within the Rohe, such as the Shotover and Nevis, comply with the B-band phosphorus criteria whereas the eastern catchments comply with the C-band criteria (Figure 43). Under the GMP and GMP+ scenarios, few band changes are seen.

Lakes

The Dunstan Rohe contains six named lakes for which modelled results are available, Moke Lake, Lake Luna, Lochnagar, Downeys Dam, Lake Hayes, and Lake Dunstan. The results for Lake Dunstan are reported in the whole of the Clutha FMU section as it receives the combined reductions of the Dunstan and Upper Lakes Rohe.

Nitrogen

For total nitrogen, Moke Lake, Lake Luna, and Lochnagar are all *very likely* to comply with the C and B-band total nitrogen target attribute state under all scenarios. For the A-band target attribute state, Lochnagar and Lake Luna are *very likely* to comply under all scenarios. Moke Lake is *unlikely* comply with the A-band target attribute state under all three scenarios.

Downeys Dam is *very likely* to comply with the C-band, *about as likely as not* to comply with the B-band, and *very unlikely* to comply with the A-band target attribute state across all three scenarios.

Lake Hayes is *very likely* to comply with the C-band target attribute state across all scenarios. The B-band target attribute state is *as likely as not* to *likely* to be complied with under the current, GMP and GMP+ scenarios. The A-band target attribute state is *very unlikely* to be complied with under all scenarios.

Phosphorus

For total phosphorus, Moke Lake is *very likely* to comply with the C-band target attribute state under all three scenarios. The B-band target attribute state is *unlikely* to be complied with under all three scenarios whereas the A-band target attribute state is *very unlikely* to be complied with under any modelled scenario.

Lake Luna is *very likely* to comply with the C-band target attribute state under all scenarios. Under the current and GMP scenarios, compliance with the B-band target attribute state is *likely* whereas under the GMP+ scenario compliance is *very likely*. The A-band target attribute state is *unlikely* to be complied with under all three scenarios.

Lochnagar is *very likely* to comply with the C-band target attribute state under all three scenarios and *very unlikely* to comply with the B- and A-band target attribute state for all scenarios.

Downeys Dam is *very likely* to comply with the C-band target attribute state and *very unlikely* to comply with the B-band and A-band target attribute states under all scenarios.

Lake Hayes is *very likely* to comply with the C-band target attribute state and *very unlikely* to comply with the B- and A-band target attribute states under all scenarios

Table 44: Probability of compliance of lakes in the Dunstan Rohe with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval.

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Moke Lake	A	34 (27 - 42)	34 (27 - 42)	35 (28 - 43)	2 (1 - 6)	2 (1 - 6)	3 (1 - 7)
Moke Lake	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	24 (18 - 32)	24 (18 - 32)	27 (20 - 35)
Moke Lake	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	94 (89 - 97)	94 (89 - 97)	94 (89 - 97)
Lake Luna	A	95 (90 - 98)	95 (90 - 98)	96 (91 - 98)	27 (20 - 35)	27 (20 - 35)	32 (25 - 40)
Lake Luna	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	72 (64 - 79)	73 (65 - 80)	82 (75 - 87)
Lake Luna	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lochnagar	A	99 (96 - 100)	99 (96 - 100)	99 (96 - 100)	2 (1 - 6)	2 (1 - 6)	2 (1 - 6)
Lochnagar	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	7 (4 - 12)	7 (4 - 12)	9 (5 - 15)
Lochnagar	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	89 (83 - 93)	90 (84 - 94)	90 (84 - 94)
Downeys Dam	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	2 (1 - 6)	2 (1 - 6)	2 (1 - 6)
Downeys Dam	B	52 (44 - 60)	52 (44 - 60)	53 (45 - 61)	3 (1 - 7)	3 (1 - 7)	3 (1 - 7)
Downeys Dam	C	98 (94 - 99)	98 (94 - 99)	98 (94 - 99)	82 (75 - 87)	82 (75 - 87)	82 (75 - 87)
Lake Hayes	A	0 (0 - 3)	1 (0 - 4)	1 (0 - 4)	2 (1 - 6)	2 (1 - 6)	2 (1 - 6)
Lake Hayes	B	58 (50 - 66)	60 (52 - 68)	66 (58 - 73)	7 (4 - 12)	7 (4 - 12)	7 (4 - 12)

		Total Nitrogen			Total Phosphorus		
Lake Name	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+
Lake Hayes	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	87 (80 - 92)	87 (80 - 92)	89 (83 - 93)

Manuherekia Rohe

Land use characteristics

Land use in the Manuherekia Rohe (Table 45; Figure 44) is comprised primarily of sheep and beef (82%), mixed stock (18%), conservation (12%), and sheep (6%). In this Rohe, the GMP and GMP+ mitigations packages can be applied to approximately 82% of the FMU based on land use.

Table 45: Land use statistics for the Manuherekia Rohe.

Land Use	Area (Ha)	Percent
Arable	68.97	0.02%
Beef	5,462.52	1.80%
Commercial Use	17.14	0.01%
Conservation	37,192.99	12.27%
Dairy	5,952.29	1.96%
Dairy Support	578.23	0.19%
Exotic Forestry	284.27	0.09%
Horticulture	378.20	0.12%
Industrial Use	21.75	0.01%
Lakes & Rivers	3,153.01	1.04%
Lifestyle Block	2,316.74	0.76%
Livestock Support	2,061.65	0.68%
Majority Deer with Mixed Livestock	152.21	0.05%
Mixed Livestock	54,783.88	18.08%
Nurseries & Orchards	278.49	0.09%

Land Use	Area (Ha)	Percent
Other Animals	139.72	0.05%
Poultry	30.17	0.01%
Public Use	10.06	0.00%
Residential Use	411.96	0.14%
Road & Rail	2,133.36	0.70%
Sheep	21,097.14	6.96%
Sheep & Beef	159,316.81	52.57%
Small Land Holding	1,143.61	0.38%
Specialist Deer	566.42	0.19%
Tourism & Recreational Use	108.21	0.04%
Unknown Land Use	3,028.17	1.00%
Unknown Land Use - Indigenous Cover	444.33	0.15%
Unknown Land Use - Non-agricultural	28.45	0.01%
Unknown Land Use - Pastoral Cover	1,891.19	0.62%

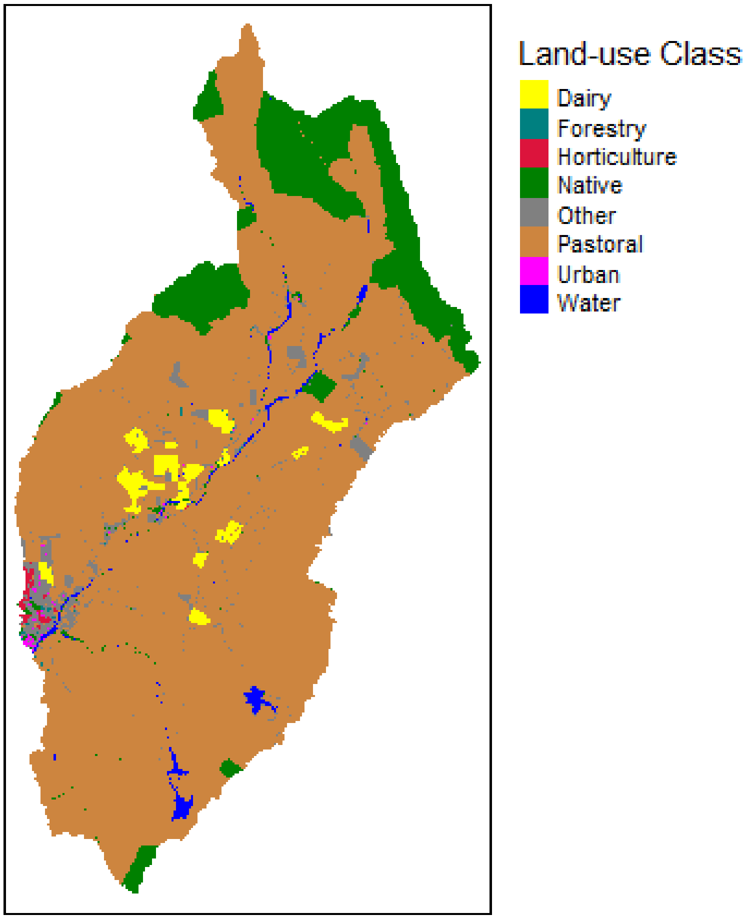

Figure 44: Land-use within the Manuherekia Rohe. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

In the Manuherekia Rohe, the GMP scenario results in approximately a 5% reduction in nitrogen and 3% reduction phosphorus emissions whereas the GMP+ scenario results in a 22% reduction of nitrogen and 15% reduction in phosphorus emissions *(*Table 46*)*. These reductions result in the FMUs overall average yield decreasing from 7.80 kg/ha/yr of nitrogen under the current scenario to 7.43 kg/ha/yr and 6.12 kg/ha/yr under the GMP and GMP+ scenarios respectively *(*Table 47*)*. The average phosphorus yield decreases from 0.41 kg/ha/yr under current, under 0.40 kg/ha/yr GMP and 0.35 kg/ha/yr under the GMP+ scenario.

Table 46: Total on-land nitrogen and phosphorus load reductions achieved through the GMP and GMP+ scenarios in the Manuherekia Rohe.

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	4.68%	110,504.04	21.54%	508,918.89
P	3.15%	3,961.41	15.71%	19,752.24

Table 47: Average yield of nitrogen and phosphorus under the current, GMP and GMP+ scenarios in the Manuherekia Rohe.

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	7.80	7.43	6.12
P	0.41	0.40	0.35

Rivers

Yields

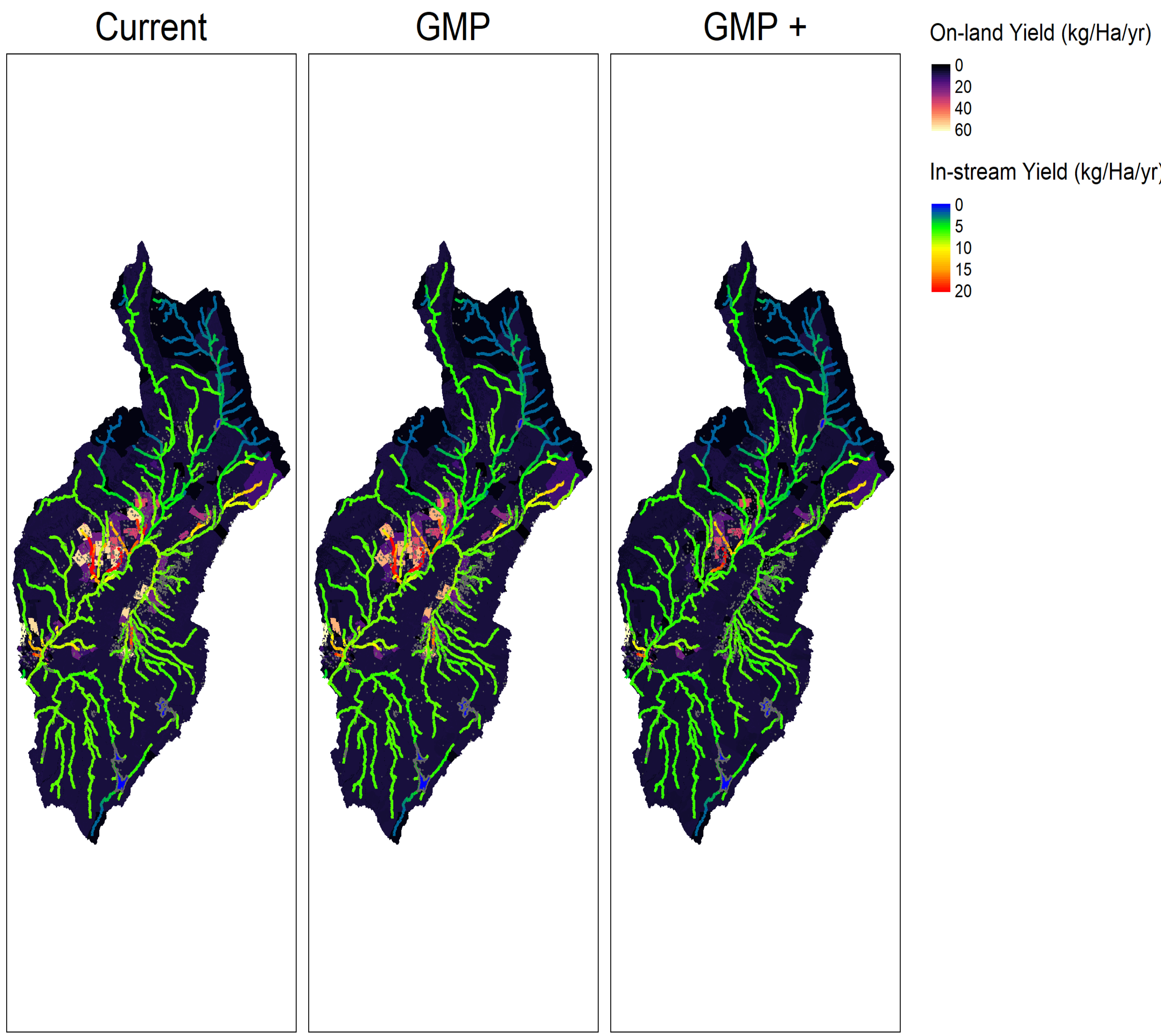

Figure 45: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for current, GMP and GMP+ scenarios in the Manuherekia Rohe.

Spatially, in the Manuherekia Rohe average upstream nitrogen yields (Figure 45) tend to be approx. 8-10 kg/ha/yr. The highest yield areas for nitrogen occur in tributaries near the confluences of

Thomson's and Lauder Creek. Under the GMP and GMP+ scenarios, yields decrease across the catchment with particularly large reductions in those areas.

Average upstream phosphorus yields range from 0.2 kg/ha/yr in the upper catchment to approximately 0.6 kg/ha/yr in the major tributaries and mainstem (Figure 46). Under the GMP and GMP+ scenario average upstream yields reduce across the entire catchment.

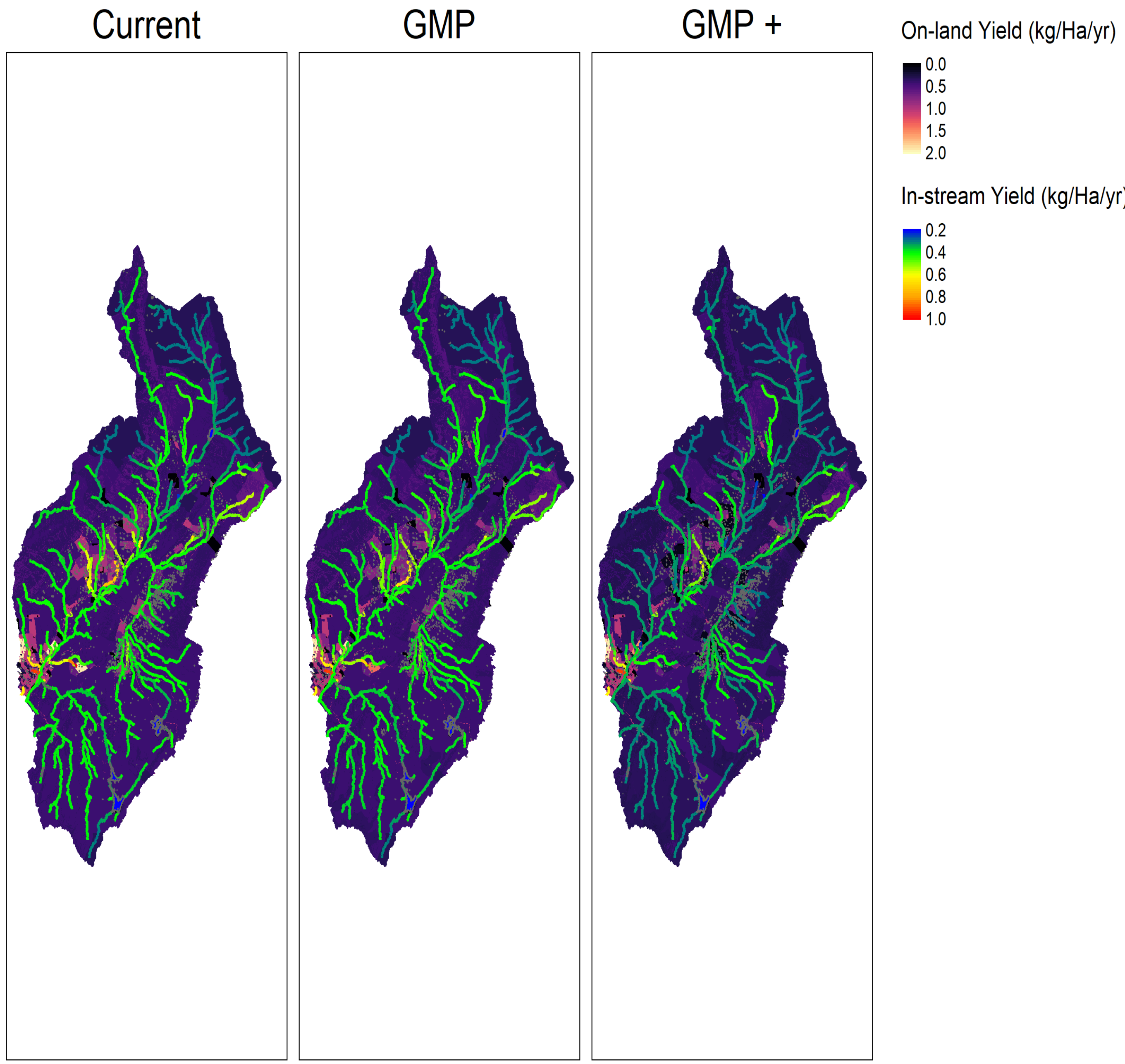

Figure 46: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for current, GMP and GMP+ scenarios in the Manuherekia Rohe.

Nitrate Toxicity

All segments in the Manuherekia Rohe comply with the A band nitrate toxicity target attribute state (Table 48) under all modelled scenarios thus *requiring no reductions*. This is also true for all management classes (Table 49). All segments in the FMU are also *very likely* to comply with the A-band nitrate toxicity criteria (Figure 47).

Table 48: Percent of river segments in the Manuherekia Rohe complying with potential nitrate toxicity target attribute states with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,696
B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,696
C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,696

Table 49: Percent of river segments in the Manuherekia Rohe complying with potential nitrate toxicity target attribute states, split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity					
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
M	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	466
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	466
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	466
H	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	790

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	790
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	790
L	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	20
L	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	20
L	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	20
Lk Upper	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	66
Lk Upper	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	66
Lk Upper	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	66

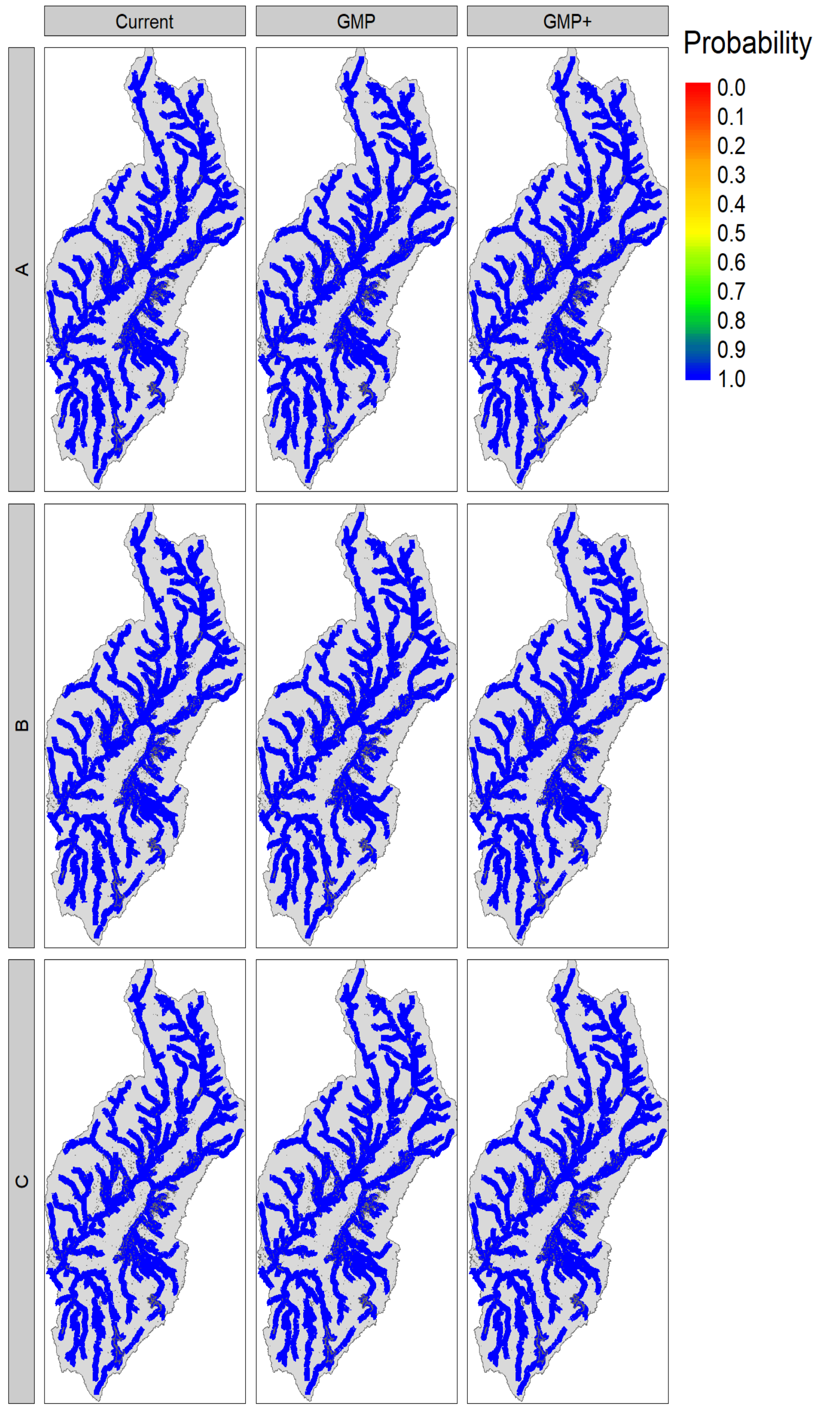

Figure 47: Individual segment probability of achieving the A, B and C nitrate toxicity target attribute states under the current, GMP and GMP+ scenarios in the Manuherekia Rohe.

Periphyton

For total nitrogen in relation to the periphyton biomass nutrient criteria (Table 50), *nearly all* segments in the Manuherekia Rohe comply with the C-band total nitrogen criteria under the current scenario. Confidence intervals indicate *no reduction is required* to comply with this criterion. *Nearly all*, segments also comply with the B-band total nitrogen criteria under the current scenario. Reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios the proportion of segments expected to comply improves slightly. However, the upper confidence interval still fails to overlap 100% indicating reductions beyond GMP+ *are required* for all segments to comply with the B-band criteria.

For total phosphorus in relation to the periphyton biomass nutrient criteria (Table 50), *nearly all* segments in the Manuherekia Rohe comply with the C-band criteria under the current scenario. Confidence intervals indicate reductions *may be* required to comply in all segments. Under the GMP scenario, the proportion of segments expected to comply does not improve. The proportion improves slightly under the GMP+ scenario. However, the mean fails to overlap 100% indicating reductions beyond GMP+ *may be* required. *Some* segments comply with the B-band total phosphorus criteria under the current scenario indicating reductions *are required* for all segments comply. Under the GMP scenario, the proportion of segments expected to comply does not increase. Under the GMP+ scenario, the proportion expected to comply increases slightly. However, both the mean and upper confidence interval fail to overlap 100% indicating reductions beyond GMP+ *are required* to comply with the B-band criteria in all segments.

Few segments in any class comply with the A-band criteria for both total nitrogen and total phosphorus. This indicates the A-band nutrient criteria would not be expected to be complied with in 80% of segments even under natural conditions. In the case that segments do comply, confidence intervals are wide indicating high uncertainty.

When split by management class, for the total nitrogen C-band criteria (Table 51), *nearly all* mountain, hill, and upper lake segments in the Manuherekia Rohe comply currently. *No reduction is required* for these classes to comply as the lower confidence interval overlaps 100%. Lowland segments comprise a small portion of the FMU, represented by only 20 segments. *Nearly all*, lowland segments comply with the C-band total nitrogen criteria currently however reductions *may be* required. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves. The mean estimate and lower confidence interval still fail to overlap 100% indicating reductions beyond GMP+ *may be* required for all segments to comply.

When split by management class, for the total nitrogen B-band criteria (Table 51), *nearly all* mountain and upper lake class segments comply currently. Confidence intervals indicate *no reduction is required* for all segments to comply with this criterion. For hill segments, *most* segments comply with the B-band criteria under the current scenario. Confidence intervals indicate high uncertainty in the required reduction to comply with the criteria. The mean and lower confidence interval indicate *reductions are likely required* for all segments to comply. Under the GMP and GMP+ scenarios the proportion of segments expect to comply improves. However, further *reductions are likely required* for all segments to comply. *Few* lowland segments comply with the B-band criteria under any modelled scenario. This indicates reductions beyond GMP+ *are required* for all lowland segments to comply with the B-band criteria.

When split by management class, for the total phosphorus C-band criteria (Table 51), *nearly all* mountain and upper lake segments comply currently. Confidence intervals indicate *no reduction is required* to comply with this criterion. For hill-fed and lowland segments, nearly all segments currently comply with the C-band total phosphorus criteria. Confidence intervals indicate reductions *may be* required for all segments to comply in both classes. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves. However, confidence intervals indicate reductions beyond GMP+ *may be* required for all segments to comply.

When split by management class, for the total phosphorus B-band criteria (Table 51), *most* mountain segments comply with the B-band phosphorus criteria under the current scenario. Reductions *are likely required* for all segments to comply. Under the GMP scenario, the proportion of segments expected to comply does not improve. Under the GMP+ scenario, the proportion of segments expected to comply improves to *nearly all*. However, confidence intervals indicate reductions beyond GMP+ *may be* required for all segments to comply. *Few* segments in the hill, lowland, or upper lake class comply with the B-band total phosphorus criteria under any scenario. As upper confidence intervals fail to overlap 100% under any scenario, there is 95% confidence reductions beyond GMP+ *are required* to comply with the B-band criteria in all segments.

Table 50: Percent of river segments in the Manuherekia Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			Total Phosphorus				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	5 (0 - 30)	6 (0 - 32)	6 (0 - 35)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	1,343
B	79 (44 - 99)	80 (44 - 99)	84 (46 - 99)	28 (17 - 35)	28 (17 - 35)	29 (18 - 37)	0	1,343
C	100 (99 - 100)	100 (100 - 100)	100 (100 - 100)	93 (57 - 100)	93 (60 - 100)	95 (73 - 100)	0	1,343

Table 51: Percent of river segments in the Manuherekia Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria, split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	A	12 (0 - 80)	13 (0 - 83)	14 (0 - 89)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	466
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	78 (49 - 100)	78 (49 - 100)	82 (52 - 100)	0	466

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	466
H	A	2 (0 - 5)	2 (0 - 6)	2 (0 - 7)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	790
H	B	67 (7 - 100)	69 (7 - 100)	75 (11 - 100)	1 (0 - 0)	1 (0 - 1)	2 (0 - 4)	0	790
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	88 (29 - 100)	89 (35 - 100)	92 (56 - 100)	0	790
L	A	0 (0 - 0)	0 (0 - 0)	1 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	20
L	B	1 (0 - 0)	1 (0 - 0)	2 (0 - 1)	0 (0 - 0)	0 (0 - 0)	2 (0 - 5)	0	20
L	C	92 (65 - 100)	94 (70 - 100)	98 (85 - 100)	83 (5 - 100)	85 (10 - 100)	90 (35 - 100)	0	20
Lk Upper	A	2 (0 - 0)	2 (0 - 0)	2 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	66
Lk Upper	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	2 (0 - 0)	2 (0 - 0)	2 (0 - 0)	0	66
Lk Upper	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	97 (95 - 100)	98 (97 - 100)	99 (100 - 100)	0	66

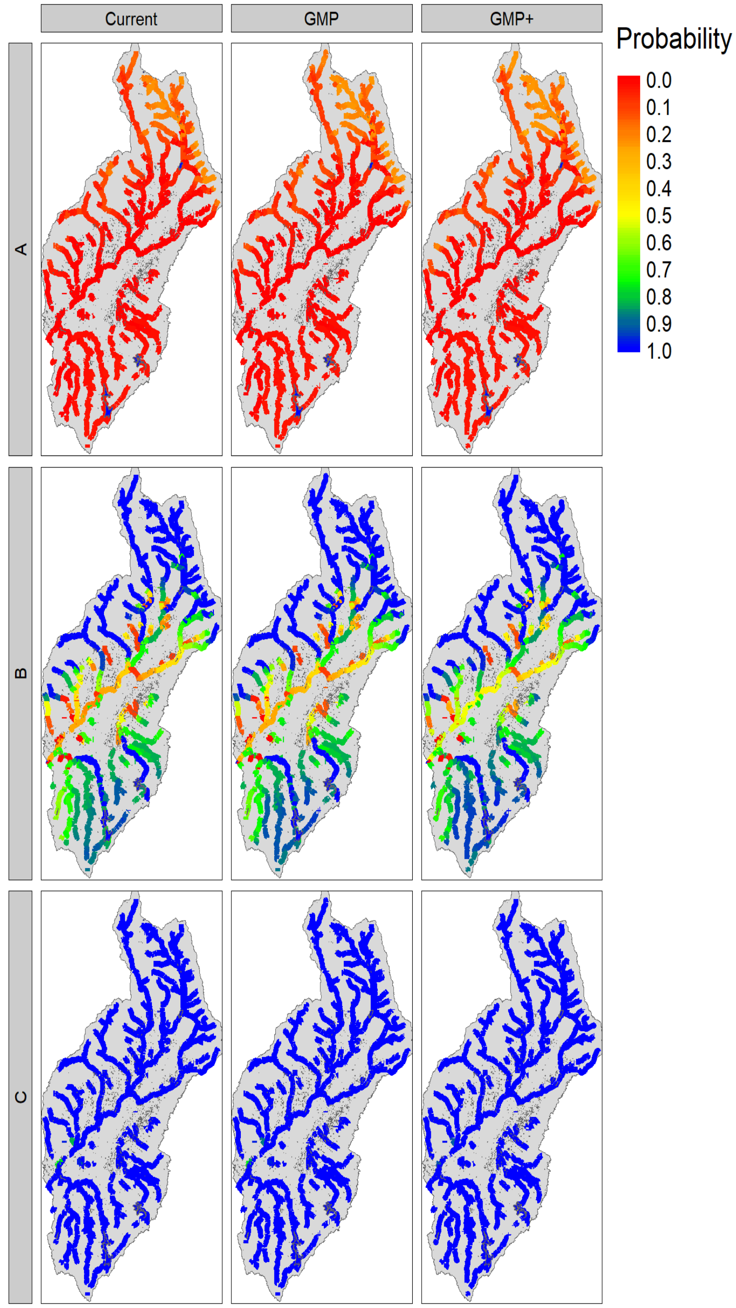

Figure 48: Individual segment probability of complying with the total nitrogen A, B and C periphyton nutrient criteria under the current, GMP and GMP+ scenarios in the Manuherekia Rohe.

Spatially, for total nitrogen (Figure 48), the majority of the Manuherekia Rohe is *very likely* to comply with the C-band criteria under all scenarios. For the B-band criteria, upper catchments of the mainstem, Dunstan Creek, Lauder Creek and Thompson's creek are *very likely* to comply. The majority of the mainstem of the Manuherekia and lower elevation tributaries are *unlikely* to comply with the B-band criteria under the current scenario but improve under the GMP and GMP+ scenario to *as likely as not*. All segments are *very unlikely* to comply with the A-band criteria except for some high elevation tributaries which are *unlikely*.

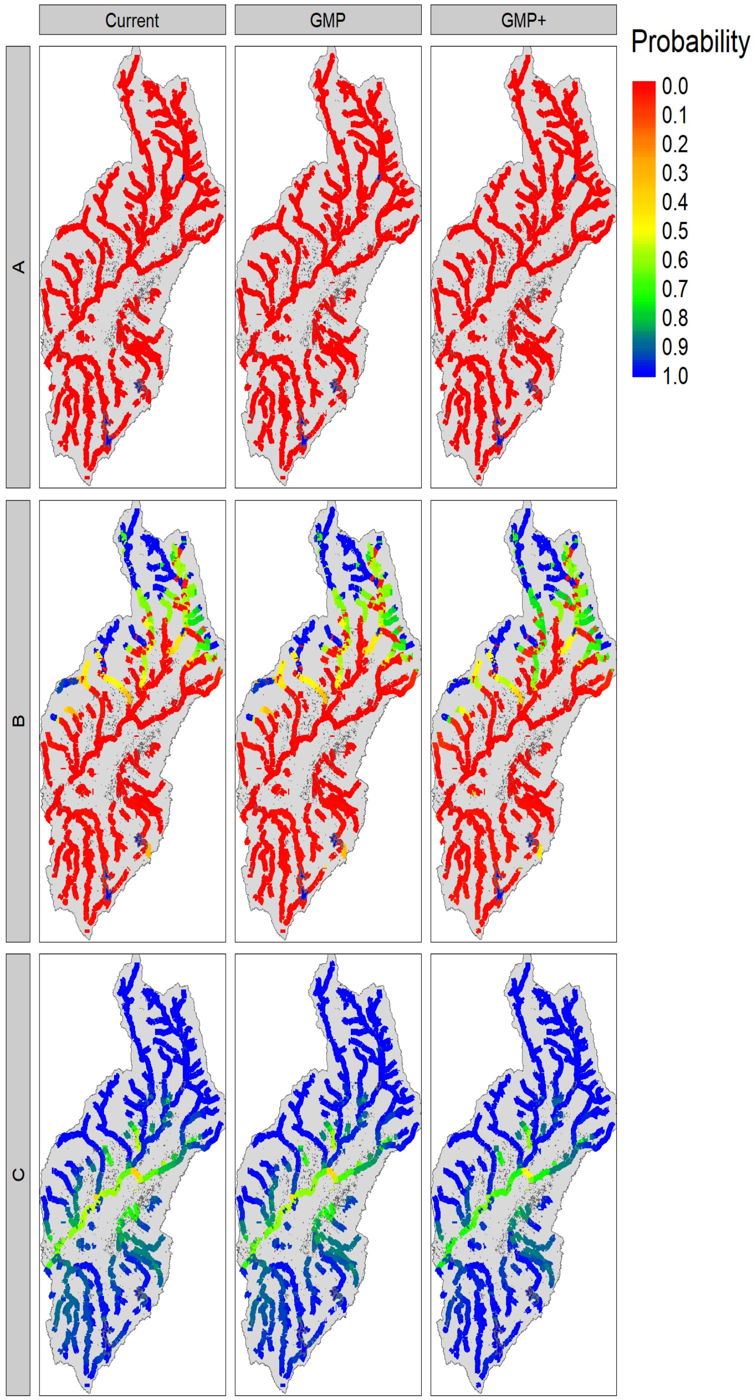

Figure 49: Individual segment probability of complying with the total phosphorus A, B and C periphyton nutrient criteria under the current, GMP and GMP+ scenarios in the Manuherekia Rohe.

Spatially, for phosphorus (Figure 49), the majority of the Manuherekia Rohe is *very likely* to comply with the C-band criteria under all scenarios with the mainstem *likely* to comply. The probability of the mainstem complying with C-band criteria improves under the GMP and GMP+ scenarios. The majority of the Rohe is *very unlikely* to comply with the B-band criteria under any scenario outside of headwaters which are *likely* to *very likely* to comply with the B-band criteria. All segments are *very unlikely* to comply with the A-band criteria under all scenarios.

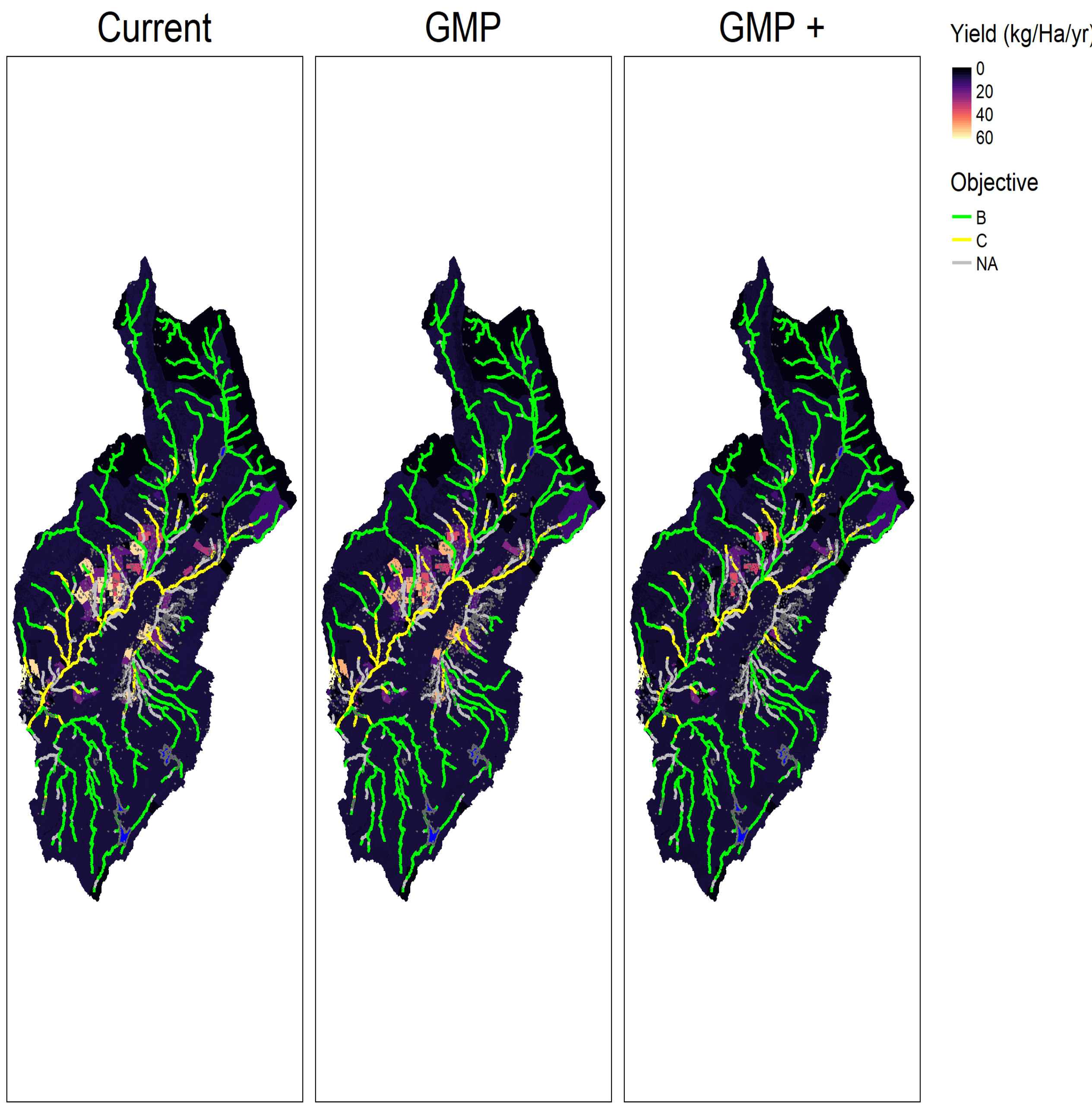

Figure 50: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization total nitrogen periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios in the Manuherekia Rohe.

Mean realization comparisons for *total* nitrogen result in the in the majority of the Rohe complying with the B-band criteria and the mainstem complying with the C-band criteria under all scenarios (Figure 50). Areas of the lower Manuherekia mainstem improve from the C-band to B-band under the GMP+ scenario.

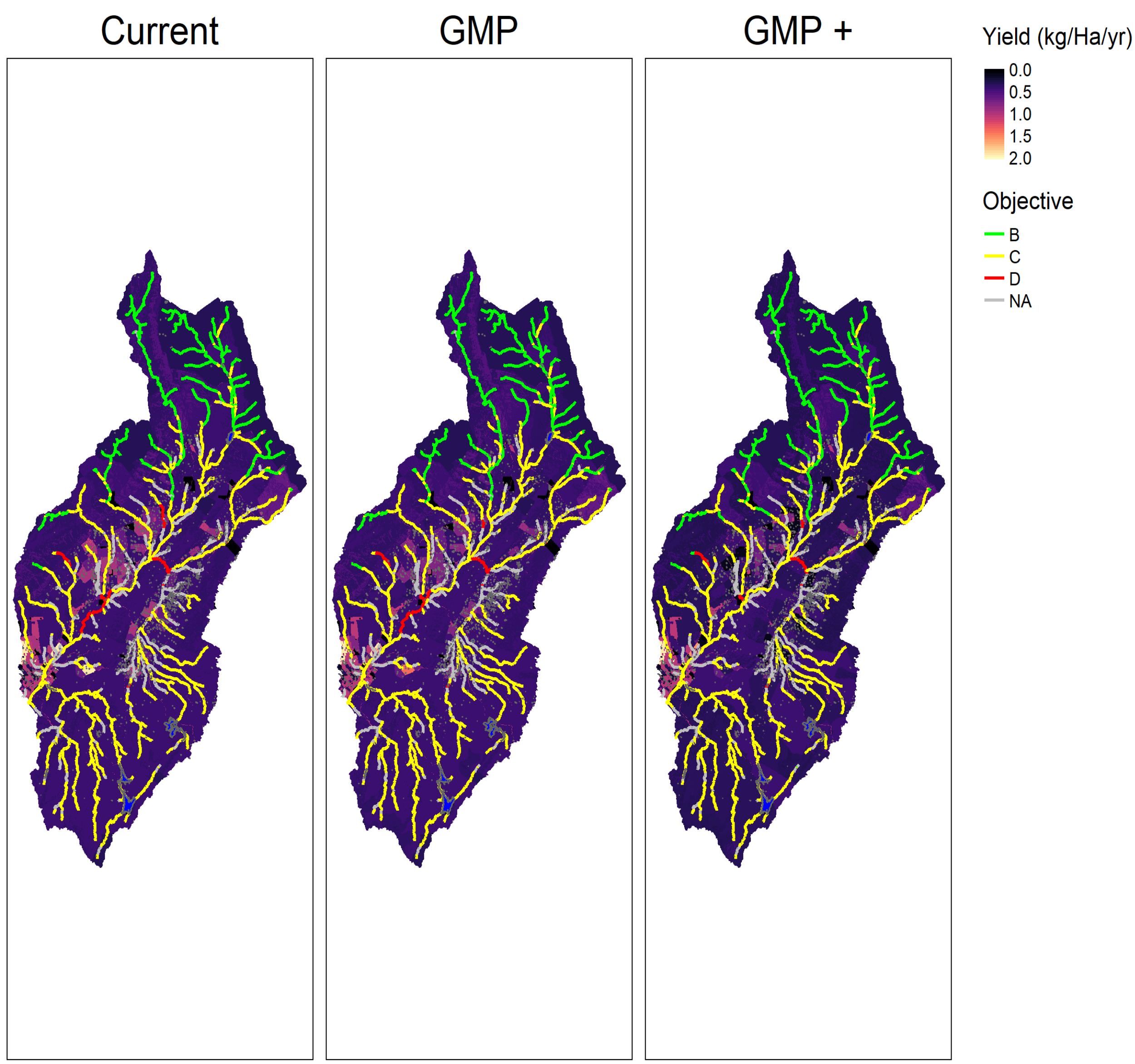

Figure 51: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios in the Manuherekia Rohe.

Mean realization comparisons for total phosphorus (Figure 51) result in the in the majority of the Rohe complying with the C-band criteria with the exception of head water catchments of the mainstem, Dunstan Creek, Lauder Creek, and Thompson's creek complying with the B-band criteria. Segments of the mainstem and other minor tributaries fail to comply with the C-band. Under the GMP+ scenario, segments of the mainstem of the Manuherekia river improve to complying with the C-band criteria.

Lakes

The Manuherekia Rohe contains six named lakes for which modelling results are available: Idaburn Dam, Falls Dam, Greenland Reservoir, Manorburn Reservoir, Lower Manor burn Dam, and Poolburn Reservoir (Table 52).

Nitrogen

For total nitrogen, all lakes are *very likely* to comply with the C-band target attribute state across all scenarios. Greenland, Manorburn, Falls Dam, and Poolburn, are all also *very likely* to comply with the B-band criteria target attribute state under all scenarios. The Manorburn Reservoir is *unlikely* to comply with the A-band target attribute state for all scenarios. The Greenland Reservoir is *unlikely* to comply with the A-band target attribute state under the current scenario but improves to *as likely as not* under the GMP and GMP+ scenarios. Falls dam is *unlikely* to comply with the A-band target attribute state under all three scenarios. The Poolburn Reservoir is *unlikely* to comply with the A-band target attribute state under all three scenarios.

The Idaburn Dam is *likely* to comply with the B-band target attribute state and *very unlikely* to comply with the A-band target attribute state under all scenarios.

Lower Manorburn is *very likely* to comply with the B-band target attribute state under all three scenarios. The A-band target attribute state is *very unlikely* to be complied with in Lower Manorburn under any scenario.

Phosphorus

For total phosphorus, the Greenland Reservoir, Manorburn Reservoir, and Poolburn Reservoir are all *very likely* to comply with the C-band target attribute state across all scenarios modelled. The Greenland Reservoir is *very likely* to comply with the B band target attribute state under all scenarios. Compliance with the A-band target attribute state is *very unlikely* under the current and GMP scenarios and *unlikely* under the GMP+ scenario. The Manorburn is *likely* to *very likely* to comply with the B-band target attribute state *and very unlikely* to comply with the A-band target attribute states across all scenarios. Poolburn Reservoir is *likely* to *very likely* to comply with the B-band target attribute state and *very unlikely* to comply with the A-band target attribute state under all three scenarios.

Idaburn Dam is *likely* to comply with the C-band target attribute state and *very unlikely* to comply with the B-band or A-band target attribute states under all scenarios.

Falls Dam is *very likely* to comply with the C-band target attribute state and *very unlikely* to comply with the B- or A-band target attribute under all modelled scenarios.

Lower Manorburn is *very likely* to comply with the C-band target attribute state and *very unlikely* to comply with the B- or A-band target attribute states under all scenarios.

Table 52: Probability of compliance of lakes in the Manuherekia Rohe with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval.

		Total Nitrogen			**Total Phosphorus**		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Idaburn Dam	A	2 (1 - 6)	2 (1 - 6)	3 (1 - 7)	1 (0 - 4)	1 (0 - 4)	2 (1 - 6)
Idaburn Dam	B	68 (60 - 75)	71 (63 - 78)	77 (69 - 83)	1 (0 - 4)	1 (0 - 4)	2 (1 - 6)
Idaburn Dam	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	75 (67 - 81)	75 (67 - 81)	78 (70 - 84)
Falls Dam	A	24 (18 - 32)	28 (21 - 36)	30 (23 - 38)	1 (0 - 4)	1 (0 - 4)	1 (0 - 4)
Falls Dam	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	4 (2 - 9)	5 (2 - 10)	6 (3 - 11)
Falls Dam	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	84 (77 - 89)	84 (77 - 89)	86 (79 - 91)
Greenland Reservoir	A	35 (28 - 43)	40 (32 - 48)	48 (40 - 56)	15 (10 - 22)	15 (10 - 22)	22 (16 - 30)
Greenland Reservoir	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	83 (76 - 88)	83 (76 - 88)	87 (80 - 92)
Greenland Reservoir	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Manorburn Reservoir	A	34 (27 - 42)	34 (27 - 42)	38 (30 - 46)	14 (9 - 21)	14 (9 - 21)	15 (10 - 22)

		Total Nitrogen			Total Phosphorus		
Lake Name	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+
Manorburn Reservoir	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	80 (73 - 86)	80 (73 - 86)	82 (75 - 87)
Manorburn Reservoir	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lower Manorburn Dam	A	4 (2 - 9)	4 (2 - 9)	6 (3 - 11)	2 (1 - 6)	2 (1 - 6)	2 (1 - 6)
Lower Manorburn Dam	B	90 (84 - 94)	93 (88 - 96)	94 (89 - 97)	9 (5 - 15)	9 (5 - 15)	15 (10 - 22)
Lower Manorburn Dam	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	90 (84 - 94)	90 (84 - 94)	91 (85 - 95)
Poolburn Reservoir	A	31 (24 - 39)	33 (26 - 41)	34 (27 - 42)	12 (8 - 18)	12 (8 - 18)	14 (9 - 21)
Poolburn Reservoir	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	73 (65 - 80)	73 (65 - 80)	81 (74 - 87)
Poolburn Reservoir	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)

Roxburgh Rohe

Land use characteristics

Land use in the Roxburgh Rohe (Table 53; Figure 52) is comprised primarily of sheep and beef (65%), conservation (10%), mixed stock (6%), and sheep (6%). In this Rohe, the GMP and GMP+ mitigations packages can be applied to approximately 80% of the FMU based on land use.

Table 53: Land use statistics for the Roxburgh Rohe.

Land Use	Area (Ha)	Percent
Arable	90.82	0.05%
Beef	1,188.92	0.65%
Commercial Use	13.49	0.01%
Conservation	17,647.38	9.69%
Dairy	1,241.66	0.68%
Dairy Support	883.29	0.49%
Exotic Forestry	3,496.34	1.92%
Horticulture	211.17	0.12%
Industrial Use	130.07	0.07%
Lakes & Rivers	3,097.86	1.70%
Lifestyle Block	1,569.73	0.86%
Livestock Support	297.89	0.16%
Majority Deer with Mixed Livestock	507.72	0.28%
Mixed Livestock	11,692.51	6.42%
Nurseries & Orchards	3,305.55	1.82%
Other Animals	24.07	0.01%
Poultry	39.72	0.02%
Public Use	9.96	0.01%
Residential Use	444.58	0.24%

Land Use	Area (Ha)	Percent
Road & Rail	1,784.04	0.98%
Sheep	11,692.46	6.42%
Sheep & Beef	117,859.34	64.73%
Small Land Holding	866.74	0.48%
Specialist Deer	470.32	0.26%
Tourism & Recreational Use	67.49	0.04%
Unknown Land Use	2,111.51	1.16%
Unknown Land Use - Indigenous Cover	224.25	0.12%
Unknown Land Use - Non-agricultural	119.16	0.07%
Unknown Land Use - Pastoral Cover	989.25	0.54%

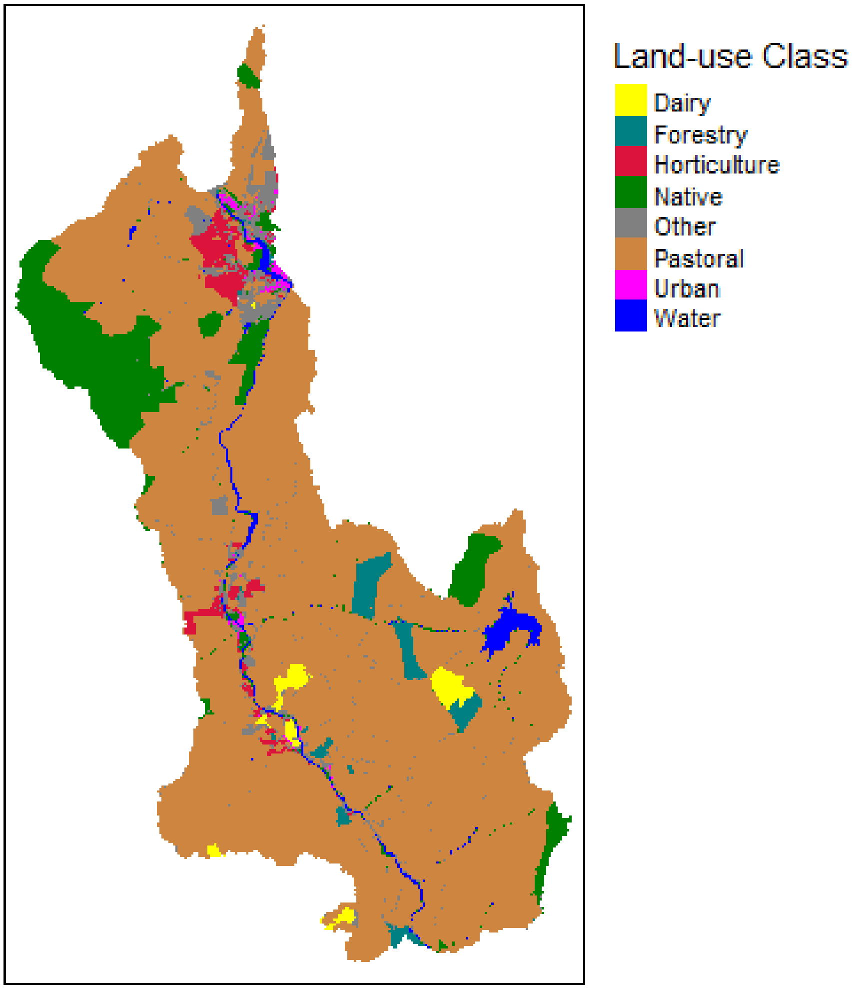

Figure 52: Land-use within the Roxburgh Rohe. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

In the Roxburgh Rohe, the GMP scenario results in approximately a 3% reduction in nitrogen and a 1% reduction in phosphorus emissions whereas the GMP+ scenario results in a 9% reduction of nitrogen and 10.4% reduction in phosphorus emissions (Table 54). These reductions result in the FMUs overall average yield decreasing from 6.76 kg/ha/yr of nitrogen under the current scenario to 6.56 kg/ha/yr and 6.17 kg/ha/yr under the GMP and GMP+ scenarios respectively (Table 55). The average phosphorus yield decreases from 0.39 kg/ha/yr under current, under 0.39 kg/ha/yr GMP and 0.35 kg/ha/yr under the GMP+ scenario.

Table 54: Total on-land nitrogen and phosphorus load reductions achieved through the GMP and GMP+ scenarios in the Roxburgh Rohe.

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	3.02%	37,163.74	8.77%	107,943.23
P	1.47%	1,045.70	10.35%	7,385.11

Table 55: Average yield of nitrogen and phosphorus under the current, GMP and GMP+ scenarios in the Roxburgh Rohe.

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	6.76	6.56	6.17
P	0.39	0.39	0.35

Rivers

Yields

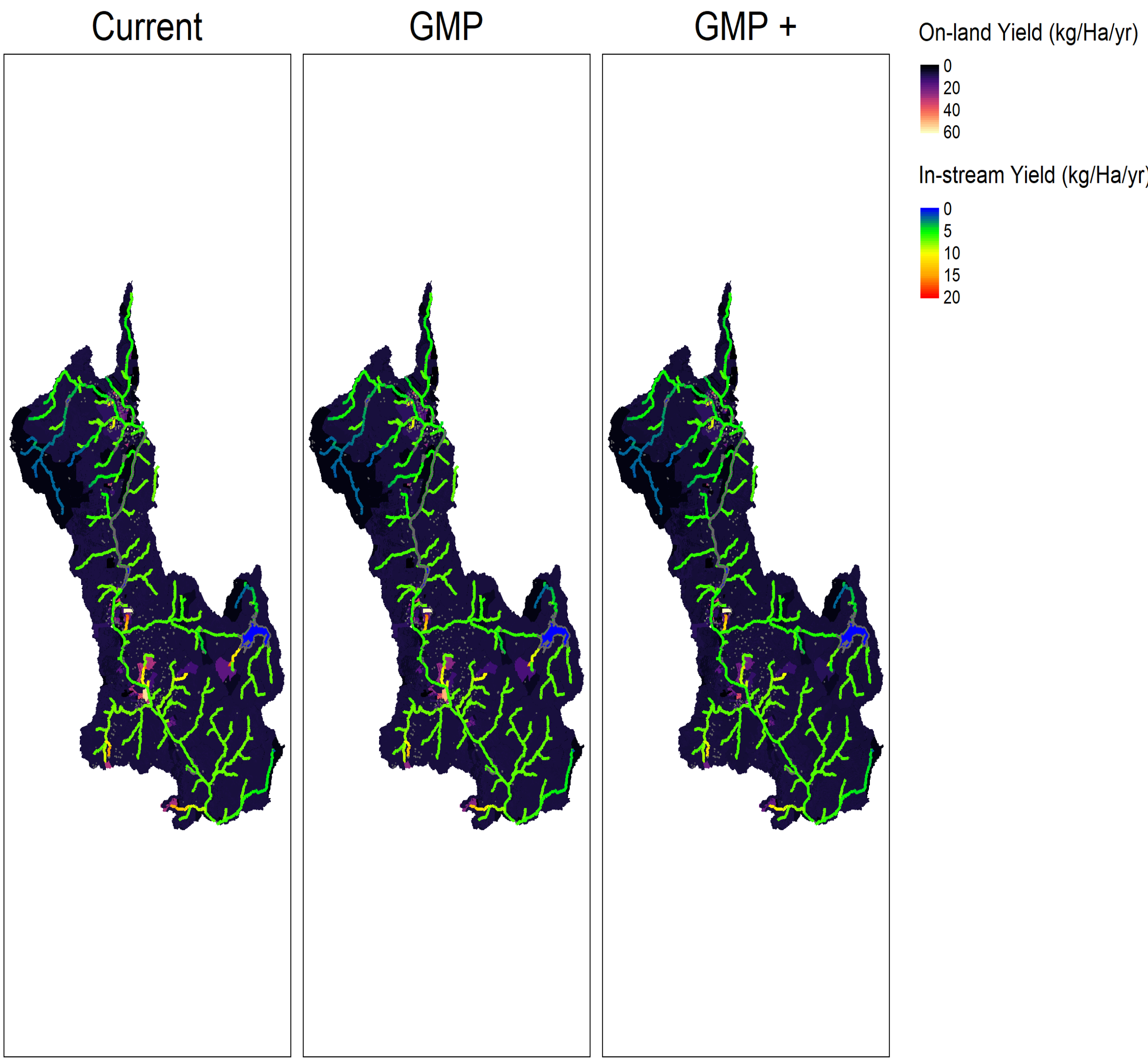

Figure 53: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios in the Roxburgh Rohe.

Spatially, the lowest yield areas for nitrogen (Figure 53) and phosphorus (Figure 54) in the Roxburgh Rohe occur in the upper Fraser catchment with higher yields prevalent throughout the rest of the Rohe. Under the GMP and GMP+ scenarios many of these segments have reduced upstream average yields.

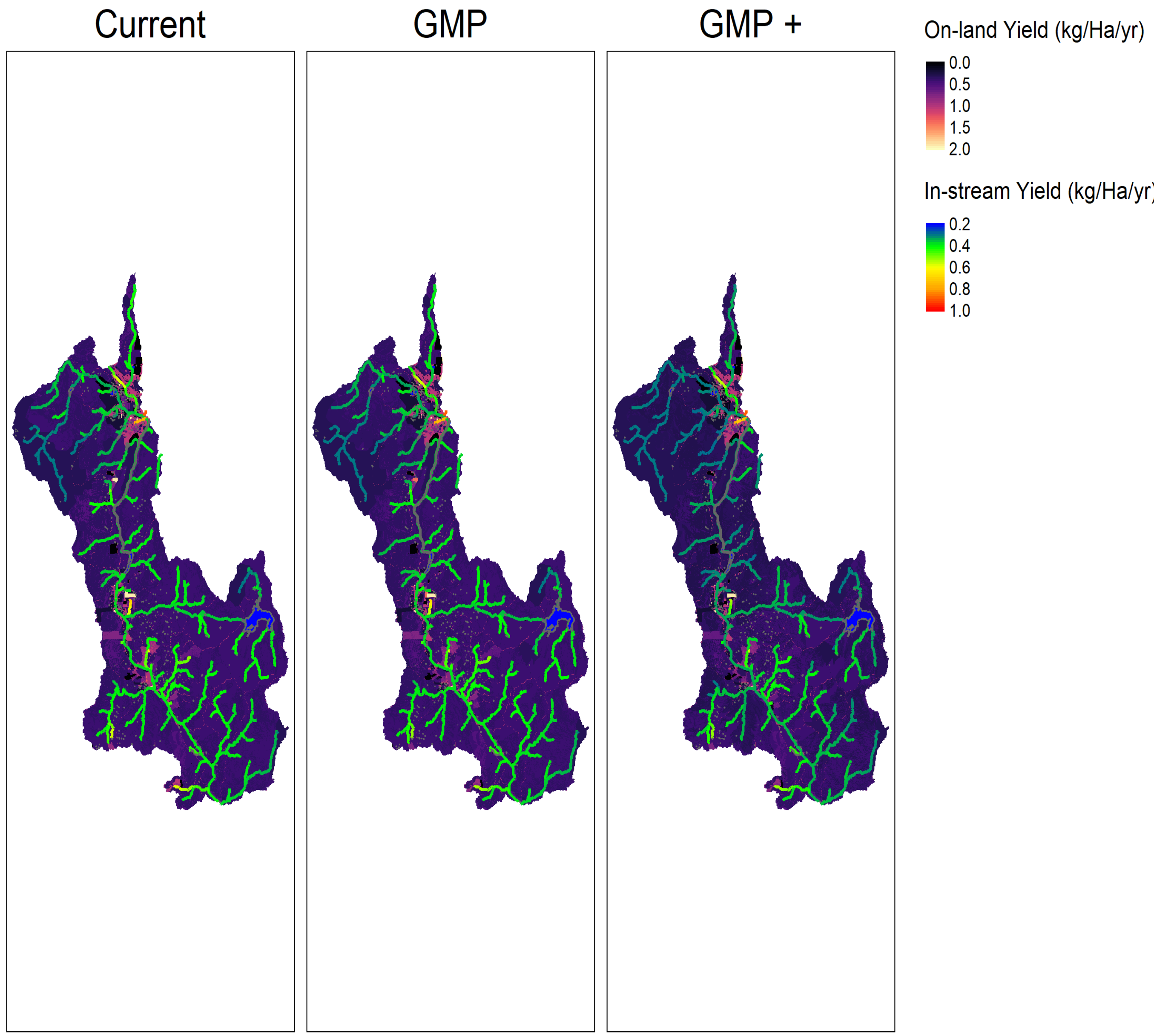

Figure 54: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios in the Roxburgh Rohe.

Nitrate Toxicity

All segments in the Roxburgh Rohe comply with the A band nitrate toxicity target attribute state (Table 48) under all modelled scenarios thus *requiring no reductions*. This is also true for all management classes (Table 57).

Table 56: Percent of river segments in the Roxburgh Rohe complying with potential nitrate toxicity target attribute states with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,090
B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,090
C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	1,090

Table 57: Percent of river segments in the Roxburgh Rohe complying with potential nitrate toxicity target attribute states, split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

	Nitrate Toxicity				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
M	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	200
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	200
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	200

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	541
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	541
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	541
L	A	100 (99 - 100)	100 (100 - 100)	100 (100 - 100)	64
L	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	64
L	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	64
Lk Lower	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	20
Lk Lower	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	20
Lk Lower	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	20

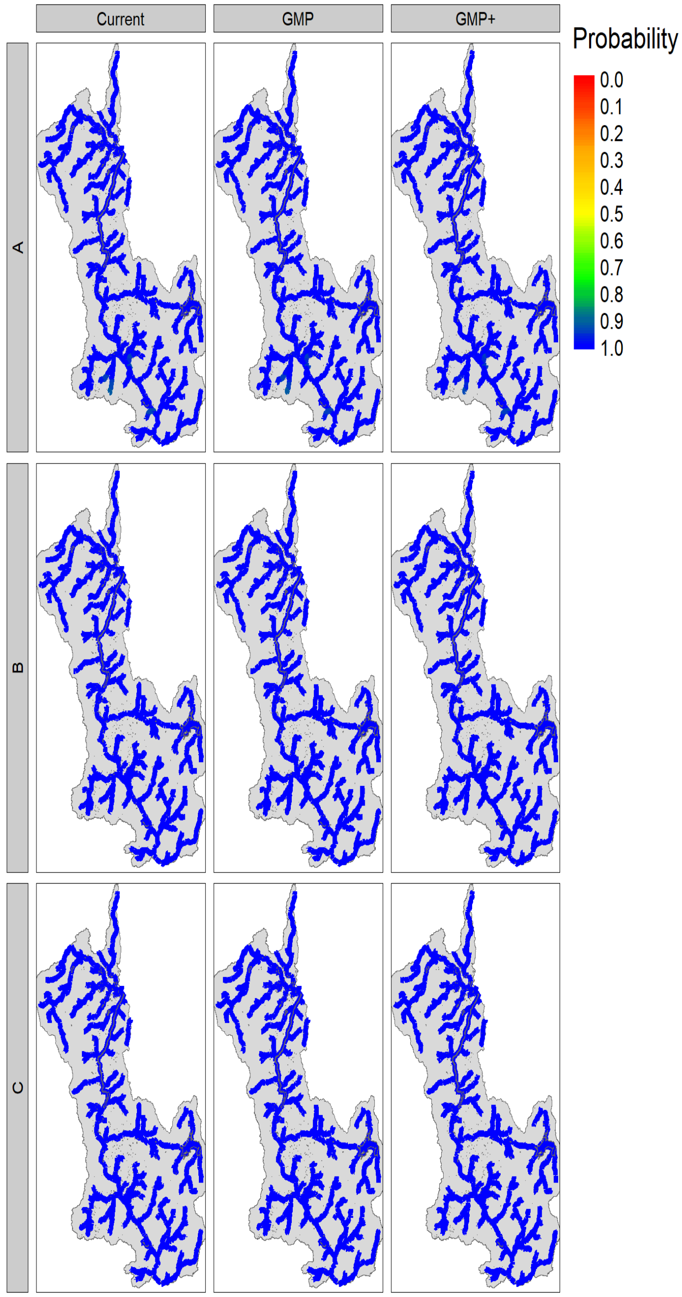

Figure 55: Individual segment probability of complying with the A, B and C nitrate toxicity target attribute states under the current, GMP and GMP+ scenarios in the Roxburgh Rohe.

All segments are very likely to comply with both the B- and A-band nitrate toxicity target attribute state (Figure 55).

Periphyton

For total nitrogen in relation to the periphyton biomass nutrient criteria (Table 58), *nearly all* of the Roxburgh Rohe complies with the C-band criteria under the current scenario. Reductions *may be* required for all segments to comply. However, the lower confidence interval and mean indicate a high proportion of segments are expected to comply under all scenarios. Under the GMP and GMP+ scenarios, there is no improvement in the proportion of segments expected to comply. *Most* segments comply with the B-band total nitrogen criteria under the current scenario. Reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios limited improvement occurs. The confidence interval still fails to overlap 100% indicating, with 95% confidence, that reductions beyond GMP+ *are required* for all segments to comply with the B-band criteria.

For total phosphorus in relation to the periphyton biomass nutrient criteria (Table 58Table 58), *nearly all* segments in the Roxburgh Rohe comply with the C-band criteria under the current scenario. Reductions *may be* required for all segments to comply. Under the GMP and GMP+ scenarios slight improvement in the proportion of segments expect to comply occurs. Further reductions *may still be required* for all segments to comply as the mean does not overlap 100%. *Some*, segments comply with the B-band criteria under the current scenario *requiring a reduction* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves. However, the upper confidence interval fails to overlap 100% indicating reductions beyond GMP+ *are required* for all segments to comply with the B-band criteria.

Few segments in any class comply with the A-band criteria for both total nitrogen and total phosphorus. This indicates the A-band nutrient criteria would not naturally be expected to be complied with in 80% of segments.

When split by management class, for the total nitrogen C-band criteria (Table 59), *all* mountain, hill, and lower lake segments in the Roxburgh Rohe comply. *No reduction is required* for these classes to comply as the lower confidence interval overlaps 100%. In the lowland class, *most* segments comply with the C-band total nitrogen criteria under the current scenario. Reductions *are likely required* in this class for all segments to comply. Under the GMP and GMP+ scenarios the mean proportion of segments expected to comply slightly improves while the confidence interval remains unchanged. Further *reductions are likely required* for all segments to comply.

When split by management class, for the total nitrogen B-band criteria (Table 59), *nearly all* mountain and lower lake segments comply. *No reduction is required* for these classes to comply as the lower confidence interval overlaps 100%. For the hill class, *most* segments comply with the B-band criteria currently. Reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly. The upper confidence interval overlaps 100% but the mean does not, which indicates reductions beyond GMP+ *are likely required* for all segments to comply. *Few* lowland segments comply under any scenario indicating reductions beyond GMP+ *are required* for all lowland segments to comply with the B-band criteria.

When split by management class, for the total phosphorus C-band criteria (Table 59), *nearly all* mountain and lowland lake segments comply under all three scenarios. *No reduction is required* for these classes to comply as the lower confidence interval overlaps 100%. *Nearly all,* hill and lowland, segments currently comply with the C-band criteria. In both classes, reductions *may be required* for all segments to comply. Under the GMP and GMP+ scenarios the proportion of segments expected to comply increases slightly in both classes. However, reductions beyond GMP+ *may be required* for all segments to comply.

When split by management class, for the total phosphorus B-band criteria (Table 59), *most* mountain segments comply under the current scenario. Reductions *are likely required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply increases. However, further reductions beyond GMP+ *are likely required* for all segments to comply. *Few* hill and lowland class segments comply with the B-band under any scenario indicating, with 95% confidence, reductions beyond GMP+ *are required* for all segments in these classes to comply with the B-band criteria. In the lower lake class, the B-band criteria is complied with in *nearly all* segments under the current, GMP and GMP+ scenarios. Confidence intervals span the entire range of outcomes indicating high uncertainty in the reduction required for this class.

Table 58: Percent of river segments in the Roxburgh Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			Total Phosphorus				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	2 (0 - 9)	3 (0 - 11)	3 (0 - 18)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	826
B	70 (36 - 94)	71 (36 - 94)	73 (40 - 94)	27 (7 - 35)	27 (7 - 35)	29 (11 - 38)	0	826
C	98 (96 - 100)	98 (96 - 100)	98 (96 - 100)	92 (59 - 100)	92 (61 - 100)	94 (67 - 100)	0	826

Table 59: Percent of river segments in the Roxburgh Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria, split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	A	5 (0 - 32)	6 (0 - 40)	7 (0 - 63)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	200
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	74 (24 - 100)	75 (24 - 100)	79 (29 - 100)	0	200

		Total Nitrogen			Total Phosphorus				
Management Class	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+	Periphyton exempt	Total segments
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	200
H	A	1 (0 - 2)	2 (0 - 2)	2 (0 - 4)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	541
H	B	66 (14 - 99)	67 (14 - 100)	70 (21 - 100)	11 (1 - 12)	11 (2 - 13)	12 (6 - 18)	0	541
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	90 (45 - 100)	91 (48 - 100)	92 (57 - 100)	0	541
L	A	1 (0 - 0)	1 (0 - 0)	1 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	64
L	B	2 (0 - 27)	2 (0 - 27)	2 (0 - 27)	1 (0 - 0)	1 (0 - 0)	1 (0 - 0)	0	64
L	C	76 (42 - 100)	78 (42 - 100)	79 (42 - 100)	81 (34 - 100)	81 (34 - 100)	83 (36 - 100)	0	64
Lk Lower	A	3 (0 - 0)	3 (0 - 0)	3 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	20
Lk Lower	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	83 (0 - 100)	83 (0 - 100)	85 (0 - 100)	0	20
Lk Lower	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	20

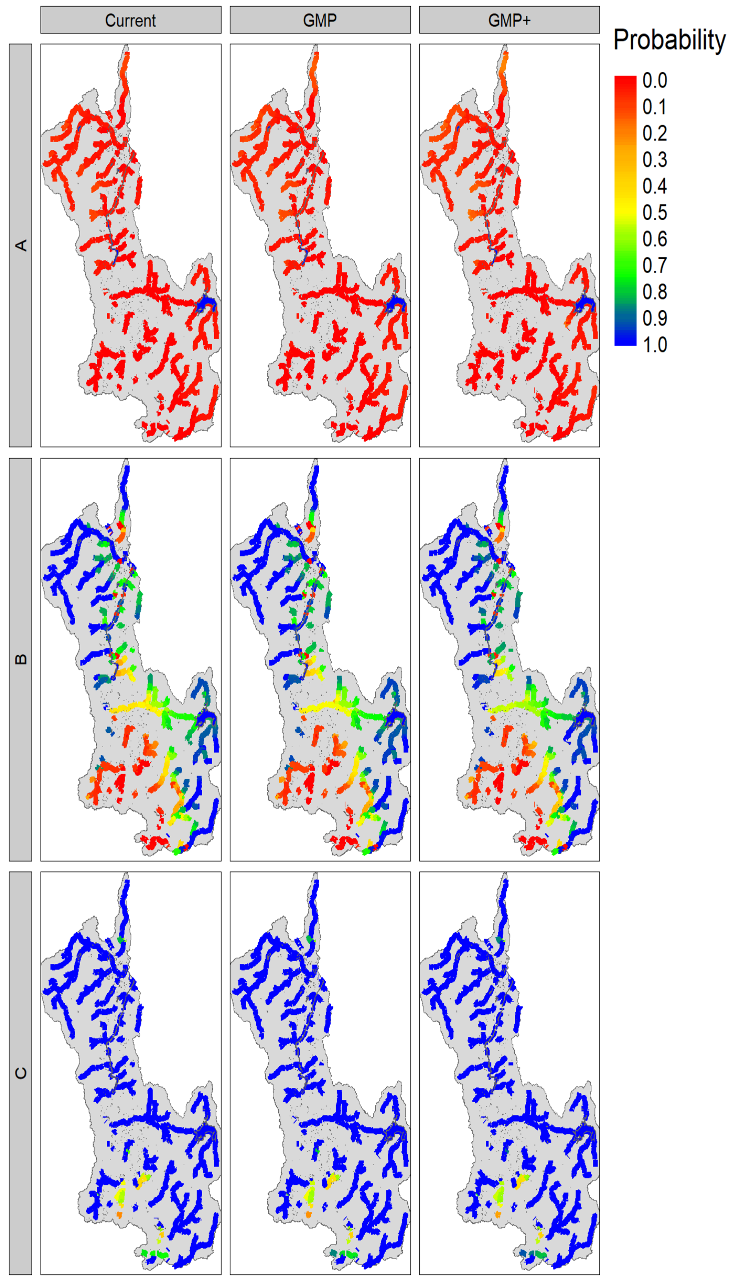

Figure 56: Individual segment probability of complying with the total nitrogen A, B and C periphyton nutrient criteria under the current, GMP and GMP+ scenarios in the Roxburgh Rohe.

Spatially, for total nitrogen, the majority of the Roxburgh Rohe is *very likely* to comply with the C-band criteria under all scenarios (Figure 56). For the B-band criteria, the upper Fraser and Teviot are *very likely* to comply whereas the rest of the Rohe ranges from *very unlikely* to *likely* to comply. All segments are *very unlikely* to comply with the A-band criteria. Very limited improvement in probability occurs under the GMP and GMP+ scenarios.

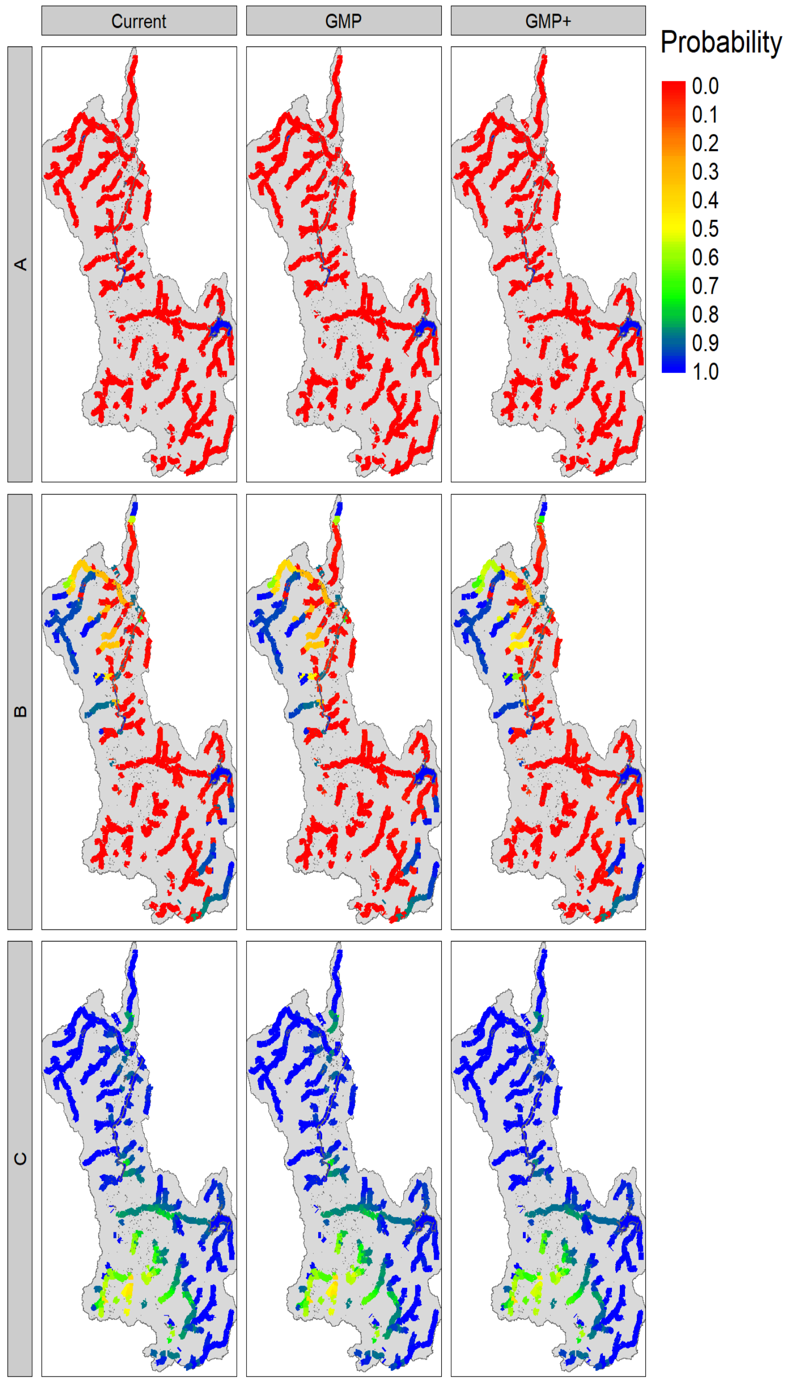

Figure 57: Individual segment probability of complying with the total phosphorus A, B and C periphyton nutrient criteria under the current, GMP and GMP+ scenarios in the Roxburgh Rohe.

Spatially, for total phosphorus, the majority of the Roxburgh Rohe is *likely* to *very likely* to comply with the C-band criteria under all scenarios (Figure 57). The upper Fraser catchment and other headwater segments are *very likely* to comply with the B-band criteria whereas the majority of the Rohe is *very unlikely* to comply. All segments are *very unlikely* to comply with the A-band criteria. Very limited improvement in probability occurs under the GMP and GMP+ scenarios.

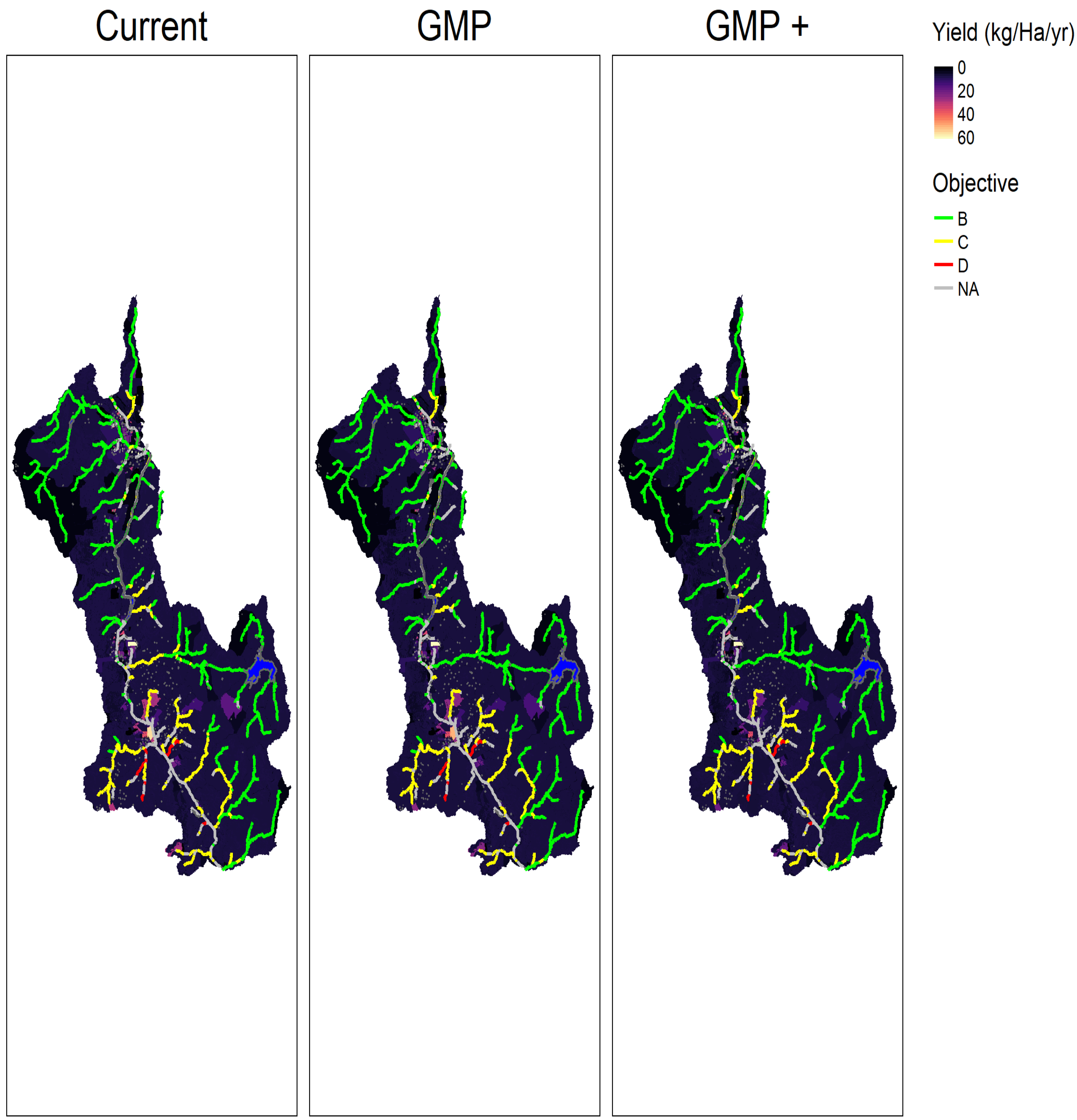

Figure 58: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization total nitrogen periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios in the Roxburgh Rohe.

Mean realization comparisons for total nitrogen result in the in the majority of the Rohe complying with the B-band criteria (Figure 58). A small number of segments fail to comply with the C-band criteria. Few band changes occur under the GMP and GMP+ scenarios.

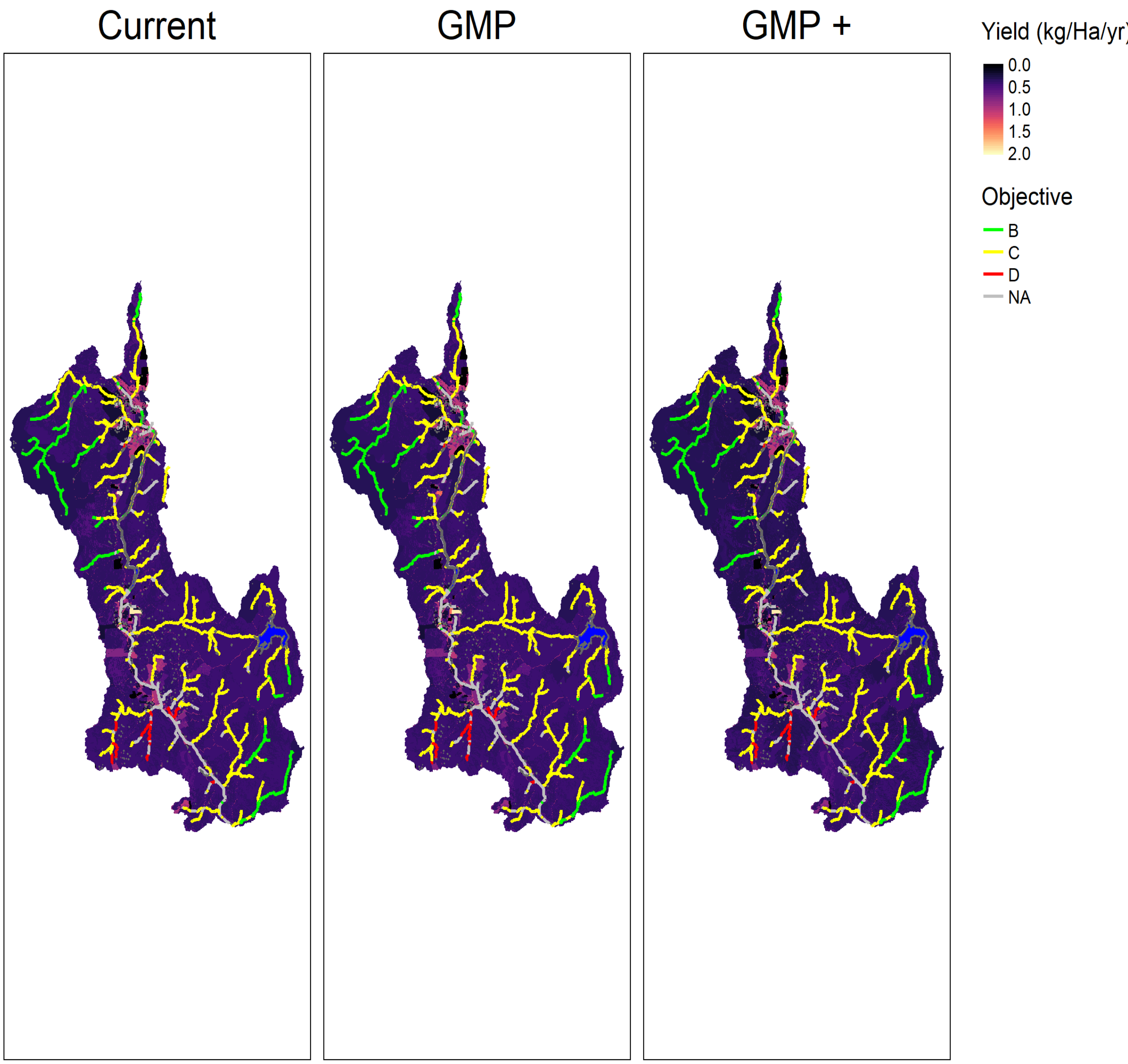

Figure 59: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios in the Roxburgh Rohe.

Mean realization comparisons for total phosphorus result in the in the majority of the Rohe complying with the C-band criteria. The upper Fraser and other minor tributaries comply with the B-band criteria (Figure 59). Few to no band changes occur under the GMP and GMP+ scenarios.

Lakes

The Roxburgh Rohe contains five named lakes for which modelled results are available (Table 60): Lake Onslow, Butchers Dam, Conroys Dam, Fraser Dam and Lake Roxburgh. The results for Lake Roxburgh are reported in the whole of the Clutha FMU section as it receives the combined reductions of the Upper Lakes, Dunstan, Roxburgh, and Manuherekia Rohe.

Nitrogen

For total nitrogen, all four lakes are *very likely* to comply with the C-band target attribute state under all scenarios. Lake Onslow and Fraser Dam are also *very likely* to comply with the B-band target and *likely* to comply with the A-band target attribute states under all scenarios. Fraser Dam is *very likely* to comply with the A-band criteria under all scenarios. Butchers Dam and Conroys Dam are *very likely* to comply with the B-band target attribute state *very unlikely* to comply with the A-band under all scenarios.

Phosphorus

For total phosphorus, Lake Onslow is *very likely* to comply with the C-band and B-band target attribute states under all scenarios. Compliance with the A-band target attribute state is *likely* under all scenarios. The Fraser Dam is *likely* to comply with the C-band target attribute state under all scenarios. The B- and A-band target attribute states are *very unlikely* to be complied with under any scenario. Butchers Dam is *very likely* to comply with the C-band target attribute state under and *very unlikely* to comply with the B- and A-band target attribute states under all scenarios. Conroys Dam is *likely* to comply with the C-band target attribute state and *very unlikely* to comply with the B- and A-band target attribute state under all scenarios.

Table 60: Probability of compliance of lakes in the Roxburgh Rohe with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval.

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Lake Onslow	A	70 (62 - 77)	72 (64 - 79)	76 (68 - 82)	64 (56 - 71)	64 (56 - 71)	70 (62 - 77)
Lake Onslow	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lake Onslow	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Butchers Dam	A	4 (2 - 9)	4 (2 - 9)	8 (5 - 14)	2 (1 - 6)	2 (1 - 6)	2 (1 - 6)
Butchers Dam	B	91 (85 - 95)	94 (89 - 97)	95 (90 - 98)	7 (4 - 12)	7 (4 - 12)	9 (5 - 15)
Butchers Dam	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	87 (80 - 92)	87 (80 - 92)	90 (84 - 94)
Conroys Dam	A	2 (1 - 6)	3 (1 - 7)	3 (1 - 7)	1 (0 - 4)	1 (0 - 4)	2 (1 - 6)
Conroys Dam	B	71 (63 - 78)	75 (67 - 81)	81 (74 - 87)	0 (0 - 3)	0 (0 - 3)	1 (0 - 4)
Conroys Dam	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	75 (67 - 81)	75 (67 - 81)	77 (69 - 83)

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Fraser Dam	A	70 (62 - 77)	72 (64 - 79)	74 (66 - 81)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Fraser Dam	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Fraser Dam	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	65 (57 - 72)	66 (58 - 73)	71 (63 - 78)

Lower Clutha Rohe

Land use characteristics

Land use in the Lower Clutha Rohe (Table 61; Figure 60) is comprised primarily of sheep and beef (41%), dairy (16%), exotic forestry (9%), sheep (8%), mixed stock (7%) and conservation (7%). In this Rohe, the GMP and GMP+ mitigations packages can be applied to approximately 77% of the FMU based on land use.

Table 61: Land use statistics for the Lower Clutha Rohe.

Land Use	Area (Ha)	Percent
Arable	2,105.06	0.55%
Beef	5,519.05	1.45%
Commercial Use	29.21	0.01%
Conservation	25,035.18	6.58%
Dairy	63,249.46	16.62%
Dairy Support	3,980.24	1.05%
Exotic Forestry	34,816.79	9.15%
Horticulture	111.15	0.03%
Industrial Use	165.18	0.04%
Lakes & Rivers	3,994.48	1.05%
Lifestyle Block	744.69	0.20%
Livestock Support	4,638.62	1.22%
Majority Deer with Mixed Livestock	787.59	0.21%
Mixed Livestock	26,586.90	6.99%
Nurseries & Orchards	14.87	0.00%
Other Animals	459.33	0.12%
Poultry	8.42	0.00%
Public Use	31.45	0.01%
Residential Use	524.99	0.14%

Land Use	Area (Ha)	Percent
Road & Rail	5,656.64	1.49%
Sheep	30,208.26	7.94%
Sheep & Beef	157,460.47	41.39%
Small Land Holding	679.86	0.18%
Specialist Deer	1,694.94	0.45%
Tourism & Recreational Use	333.73	0.09%
Unknown Land Use	8,007.63	2.10%
Unknown Land Use - Indigenous Cover	904.92	0.24%
Unknown Land Use - Non-agricultural	124.50	0.03%
Unknown Land Use - Pastoral Cover	2,598.64	0.68%

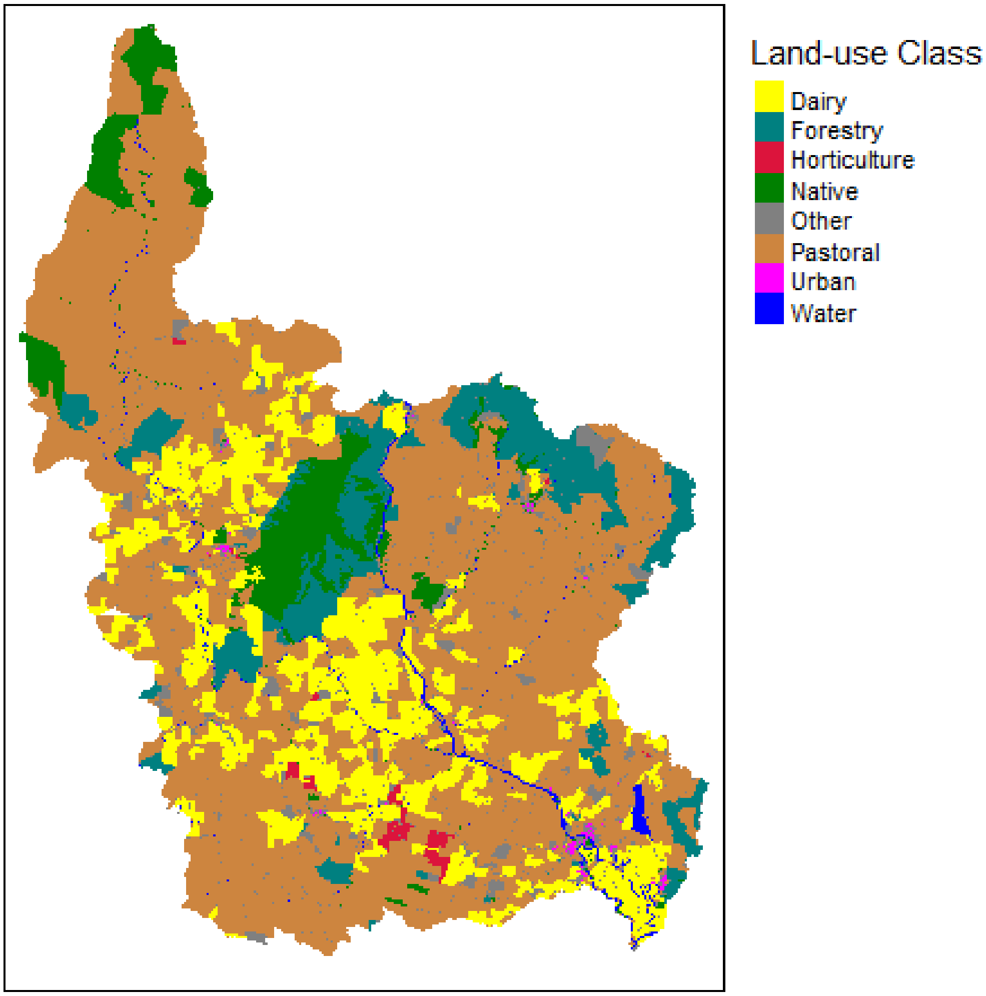

Figure 60: Land-use within the Lower Clutha Rohe. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

In the Lower Clutha Rohe, the GMP scenario results in approximately a 10% reduction in nitrogen and a 7% reduction in phosphorus emissions whereas the GMP+ scenario results in a 19% reduction of nitrogen and 9% reduction in phosphorus emissions (Table 62). These reductions result in the Rohe's overall average yield decreasing from 10.60 kg/ha/yr of nitrogen under the current scenario to 9.85 kg/ha/yr and 8.80 kg/ha/yr under the GMP and GMP+ scenarios respectively (Table 63). The average phosphorus yield decreases from 0.49 kg/ha/yr under current, under 0.46 kg/ha/yr GMP and 0.44 kg/ha/yr under the GMP+ scenario.

Table 62: Total on-land nitrogen and phosphorus load reductions achieved through GMP and GMP+ scenarios in the Lower Clutha Rohe.

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	9.60%	398,104.88	19.29%	799,882.57
P	6.49%	12,027.22	9.00%	16,690.07

Table 63: Average yield of nitrogen and phosphorus under current, GMP and GMP+ scenarios in the Lower Clutha Rohe.

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	10.90	9.85	8.80
P	0.49	0.46	0.44

Rivers

Yields

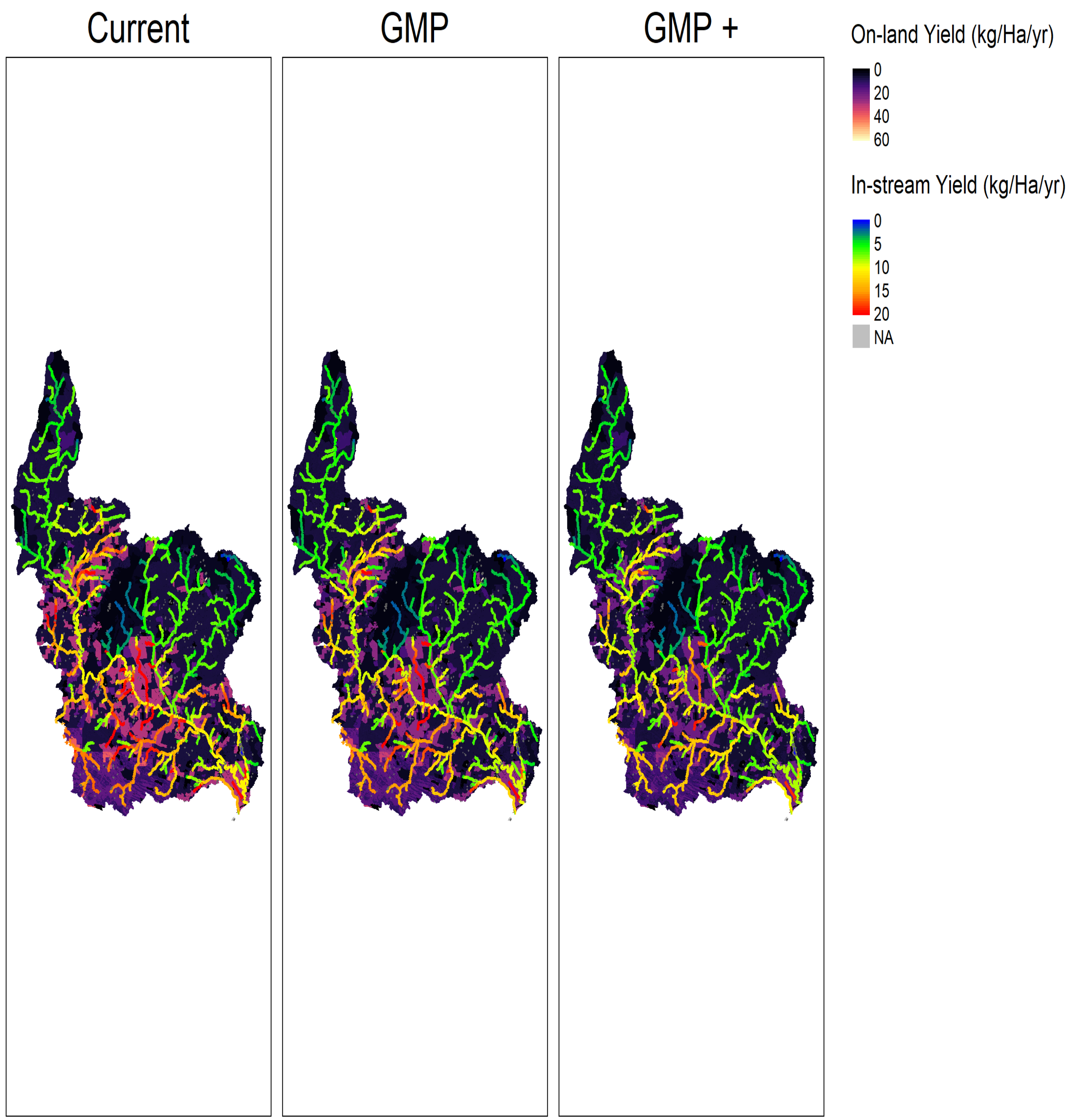

Figure 61: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios in the Lower Clutha Rohe.

Spatially, the lowest yield areas for nitrogen (Figure 61) and phosphorus (Figure 62) in the Lower Clutha Rohe occur in upper catchments with average upstream yield increasing down the catchment. The GMP and GMP+ scenarios lead to reduced upstream average yields of both nitrogen and phosphorus across the Rohe.

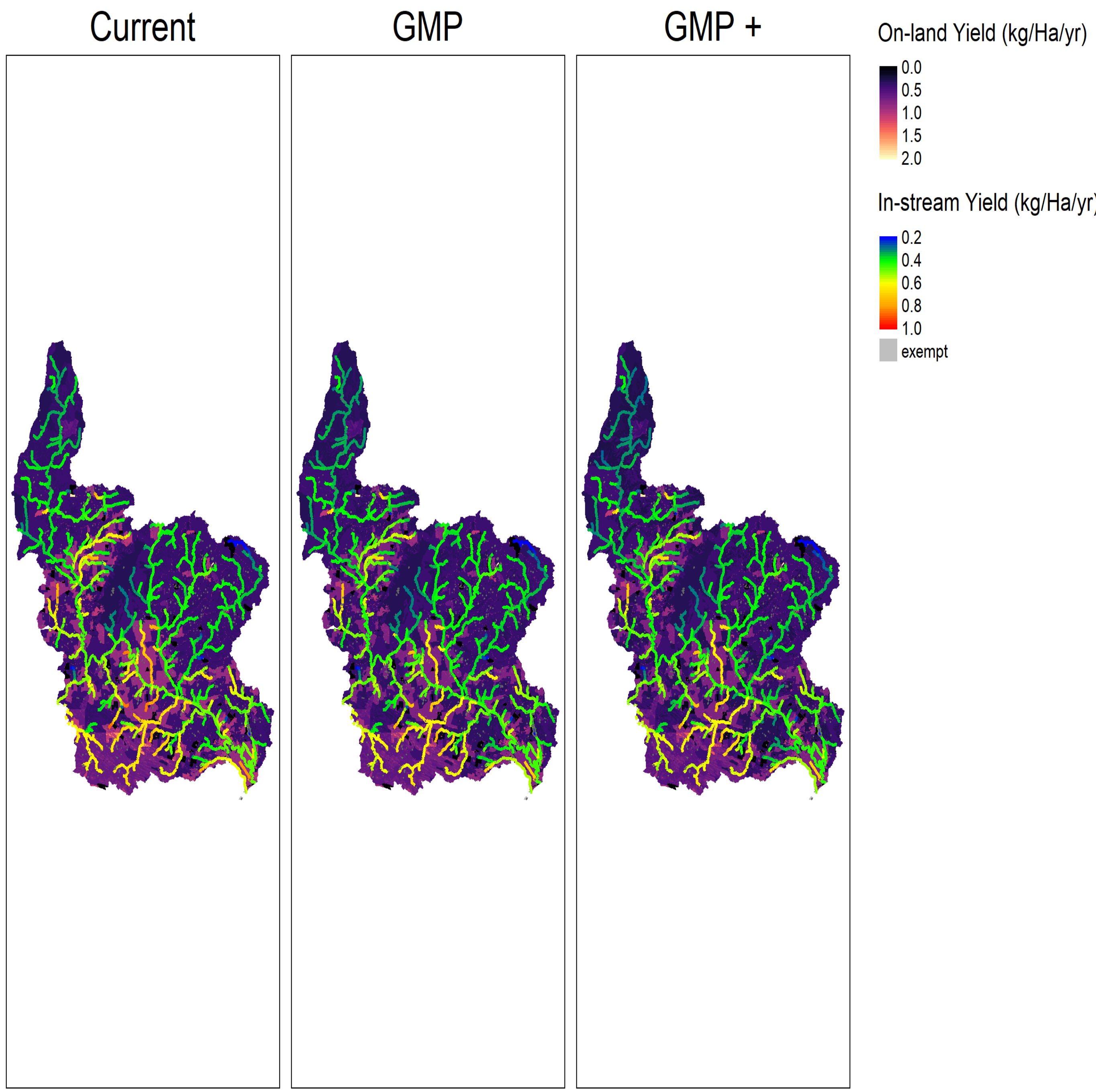

Figure 62: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios in the Lower Clutha Rohe.

Nitrate Toxicity

Nearly all segments in the Lower Clutha Rohe, comply with the B-band nitrate toxicity target attribute state (Table 64) under all three scenarios. Confidence intervals and mean estimate indicate *no reduction* is required for all segments to comply. Overlap in the C and B-band nitrate toxicity outcomes indicates the reductions required for both bands are within the uncertainty of the load estimates. For the A-band nitrate toxicity target attribute state, *nearly all* segments currently comply. Reductions *may be* required for all segments to comply. The proportion of the network expected to comply increases under the GMP and GMP+ scenarios. Confidence intervals indicate further reductions beyond GMP+ *may be* required for all segments to comply.

When split by management class (Table 65), *nearly all* segments currently comply with the B-band nitrate toxicity target attribute state in all classes *requiring no reductions*. For the A-band nitrate toxicity target attribute state, *nearly all* mountain and hill class segments currently comply *requiring no reduction*. Under the current scenario, *most* lowland segments comply and *likely require a reduction* for all segments to comply. The proportion of segments expected to comply improves slightly under the GMP and GMP+ scenario to *nearly all* segments comply. However, the mean and lower confidence interval indicate further reductions beyond GMP+ *may be* required for all segments to comply with the A-band target attribute state.

Table 64: Percent of river segments in the Lower Clutha Rohe complying with potential nitrate toxicity target attribute states with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	84 (50 - 100)	87 (52 - 100)	90 (55 - 100)	2,399
B	100 (99 - 100)	100 (99 - 100)	100 (99 - 100)	2,399
C	99 (98 - 100)	99 (99 - 100)	100 (100 - 100)	2,399

Table 65: Percent of river segments in the Lower Clutha Rohe complying with potential nitrate toxicity target attribute states, split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity					
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
M	A	100 (98 - 100)	100 (98 - 100)	100 (98 - 100)	91
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	91
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	91

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	A	99 (98 - 100)	99 (98 - 100)	100 (99 - 100)	612
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	612
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	612
L	A	76 (25 - 100)	80 (26 - 100)	84 (32 - 100)	979
L	B	99 (98 - 100)	100 (98 - 100)	100 (99 - 100)	979
L	C	98 (98 - 100)	99 (98 - 100)	99 (100 - 100)	979

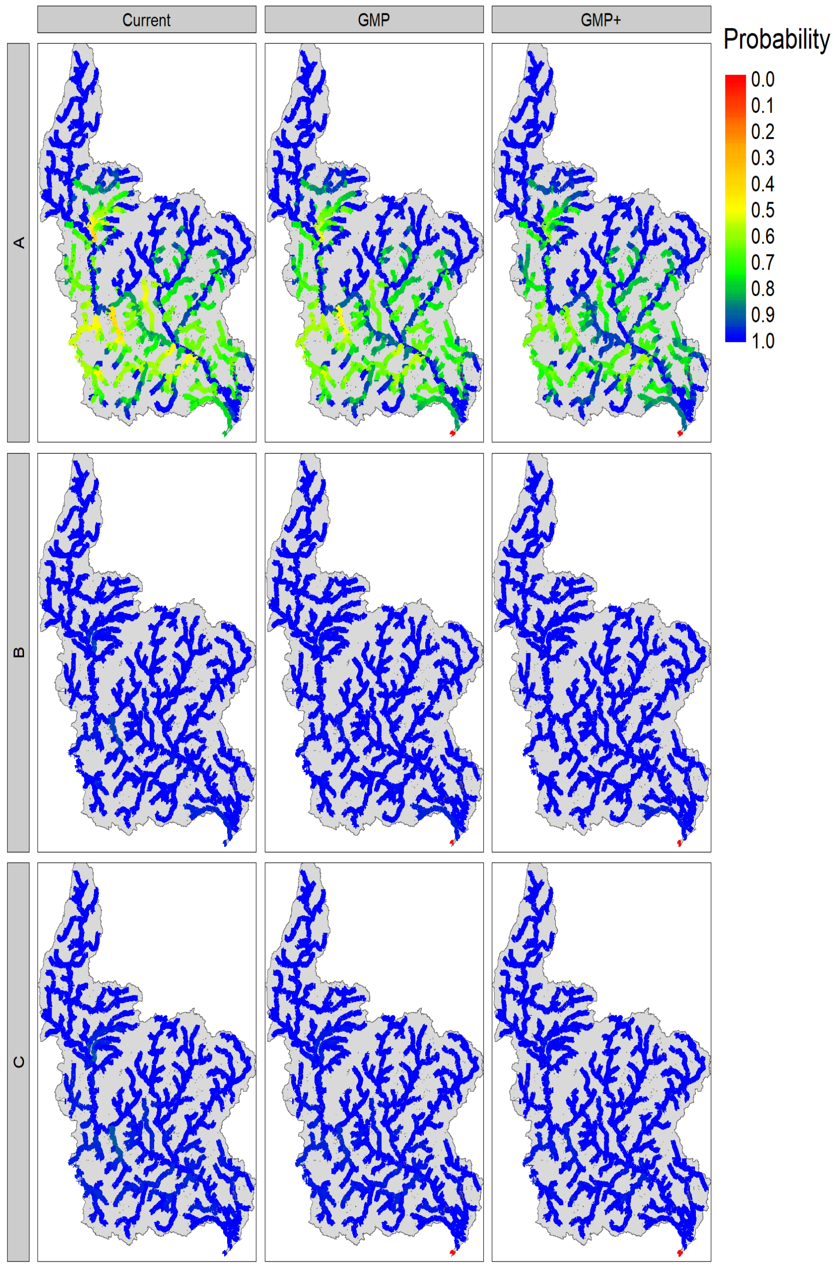

Figure 63: Individual segment probability of complying with the A, B and C nitrate toxicity target attribute states under the current, GMP and GMP+ scenarios in the Lower Clutha Rohe.

Spatially, the majority of the Rohe is very likely to comply with the B-band nitrate toxicity target attribute state (Figure 63). For the A-band target attribute state, upper catchments are generally very likely to comply. In lower to mid catchments, probabilities range from as likely as not to likely to comply with the A-band target attribute state. Under the GMP and GMP+ scenarios, the probability of complying with the A-band target attribute state increases relative to the current scenario.

Periphyton

For total nitrogen in relation to the periphyton biomass nutrient criteria (Table 66), *about half* of the segments in the Lower Clutha Rohe comply with the C-band criteria under the current scenario *requiring a reduction* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves to *most*. Confidence intervals indicate reductions beyond GMP+ *are likely required* for all segments to comply. For the B-band total nitrogen criteria, *some* segments comply under all three scenarios with limited improvement. Reductions beyond GMP+ *are required* for all segments to comply with the B-band criteria.

For total phosphorus in relation to the periphyton biomass C-band nutrient criteria (Table 66), *most* segments in the Lower Clutha Rohe comply under the current scenario. A reduction *is required* for all segments to comply as the upper confidence interval fails to overlap 100%. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves but still fails to overlap 100%. This indicates a reduction beyond GMP+ *is required* for all segments to comply with the C-band criteria. For total phosphorus in relation to the periphyton biomass B-band nutrient criteria, *some* segments comply with the B-band criteria under the scenarios. The upper confidence interval remains well below 100% indicating reductions beyond GMP+ *are required* for all segments to comply.

Few segments in any class comply with the A-band criteria for both total nitrogen and total phosphorus. This indicates the A-band nutrient criteria would not naturally be expected to be complied with in 80% of segments.

When split by management class for the total nitrogen C-band criteria (

Table 67), *all* mountain and hill segments in the Lower Clutha Rohe comply under all scenarios indicating *no reductions are required* for this management class. *Some* lowland segments comply with the C-band criteria under the current scenario indicating reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios the proportion expected to comply improves compared with the current scenario but still fail to overlap 100%. Therefore, a reduction beyond GMP+ *is required* for all lowland segments to comply with the C-band criteria.

When split by management class for the total nitrogen B-band criteria (

Table 67), *all* mountain segments comply under the current scenario *requiring no reduction*. For the hill class, *most* segments comply under the current scenario *requiring a reduction* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly but fails to overlap 100% in the upper confidence interval. Therefore, reductions beyond GMP+ *are required* for all segments to comply. *Few* lowland segments comply with the B-band criteria under any scenario. Reductions beyond GMP+ *are required* for these segments to comply with the B-band criteria.

When split by management class for the total phosphorus C-band criteria (

Table 67), *all* mountain segments comply under the current scenario (100%; 100-100) therefore *requiring no reduction*. For the hill-fed class, *nearly all* segments comply with the C-band phosphorus criteria under the current scenario. However, the mean and lower confidence interval indicate this class *may require* a reduction for all segments to comply. Under the GMP and GMP+ scenario the proportion of segments expected to comply improves slightly. However, confidence intervals indicate reductions beyond GMP+ *may be* required for all segments to comply. In the lowland management class, *about half* of segments comply with the C-band criteria under the current scenario *requiring a reduction* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly. However, the upper confidence interval still fails to overlap 100% indicating 95% confidence a reduction beyond GMP+ *is required* for all segments in this class to comply.

When split by management class for the total phosphorus B-band criteria (

Table 67), *nearly all* mountain segments comply under the current scenario. Confidence intervals indicate a reduction *may be* required for all segments to comply. Under the GMP and GMP+ scenarios the proportion of segments expect to comply improves, particularly in the lower confidence interval. This indicates higher confidence a greater proportion of mountain segments will comply with the criteria. However, the mean and lower confidence interval indicate reductions beyond GMP+ *may be* required for all segments to comply. For hill-fed segments, s*ome* segments comply with the B-band under the current scenario *requiring a reduction* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply with the B-band increases. However, the upper confidence interval still fails to overlap 100% indicating that further reductions *are required* for all hill segments to comply with the B-band criteria. Few lowland segments comply with the B-band criteria under any scenario and reductions beyond GMP+ *are required* for all segments in this class to comply.

Table 66: Percent of river segments in the Lower Clutha Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			Total Phosphorus				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	1 (0 - 1)	1 (0 - 2)	1 (0 - 3)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	1,687
B	28 (19 - 39)	29 (19 - 40)	29 (20 - 42)	20 (5 - 22)	20 (7 - 23)	20 (9 - 23)	0	1,687
C	59 (46 - 96)	60 (46 - 99)	62 (48 - 100)	62 (31 - 98)	64 (32 - 98)	65 (33 - 99)	0	1,687

Table 67: Percent of river segments in the Lower Clutha Rohe complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	A	4 (0 - 20)	5 (0 - 28)	5 (0 - 41)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	91
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	96 (49 - 100)	96 (66 - 100)	97 (75 - 100)	0	91

		Total Nitrogen			Total Phosphorus				
Management Class	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+	Periphyton exempt	Total segments
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	91
H	A	1 (0 - 1)	1 (0 - 2)	1 (0 - 3)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	612
H	B	61 (35 - 90)	63 (35 - 93)	64 (39 - 96)	39 (8 - 43)	39 (9 - 43)	39 (12 - 44)	0	612
H	C	100 (99 - 100)	100 (99 - 100)	100 (100 - 100)	88 (58 - 100)	89 (59 - 100)	90 (60 - 100)	0	612
L	A	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	979
L	B	0 (0 - 1)	0 (0 - 2)	0 (0 - 2)	1 (0 - 2)	1 (0 - 2)	1 (0 - 2)	0	979
L	C	29 (7 - 93)	31 (8 - 98)	34 (11 - 99)	42 (7 - 96)	45 (8 - 97)	46 (9 - 98)	0	979

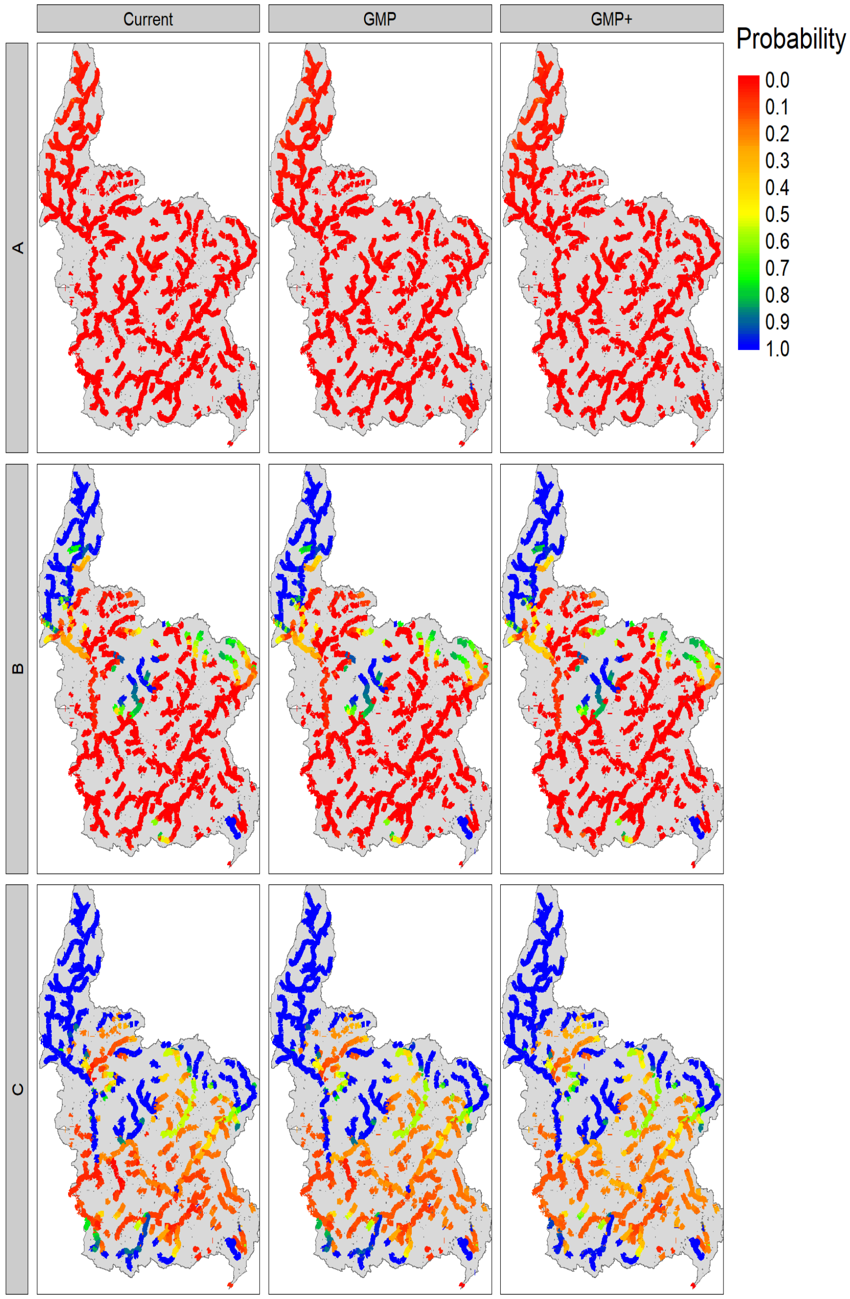

Figure 64: Individual segment probability of complying with the total nitrogen A, B and C periphyton nutrient criteria under the current, GMP and GMP+ scenarios for the Lower Clutha Rohe.

Spatially, much of the Rohe is *very unlikely* to comply with the C, B or A-band total nitrogen criteria (Figure 64). The exception are upper catchment segments, such as the headwaters of the Pomahaka catchment, which are *very likely* to achieve the C band criteria and range from *unlikely* to *very likely* to comply with the B-band criteria. All segments are *very unlikely* to comply with the A-band criteria.

Probabilities of complying with the C and B-band criteria improve in many segments under the GMP and GMP+ scenarios.

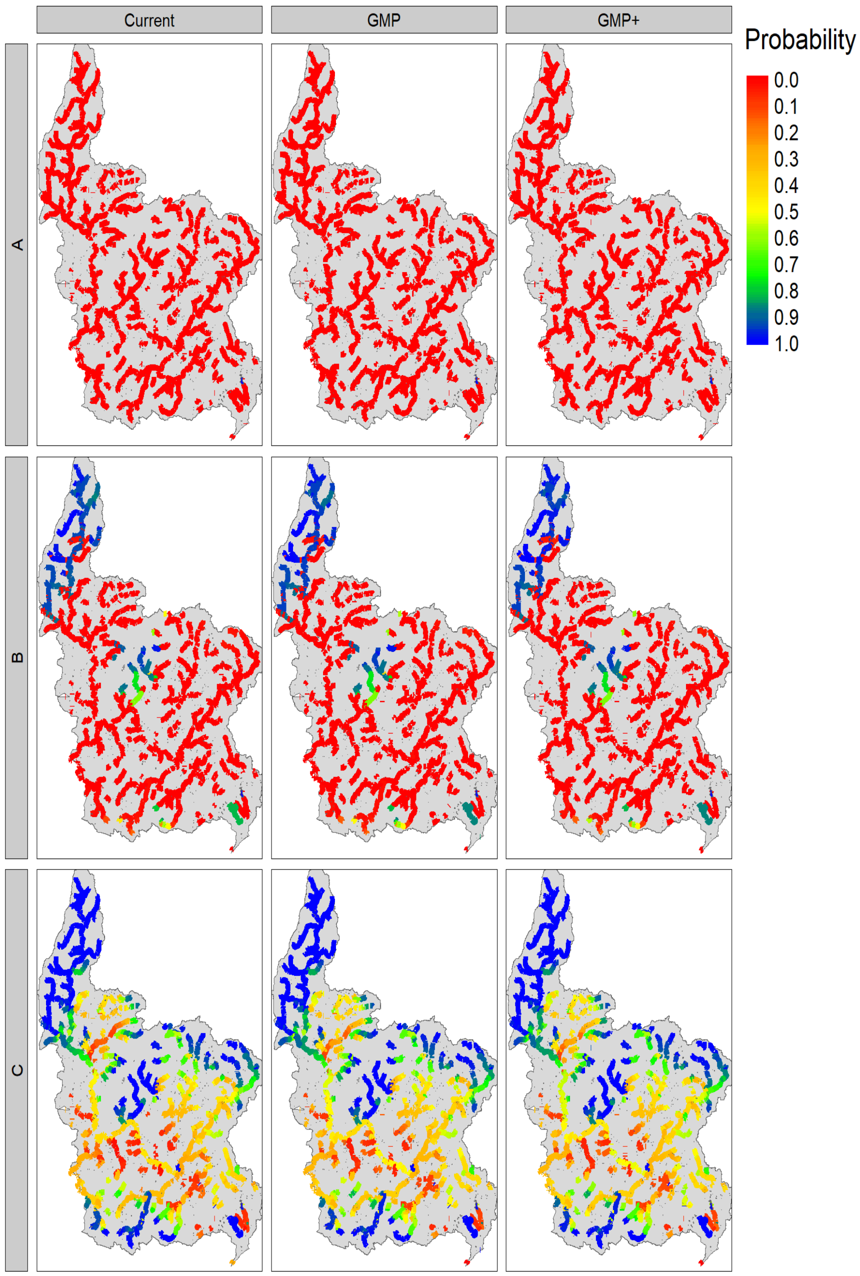

Figure 65: Individual segment probability of complying with the phosphorus A, B and C periphyton criteria under current, GMP and GMP+ scenarios in the Lower Clutha Rohe.

Spatially, for total phosphorus, the Rohe ranges from *very unlikely* to *very likely* to comply with the C-band criteria *(*Figure 65*)*. The upper reaches of the Pomahaka catchment, and other headwater areas, are *very likely* to comply with the C-band criteria. Mid-reaches of the catchment have lower probabilities of *as likely as not* and some minor tributaries are *very unlikely* to comply. Compliance with the B-band criteria is *very likely* in the upper catchment segments of the Pomahaka catchment. The rest of the Rohe is *very unlikely* to comply with the B-band criteria. All segments are *very unlikely* to comply with the A-band criteria.

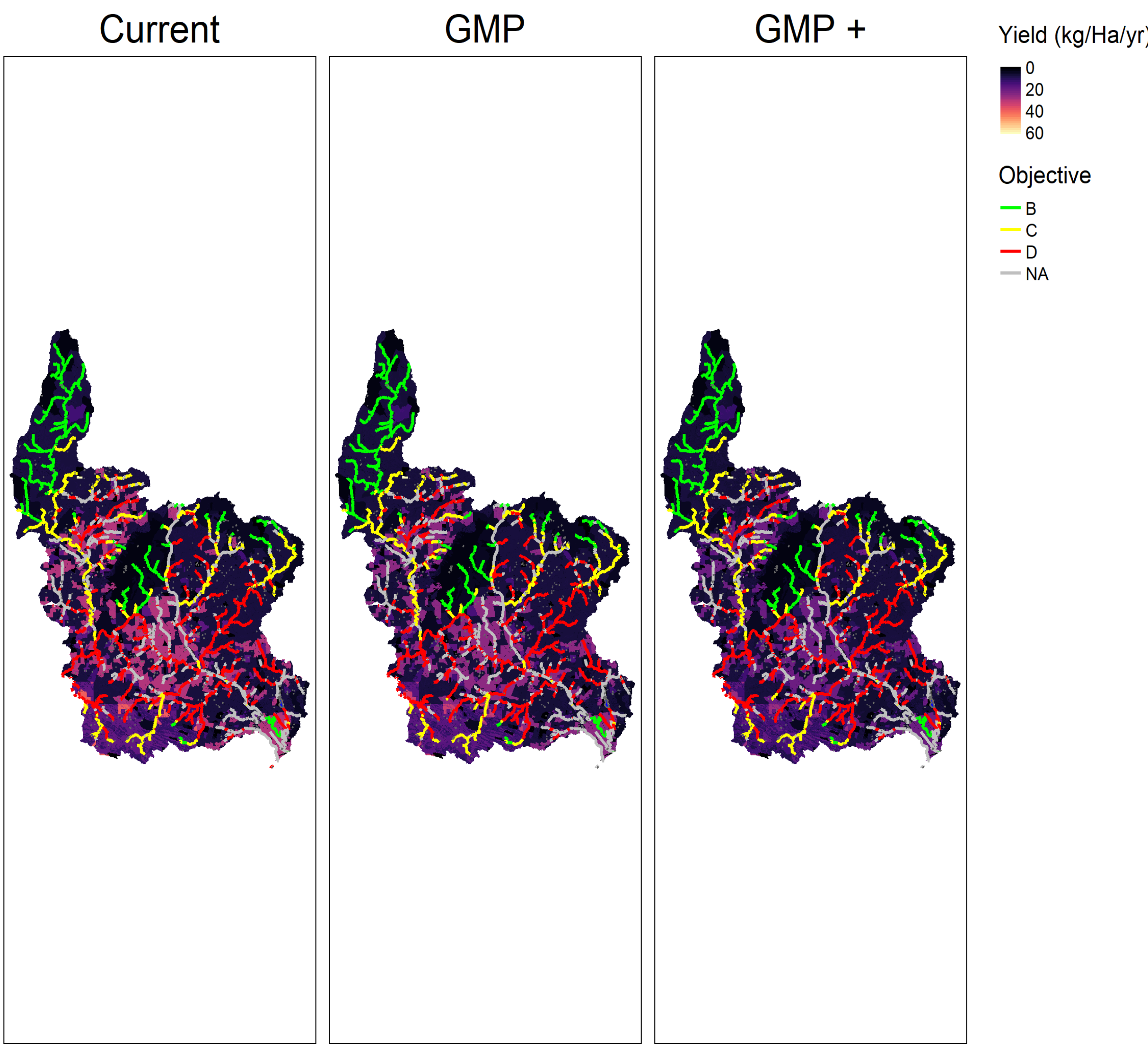

Figure 66: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization total nitrogen periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios for the Lower Clutha Rohe.

Mean realization comparisons for total nitrogen result in the in the majority of the Rohe failing to comply with the C-band criteria (Figure 66). The upper reaches of many catchments comply with the C-band criteria and the headwaters of the Pomahaka catchment comply with the B-band criteria.

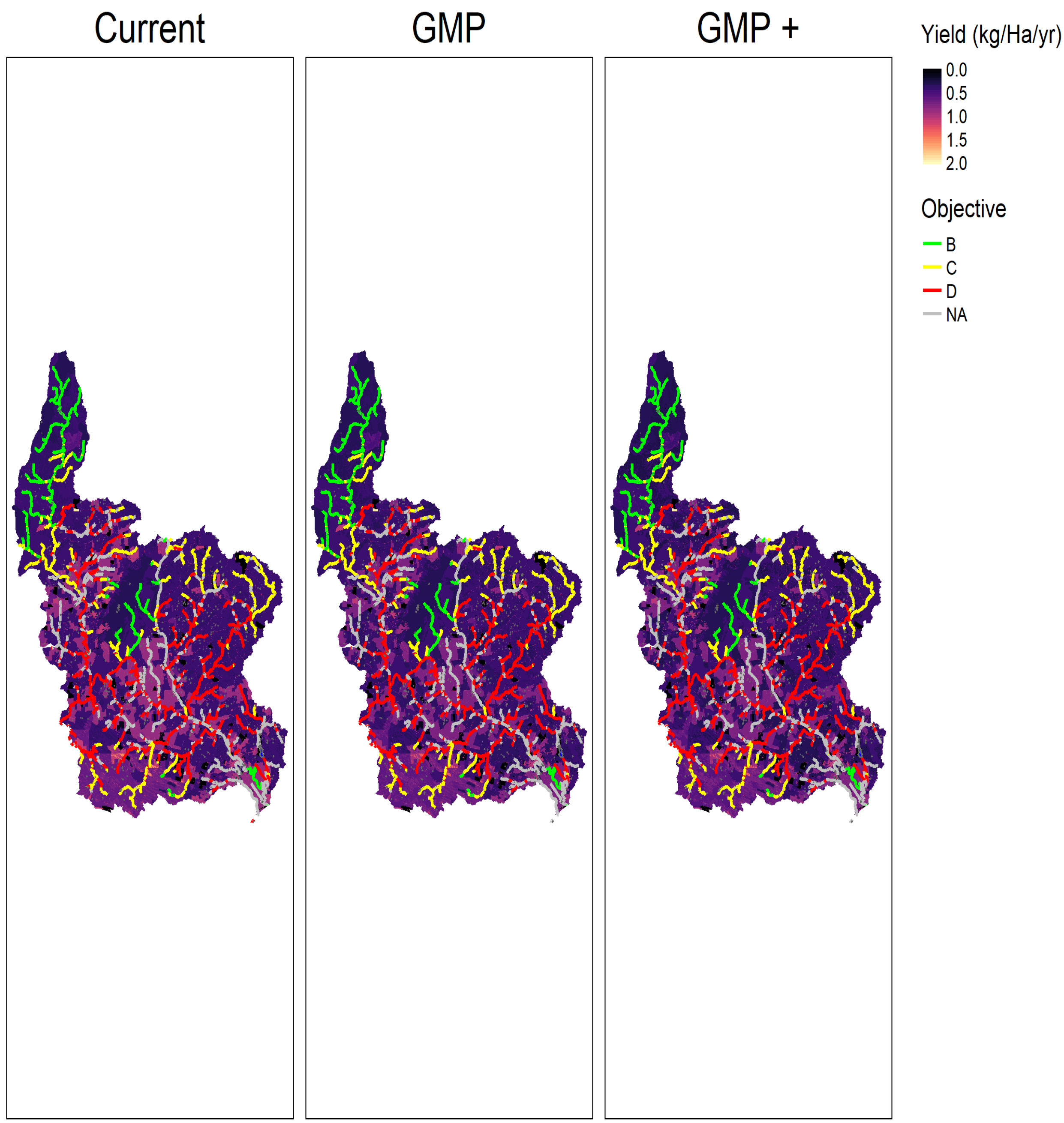

Figure 67: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios for the Lower Clutha Rohe.

Mean realization comparisons for total phosphorus result in the majority of the Rohe failing to comply with the C-band criteria with the exceptions of the upper reaches of many catchments which comply with the C or B-band criteria (Figure 67). Few band changes occur under the GMP and GMP+ scenarios.

Lakes

The Lower Clutha Rohe contains one named lake for which modelling results are available: Lake Tuakitoto (Table 68). Lake Tuakitoto is *very unlikely* to comply with C, B or A-band total nitrogen target attribute state under all scenarios (0%; 0-3) and is *very unlikely* to comply with the B and A-band total phosphorus target attribute states (0%; 0-3). Tuakitoto is *very unlikely* to *unlikely* to comply with the C-band phosphorus target attribute state under the current (22%; 16-30), GMP (25%; 19-33) and GMP+ scenarios (27%; 20-35).

Table 68: Probability of compliance of lakes in the Lower Clutha Rohe with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval.

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Lake Tuakitoto	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Lake Tuakitoto	B	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)
Lake Tuakitoto	C	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)	33 (26 - 41)	33 (26 - 41)	33 (26 - 41)

Whole of the Clutha Mata-Au Catchment

Land use characteristics

Land use across the entirety of the Clutha Mata-Au FMU (Table 69; Figure 68) is comprised primarily of sheep and beef (40%), conservation (25%), and mixed livestock (12%). In this FMU, the GMP and GMP+ mitigations packages can be applied to approximately 62% of the FMU based on land use.

Table 69: Land use statistics for the Clutha Mata-Au FMU.

Land Use	Area (Ha)	Percent
Arable	3,166.76	0.15%
Beef	21,874.17	1.06%
Commercial Use	285.03	0.01%
Conservation	507,973.10	24.50%
Dairy	75,794.69	3.66%
Dairy Support	5,441.76	0.26%
Exotic Forestry	40,248.19	1.94%
Horticulture	2,484.38	0.12%
Industrial Use	727.36	0.04%
Lakes & Rivers	92,107.79	4.44%
Lifestyle Block	13,563.30	0.65%
Livestock Support	8,075.23	0.39%
Majority Deer with Mixed Livestock	4,097.02	0.20%
Mixed Livestock	251,126.46	12.11%
Nurseries & Orchards	7,750.94	0.37%
Other Animals	901.40	0.04%
Poultry	78.31	0.00%
Public Use	114.30	0.01%
Residential Use	5,738.51	0.28%
Road & Rail	14,013.90	0.68%
Sheep	89,781.54	4.33%
Sheep & Beef	827,338.71	39.91%
Small Land Holding	5,620.11	0.27%
Specialist Deer	4,579.94	0.22%
Tourism & Recreational Use	6,593.51	0.32%

Land Use	Area (Ha)	Percent
Unknown Land Use	23,380.54	1.13%
Unknown Land Use - Indigenous Cover	49,740.37	2.40%
Unknown Land Use - Non-agricultural	501.02	0.02%
Unknown Land Use - Pastoral Cover	9,985.30	0.48%

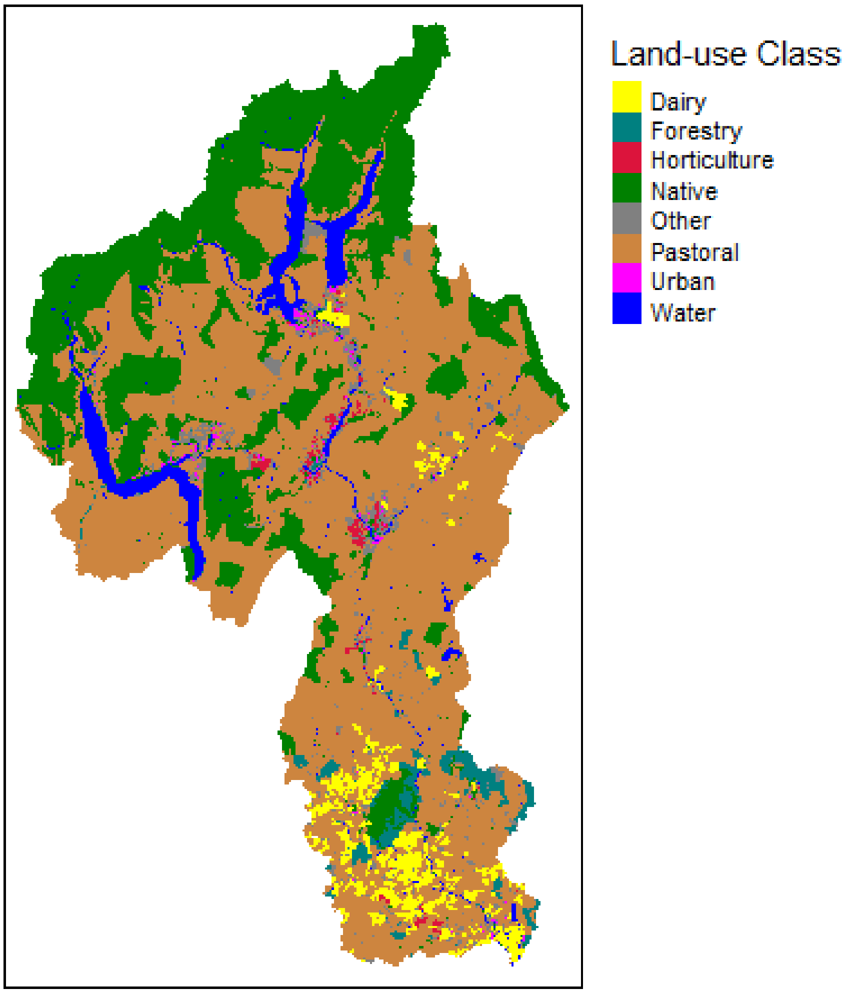

Figure 68: Land-use within the Clutha Mata-Au FMU. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

In the Clutha Mata-Au FMU, the GMP scenario results in approximately a 5% reduction in nitrogen and a 2% reduction in phosphorus emissions whereas the GMP+ scenario results in a 13% reduction of nitrogen and 9% reduction in phosphorus emissions (Table 70). These reductions result in the FMUs overall average yield decreasing from 7.15 kg/ha/yr of nitrogen under the current scenario to 6.81 kg/ha/yr and 6.20 kg/ha/yr under the GMP and GMP+ scenarios respectively *(*Table 71*)*. The average phosphorus yield decreases from 0.47 kg/ha/yr under current, 0.46 kg/ha/yr under GMP and 0.42 kg/ha/yr under the GMP+ scenario.

Table 70: Total on-land nitrogen and phosphorus load reductions achieved through the GMP and GMP+ scenarios in the Clutha Mata-Au FMU.

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	4.79%	710,024.26	13.33%	1,976,091.06
P	2.40%	23,226.55	9.04%	87,402.19

Table 71: Average yield of nitrogen and phosphorus under current, GMP and GMP+ scenarios in the Clutha Mata-Au FMU.

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	7.15	6.81	6.20
P	0.47	0.46	0.42

Rivers

Yields

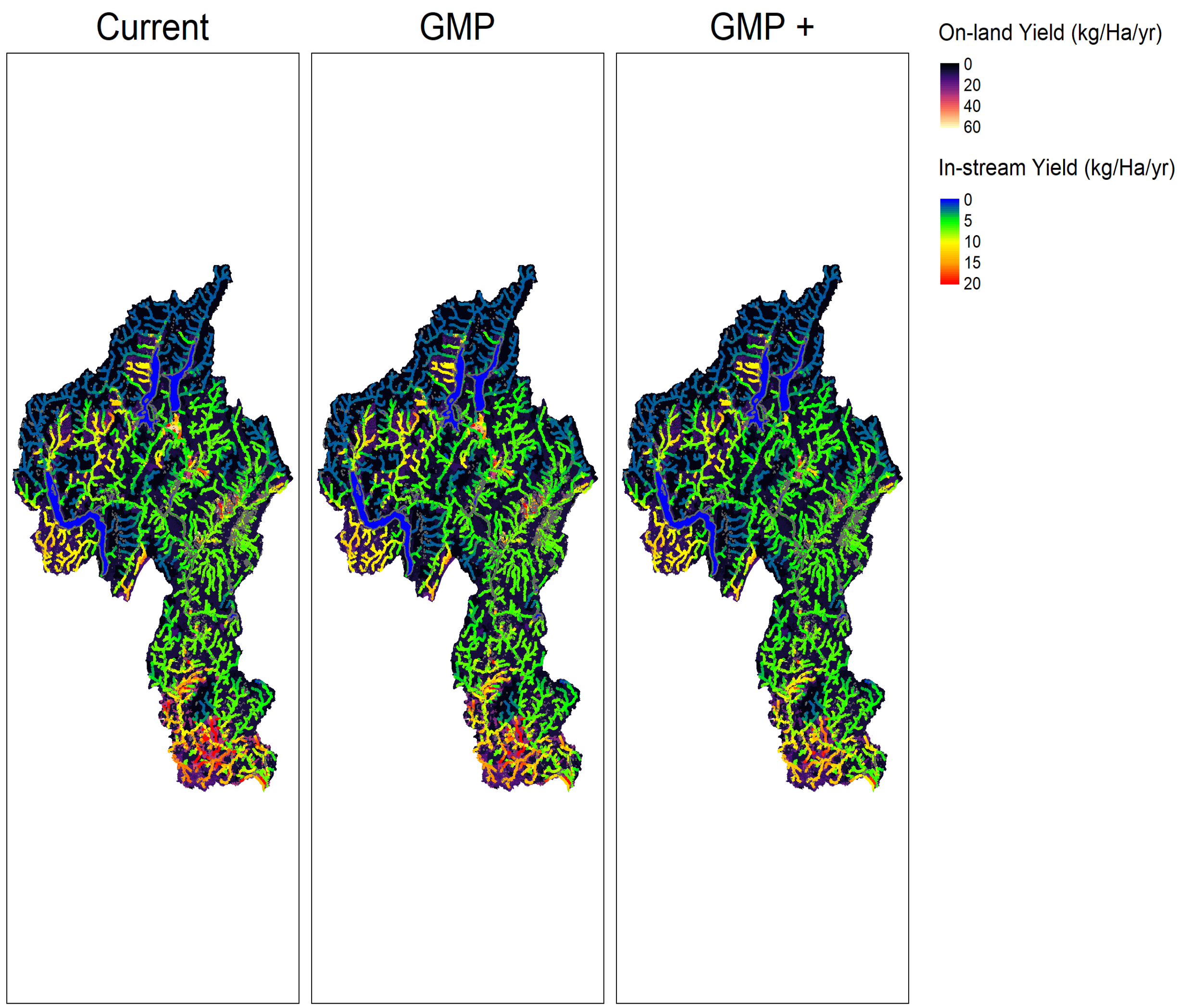

Figure 69: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios in the Clutha Mata-Au FMU.

Spatially, the highest average upstream nitrogen yields (Figure 69) occur in the Lower Clutha Rohe and the lowest yields occur in the Upper Lakes Rohe. The Upper Lakes Rohe also contains areas of higher average upstream yield. Under the GMP and GMP+ scenario average upstream yield decreases, particularly in the Lower Clutha Rohe.

For phosphorus, the highest average upstream yields occur in the Upper Lakes Rohe and appear to come from largely natural sources (Figure 70). Therefore, limited reductions occur in these areas under the GMP and GMP+ scenarios. Yield reductions are prominent throughout the rest of the FMU.

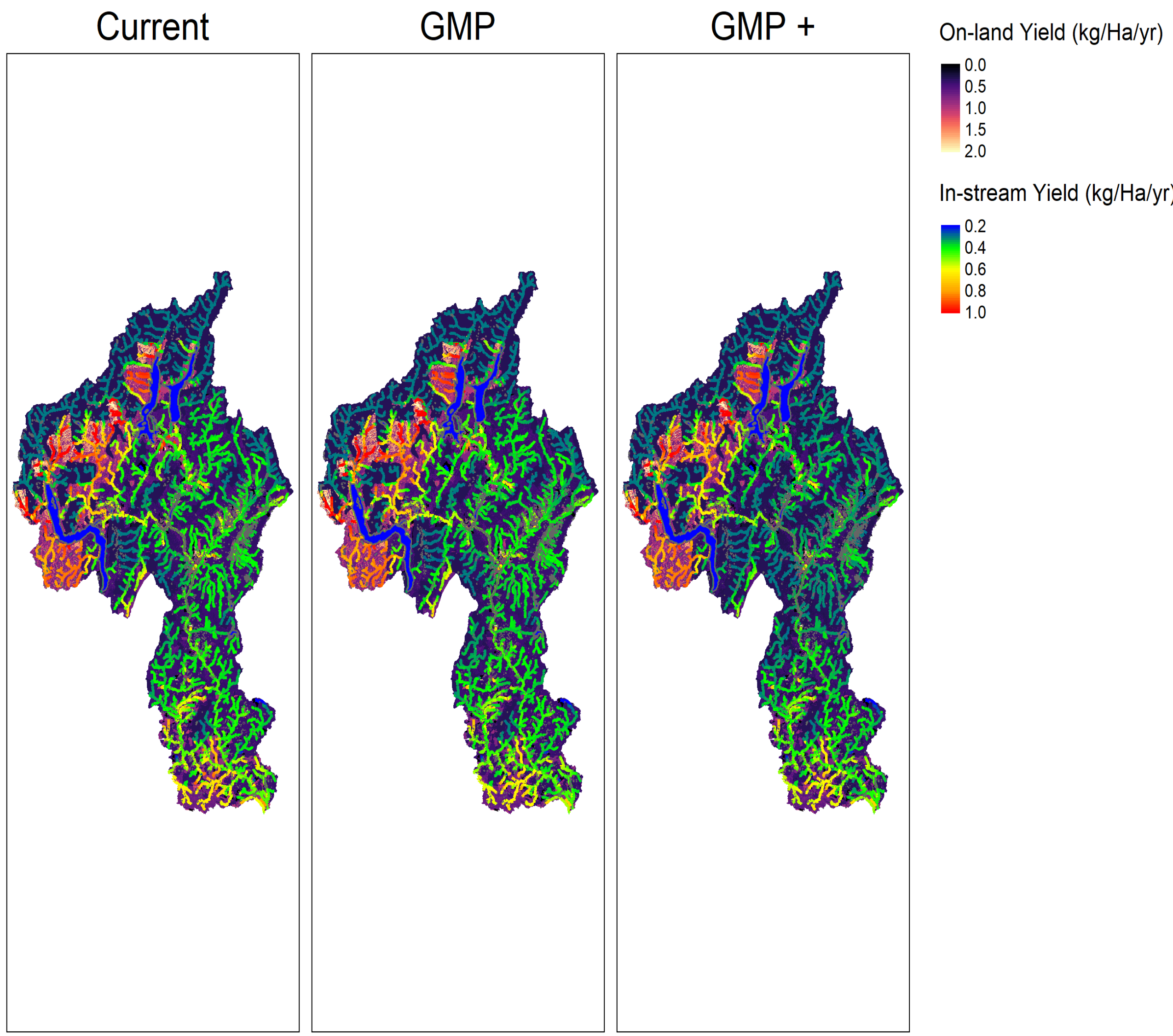

Figure 70: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for the current, GMP and GMP+ scenarios in the Clutha Mata-Au FMU.

Nitrate Toxicity

All segments in the Clutha FMU comply with the B-band nitrate toxicity target attribute state under all scenarios (Table 72) *requiring no reduction*. *Nearly all* segments in the Clutha FMU also comply with the A band nitrate toxicity target attribute state under the current scenarios. However, a reduction *may be* required for all segments to comply. Under the GMP and GMP+ scenario the proportion of segments expected to comply increases slightly. Under the GMP+ scenarios, the mean and lower confidence interval still fail to overlap 100% indicating reductions beyond GMP+ *may be* required for all segments to comply with the A-band target attribute state.

When split by management class, *all* segments comply with the B-band target attribute state across all classes *requiring no reduction* (Table 73).

All mountain, hill, upper lake, and lower lake segments also comply with the A-band nitrate toxicity target attribute state (Table 73) under all scenarios indicating *no reduction is required* for all segments in these classes to comply. For lowland segments, *nearly all* comply with the A-band target attribute state under the current scenario. The mean and lower confidence interval indicate reductions *may be* required for all segments to comply. Under the GMP and GMP+ scenario, the proportion of segments expected to comply improves. However, the lower confidence interval and mean indicate reductions beyond GMP+ *may be* required for all segments in this class to comply with the A-band target attribute state.

Table 72: Percent of river segments in the Clutha Mata-Au FMU complying with potential nitrate toxicity target attribute states, with 90 percent confidence intervals, for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	97 (91 - 100)	98 (91 - 100)	98 (92 - 100)	12,708
B	100 (97 - 100)	100 (98 - 100)	100 (99 - 100)	12,708
C	100 (99 - 100)	100 (100 - 100)	100 (100 - 100)	12,708

Table 73: Percent of river segments in the Clutha Mata-Au FMU complying with potential nitrate toxicity target attribute states, split by management class, with 90 percent confidence intervals, for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
M	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	5,983
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	5,983
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	5,983

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,390
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,390
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	3,390
L	A	81 (40 - 100)	84 (42 - 100)	88 (46 - 100)	1,105
L	B	99 (98 - 100)	100 (99 - 100)	100 (99 - 100)	1,105
L	C	99 (98 - 100)	99 (99 - 100)	100 (100 - 100)	1,105
Lk Lower	A	99 (97 - 100)	99 (97 - 100)	99 (97 - 100)	56
Lk Lower	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	56
Lk Lower	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	56
Lk Upper	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	398
Lk Upper	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	398
Lk Upper	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	398

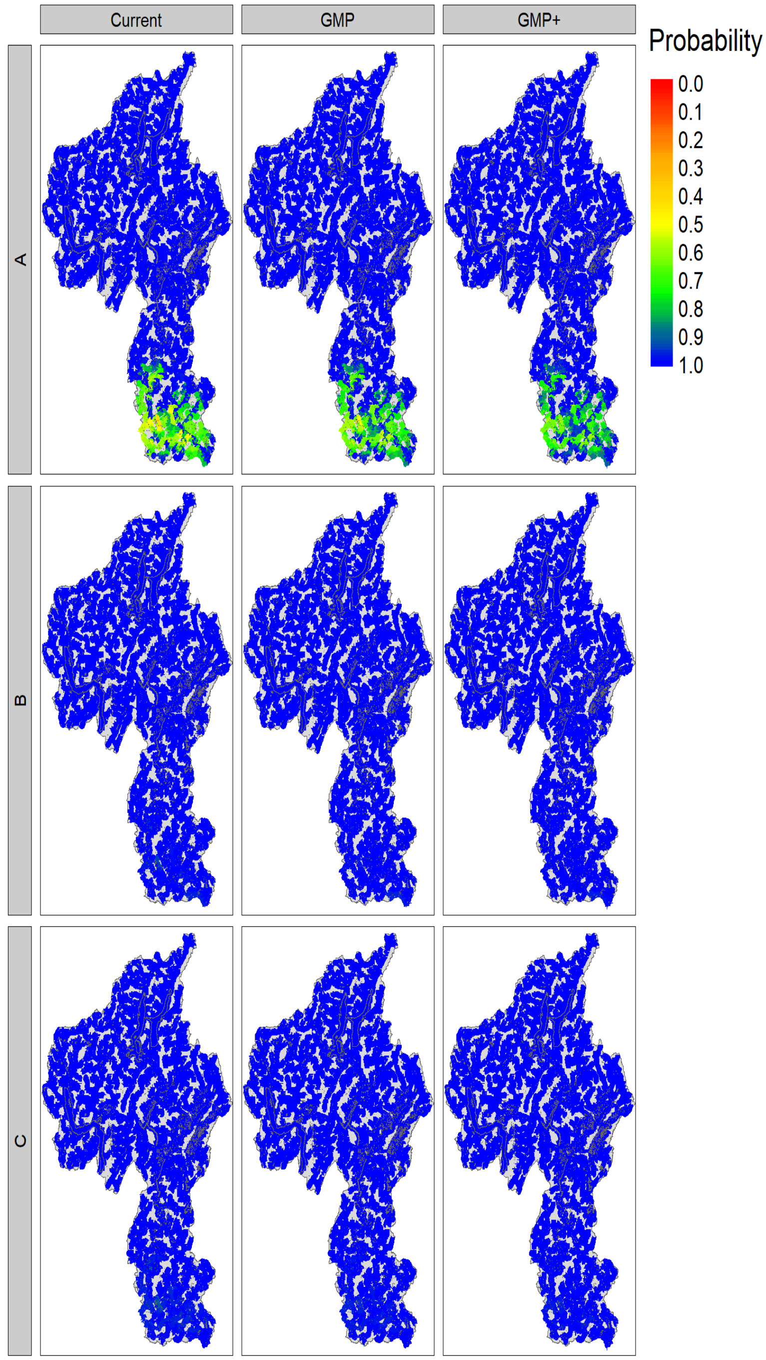

Figure 71: Individual segment probability of complying with the A, B and C nitrate toxicity target attribute states under the current, GMP and GMP+ scenarios in the Clutha Mata-Au FMU.

Spatially, all segments are *very likely* to comply with the B-band nitrate toxicity target attribute state (Figure 71). Excluding the Lower Clutha Rohe, the majority of the FMU is also *very likely* to comply with the A-band target attribute state. The Lower Clutha Rohe ranges from *as likely as not* to *very likely* to comply with the A-band target attribute state with probabilities increasing under the GMP and GMP+ scenarios.

Periphyton

For total nitrogen in relation to the periphyton biomass nutrient criteria (Table 74), *nearly all* of the Clutha FMU complies with the C-band criteria under the current scenario. Confidence intervals indicate reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves with the upper confidence interval overlapping 100%. However, the mean and lower confidence interval fail to overlap 100% indicating reductions beyond GMP+ *may be* necessary for all segments to comply. As reductions *are required* for all segments to comply with the C-band, further reductions *are required* to comply with the B or A-bands. *Nearly all* segments comply with the B-band criteria under all three scenarios and *some* segments comply with the A-band criteria.

For total phosphorus in relation to the periphyton biomass C-band nutrient criteria (Table 74), *nearly all* segments in the Clutha FMU comply under the current scenario. The mean estimate and confidence interval indicate reductions *may be* required for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly. However, further reductions beyond GMP+ *may be* required for all segments to comply. *About half* of segments comply with the B-band criteria under the current scenario *requiring reductions* for all segments to comply. Under the GMP and GMP+ scenario, the portion of segments expected to comply improves slightly. However, further reductions *are required* for all segments to comply with the B-band criteria. *No* segments comply with the A-band total phosphorus criteria under any scenario.

Some segments comply with the total nitrogen A-band criteria and *few* segments comply with the total phosphorus A-band. Given the prevalence of non-compliance within the region, even in natural settings, this suggests 80% of segments would be unlikely to comply with the A-band biomass target attribute state. Therefore, 100% of segments would not be expected to comply with this criteria even under natural settings.

When split by management class, for the total nitrogen C-band criteria (Table 75), *all* mountain, hill, upper lake and lower lake segments in the FMU currently comply *requiring no reduction*. S*ome* lowland segments comply with the C-band criteria under the current scenario. *Reductions are required* for all segments to comply. Under the GMP and GMP+ scenarios the proportion of segments expected to comply improves. Confidence intervals and mean estimates under the GMP+ scenario indicate further reductions *may be required* for all lowland segments to comply with the C-band criteria.

When split by management class for the total nitrogen B-band criteria (Table 75), *all* mountain, lower lake and upper lake segments currently comply indicating *no reduction is required*. *Most* hill segments comply with the B-band criteria under the current scenario *requiring a reduction* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply increases. However, the upper confidence interval still fails to overlap 100% under the GMP+ scenario indicating a reduction beyond GMP+ *is required* for all hill segments to comply with the B-band criteria. *Few* lowland segments comply with B-band criteria under any scenario.

When split by management class for the total phosphorus C-band criteria (Table 75), *all* mountain, lower lake and upper lake segments comply under the current scenario. *Nearly all* hill segments also currently comply. However, the mean estimate and lower confidence interval indicate reductions *may be required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of hill segments expect to comply improves. However, further reductions beyond GMP+ *may be* required for all segments to comply. *About half* of lowland segments comply under the current scenario *requiring a reduction* for all segments to comply. Despite improvements under the GMP and GMP+ scenarios, reductions beyond GMP+ *are required* for all lowland segments to comply with the C-band total phosphorus criteria.

When split by management class for the total phosphorus B-band criteria (Table 75), *nearly all* mountain and lower lake and *most* upper lake segments comply under the current scenario. However, reductions *may be* required for all segments to comply. Under the GMP and GMP+ scenarios, the portion expected to comply improves. However, reductions beyond GMP+ *may be* required for all segments to comply. *Some* hill segments and *few* lowland segments comply under any scenario indicating reductions beyond the GMP+ scenario *are required* for all segments in these classes to comply with the B-band total phosphorus criteria.

Table 74: Percent of river segments in the Clutha Mata-Au FMU complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			Total Phosphorus				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	23 (0 - 59)	24 (0 - 60)	25 (0 - 63)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	10,932
B	83 (71 - 90)	83 (72 - 90)	84 (73 - 90)	64 (55 - 69)	64 (56 - 69)	65 (57 - 72)	0	10,932
C	93 (91 - 99)	94 (91 - 100)	94 (92 - 100)	93 (80 - 100)	93 (81 - 100)	93 (83 - 100)	0	10,932

Table 75: Percent of river segments in the Clutha Mata-Au FMU complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	A	36 (0 - 91)	37 (0 - 93)	39 (0 - 96)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	5,983
M	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	95 (88 - 100)	96 (88 - 100)	96 (90 - 100)	0	5,983

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
M	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	5,983
H	A	8 (0 - 24)	8 (0 - 26)	9 (0 - 29)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	3,390
H	B	76 (40 - 98)	77 (41 - 99)	80 (45 - 99)	27 (18 - 34)	27 (18 - 35)	28 (20 - 43)	0	3,390
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	93 (65 - 100)	94 (67 - 100)	95 (74 - 100)	0	3,390
L	A	0 (0 - 1)	1 (0 - 1)	1 (0 - 1)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	1,105
L	B	1 (1 - 5)	1 (1 - 5)	2 (1 - 6)	1 (0 - 3)	1 (0 - 3)	2 (0 - 3)	0	1,105
L	C	36 (13 - 94)	38 (14 - 98)	41 (16 - 100)	47 (11 - 96)	50 (12 - 98)	51 (13 - 98)	0	1,105
Lk Lower	A	3 (0 - 0)	3 (0 - 0)	3 (0 - 9)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	56
Lk Lower	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	84 (0 - 100)	84 (0 - 100)	86 (0 - 100)	0	56
Lk Lower	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	56
Lk Upper	A	16 (0 - 41)	16 (0 - 41)	17 (0 - 55)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	398

		Total Nitrogen			Total Phosphorus				
Management Class	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+	Periphyton exempt	Total segments
Lk Upper	B	100 (99 - 100)	100 (99 - 100)	100 (99 - 100)	70 (50 - 83)	71 (50 - 83)	72 (50 - 83)	0	398
Lk Upper	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (99 - 100)	100 (99 - 100)	100 (100 - 100)	0	398

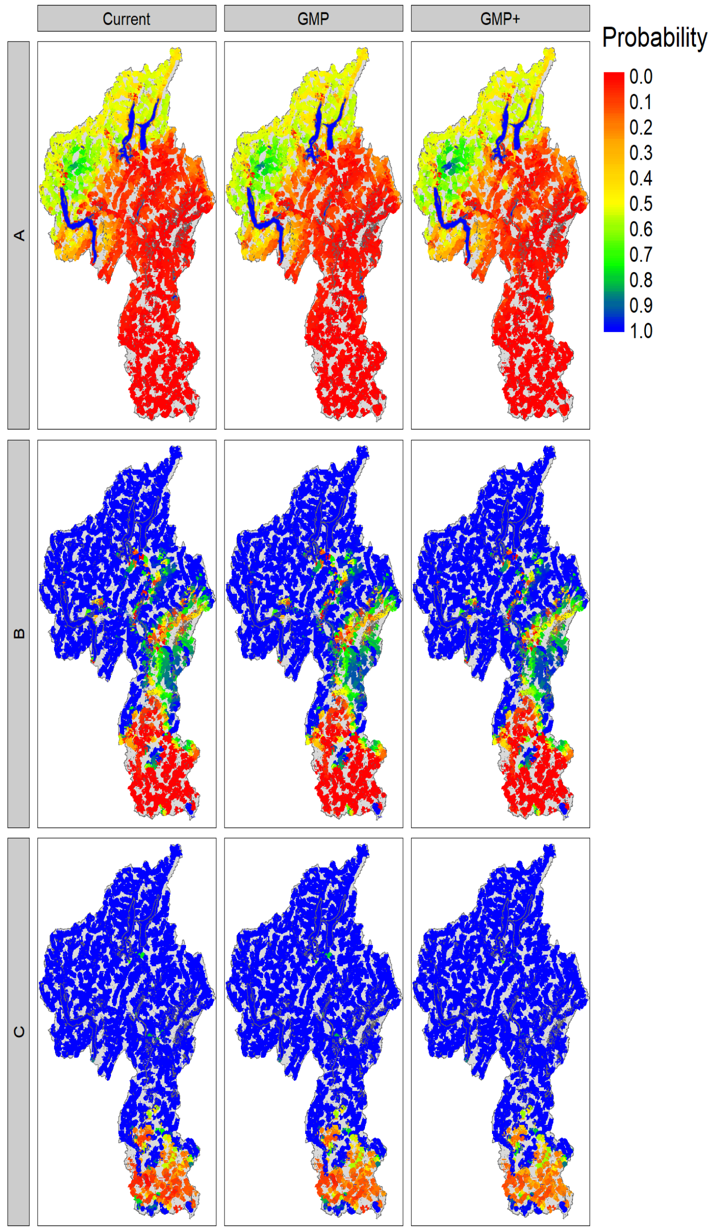

Figure 72:Individual segment probability of complying with the total nitrogen A, B and C periphyton nutrient criteria under the current, GMP and GMP+ scenarios for the Clutha Mata-Au FMU.

Spatially, the majority of the Clutha FMU is *very likely* to comply with the C-band total nitrogen criteria with the exception of the Lower Clutha Rohe which is *very unlikely* to comply (Figure 72). For the B-band criteria, the majority of the Lower Clutha Rohe is *very unlikely* comply whereas the rest of the FMU is generally *likely to very likely* to comply. The entire FMU is *very unlikely* to comply with the A-band criteria with the exception of the Upper Lakes Rohe which is *as likely as not* to *likely* to comply. Under the GMP and GMP+ scenarios*,* some segments show increased probabilities of complying with the C and B-band criteria.

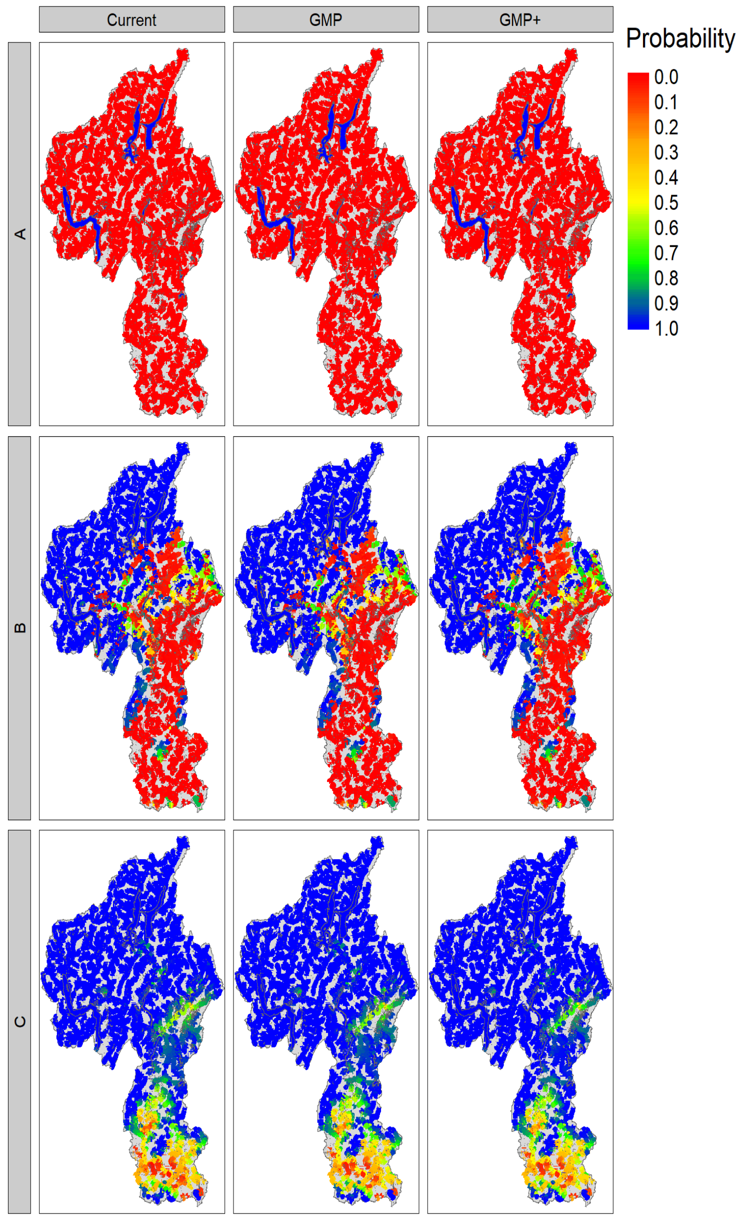

Figure 73: Individual segment probability of complying with the total phosphorus A, B and C periphyton nutrient criteria under the current, GMP and GMP+ scenarios for the Clutha Mata-Au FMU.

Spatially, the majority of the Clutha FMU is *very likely* to comply with the C-band total phosphorus criteria whereas lower areas, such as the Lower Clutha Rohe, are *as likely as not* to likely to comply (Figure 73). For the B-band criteria, the majority of the FMU is *very unlikely* to comply with the exception of the Upper Lakes Rohe which is *likely* to *very likely* to comply with the B-band criteria. The entire FMU is *very unlikely* to comply with the A-band criteria. Under the GMP and GMP+ scenarios some segments show increased probabilities of complying with the C or B-band criteria.

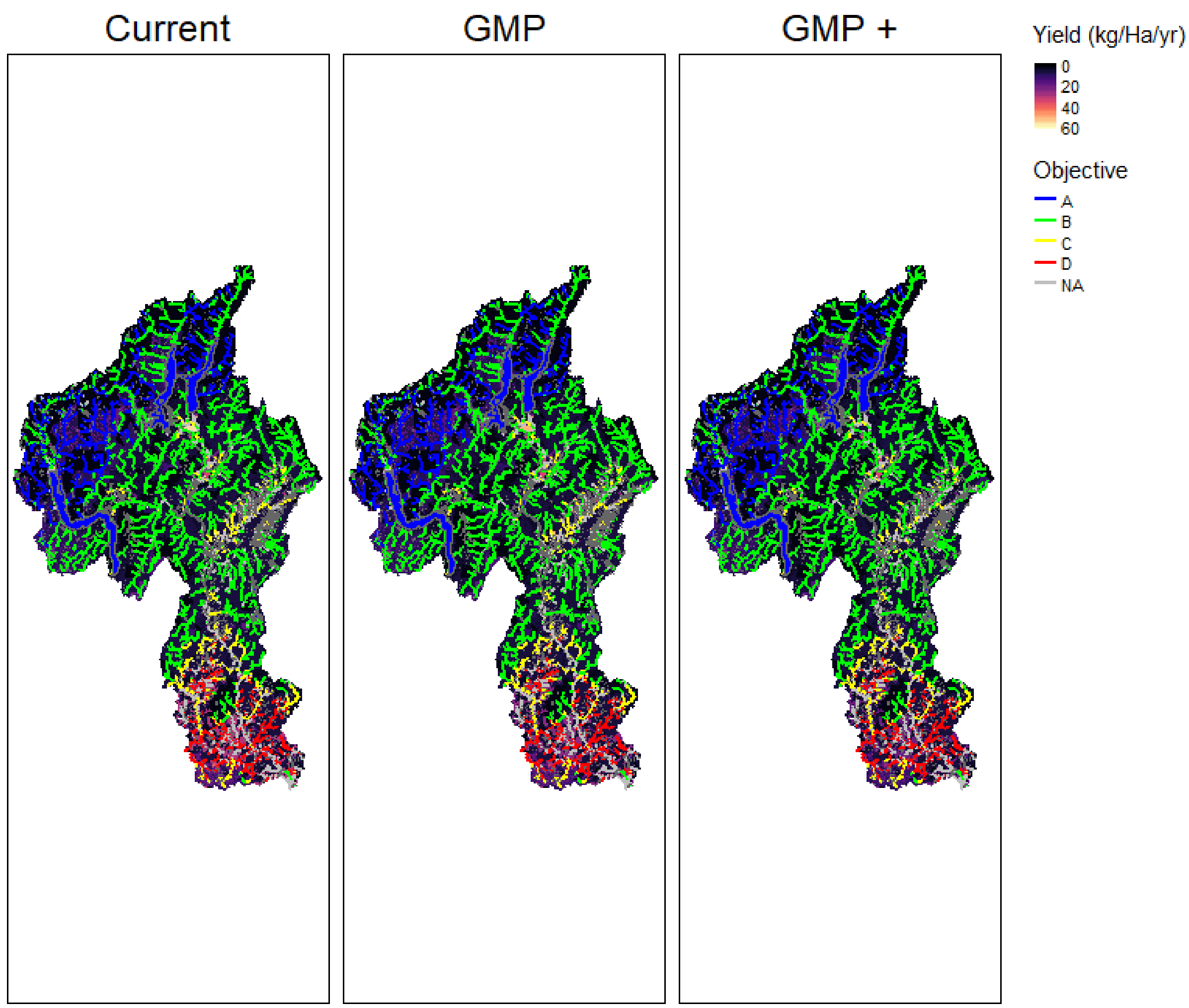

Figure 74: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization total nitrogen periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios in the Clutha Mata-Au FMU.

Mean realization comparisons for total nitrogen, show the Upper Lakes Rohe complies with the B- and often A-band criteria. Areas of the Dunstan Rohe, Manuherekia, and Roxburgh Rohe comply with the B-band criteria (Figure 74). Lower areas of the FMU comply with C-band criteria with the exception of the Lower Clutha Rohe which fails to comply with the C-band criteria. Few band improvements occur under the GMP and GMP+ scenarios.

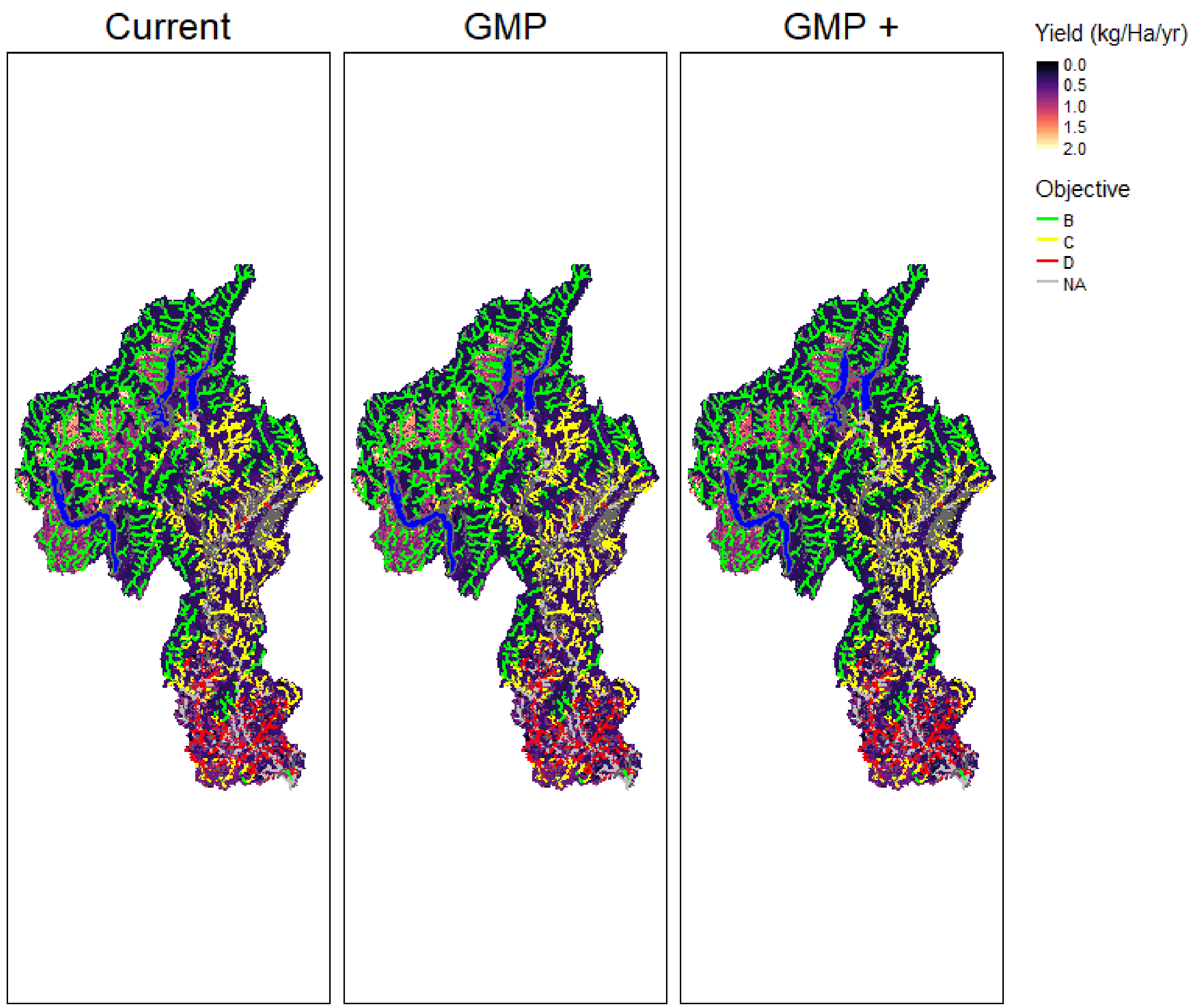

Figure 75: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios in the Clutha Mata-Au FMU.

Mean realization comparisons for total phosphorus, show the Upper Lakes Rohe and upper areas of the Dunstan and Manuherekia Rohe tend to comply with the B-band criteria (Figure 75). Lower areas of the Dunstan, and Manuherekia Rohe tend to comply with the C-band criteria. The majority of the Lower Clutha Rohe fails to comply with the C-band criteria. Few band improvements occur under the GMP and GMP+ scenarios.

Lakes

There are two mainstem lakes in the Whole of Clutha FMU which receive reductions from upstream Rohe and thus are reported solely in this section: Lakes Dunstan and Roxburgh (Table 76).

For total nitrogen, Lakes Dunstan and Roxburgh are *very likely* to comply with both the C- and B-band target attribute states under all scenarios therefore requiring no reduction for this target attribute state. Compliance with the A-band target attribute state is *likely* in Lake Dunstan under the current scenario with improvement under the GMP and GMP+ scenario. Lake Roxburgh is *very likely* to comply with the A-band target attribute state under the current scenario with improvement under the GMP and GMP+ scenarios.

For total phosphorus, Lakes Dunstan and Roxburgh are *very likely* to comply with the C-band target attribute state under all scenarios. Lake Roxburgh is also *very likely* to comply with the B-band target attribute state under all scenarios. Compliance with the A-band target attribute state in Lake Roxburgh is also *very likely*. Lake Dunstan is *as likely as not* to comply with the B-band criteria. Compliance with the A-band target attribute state in Lake Dunstan is *very unlikely* under all scenarios.

Table 76: Probability of compliance of lakes on the Clutha Mata-Au mainstem with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval.

		Total Nitrogen			Total Phosphorus		
Lake Name	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Lake Dunstan	A	63 (55 - 71)	65 (57 - 72)	70 (62 - 77)	3 (1 - 7)	4 (2 - 9)	5 (2 - 10)
Lake Dunstan	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	47 (39 - 55)	47 (39 - 55)	55 (47 - 63)
Lake Dunstan	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	98 (94 - 99)	98 (94 - 99)	99 (96 - 100)
Lake Roxburgh	A	93 (88 - 96)	93 (88 - 96)	93 (88 - 96)	98 (94 - 99)	98 (94 - 99)	98 (94 - 99)
Lake Roxburgh	B	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)
Lake Roxburgh	C	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)	100 (97 - 100)

Catlins FMU

Land use characteristics

Land use in the Catlins FMU (Table 77; Figure 76) is comprised primarily of sheep and beef (38%), conservation (29%), dairy (7%), and exotic forestry (7%). In this FMU, the GMP and GMP+ mitigations packages can be applied to approximately 57% of the FMU based on land use.

Table 77: Land use statistics for the Catlins FMU.

Land Use	Area (Ha)	Percent
Beef	1,060.82	0.83%
Commercial Use	2.31	0.00%
Conservation	36,983.26	28.84%
Dairy	9,119.93	7.11%
Dairy Support	983.50	0.77%
Exotic Forestry	8,662.49	6.75%
Horticulture	2.90	0.00%
Industrial Use	9.50	0.01%
Lakes & Rivers	865.64	0.67%
Lifestyle Block	244.72	0.19%
Livestock Support	948.64	0.74%
Majority Deer with Mixed Livestock	379.01	0.30%
Mixed Livestock	5,547.62	4.33%
Public Use	6.22	0.00%
Residential Use	100.08	0.08%
Road & Rail	1,791.78	1.40%
Sheep	5,515.22	4.30%
Sheep & Beef	48,494.70	37.81%
Small Land Holding	134.94	0.11%

Land Use	Area (Ha)	Percent
Specialist Deer	825.11	0.64%
Tourism & Recreational Use	323.71	0.25%
Unknown Land Use	2,590.44	2.02%
Unknown Land Use - Indigenous Cover	2,650.87	2.07%
Unknown Land Use - Non-agricultural	66.98	0.05%
Unknown Land Use - Pastoral Cover	947.24	0.74%

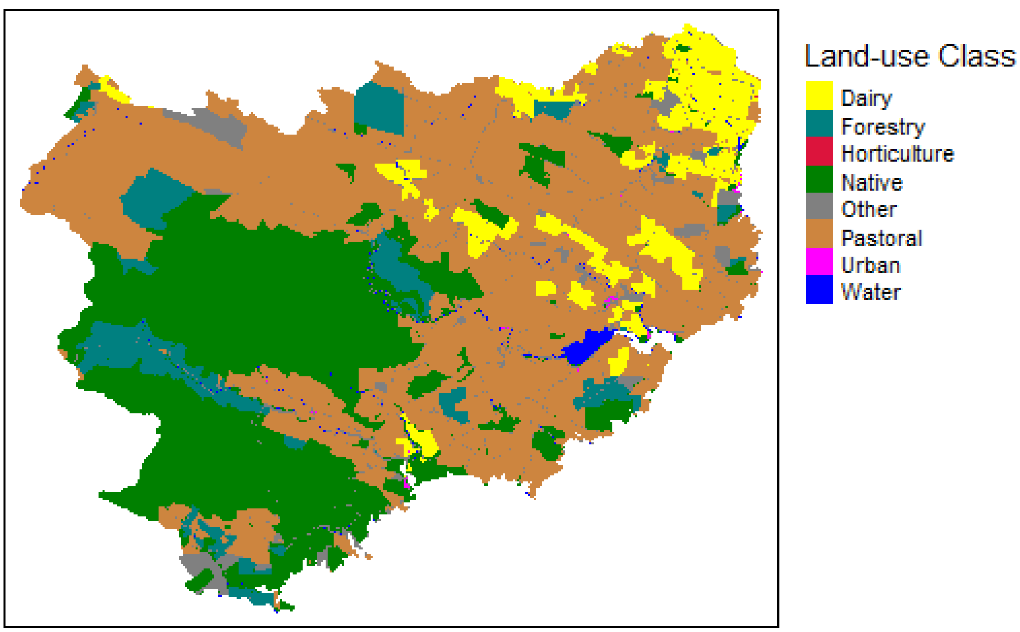

Figure 76: Land-use within the Catlins FMU. To simplify presentation, land-use classes were aggregated from those in Appendix 2 to those presented in the legend.

In the Catlins FMU, the GMP scenario results in approximately a 9% reduction in nitrogen and a 7% reduction in phosphorus whereas the GMP+ scenario results in a 17% reduction of nitrogen emissions and 13% reduction in phosphorus emissions (Table 78). These reductions result in the FMUs overall average yield decreasing from 9.32 kg/ha/yr of nitrogen under the current scenario to 8.49 kg/ha/yr and 7.74 kg/ha/yr under the GMP and GMP+ scenarios, respectively. The average phosphorus yield decreases from 0.48 kg/ha/yr under current, under 0.45 kg/ha/yr GMP and 0.42 kg/ha/yr under the GMP+ scenario (Table 79).

Table 78: Total on-land nitrogen and phosphorus load reductions achieved through the GMP and GMP+ scenarios in the Catlins FMU.

Nutrient	GMP Reduction (%)	GMP Reduction (kg)	GMP+ Reduction (%)	GMP+ Reduction (kg)
N	8.89%	106,198.47	16.98%	202,986.64
P	7.31%	4,511.44	12.82%	7,910.86

Table 79: Average yield of nitrogen and phosphorus under the current, GMP and GMP+ scenarios in the Catlins FMU.

Nutrient	Current yield (kg/Ha/yr)	GMP yield (kg/Ha/yr)	GMP+ yield (kg/Ha/yr)
N	9.32	8.49	7.74
P	0.48	0.45	0.42

Rivers

Yields

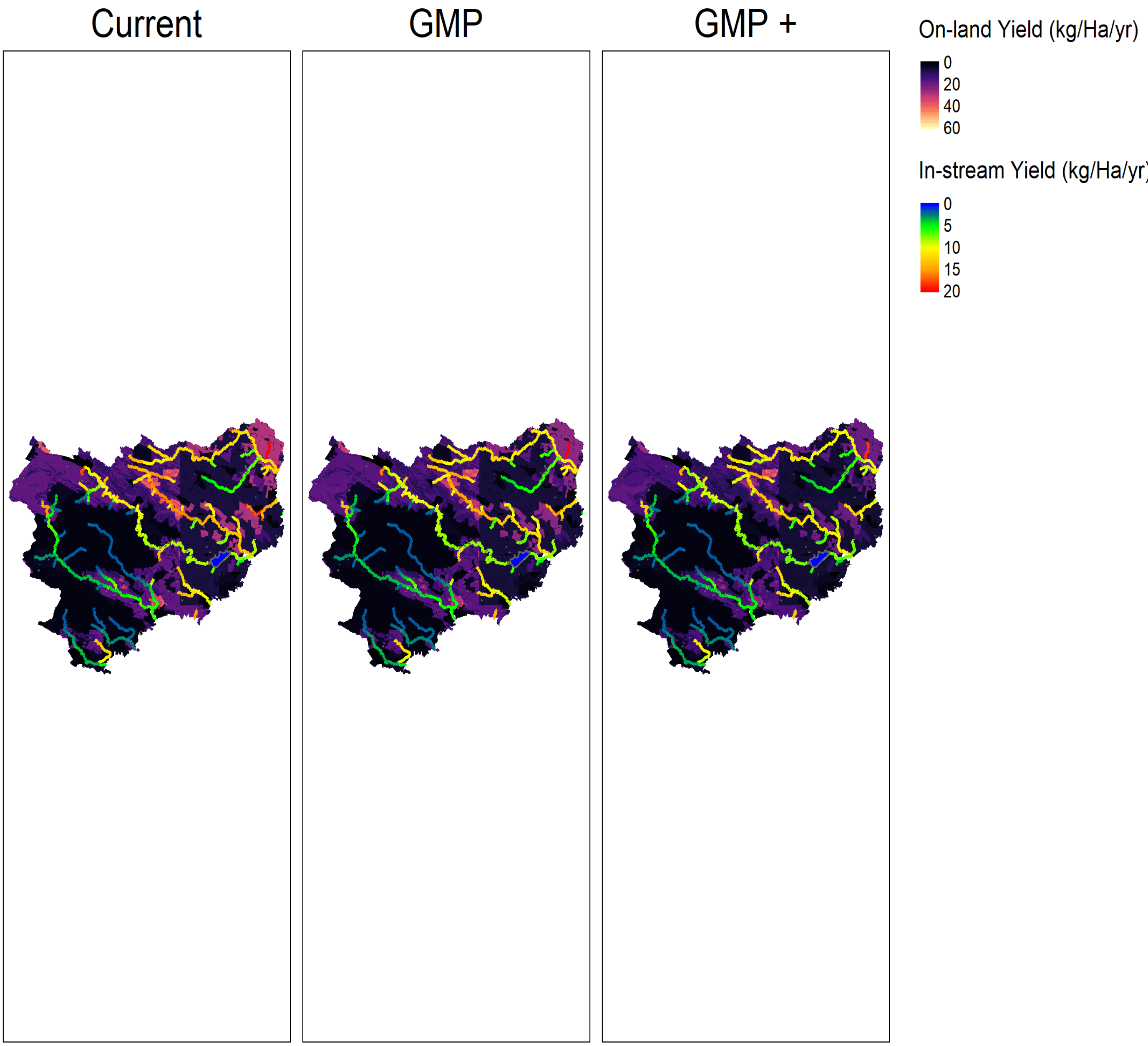

Figure 77: Average upstream nitrogen yield (kg/Ha/yr) aggregated on segment for current, GMP and GMP+ scenarios for the Catlins FMU.

Spatially, the lowest yield areas for nitrogen (Figure 77) and phosphorus (Figure 78) in the Catlins FMU occur in the southern areas with higher yields present in the Catlins, Owaka and Puerua rivers. The GMP and GMP+ scenarios lead to reduced upstream average yields of both nitrogen and phosphorus across the FMU.

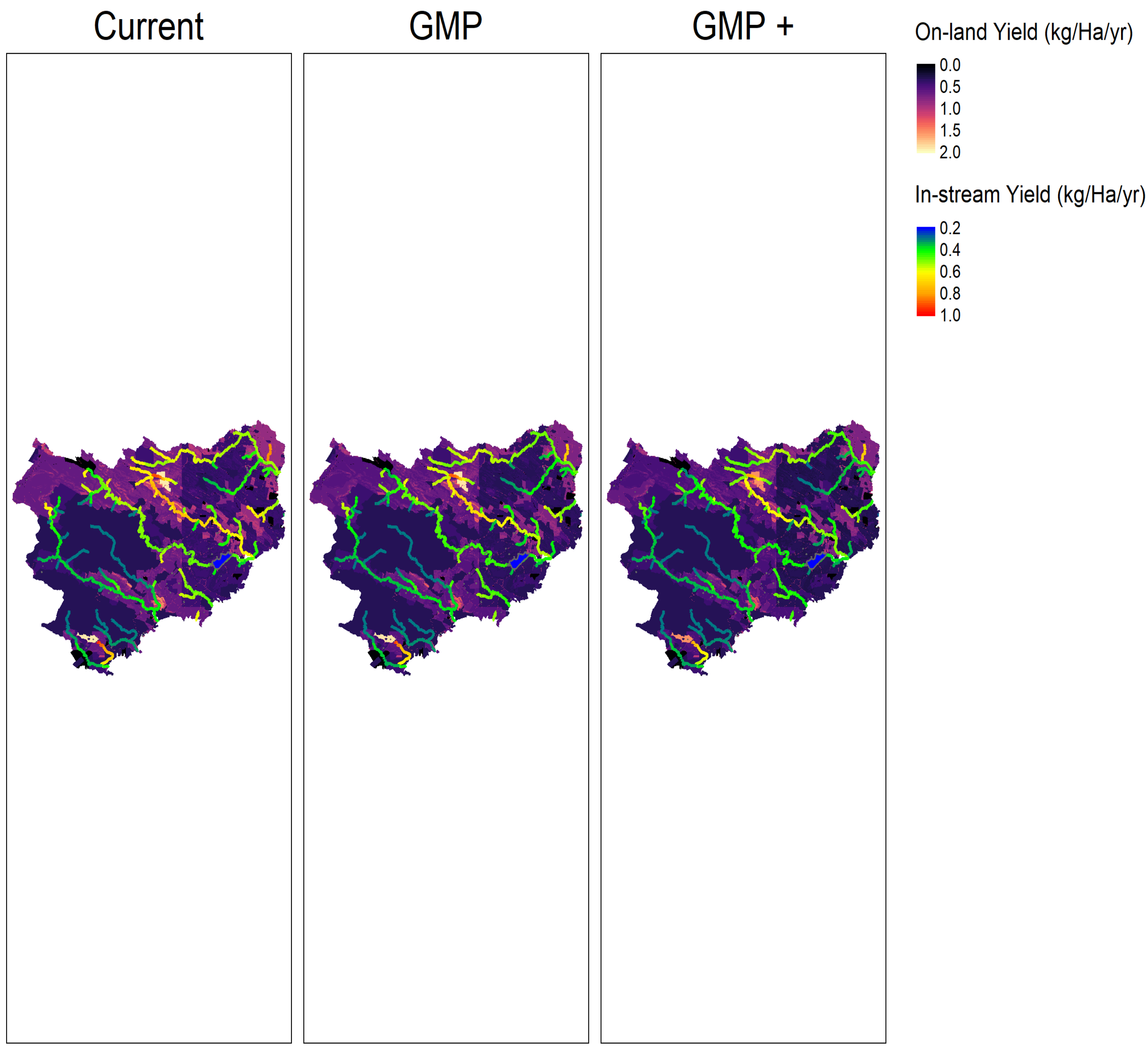

Figure 78: Average upstream phosphorus yield (kg/Ha/yr) aggregated on segment for current, GMP and GMP+ scenarios for the Catlins FMU.

Nitrate Toxicity

Nearly all segments in the Catlins FMU comply with the B-band nitrate toxicity target attribute state (Table 80) all scenarios *requiring no reduction*. *Nearly all* segments also comply with the A-band under the current scenario. However, the mean and lower confidence interval indicate a reduction *may be* required for all segments to comply. Under the GMP and GMP+ scenarios the proportion of segments expected to comply improves slightly. Reductions beyond GMP+ *may be* required for all segments to comply with the A-band criteria.

When split by management class (Table 81), *nearly all* hill-fed segments comply with the B-band and A-band nitrate toxicity target attribute state across all scenarios indicating *no reduction is required* for this class to comply. For lowland segments, *nearly all* segments comply with the B-band target attribute state under all three scenarios. The mean estimate indicates *no reduction is required* in this class. The A-band target attribute state is complied with in *nearly all* lowland segments under the current scenario. However, the mean and lower confidence interval indicate reductions *may be* required for all segments to comply. The proportion of segments expected to comply increases slightly under the GMP and GMP+ scenarios. However, reductions beyond GMP+ *may be* required for all lowland segments to comply with the A-band criteria. Lower lake segments comprise a small portion of the FMU (1 segment) and thus are not reported.

Table 80: Percent of river segments in the Catlins FMU complying with potential nitrate toxicity target attribute states with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity				
Target attribute state	**Current**	**GMP**	**GMP+**	**Count**
A	95 (84 - 100)	96 (86 - 100)	97 (88 - 100)	715
B	100 (97 - 100)	100 (98 - 100)	100 (98 - 100)	715
C	100 (98 - 100)	100 (99 - 100)	100 (100 - 100)	715

Table 81: Percent of river segments in the Catlins FMU complying with potential nitrate toxicity target attribute states, split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. The national bottomline is the B-band.

Nitrate Toxicity					
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
H	A	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	83
H	B	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	83
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	83
L	A	94 (82 - 100)	96 (84 - 100)	97 (87 - 100)	563

		Nitrate Toxicity			
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Count**
L	B	100 (96 - 100)	100 (97 - 100)	100 (98 - 100)	563
L	C	100 (97 - 100)	100 (99 - 100)	100 (100 - 100)	563

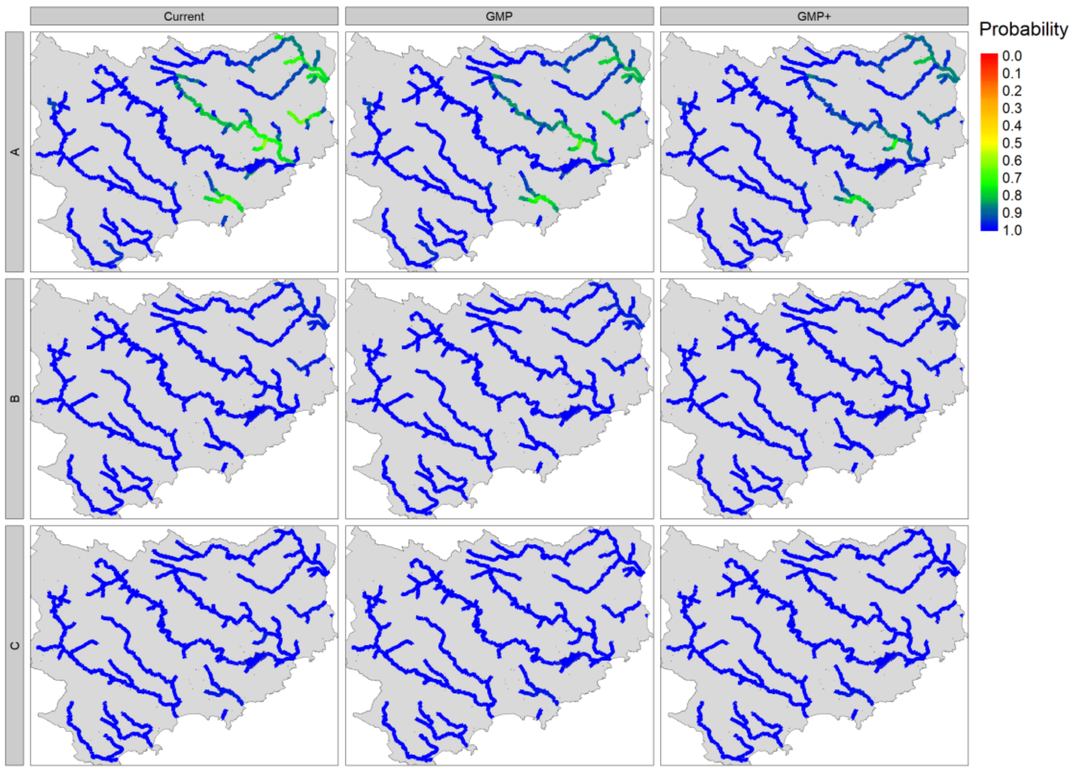

Figure 79: Individual segment probability of complying with the A, B and C nitrate toxicity target attribute states under the current, GMP and GMP+ scenarios for the Catlins FMU.

Spatially, for nitrate toxicity, the entire FMU is *very likely* to comply with the B-band target attribute state (Figure 79). The majority of the FMU is also *very likely* to comply with the A-band target attribute state except for areas of the Owaka and Puerua rivers which range from *likely* to *very likely* to comply with the A-band target attribute state. Under the GMP and GMP+ scenarios probabilities of complying with the A-band target attribute state improve in these areas.

Periphyton

For total nitrogen in relation to the periphyton biomass C-band nutrient criteria (Table 82), *nearly all* segments in the Catlins FMU comply under the current scenario. Confidence intervals indicate reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios the proportion of segments expected to comply increases but fails to overlap 100%. This indicates a reduction beyond GMP+ *is required* for all segments to comply. *Some* segments comply with the B-band total nitrogen criteria under the current, GMP and GMP+ scenarios. Reductions beyond GMP+ *are required* for all segments to comply.

For total phosphorus in relation to the periphyton biomass C-band nutrient criteria (Table 82), *nearly all* segments in the Catlins FMU comply currently. However, reductions *are required* for all segments to comply. Under the GMP and GMP+ scenario the proportion of segments expected to comply improves. The upper confidence interval overlaps 100%. However, the mean and lower confidence interval do not which indicates reductions beyond GMP+ *may be* required for all segments to comply. *Some* segments comply with the B-band total phosphorus criteria under the current, GMP and GMP+ scenarios. Reductions beyond those achieved through GMP+ *are required* for all segments to comply with the B-band criteria.

Few segments in any class comply with the A-band criteria for both total nitrogen and total phosphorus. This indicates the A-band nutrient criteria would not naturally be expected to be complied with in 80% of segments.

When split by management class for the total nitrogen C-band criteria (Table 83), *all* hill-fed segments in the Catlins FMU comply under the current scenario indicating *no reduction is required*. *Nearly all* lowland segments also comply under the current scenario. A reduction *is required* for all segments to comply as the upper confidence interval fails to overlap 100%. Under the GMP and GMP+ scenarios, the proportion of lowland segments expect to comply improves slightly. However, confidence intervals indicate reductions beyond GMP+ *are required* for all lowland segments to comply. This may require reductions in the hill management class despite those segments complying with their respective class criteria.

When split by management class for the total nitrogen B-band criteria (Table 83), *nearly all* hill-fed segments comply under the current scenarios. The mean and lower confidence interval indicate a reduction *may be* required for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expect to comply improves slightly. However, further reductions *may be* required for all hill segments to comply with the B-band criteria. *Few* lowland segments comply with the B-band total nitrogen criteria under any scenario. Reductions beyond GMP+ *are required* for all lowland class segments to comply with the B-band total nitrogen criteria.

When split by management class for the total phosphorus C-band criteria (Table 83), *all* hill class segments currently comply, and *no reductions* are required. *Nearly all* lowland segments also comply currently. However, reductions *are required* for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of segments expected to comply improves slightly. Under the GMP+ scenario the upper confidence interval overlaps 100% however, the mean and low confidence interval do not. This indicates reductions beyond GMP+ *may be* required for all segments to comply.

When split by management class for the total phosphorus B-band criteria (Table 83), *nearly all* hill class segments currently comply. Reductions *may be* required for all segments to comply. Under the GMP and GMP+ scenarios, the proportion of hill segments expected to comply improves slightly. However, further reductions beyond GMP+ *may be* required for all segments to comply. *Some* segments in the lowland class comply with the B-band criteria. There is 95% confidence that a *reduction is required* for all lowland segments to comply. Under the GMP and GMP+ scenario, the proportion of segments expect to comply improves slightly. Reductions beyond GMP+ *are required* for all segments to comply.

Table 82: Percent of river segments in the Catlins FMU complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

	Total Nitrogen			Total Phosphorus				
Target attribute state	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
A	1 (0 - 8)	1 (0 - 8)	1 (0 - 9)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	647
B	24 (13 - 40)	25 (14 - 42)	26 (14 - 43)	31 (13 - 54)	33 (14 - 59)	35 (14 - 63)	0	647
C	87 (78 - 96)	88 (82 - 97)	89 (84 - 98)	92 (84 - 99)	93 (85 - 100)	94 (86 - 100)	0	647

Table 83: Percent of river segments in the Catlins FMU complying with the Snelder et al., 2023 20% under protection risk periphyton nutrient criteria split by management class, with 90 percent confidence intervals for the current, GMP and GMP+ scenarios. Segments which do not support periphyton growth (i.e. soft bottom streams) have been removed prior to analysis.

		Total Nitrogen			Total Phosphorus				
Management Class	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**	**Periphyton exempt**	**Total segments**
H	A	6 (0 - 57)	6 (0 - 57)	6 (0 - 57)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	83
H	B	93 (79 - 100)	94 (81 - 100)	95 (84 - 100)	88 (33 - 100)	89 (33 - 100)	90 (33 - 100)	0	83

		Total Nitrogen			Total Phosphorus				
Management Class	Target attribute state	Current	GMP	GMP+	Current	GMP	GMP+	Periphyton exempt	Total segments
H	C	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	100 (100 - 100)	0	83
L	A	0 (0 - 2)	0 (0 - 2)	0 (0 - 2)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	0	563
L	B	14 (2 - 32)	15 (2 - 33)	16 (3 - 35)	23 (3 - 48)	24 (3 - 53)	27 (4 - 58)	0	563
L	C	85 (75 - 96)	86 (79 - 97)	88 (81 - 98)	91 (82 - 99)	92 (82 - 99)	93 (84 - 100)	0	563

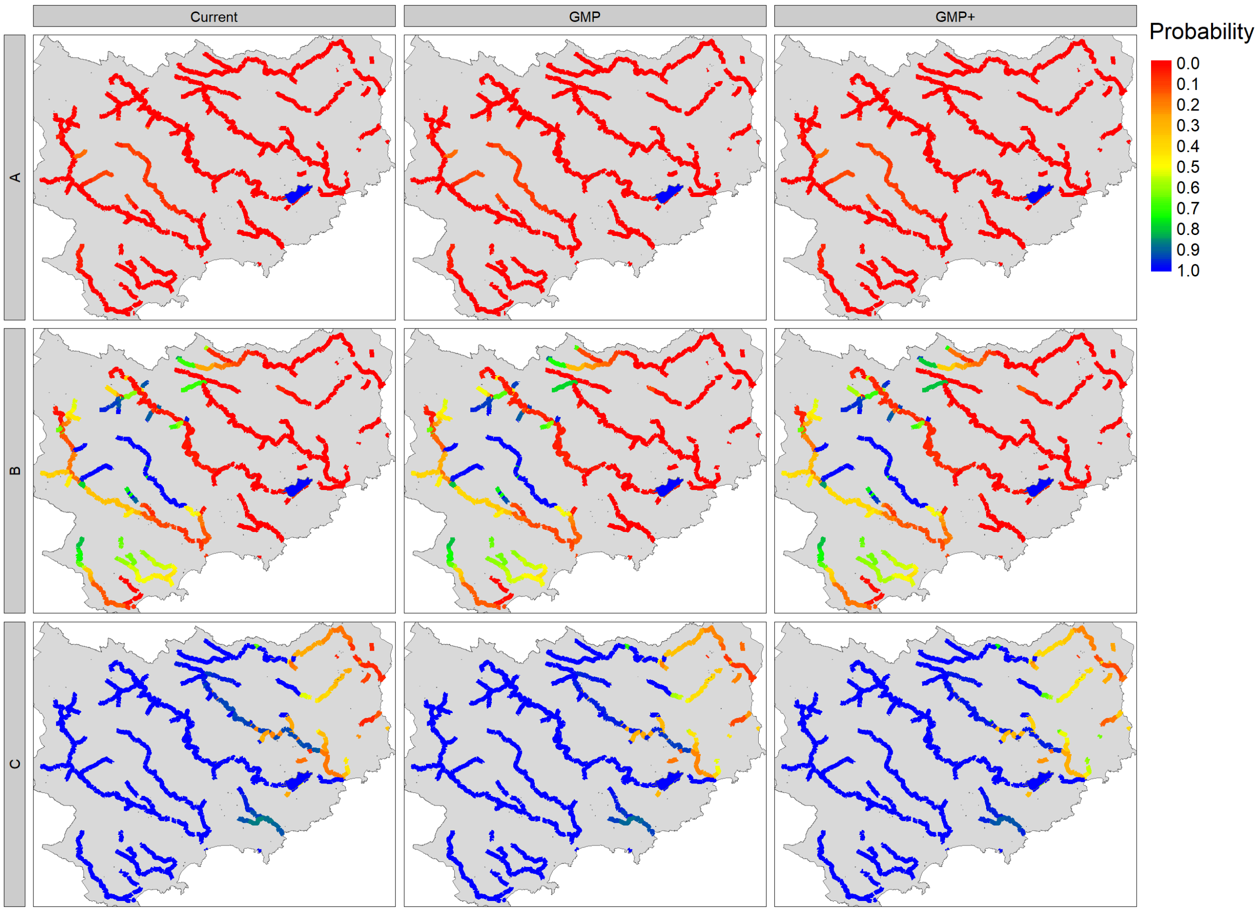

Figure 80: Individual segment probability of complying with the total nitrogen A, B and C periphyton criteria under the current, GMP and GMP+ scenarios for the Catlins FMU.

Spatially, for total nitrogen, southern areas of the Catlins FMU are *very likely* to comply with the C-band total nitrogen (Figure 80) and total phosphorus (Figure 81) criteria. *Some* areas north of the Catlins river are unlikely to very unlikely to comply with the C-band objective. For the B-band criteria, the majority of the FMU is very unlikely to comply with the total nitrogen criteria. All segments are very unlikely to comply with the A-band criteria. Under the GMP and GMP+ scenarios, probabilities of complying with the C and B-band criteria improve across the FMU.

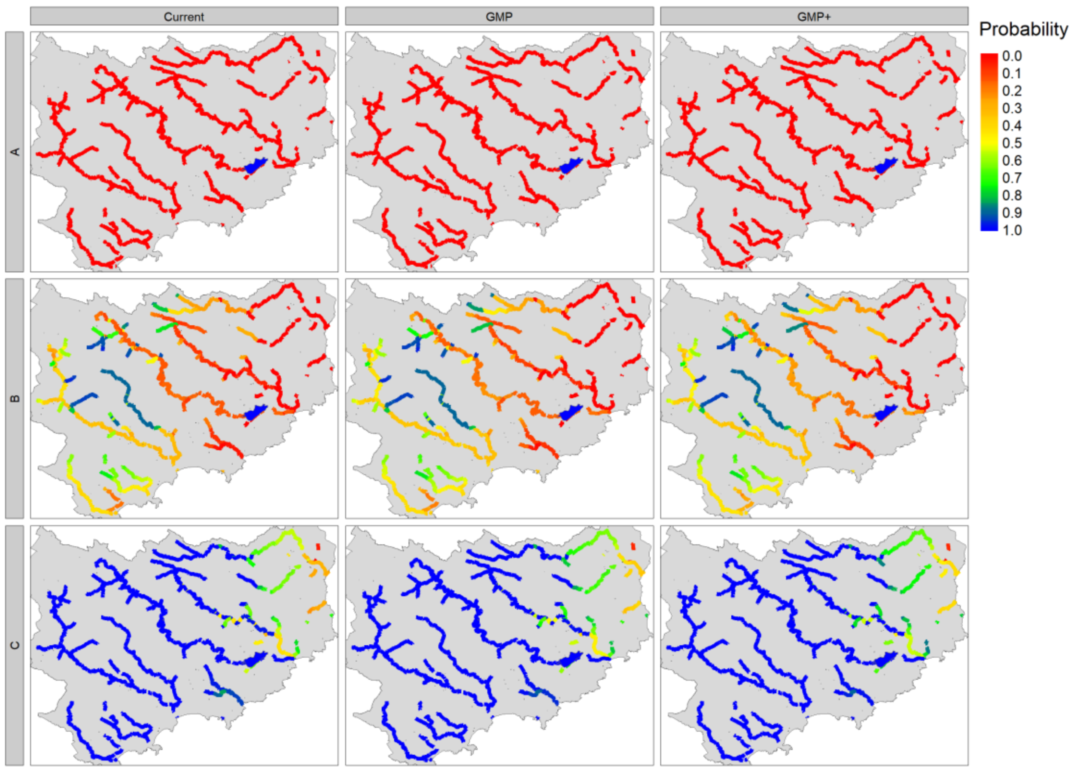

Figure 81: Individual segment probability of complying with the total phosphorus A, B and C periphyton criteria under the current, GMP and GMP+ scenarios for the Catlins FMU.

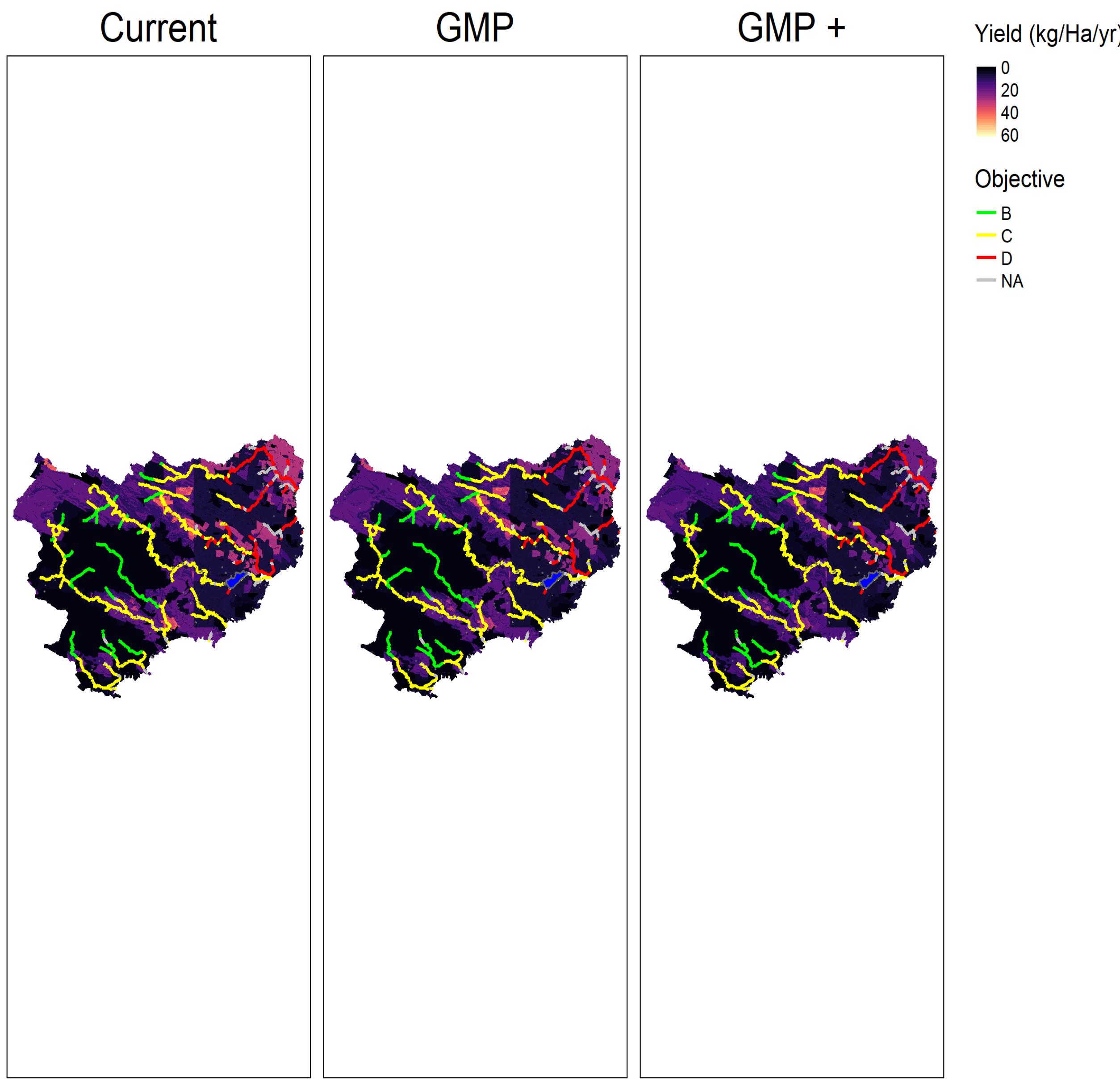

Figure 82: Maps of on-land nitrogen yield (kg/Ha/yr) and mean realization total nitrogen periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios for the Catlins FMU.

Mean realization comparisons for both total nitrogen (Figure 82) and total phosphorus (Figure 83) result in the majority of the FMU complying with the C-band criteria with the exception of the Owaka and Puerua catchments which have segments that fail to comply with the C-band criteria. Few band changes are seen under the GMP and GMP+ scenarios.

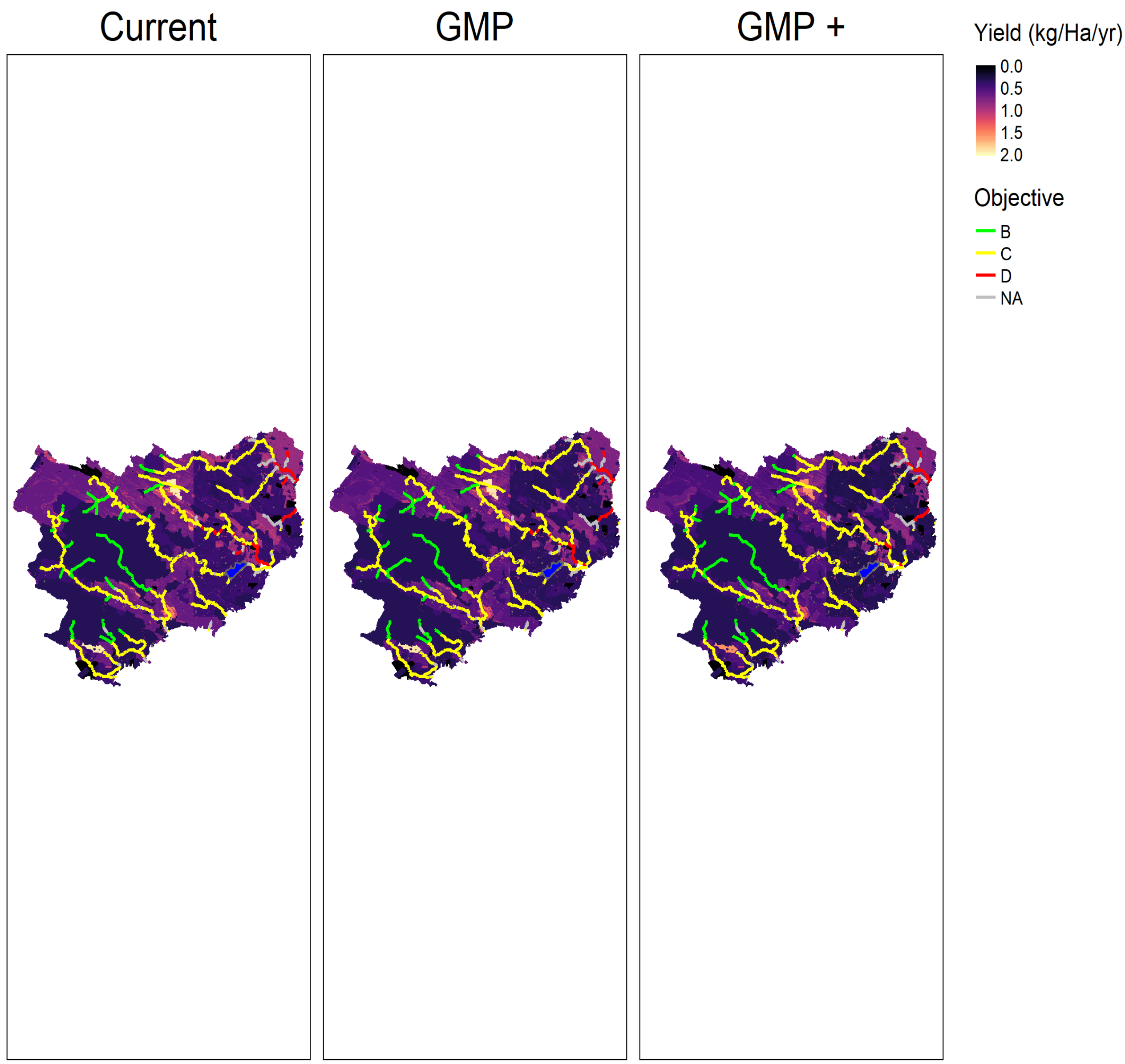

Figure 83: Maps of on-land phosphorus yield (kg/Ha/yr) and mean realization total phosphorus periphyton target attribute band outcome for each river segment under the current, GMP and GMP+ scenarios for the Catlins FMU

Estuaries

The Catlins FMU contains four estuaries where modelling results are available (Table 84). For total nitrogen, the Catlins river estuary is *likely* to comply with the C-band target attribute state under the current scenario. This improves to *very likely* to comply under the GMP and GMP+ scenarios. The B-band target attribute state is *as likely as not* to be complied with under all three scenarios. The Catlins estuary is *very unlikely* to comply with the A-band under any modelled scenario.

Under all three scenarios, the Tahakopa Estuary is *likely* to comply with the C-band target attribute state, *unlikely* to comply with the B-band target attribute state, and *very unlikely* to comply with the A-band target attribute state. Under the GMP and GMP+ scenarios, the probabilities of complying with the C- and B-bands improve.

The Tautuku River Estuary is *likely* to comply with the C-band target attribute state under all three scenarios. The B-band target attribute state is *unlikely* to be complied with. The A-band target attribute state is *very unlikely* under all modelled scenarios.

The Waipati Estuary is currently *likely* to comply with the C-band target attribute state, *unlikely* to *as likely as not* to comply with the B-band target attribute state, and *very unlikely* to comply with the A-band target attribute state. Under the GMP and GMP+ scenarios the probabilities of complying with the C-, B- , and A-band target attribute states increases.

Table 84: Probability of compliance of estuaries in the Catlins FMU with potential target attribute states across the Monte Carlo realisations with a Bernouilli 90% confidence interval. Where total phosphorus probabilities are blank, total phosphorus is not considered to be a key nutrient for estuary health.

		Total Nitrogen			Total Phosphorus		
Estuary	**Target attribute state**	**Current**	**GMP**	**GMP+**	**Current**	**GMP**	**GMP+**
Catlins River	A	0 (0 - 3)	0 (0 - 3)	0 (0 - 3)			
Catlins River	B	42 (34 - 50)	53 (45 - 61)	55 (47 - 63)			
Catlins River	C	73 (65 - 80)	82 (75 - 87)	88 (82 - 92)			
Tahakopa River	A	0 (0 - 3)	0 (0 - 3)	1 (0 - 4)			
Tahakopa River	B	27 (20 - 35)	29 (22 - 37)	32 (25 - 40)			
Tahakopa River	C	71 (63 - 78)	75 (67 - 81)	76 (68 - 82)			
Tautuku River	A	1 (0 - 4)	1 (0 - 4)	1 (0 - 4)			
Tautuku River	B	28 (21 - 36)	30 (23 - 38)	31 (24 - 39)			
Tautuku River	C	73 (65 - 80)	75 (67 - 81)	76 (68 - 82)			
Waipati Estuary	A	1 (0 - 4)	1 (0 - 4)	2 (1 - 6)			
Waipati Estuary	B	36 (29 - 44)	40 (32 - 48)	44 (36 - 52)			
Waipati Estuary	C	63 (55 - 71)	66 (58 - 73)	74 (66 - 81)			

Discussion

Comparisons of reductions in nitrogen and phosphorus achieved through the GMP and GMP+ packages indicate that while “on-land” reductions can be achieved, and can be sizeable, these reductions often deliver mixed instream outcomes. In locations where nitrate toxicity does not currently meet the A-band target attribute state, the GMP and GMP+ scenarios resulted in an increased probability of compliance. However, for periphyton in rivers, phytoplankton in lakes, and macro algae in estuaries, the reductions achieved through the GMP and GMP+ mitigations generally did not result in receiving environments improving multiple bands. Instead, outcomes for these attributes are likely to improve within the current band.

On-land reductions

On-land reductions achieved under the GMP packages ranged substantially from approximately 8-9% in the North Otago and Taieri FMUs to approximately 1% in the Upper Clutha FMU. Catchments with a larger portion of agricultural land use support larger reduction potential as more mechanisms exist through which reductions can be achieved (Sise et al. 2022). However, these areas are also likely to have larger required reductions (T. Snelder and Fraser 2023). Reductions achieved under the GMP+ scenario are often double, or triple, that achieved under GMP. In some FMUs, this resulted in reductions of over 20%, such as in the North Otago FMU. These FMUs tend to have large areas of dairy which has higher emissions but also high mitigation levels allowing for larger potential reductions (Sise et al. 2022). FMUs with a large portion of sheep and beef farming, but a relatively small dairy component, tended to have lower reductions despite large pastoral components, such as in the Roxburgh FMU.

The current reductions modelled apply to sheep, beef, dairy, and other pastoral categories of land use. Additional reductions may be achieved through improved management of other land use types such as horticulture, forestry, or urban landscapes. Further, additional mitigations for which reductions could not be estimated at a regional scale, such as critical source area management, are likely to result in further reductions which may be large (Sise et al. 2022).

While mitigation effectiveness and base loss are both uncertain this analysis has not quantified the uncertainty from these components. The associated uncertainty is likely to be large- see limitations.

Rivers

Nitrate Toxicity

In order to comply with the national bottom line for nitrate toxicity (i.e., the B-band), the majority of FMUs do not require any reduction as 100% of segments comply. In the Lower Clutha FMU, reductions may be required as 98% of segments comply. To comply with the A-band target attribute state in 100% of segments, reductions may be needed in the Catlins, Lower Clutha, Taieri, Dunedin & Coast, and North Otago FMUs. All of these FMUs show both a high mean percentage of segments currently complying with the A-band target attribute state, with upper confidence intervals overlapping 100%, and a high probability for individual segments which range from *likely* to *very likely* to comply. As a result, a large portion of these FMUs are currently likely to comply with the A-band target attribute state.

When split by management class, reductions are generally not required for the mountain or hill-fed classes to comply with the A-band target attribute state. However, lowland class rivers may require reductions. As the lowland river class is often a downstream receiving environment of mountain or hill-fed classes, reductions achieved in these classes will contribute to outcomes in the lowland class.

The GMP and GMP+ scenarios lead to both the segment probabilities, and percentage of segments complying with the A-band target attribute state improving.

Periphyton

Periphyton outcomes varied across the FMUs. For all segments to comply with the C-band total nitrogen criteria, nitrogen reductions are required in the Catlins, Lower Clutha, Dunedin, and North Otago FMUs as neither the mean nor upper confidence intervals overlap 100%. Reductions may also be required in the Taieri FMU and Roxburgh Rohe as the mean does not overlap 100%.

For all segments to comply with the C-band total phosphorus criteria, reductions are required in Lower Clutha, Dunedin, and Taieri as the mean and upper confidence interval fail to overlap 100%. The North Otago, Manuherekia, Roxburgh, and Catlins may also require reductions as the mean fails to overlap 100%.

For all segments to comply with the B-band criteria, all FMUs/Rohe require reductions of both nitrogen and phosphorus except for the Upper Lakes Rohe which may not require reductions.

As few to no segments comply with the A-band, despite many segments in the Upper Lakes and across the wider region representing natural state, it is unlikely that this band is an achievable target at a 20% under protection risk. This may occur due to the combination of the selected under protection risk and the biomass objective. The nutrient criteria used here is a 20% under protection risk and biomass objective for the A-band is 50mg/m^3 of chlorophyll-a. This means that if all segments achieved the nitrogen and phosphorus criteria, 80% of segments would be expected to achieve the associated biomass outcome. As “natural” segments have failed to comply with these criteria, this may suggest that 80% of segments may not naturally achieve the A-band periphyton biomass objective.

When split by management class, mountain class segments generally comply with the B-band criteria and hill-fed segments comply with the B or C-band criteria. Lowland segments tend to comply with the C-band criteria, though many fail to comply. Compared to the whole of FMU compliance, the confidence bands are often larger when split by management class. This is due to spatial scale. The management class analysis occurs at a finer spatial scale. This enables accounting for natural heterogeneity present in river systems but does come at the cost of increased uncertainty.

Under the GMP and GMP+ scenarios, the mean percentage of segments complying with a given band generally increased, but only by a small amount (i.e., <5%). This improvement is within the uncertainty of the required reductions. This suggests that, while on-land reductions can appear large, such as over a 20% reduction of nitrogen in North Otago, multi-band periphyton improvements are unlikely to result and would require larger reductions. Instead, within band improvements, or improvement of declining trends, are more likely to occur under these scenarios.

For the C-band criteria, the reductions achieved in some FMUs such as North Otago, Dunedin & Coast, Lower Clutha, and Catlins, under the GMP and GMP+ scenarios overlap the load reductions required by Snelder and Fraser (2023). However, our analysis indicates there is 95% confidence that reductions beyond GMP+ are required for all segments to comply in some FMUs. While counter intuitive, this is an expected result. Our analysis uses percentage of segments complying whereas the analysis in Snelder and Fraser provides total load reduction required as bulk load. The bulk load sums the total load reduction required across the FMU for all criteria to be met. For FMUs with multiple catchments, this means the proportional load reduction required across individual catchments may vary from none to large reductions. This creates a discrepancy in spatial scale of the analyses. As the mitigation packages in our analysis are applied across an FMU, achieving the bulk required reductions calculated by Snelder and Fraser does not mean the reductions have occurred in locations which would result in all segments complying. Snelder and Fraser's estimates also include reductions required to comply with lake and estuary target attribute states whereas the segment compliance tables presented here focus on periphyton.

To comply with the B-band criteria for periphyton biomass in all segments and classes, reductions beyond GMP+ would be required in all FMUs except for the Upper Lakes Rohe.

Lakes

Lake outcomes under the current scenario varied with headwater lakes (generally at higher elevations), such as Manorburn, and Lucidus having high probabilities of complying with the A- and B-band total nitrogen target attribute states while lower elevation, mid to lower catchment, shallow lakes such as Tuakitoto, Waihola, and Waipori, have a high probability of failing to comply with the C-band nitrogen target attribute state.

For phosphorus, many lakes in the Upper Lakes FMU surrounded by natural landscapes, such as Lake Lucidus, Nigel, Ned Mckellar and Diamond, have low probabilities of complying with the B and A-band phosphorus target attribute state. Given their predominantly natural surroundings, the estimated phosphorus loads are likely to be from natural sources or an artefact of the load modelling assumptions made in model 2. The large lakes in the Upper Lakes FMU, including Wanaka, Wakatipu and Hawea, have a high probability of complying with the A-band target attribute state. Lower elevation shallow lakes, such as Tuakitoto, Waipori, and Waihola, have low to medium probabilities of complying with the C-band target attribute state.

The lake required reduction models do not incorporate internal loading and use nutrient criteria from the NPSFM 2020 which may not be suitable for all lakes, particularly the oligotrophic to micro-trophic lakes of Otago (Wanaka, Wakatipu-Hawea). In these lakes, nutrient concentrations are extremely low. Even a small increase in concentration may result in a large change to the lake ecology. If a lake is subject to excessive internal loading, complying with the required nutrient reduction(s) predicted by this modelling does not mean the lake will comply with the NPSFM nutrient criteria (NPSFM 2020 Tables 3, 4). In this case the lake may not achieve the phytoplankton outcome (NPSFM 2020, Table 1). As a result, the magnitude of required load reduction is uncertain (see limitations).

Under the GMP and GMP+ scenarios, predicted nutrient yields are consistently lower than the current scenario meaning any outcomes in the lakes arising from the GMP and GMP+ scenarios are likely to be beneficial. The probability of complying with both the nitrogen and phosphorus C-band criteria improves a small amount for the lower elevation lakes. Larger probability changes (such as a 20% increase) did not occur under any scenario indicating mitigation-based reductions are likely to lead to improvements within the current bands or improvement in trend slope rather than multi-band improvements (e.g., from C to A).

Estuaries

Estuary outcomes varied based on estuary type with many shallow intertidal dominated estuaries (SIDE) (such as Otago Harbour, Blueskin Bay, Papanui Inlet) having high probabilities of complying with the B and A-band objectives whereas shallow, short residence time tidal river estuaries (SSRTRE) where mouth closures can occur (such as the Kakanui, Kaikorai, or Tokomairiro) often have lower probabilities of complying with the C-band and B-band objectives. While the SIDE estuary probabilities are closer to reflecting the results of available monitoring (see Appendix 4), variation still occurs, with the SSRTRE estuaries results are even more variable. Both SIDE and SSRTRE estuaries can be subject to differing flushing flows, low-flow mouth closures (SSRTRE estuaries), and other factors which may result in larger spatio-temporal variation of state. For example, upper areas of estuaries may have more algal growth than the lower estuary or have recently been scoured by a flood. As result, it is very difficult to determine the magnitude of nutrient reductions required for estuaries and their associated uncertainty. The modelling also does not take account of many other factors such as internal cycling, macroalgae uptake or de-nitrification and therefore it is likely best used as a screening tool for identifying estuaries where further studies may be beneficial.

While the magnitude of reduction required to comply with the objective bands is uncertain, the GMP and GMP+ scenarios result in improved probabilities because of decreased nitrogen loads from the mitigation suites. Therefore, the ecological state of estuaries would be expected to improve if any change were to be detectable in these systems.

Limitations

Results of the modelling have a high level of both statistical and non-statistical uncertainty. We acknowledge the linking analysis and underlying models have limitations which are discussed here with the intent to create awareness for users applying the model rather than a critique of the approach of the four component models. Full limitations of component models are discussed in their own respective reports (Srinivasan et al. 2021; Plew 2021; Snelder et al. 2022; Couldrey 2022; Sise et al. 2022; T. Snelder and Fraser 2023).

Models 1 and 2

The models to determine nutrient criteria to provide for periphyton, lake and estuary target attribute states are uncertain. The nutrient criteria models for periphyton indicate saturating concentrations for all four nutrient forms and that the associated biomass at the saturating concentration reaches a “ceiling” beyond which there is no further biomass response to increasing nutrient concentrations. This ceiling generally occurs before exceeding the national bottom line (NBL). The model therefore does not predict periphyton biomass much more than the national bottom line, even at very high nutrient concentrations. Sites below the NBL were included in the original dataset when developing the nutrient criteria for periphyton. However, these values were unable to be associated with any predictor variables and, as a result, they cannot be explained in terms of nutrient concentrations. Snelder et al. (2023) models and criteria are best information available about the relationship between nutrients and periphyton biomass (see Appendix 3). The criteria provide a basis for achieving periphyton objectives but will be insufficient in some areas; some sites will exceed biomass thresholds while complying with the nutrient criteria.

Nutrient reduction modelling for lake outcomes utilizes a simple box model approach (T. Snelder and Fraser 2023). This approach does not take account of existing internal nutrient cycling that will be present in lakes and was calibrated using a limited dataset. Therefore, the reduction uncertainty is large and while the required reduction may be achieved, actual changes in state may be delayed until the internal nutrient cycling has diminished. Further, the nutrient criteria used to determine required reductions are those from the NPSFM2020. Many lakes in Otago (such as Wanaka, Wakatipu and Hawea) are classed as Oligotrophic to micro-trophic. In these systems, complying with the bottom threshold of the A-band criteria may represent a reduction in water quality, as the NOF criteria are insufficiently stringent to maintain existing water quality. As a result, determining the magnitude of reductions required to maintain state in these systems requires targeted, detailed investigations.

The simple estuary modelling approach was developed primarily as a screening tool to support high level decision making, it is acknowledged that the approach has some limitations and more in-depth studies will likely be needed where estuaries are prioritized for management. Where real data were unavailable, the model parameters were sourced from Coastal Explorer and the New Zealand Estuary Classification those databases use desktop information to calculate estuary volume, tidal prism, area, and fetch, and may not reflect the true dilution characteristics of estuary. The modelling is based on whole estuary dilution and annual average nutrient loads; therefore it does not take into account seasonal nutrient loading patterns, events or the effects of localised hydrology (e.g., poorly flushed areas). Further, the simple dilution models predict the potential TN concentration in an estuary to assess the potential susceptibility of the estuary to macroalgal blooms by using a direct relationship between macroalgal response and TN concentration. These simple models do not take into account other factors that may limit macroalgal growth (e.g., recent floods or scour events, lack of suitable substrate, internal nutrient sources, light availability etc) or factors that might alter the potential TN concentration under a real-world scenario (e.g., uptake of TN by plants, microbial processes such as nitrification and denitrification etc). Considering the limitations outlined above, these simple dilution models should be used in combination with a suite of other tools (e.g., SoE monitoring data, other modelling) and are best interpreted by considering directionality of change opposed to likelihood of achieving an objective. See Plew (2021) for more detailed discussion of estuary limitations.

The uncertainty present in the required load reduction estimates is represented through the Monte Carlo realisations and carried through into the confidence intervals presented.

Models 3 and 4

The predicted source loss and model farm reduction percentages are also uncertain. Model farm uncertainty has been reduced by attempting to best align model farms to appropriate regions of Otago and creating an "average model farm". By using an "average model farm", the reduction value is more likely to appropriately represent groups of farms than actual reductions achieved on a particular farm. Thus, based on the modelling presented here, determining farm nutrient allocations for regulatory purposes is not possible and the model should not be used on farm level spatial scales.

The linking of models three and four requires matching model farm reductions to typologies on which they are applied. At times, a typology match is not suitable and therefore mitigations are not applied to that parcel. In this situation, a greater reduction may be achieved than that modelled as some level of reduction would occur if the mitigation package were implemented.

Further, the GMP and GMP+ mitigation suite applied was developed for pasture, or grazing based, farms which comprise a significant portion of Otago's land use. Additional emission reductions may be achieved through applying mitigations on forestry, horticulture, arable, urban, and other major anthropogenic land uses but have not yet been included in the modelling and should be an area of further development.

The uncertainty present in model farms and source loss predictions is acknowledged as large, but not quantified. It may be possible to better represent the uncertainty of Srinivasan et al., by incorporating a Monte Carlo approach. This should be explored in future model development.

Linking Analysis

Our linking analysis uses a 1:1 ratio of on land reduction to that occurring in the receiving environment. The process for a given contaminant (such as N or P) to travel from a farm source a water body can be complex, with multiple possible pathways, time frames and biophysical processes at play. The contaminant load can also be reduced (attenuated) by processes such as de-nitrification. The attenuation or reduction of contaminant loads as they migrate from the farm to waterways is an area of active research, and there is limited data to quantify this process. As a result, we use a 1:1 ratio. The uncertainty present in the relationship is currently unquantifiable.

The linking analysis also assumes a stationary load with immediately implementation and "flow through" of nutrients with no lag effects. If non-stationarity is present, such as an increasing nutrient trend, the required reductions may be larger than those used in the linking analysis. The full implementation of either the GMP or GMP+ scenario is unlikely to occur on every land-use and will likely occur over several years. Both implementation lag, and natural lag, would need to lapse before on-land changes are fully evident in-stream. The modelling results presented in this report are best viewed as a full "outcome" that may eventuate post full implementation and lags.

The linking analysis routes reductions using the river environment classification (REC) and its water shed component. In Otago, on rare occasion, REC river lines can follow water races or alternative flow paths that do not reflect reality. Load reductions may be routed down these lines. The impact of this on an FMU or Rohe scale is likely to be very minor.

Implications

The analysis presented here has both quantified, and unquantified, uncertainty. These uncertainties should be considered when interpreting results. Results for individual segments are highly uncertain, but broad-scale patterns and relativities between scenarios are more likely to be useful in a planning context.

A pragmatic response to the uncertainty present is to consider the magnitude of relativities under the different scenarios and adaptively manage where results indicate target attribute state may be achieved. For example, if the FMUs upper confidence interval overlaps 100% and the mean nears 100% for the class under the GMP scenario, it may be logical to implement the scenario and measure the results before implementing further actions. Where the upper confidence interval and mean do not approach or overlap 100% for the target attribute state under the GMP+ scenario, further reductions are likely to be required in the future. In this case, it is important to consider whether the additional investment required under a GMP+ scenario is justified when more change is likely to be required.

Conclusion

To investigate whether suites of mitigation measures achieve potential instream ecosystem health target attribute states, this study linked nitrogen and phosphorus reductions through two mitigation scenarios to the in-stream reductions required to comply with the potential target attribute states. Given the uncertainty and limitations present, our findings are best interpreted as indicating the magnitude of instream and on-land change likely to occur under these scenarios. Comparisons of reductions in nitrogen and phosphorus achieved through the GMP and GMP+ packages indicate that while large “on-land” reductions can be achieved, these reductions generally do not result in the state of receiving environments changing target attribute bands. Instead, these scenarios are likely to result in improvements in water quality that result in movement within a target attribute band or improvement in trend. Therefore, where the target attribute state is set at, or near, the baseline state, the mitigation scenarios are likely to result in compliance. Reductions beyond GMP+ may be required to comply with the target attribute state if it is set above the baseline state.

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Appendix 1

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MEMORANDUM

To:	Error! Unknown document property name.
From:	**Tapuwa Marapara**
Date:	Error! Unknown document property name.
Re:	Error! Unknown document property name.

Name	Role	Date Completed
Tapuwa Marapara	Author	29/04/2022
	Internal Reviewer	
Graeme Doole (AgResearch Ltd)	External Reviewer	10/10/2022

1. Introduction

Development of the Land and Water Regional Plan (LWRP) requires the science team to provide effective environmental management strategies that improve water quality across the Otago region. Development of effective environmental management strategies is guided by the understanding of connections between contaminant sources and receiving environments, i.e., where contaminants originate from, within the catchments and their pathway to receiving waters.

Landscape characteristics such as topography, soil and climate influence the vulnerability risk of contaminant transport to water, while a diverse set of farm inputs, feedstock and soil management practices influence land use pressures that determine contaminant pathways. Aligning landscape characteristics (topography, soil and climate) with land use pressures (land use activity/farm type) provides ‘typologies’ (Monaghan et al., 2021; Srinivasan et al., 2021) to which contaminant (N & P) discharges can be benchmarked. Knowing the variation of N & P loss across various typologies enables the alignment of management strategies with spatial extents of land use pressures and landscape features that determine vulnerability (Monaghan et al., 2021).

2. Farm/land use typology approach

New Zealand modelled and assumed values for N & P on-land annual losses (kg/ha/yr) in combined drainage and surface runoff flows were assigned to land use typologies that represent the Otago region. Otago's land use typologies were developed by combining spatial datasets of climate (rainfall and soil temperature), topography (slope), soil properties (e.g., drainage class) and land use (e.g., sheep, dairy, forestry, deer and others), all of which influence N & P losses from land to water. The combination of the spatial datasets led to the identification of 166 possible land use typologies for Otago (**Insert 2**).

The N & P loss values that were assigned to the Otago's typologies are based on the modelled and assumed values of pastoral and non-pastoral land use typologies derived from Table 3 in Srinivasan et al. (2021) (**Insert 1**) and the framework developed by Monaghan et al. (2021). The assigning process of N & P loss values was also guided by expert knowledge (Dr Ross Monaghan) and another NZ-based study (Drewry, 2018) for land use typologies that were not provided in the table by Srinivasan et al. (2021) (**Insert 1**). It is worth noting that there is more confidence with N loss estimates than P loss values which are P loss "risk" estimates. Also evident in **Insert 1** are the wide ranges of N and P loss per land use typology. While the typology approach uses a value of central tendency to represent losses from different land use activities, it also recognises that within any typology there can be a reasonably wide range of contaminant losses due to land management decisions and ranges in vulnerability factors (soil, topography and climate).

Insert 1 Image of Table 3 with N&P loss values for typologies from Srinivasan et al. (2021)

Table 3. Inventory of modelled and assumed yields of N and P for pastoral farm typologies and other categories of land use or cover. Values are assumed to represent N and P losses in combined drainage and surface runoff flows, although it should be recognised that studies (measured and modelled) did not always measure or model secondary pathways of loss; further details can be found in Monaghan et al. (in preparation) and Drewry (2018).

Land use	Slope	Moisture	N loss (kg N ha^{-1} y^{-1})		P loss (kg P ha^{-1} y^{-1})	
			Median	Range*	Median	Range*
Dairy	Flat	Dry	29.5	23–38	0.85	0.6–1.2
		Moist	39	29–45	1.05	0.6–1.4
		Wet	48.5	34–55	1.25	0.6–1.4
		Irrigated	55.5	33–82	0.95	0.8–1.1
	Rolling	Dry	27	22–36	1.0	0.9–1.6
		Moist	32	25–44	1.5	0.9–1.9
		Wet	45	28–53	1.8	0.9–1.9
		Irrigated	52	29–63	1.3	1.1–1.6
	Easy Hill	Dry	28	26–36	1.0	0.9–1.6
		Moist	32	25–44	1.5	0.9–1.9
		Wet	45	28–53	1.8	0.9–1.9
		Irrigated	52	29–63	1.3	1.1–1.6
Sheep / Sheep & Beef	Flat	Dry	7		0.4	
		Moist	18	15–21	0.6	
		Wet	24	18–30	0.75	0.7–0.8
		Irrigated	20	17–23	0.6	
	Rolling	Dry	7.5	7–8	0.35	0.3–0.4
		Moist	11.5	9–14	0.7	
		Wet	17.5	11–24	0.8	
		Irrigated	11.5	9–14	0.7	
	Easy Hill	Dry	5	4–6	0.5	
		Moist	8.5	8–9	1.0	
		Wet	9	7–11	1.6	
	Steep	Dry	4.5	4–5	0.6	
		Moist	6	4–8	1.6	
		Wet	6.5	5–8	2.8	
Beef	Flat	Dry	13		0.6	
		Moist	32	27–37	0.7	
		Wet	38	32–44	1.15	1.0–1.3
		Irrigated	34.5	29–40	0.8	
	Rolling	Dry	13	12–14	0.5	
		Moist	20.5	15–26	0.9	
		Wet	27	20–34	1.2	
		Irrigated	20.5	15–26	1.2	
	Easy Hill	Dry	9	7–11	0.7	
		Moist	15.5	14–17	1.5	
		Wet	15.5	12–19	2.4	
	Steep	Dry	8	6–10	1.0	
		Moist	10.5	8–13	2.4	
		Wet	12	10–14	4.3	
Deer	All	Dry	7	7–9	0.75	0.2–1.0
		Moist	12	9–12	1.9	0.4–2.8
		Wet	18		0.8	0.6–1.0
Other pastoral support land used for winter forage crop grazing	Flat	Dry	17	17–18	0.35	0.3–0.4
		Moist	41	32–41	0.65	0.5–0.8
		Wet	49	39–49	1.0	0.8–2.0
		Irrigated	36	31–45	0.7	0.6–0.8
	Rolling	Dry	17	17–19	0.4	0.3–0.4
		Moist	33	25–36	0.8	0.7–0.8
		Wet	45	33–45	1.4	0.8–2.1
		Irrigated	35	31–36	0.8	0.7–1.0
Arable and mixed Crops	Flat	All	13.5	1–113	0.1	0.1–2.9
Vegetable growing	Flat	All	72	2–220	1.9	
Viticulture	Flat	Unknown	10	1–37	0.2	0.1–0.5

Table 3. Continued.

Land use	Slope	Moisture	N loss (kg N ha^{-1} y^{-1})		P loss (kg P ha^{-1} y^{-1})	
			Median	Range*	Median	Range*
Forestry	All	All	4	1–28	0.4	0.1–1.3
Native Bush	All	All	2	1–7.1	0.3	0.1–0.6

*Ranges reflect variation caused by contrasting soil drainage and temperature typology attributes.

Insert 2 Land use typologies and their associated N & P losses for Otago Region. N & P values are based on Srinivasan et al. (2021), Expert opinion (Ross Monaghan) and Drewry, (2018)

Land_Use	Wetness	Slope	N loss (kg N/ha/yr)	P loss (kg P/ha/yr)
Arable		Flat/Undulating (<7°)	13.5	0.1
Arable	Dry	Easy Hill (15-25°)	13.5	0.1
Arable	Dry	Flat/Undulating (<7°)	13.5	0.1
Arable	Dry	Rolling (7-15°)	13.5	0.1
Arable	Dry	Steep (>25°)	13.5	0.1
Arable	Irrigated (>50%)	Easy Hill (15-25°)	13.5	0.1
Arable	Irrigated (>50%)	Rolling (7-15°)	13.5	0.1
Arable	Irrigated (>50%)	Steep (>25°)	13.5	0.1
Arable	Irrigated (>50%)	Flat/Undulating (<7°)	13.5	0.1
Arable	Irrigated (>50%)		13.5	0.1
Arable	Moist	Easy Hill (15-25°)	13.5	0.1
Arable	Moist	Flat/Undulating (<7°)	13.5	0.1
Arable	Moist	Rolling (7-15°)	13.5	0.1
Beef		Flat/Undulating (<7°)	13	0.6
Beef		Rolling (7-15°)	13	0.5
Beef	Dry		9	0.7
Beef	Dry	Easy Hill (15-25°)	9	0.7
Beef	Dry	Flat/Undulating (<7°)	13	0.6
Beef	Dry	Rolling (7-15°)	13	0.5
Beef	Dry	Steep (>25°)	8	1

Beef	Irrigated (>50%)	Easy Hill (15-25°)	15.5	1.5
Beef	Irrigated (>50%)	Flat/Undulating (<7°)	34.5	0.8
Beef	Irrigated (>50%)	Rolling (7-15°)	20.5	1.2
Beef	Irrigated (>50%)	Steep (>25°)		
Beef	Moist	Easy Hill (15-25°)	15.5	1.5
Beef	Moist	Flat/Undulating (<7°)	32	0.7
Beef	Moist	Rolling (7-15°)	20.5	0.9
Beef	Moist	Steep (>25°)	10.5	2.4
Beef	Wet	Easy Hill (15-25°)	15.5	2.4
Beef	Wet	Flat/Undulating (<7°)	38	1.15
Beef	Wet	Rolling (7-15°)	27	1.2
Commercial Use		Flat/Undulating (<7°)	5	1
Commercial Use			5	1
Commercial Use		Rolling (7-15°)	5	1
Commercial Use	Dry	Flat/Undulating (<7°)	5	1
Commercial Use	Dry	Easy Hill (15-25°)	5	1
Commercial Use	Dry	Rolling (7-15°)	5	1
Commercial Use	Dry	Steep (>25°)	5	1
Commercial Use	Moist	Flat/Undulating (<7°)	5	1
Commercial Use	Moist	Rolling (7-15°)	5	1
Commercial Use	Moist	Easy Hill (15-25°)	5	1
Commercial Use	Moist	Steep (>25°)	5	1
Commercial Use	Wet	Flat/Undulating (<7°)	5	1
Conservation			2	0.3
Conservation		Easy Hill (15-25°)	2	0.3
Conservation		Flat/Undulating (<7°)	2	0.3
Conservation		Rolling (7-15°)	2	0.3
Conservation		Steep (>25°)	2	0.3
Conservation	Dry		2	0.3
Conservation	Dry	Easy Hill (15-25°)	2	0.3

Conservation	Dry	Flat/Undulating (<7°)	2	0.3
Conservation	Dry	Rolling (7-15°)	2	0.3
Conservation	Dry	Steep (>25°)	2	0.3
Conservation	Irrigated (>50%)	Flat/Undulating (<7°)	2	0.3
Conservation	Irrigated (>50%)	Rolling (7-15°)	2	0.3
Conservation	Moist		2	0.3
Conservation	Moist	Easy Hill (15-25°)	2	0.3
Conservation	Moist	Flat/Undulating (<7°)	2	0.3
Conservation	Moist	Rolling (7-15°)	2	0.3
Conservation	Moist	Steep (>25°)	2	0.3
Conservation	Wet		2	0.3
Conservation	Wet	Easy Hill (15-25°)	2	0.3
Conservation	Wet	Flat/Undulating (<7°)	2	0.3
Conservation	Wet	Rolling (7-15°)	2	0.3
Conservation	Wet	Steep (>25°)	2	0.3
Dairy		Flat/Undulating (<7°)	29.5	0.85
Dairy		Rolling (7-15°)	27	1
Dairy		Easy Hill (15-25°)	28	1
Dairy	Dry		29.5	0.85
Dairy	Dry	Easy Hill (15-25°)	28	1
Dairy	Dry	Flat/Undulating (<7°)	29.5	0.85
Dairy	Dry	Rolling (7-15°)	27	1
Dairy	Dry	Steep (>25°)	5	1
Dairy	Irrigated (>50%)		55.5	0.95
Dairy	Irrigated (>50%)	Easy Hill (15-25°)	52	1.3
Dairy	Irrigated (>50%)	Flat/Undulating (<7°)	55.5	0.95
Dairy	Irrigated (>50%)	Rolling (7-15°)	52	1.3
Dairy	Irrigated (>50%)	Steep (>25°)	5	1
Dairy	Moist		39	1.05
Dairy	Moist	Easy Hill (15-25°)	32	1.5
Dairy	Moist	Flat/Undulating (<7°)	39	1.05

Dairy	Moist	Steep (>25°)	5	1
Dairy	Moist	Rolling (7-15°)	32	1.5
Dairy Support	Dry	Easy Hill (15-25°)	17	0.4
Dairy Support	Dry	Flat/Undulating (<7°)	17	0.4
Dairy Support	Dry	Rolling (7-15°)	17	0.4
Dairy Support	Dry	Steep (>25°)	17	0.4
Dairy Support	Dry		17	0.4
Dairy Support	Irrigated (>50%)	Easy Hill (15-25°)	17	0.4
Dairy Support	Irrigated (>50%)	Flat/Undulating (<7°)	17	0.4
Dairy Support	Irrigated (>50%)	Rolling (7-15°)	17	0.4
Exotic Forestry		Flat/Undulating (<7°)	4	0.4
Exotic Forestry		Easy Hill (15-25°)	4	0.4
Exotic Forestry		Rolling (7-15°)	4	0.4
Exotic Forestry	Dry		4	0.4
Exotic Forestry	Dry	Easy Hill (15-25°)	4	0.4
Exotic Forestry	Dry	Flat/Undulating (<7°)	4	0.4
Exotic Forestry	Dry	Rolling (7-15°)	4	0.4
Exotic Forestry	Dry	Steep (>25°)	4	0.4
Exotic Forestry	Irrigated (>50%)	Easy Hill (15-25°)	4	0.4
Exotic Forestry	Irrigated (>50%)	Flat/Undulating (<7°)	4	0.4
Exotic Forestry	Irrigated (>50%)	Rolling (7-15°)	4	0.4
Exotic Forestry	Moist		4	0.4
Exotic Forestry	Moist	Easy Hill (15-25°)	4	0.4
Exotic Forestry	Moist	Flat/Undulating (<7°)	4	0.4
Exotic Forestry	Moist	Rolling (7-15°)	4	0.4
Exotic Forestry	Moist	Steep (>25°)	4	0.4
Exotic Forestry	Wet	Flat/Undulating (<7°)	4	0.4
Exotic Forestry	Wet	Rolling (7-15°)	4	0.4
Horticulture	Dry	Easy Hill (15-25°)	72	1.9
Horticulture	Dry	Flat/Undulating (<7°)	72	1.9

Horticulture	Dry	Rolling (7-15°)	72	1.9
Horticulture	Dry	Steep (>25°)	72	1.9
Horticulture	Irrigated (>50%)	Easy Hill (15-25°)	72	1.9
Horticulture	Irrigated (>50%)	Flat/Undulating (<7°)	72	1.9
Horticulture	Irrigated (>50%)	Rolling (7-15°)	72	1.9
Horticulture	Irrigated (>50%)	Steep (>25°)	72	1.9
Industrial Use			5	1
Industrial Use		Flat/Undulating (<7°)	5	1
Industrial Use		Easy Hill (15-25°)	5	1
Industrial Use		Rolling (7-15°)	5	1
Industrial Use		Steep (>25°)	5	1
Industrial Use	Dry		5	1
Industrial Use	Dry	Easy Hill (15-25°)	5	1
Industrial Use	Dry	Flat/Undulating (<7°)	5	1
Industrial Use	Dry	Rolling (7-15°)	5	1
Industrial Use	Dry	Steep (>25°)	5	1
Industrial Use	Moist	Easy Hill (15-25°)	5	1
Industrial Use	Moist	Flat/Undulating (<7°)	5	1
Industrial Use	Moist	Rolling (7-15°)	5	1
Industrial Use	Moist	Steep (>25°)	5	1
Lifestyle Block			5	1
Lifestyle Block		Easy Hill (15-25°)	5	1
Lifestyle Block		Flat/Undulating (<7°)	5	1
Lifestyle Block		Rolling (7-15°)	5	1
Lifestyle Block		Steep (>25°)	5	1
Lifestyle Block	Dry		5	1
Lifestyle Block	Dry	Easy Hill (15-25°)	5	1
Lifestyle Block	Dry	Flat/Undulating (<7°)	5	1
Lifestyle Block	Dry	Rolling (7-15°)	5	1
Lifestyle Block	Dry	Steep (>25°)	5	1
Lifestyle Block	Irrigated (>50%)	Flat/Undulating (<7°)	5	1
Lifestyle Block	Irrigated (>50%)	Rolling (7-15°)	5	1

Lifestyle Block	Irrigated (>50%)	Easy Hill (15-25°)	5	1
Lifestyle Block	Irrigated (>50%)	Steep (>25°)	5	1
Lifestyle Block	Moist		5	1
Lifestyle Block	Moist	Easy Hill (15-25°)	5	1
Lifestyle Block	Moist	Flat/Undulating (<7°)	5	1
Lifestyle Block	Moist	Rolling (7-15°)	5	1
Lifestyle Block	Moist	Steep (>25°)	5	1
Lifestyle Block	Wet	Easy Hill (15-25°)	5	1
Lifestyle Block	Wet	Flat/Undulating (<7°)	5	1
Lifestyle Block	Wet	Rolling (7-15°)	5	1
Livestock Support		Flat/Undulating (<7°)	17	0.4
Livestock Support		Rolling (7-15°)	17	0.4
Livestock Support	Dry		17	0.4
Livestock Support	Dry	Easy Hill (15-25°)	17	0.4
Livestock Support	Dry	Flat/Undulating (<7°)	17	0.35
Livestock Support	Dry	Rolling (7-15°)	17	0.4
Livestock Support	Dry	Steep (>25°)	17	0.4
Livestock Support	Irrigated (>50%)	Flat/Undulating (<7°)	36	0.7
Livestock Support	Irrigated (>50%)	Rolling (7-15°)	35	0.8
Livestock Support	Irrigated (>50%)	Easy Hill (15-25°)	35	0.8
Livestock Support	Irrigated (>50%)	Steep (>25°)	5	1
Livestock Support	Moist	Flat/Undulating (<7°)	41	0.65
Livestock Support	Moist	Rolling (7-15°)	33	0.8
Livestock Support	Moist	Easy Hill (15-25°)	33	0.8
Livestock Support	Moist	Steep (>25°)	5	1
Majority Deer with Mixed Livestock	Dry		7	0.75
Majority Deer with Mixed Livestock	Dry	Easy Hill (15-25°)	7	0.75
Majority Deer with Mixed Livestock	Dry	Flat/Undulating (<7°)	7	0.75
Majority Deer with Mixed Livestock	Dry	Rolling (7-15°)	7	0.75

Majority Deer with Mixed Livestock	Dry	Steep (>25°)	7	0.75
Majority Deer with Mixed Livestock	Irrigated (>50%)	Flat/Undulating (<7°)	12	1.9
Majority Deer with Mixed Livestock	Irrigated (>50%)	Rolling (7-15°)	12	1.9
Majority Deer with Mixed Livestock	Irrigated (>50%)	Easy Hill (15-25°)	12	1.9
Majority Deer with Mixed Livestock	Irrigated (>50%)	Steep (>25°)		
Majority Deer with Mixed Livestock	Moist	Flat/Undulating (<7°)	12	1.9
Majority Deer with Mixed Livestock	Moist	Rolling (7-15°)	12	1.9
Majority Deer with Mixed Livestock	Moist	Easy Hill (15-25°)	12	1.9
Mixed Livestock	Dry		7	0.4
Mixed Livestock	Dry	Easy Hill (15-25°)	5	0.5
Mixed Livestock	Dry	Flat/Undulating (<7°)	7	0.4
Mixed Livestock	Dry	Rolling (7-15°)	7.5	0.4
Mixed Livestock	Dry	Steep (>25°)	4.5	0.6
Mixed Livestock	Irrigated (>50%)	Flat/Undulating (<7°)	18	0.6
Mixed Livestock	Irrigated (>50%)	Rolling (7-15°)	12	0.7
Mixed Livestock	Irrigated (>50%)	Easy Hill (15-25°)	9	1
Mixed Livestock	Irrigated (>50%)	Steep (>25°)	6	1.6
Mixed Livestock	Moist		18	0.6
Mixed Livestock	Moist	Easy Hill (15-25°)	9	1
Mixed Livestock	Moist	Flat/Undulating (<7°)	18	0.6
Mixed Livestock	Moist	Rolling (7-15°)	12	0.7
Mixed Livestock	Moist	Steep (>25°)	6	1.6
Mixed Livestock	Wet	Easy Hill (15-25°)	9	1
Mixed Livestock	Wet	Flat/Undulating (<7°)	18	0.6
Mixed Livestock	Wet	Rolling (7-15°)	12	0.7
Mixed Livestock	Wet	Steep (>25°)	6	1.6
Nurseries & Orchards	Dry		10	0.2
Nurseries & Orchards	Dry	Easy Hill (15-25°)	10	0.2

Nurseries & Orchards	Dry	Flat/Undulating (<7°)	10	0.2
Nurseries & Orchards	Dry	Rolling (7-15°)	10	0.2
Nurseries & Orchards	Dry	Steep (>25°)	10	0.2
Nurseries & Orchards	Irrigated (>50%)	Easy Hill (15-25°)	10	0.2
Nurseries & Orchards	Irrigated (>50%)	Flat/Undulating (<7°)	10	0.2
Nurseries & Orchards	Irrigated (>50%)	Rolling (7-15°)	10	0.2
Other Animals			5	1
Other Animals		Flat/Undulating (<7°)	5	1
Other Animals		Rolling (7-15°)	5	1
Other Animals		Easy Hill (15-25°)	5	1
Other Animals		Steep (>25°)	5	1
Other Animals	Dry		5	1
Other Animals	Dry	Easy Hill (15-25°)	5	1
Other Animals	Dry	Flat/Undulating (<7°)	5	1
Other Animals	Dry	Rolling (7-15°)	5	1
Other Animals	Dry	Steep (>25°)	5	1
Other Animals	Irrigated (>50%)	Flat/Undulating (<7°)	5	1
Other Animals	Irrigated (>50%)	Rolling (7-15°)	5	1
Other Animals	Irrigated (>50%)	Easy Hill (15-25°)	5	1
Other Animals	Irrigated (>50%)	Steep (>25°)	5	1
Other Animals	Moist	Easy Hill (15-25°)	5	1
Other Animals	Moist	Flat/Undulating (<7°)	5	1
Other Animals	Moist	Rolling (7-15°)	5	1
Other Animals	Moist	Steep (>25°)	5	1
Poultry	Dry	Flat/Undulating (<7°)	5	1
Poultry	Dry	Rolling (7-15°)	5	1
Poultry	Dry	Easy Hill (15-25°)	5	1
Poultry	Dry	Steep (>25°)	5	1
Poultry	Irrigated (>50%)	Flat/Undulating (<7°)	5	1
Public Use		Flat/Undulating (<7°)	5	1

Public Use		Rolling (7-15°)	5	1
Public Use	Dry		5	1
Public Use	Dry	Easy Hill (15-25°)	5	1
Public Use	Dry	Flat/Undulating (<7°)	5	1
Public Use	Dry	Rolling (7-15°)	5	1
Public Use	Dry	Steep (>25°)	5	1
Public Use	Moist	Easy Hill (15-25°)	5	1
Public Use	Moist	Steep (>25°)	5	1
Public Use	Moist	Flat/Undulating (<7°)	5	1
Public Use	Moist	Rolling (7-15°)	5	1
Residential Use			5	1
Residential Use		Easy Hill (15-25°)	5	1
Residential Use		Flat/Undulating (<7°)	5	1
Residential Use		Rolling (7-15°)	5	1
Residential Use		Steep (>25°)	5	1
Residential Use	Dry		5	1
Residential Use	Dry	Easy Hill (15-25°)	5	1
Residential Use	Dry	Flat/Undulating (<7°)	5	1
Residential Use	Dry	Rolling (7-15°)	5	1
Residential Use	Dry	Steep (>25°)	5	1
Residential Use	Moist		5	1
Residential Use	Moist	Flat/Undulating (<7°)	5	1
Residential Use	Moist	Easy Hill (15-25°)	5	1
Residential Use	Moist	Rolling (7-15°)	5	1
Residential Use	Moist	Steep (>25°)	5	1
Residential Use	Wet	Easy Hill (15-25°)	5	1
Residential Use	Wet	Flat/Undulating (<7°)	5	1
Residential Use	Wet	Rolling (7-15°)	5	1
Road & Rail			5	1
Road & Rail		Easy Hill (15-25°)	5	1
Road & Rail		Flat/Undulating (<7°)	5	1

Road & Rail		Rolling (7-15°)	5	1
Road & Rail		Steep (>25°)	5	1
Road & Rail	Dry		5	1
Road & Rail	Dry	Easy Hill (15-25°)	5	1
Road & Rail	Dry	Flat/Undulating (<7°)	5	1
Road & Rail	Dry	Rolling (7-15°)	5	1
Road & Rail	Dry	Steep (>25°)	5	1
Road & Rail	Moist		5	1
Road & Rail	Moist	Easy Hill (15-25°)	5	1
Road & Rail	Moist	Flat/Undulating (<7°)	5	1
Road & Rail	Moist	Rolling (7-15°)	5	1
Road & Rail	Moist	Steep (>25°)	5	1
Road & Rail	Wet		5	1
Road & Rail	Wet	Flat/Undulating (<7°)	5	1
Road & Rail	Wet	Easy Hill (15-25°)	5	1
Road & Rail	Wet	Rolling (7-15°)	5	1
Road & Rail	Wet	Steep (>25°)	5	1
Sheep			7	0.4
Sheep		Easy Hill (15-25°)	5	0.5
Sheep		Flat/Undulating (<7°)	7	0.4
Sheep		Rolling (7-15°)	7.5	0.35
Sheep		Steep (>25°)	4.5	0.6
Sheep	Dry		7	0.4
Sheep	Dry	Easy Hill (15-25°)	5	0.5
Sheep	Dry	Flat/Undulating (<7°)	7	0.4
Sheep	Dry	Rolling (7-15°)	7.5	0.35
Sheep	Dry	Steep (>25°)	4.5	0.6
Sheep	Irrigated (>50%)	Flat/Undulating (<7°)	20	0.6
Sheep	Irrigated (>50%)	Rolling (7-15°)	11.5	0.7
Sheep	Irrigated (>50%)	Steep (>25°)	5	1
Sheep	Irrigated (>50%)	Easy Hill (15-25°)	8.5	1
Sheep	Moist		18	0.6

Sheep	Moist	Easy Hill (15-25°)	8.5	1
Sheep	Moist	Flat/Undulating (<7°)	18	0.6
Sheep	Moist	Rolling (7-15°)	11.5	0.7
Sheep	Moist	Steep (>25°)	6	1.6
Sheep	Wet	Easy Hill (15-25°)	9	1.6
Sheep	Wet	Flat/Undulating (<7°)	24	0.75
Sheep	Wet	Rolling (7-15°)	17.5	0.8
Sheep	Wet	Steep (>25°)		
Sheep & Beef				
Sheep & Beef		Flat/Undulating (<7°)	7	0.4
Sheep & Beef		Rolling (7-15°)	8	0.4
Sheep & Beef		Steep (>25°)	7	0.4
Sheep & Beef		Easy Hill (15-25°)	7	0.4
Sheep & Beef	Dry	Easy Hill (15-25°)	5	0.5
Sheep & Beef	Dry	Flat/Undulating (<7°)	7	0.4
Sheep & Beef	Dry	Rolling (7-15°)	7.5	0.35
Sheep & Beef	Dry	Steep (>25°)	4.5	0.6
Sheep & Beef	Irrigated (>50%)			
Sheep & Beef	Irrigated (>50%)	Flat/Undulating (<7°)	20	0.6
Sheep & Beef	Irrigated (>50%)	Steep (>25°)	4.5	0.6
Sheep & Beef	Irrigated (>50%)	Easy Hill (15-25°)	8.5	1
Sheep & Beef	Irrigated (>50%)	Rolling (7-15°)	11	0.7
Sheep & Beef	Moist			
Sheep & Beef	Moist	Easy Hill (15-25°)	8.5	1
Sheep & Beef	Moist	Flat/Undulating (<7°)	18	0.6
Sheep & Beef	Moist	Rolling (7-15°)	11.5	0.7
Sheep & Beef	Moist	Steep (>25°)	6	1.6
Sheep & Beef	Wet			
Sheep & Beef	Wet	Easy Hill (15-25°)	9	1.6
Sheep & Beef	Wet	Flat/Undulating (<7°)	24	0.75
Sheep & Beef	Wet	Rolling (7-15°)	17.5	0.8

Sheep & Beef	Wet	Steep (>25°)	6.5	2.8
Small Land Holding		Flat/Undulating (<7°)	5	1
Small Land Holding		Rolling (7-15°)	5	1
Small Land Holding	Dry		5	1
Small Land Holding	Dry	Easy Hill (15-25°)	5	1
Small Land Holding	Dry	Flat/Undulating (<7°)	5	1
Small Land Holding	Dry	Rolling (7-15°)	5	1
Small Land Holding	Dry	Steep (>25°)	5	1
Small Land Holding	Irrigated (>50%)	Easy Hill (15-25°)	5	1
Small Land Holding	Irrigated (>50%)	Flat/Undulating (<7°)	5	1
Small Land Holding	Irrigated (>50%)	Rolling (7-15°)	5	1
Small Land Holding	Irrigated (>50%)	Steep (>25°)	5	1
Small Land Holding	Moist	Easy Hill (15-25°)	5	1
Small Land Holding	Moist	Flat/Undulating (<7°)	5	1
Small Land Holding	Moist	Rolling (7-15°)	5	1
Small Land Holding	Moist	Steep (>25°)	5	1
Small Land Holding	Wet	Flat/Undulating (<7°)	5	1
Small Land Holding	Wet	Rolling (7-15°)	5	1
Specialist Deer	Dry	Easy Hill (15-25°)	7	0.75
Specialist Deer	Dry	Flat/Undulating (<7°)	7	0.75
Specialist Deer	Dry	Rolling (7-15°)	7	0.75
Specialist Deer	Dry	Steep (>25°)	7	0.75
Specialist Deer	Dry		7	0.75
Specialist Deer	Irrigated (>50%)	Flat/Undulating (<7°)	12	1.9
Specialist Deer	Irrigated (>50%)	Rolling (7-15°)	12	1.9
Specialist Deer	Irrigated (>50%)	Easy Hill (15-25°)	12	1.9
Specialist Deer	Irrigated (>50%)	Steep (>25°)	12	1.9
Specialist Deer	Moist	Flat/Undulating (<7°)	12	1.9
Specialist Deer	Moist	Rolling (7-15°)	12	1.9
Specialist Deer	Wet	Easy Hill (15-25°)	18	0.8

Specialist Deer	Wet	Flat/Undulating (<7°)	18	0.8
Specialist Deer	Wet	Rolling (7-15°)	18	0.8
Tourism & Recreational Use			5	1
Tourism & Recreational Use		Easy Hill (15-25°)	5	1
Tourism & Recreational Use		Flat/Undulating (<7°)	5	1
Tourism & Recreational Use		Rolling (7-15°)	5	1
Tourism & Recreational Use		Steep (>25°)	5	1
Tourism & Recreational Use	Dry		5	1
Tourism & Recreational Use	Dry	Easy Hill (15-25°)	5	1
Tourism & Recreational Use	Dry	Flat/Undulating (<7°)	5	1
Tourism & Recreational Use	Dry	Rolling (7-15°)	5	1
Tourism & Recreational Use	Dry	Steep (>25°)	5	1
Tourism & Recreational Use	Irrigated (>50%)	Flat/Undulating (<7°)	5	1
Tourism & Recreational Use	Moist		5	1
Tourism & Recreational Use	Moist	Easy Hill (15-25°)	5	1
Tourism & Recreational Use	Moist	Flat/Undulating (<7°)	5	1
Tourism & Recreational Use	Moist	Rolling (7-15°)	5	1
Tourism & Recreational Use	Moist	Steep (>25°)	5	1
Tourism & Recreational Use	Wet	Easy Hill (15-25°)	5	1
Tourism & Recreational Use	Wet	Flat/Undulating (<7°)	5	1
Tourism & Recreational Use	Wet	Rolling (7-15°)	5	1
Tourism & Recreational Use	Wet	Steep (>25°)	5	1
Unknown Land Use				
Unknown Land Use		Easy Hill (15-25°)		
Unknown Land Use		Flat/Undulating (<7°)		
Unknown Land Use		Rolling (7-15°)		
Unknown Land Use		Steep (>25°)		
Unknown Land Use	Dry			
Unknown Land Use	Dry	Easy Hill (15-25°)		
Unknown Land Use	Dry	Flat/Undulating (<7°)		
Unknown Land Use	Dry	Rolling (7-15°)		

Unknown Land Use	Dry	Steep (>25°)		
Unknown Land Use	Irrigated (>50%)	Easy Hill (15-25°)		
Unknown Land Use	Irrigated (>50%)	Flat/Undulating (<7°)		
Unknown Land Use	Irrigated (>50%)	Rolling (7-15°)		
Unknown Land Use	Irrigated (>50%)	Steep (>25°)		
Unknown Land Use	Moist			
Unknown Land Use	Moist	Easy Hill (15-25°)		
Unknown Land Use	Moist	Flat/Undulating (<7°)		
Unknown Land Use	Moist	Rolling (7-15°)		
Unknown Land Use	Moist	Steep (>25°)		
Unknown Land Use	Wet	Flat/Undulating (<7°)		
Unknown Land Use	Wet	Rolling (7-15°)		
Unknown Land Use	Wet	Easy Hill (15-25°)		
Unknown Land Use	Wet	Steep (>25°)		
Unknown Land Use - Indigenous Cover			2	0.3
Unknown Land Use - Indigenous Cover		Easy Hill (15-25°)	2	0.3
Unknown Land Use - Indigenous Cover		Flat/Undulating (<7°)	2	0.3
Unknown Land Use - Indigenous Cover		Rolling (7-15°)	2	0.3
Unknown Land Use - Indigenous Cover		Steep (>25°)	2	0.3
Unknown Land Use - Indigenous Cover	Dry		2	0.3
Unknown Land Use - Indigenous Cover	Dry	Easy Hill (15-25°)	2	0.3
Unknown Land Use - Indigenous Cover	Dry	Flat/Undulating (<7°)	2	0.3
Unknown Land Use - Indigenous Cover	Dry	Rolling (7-15°)	2	0.3
Unknown Land Use - Indigenous Cover	Dry	Steep (>25°)	2	0.3
Unknown Land Use - Indigenous Cover	Irrigated (>50%)	Flat/Undulating (<7°)	2	0.3
Unknown Land Use - Indigenous Cover	Moist		2	0.3

Unknown Land Use - Indigenous Cover	Moist	Easy Hill (15-25°)	2	0.3
Unknown Land Use - Indigenous Cover	Moist	Flat/Undulating (<7°)	2	0.3
Unknown Land Use - Indigenous Cover	Moist	Rolling (7-15°)	2	0.3
Unknown Land Use - Indigenous Cover	Moist	Steep (>25°)	2	0.3
Unknown Land Use - Indigenous Cover	Wet		2	0.3
Unknown Land Use - Indigenous Cover	Wet	Easy Hill (15-25°)	2	0.3
Unknown Land Use - Indigenous Cover	Wet	Flat/Undulating (<7°)	2	0.3
Unknown Land Use - Indigenous Cover	Wet	Rolling (7-15°)	2	0.3
Unknown Land Use - Indigenous Cover	Wet	Steep (>25°)	2	0.3
Unknown Land Use - Non-agricultural			2	0.3
Unknown Land Use - Non-agricultural		Flat/Undulating (<7°)	2	0.3
Unknown Land Use - Non-agricultural		Rolling (7-15°)	2	0.3
Unknown Land Use - Non-agricultural		Easy Hill (15-25°)	2	0.3
Unknown Land Use - Non-agricultural	Dry	Easy Hill (15-25°)	2	0.3
Unknown Land Use - Non-agricultural	Dry	Flat/Undulating (<7°)	2	0.3
Unknown Land Use - Non-agricultural	Dry	Rolling (7-15°)	2	0.3
Unknown Land Use - Non-agricultural	Dry	Steep (>25°)	2	0.3
Unknown Land Use - Non-agricultural	Dry		2	0.3
Unknown Land Use - Non-agricultural	Moist	Easy Hill (15-25°)	2	0.3
Unknown Land Use - Non-agricultural	Moist	Flat/Undulating (<7°)	2	0.3
Unknown Land Use - Non-agricultural	Moist	Rolling (7-15°)	2	0.3
Unknown Land Use - Non-agricultural	Moist	Steep (>25°)	2	0.3

Unknown Land Use - Non-agricultural	Wet	Flat/Undulating (<7°)	2	0.3
Unknown Land Use - Non-agricultural	Wet	Rolling (7-15°)	2	0.3
Unknown Land Use - Pastoral Cover			5	1
Unknown Land Use - Pastoral Cover		Easy Hill (15-25°)	5	1
Unknown Land Use - Pastoral Cover		Flat/Undulating (<7°)	5	1
Unknown Land Use - Pastoral Cover		Rolling (7-15°)	5	1
Unknown Land Use - Pastoral Cover		Steep (>25°)	5	1
Unknown Land Use - Pastoral Cover	Dry		5	1
Unknown Land Use - Pastoral Cover	Dry	Easy Hill (15-25°)	5	0.5
Unknown Land Use - Pastoral Cover	Dry	Flat/Undulating (<7°)	7	0.4
Unknown Land Use - Pastoral Cover	Dry	Rolling (7-15°)	7.5	0.35
Unknown Land Use - Pastoral Cover	Dry	Steep (>25°)	4.5	0.6
Unknown Land Use - Pastoral Cover	Irrigated (>50%)	Flat/Undulating (<7°)	20	0.6
Unknown Land Use - Pastoral Cover	Irrigated (>50%)	Rolling (7-15°)	11.5	0.7
Unknown Land Use - Pastoral Cover	Irrigated (>50%)	Easy Hill (15-25°)	8.5	1
Unknown Land Use - Pastoral Cover	Moist			
Unknown Land Use - Pastoral Cover	Moist	Easy Hill (15-25°)	8.5	1
Unknown Land Use - Pastoral Cover	Moist	Flat/Undulating (<7°)	18	0.6
Unknown Land Use - Pastoral Cover	Moist	Rolling (7-15°)	11.5	0.7
Unknown Land Use - Pastoral Cover	Moist	Steep (>25°)	6	1.6
Unknown Land Use - Pastoral Cover	Wet	Easy Hill (15-25°)	9	1.6
Unknown Land Use - Pastoral Cover	Wet	Flat/Undulating (<7°)	24	0.75

Unknown Land Use - Pastoral Cover	Wet	Rolling (7-15°)	17.5	0.8
Unknown Land Use - Pastoral Cover	Wet	Steep (>25°)	6.5	2.8

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Appendix 2

Table x: Aggregated land use category for maps and the original category

Aggregated class	Original
Dairy	Dairy, Dairy Support
Forestry	Exotic forestry
Horticulture	Nurseries & Orchards, Horticulture, Arable
Water	Lakes & Rivers
Pastoral	Other Animals, Majority deer with Mixed livestock, Specialist deer, Livestock support, Unknown land use- pastoral cover, beef, sheep, sheep and beef, mixed stock
Urban	Residential use, Industrial use
Native	Unknown land use- indigenous cover, Conservation

Appendix 3

LWP
landwaterpeople

Memorandum: Test of revised periphyton nutrient criteria for Otago and Southland Regions

Author: Ton Snelder

Version 2, 6 November 2023

Introduction

Snelder et al. (2022) derived nutrient concentration criteria to achieve the target attribute states for river periphyton set out in the National Policy Statement – Freshwater Management (NPS-FM; NZ Government, 2020). The approach was based on fitting ordinary least squares regression (OLS) models to chlorophyll observations (summarized as the 92nd percentile of the observations and referred to hereafter as Chla92) at 251 monitoring sites distributed across New Zealand. The model explanatory variables comprised nutrient concentrations (summarised as median values of the observations of dissolved inorganic nitrogen (DIN), dissolved reactive phosphorus (DRP), total nitrogen (TN) and total phosphorus (TP)) and other environmental observations at the sites including substrate composition, shade and hydrological indices. These fitted models were subsequently used to defined criteria for DIN, DRP, TN and TP to achieve fixed Chla92 thresholds (50, 120 and 200 mg m^{-2}).

A validation of Snelder et al.'s (2022) criteria for the Otago and Southland Regions concluded that derived criteria were too permissive (i.e., the criteria concentrations are too high; LWP memo to ORC dated 22 February 2023). Validation of the periphyton nutrient concentration criteria derived by Snelder et al. (2022) using data from other regions (i.e., Wellington and the Manawatu-Wanganui regions) also showed them to be too permissive. These findings reduced confidence in the criteria of Snelder et al. (2022).

A study by Snelder and Kilroy (2023) aimed to revise the nutrient criteria based on a regression modelling approach, as used by Snelder et al. (2022), but fitting models using generalised linear models (GLM) instead of the OLS models that were used by Snelder et al. (2022). Briefly, the reason for the change in the modelling approach was because the original OLS models were positively biased. This means that, on average, the models underestimated Chla92 values for a given nutrient concentration. This meant that the models tended to appreciably under-estimate Chla92 at sites with high biomass, which in turn meant the criteria tended to be too permissive. It was anticipated that the revision would produce better nutrient criteria because the GLM models are more able to represent the distribution of the observed site biomass values, particularly for sites with high biomass, and this would reduce overall bias.

The present memo provides a validation analysis of the revised criteria for total nitrogen (TN) and total phosphorus (TP) for sites in the Otago and Southland Regions. The validation focuses on TN and TP because these were the criteria used to estimate reductions in nitrogen and phosphorus loads to achieve periphyton target attribute states in Otago (Snelder and Fraser 2023).

Revised criteria

Snelder and Kilroy (2023) provided details of the methods used to derive revised nutrient criteria for four forms of nutrients (TN, DIN, TP, DRP) to achieve three biomass targets (50, 120 and 200 mg m^{-2}) for 21 River Environment Classification (REC) Source-of-flow classes. Briefly, the GLM models were derived from the data that was used by Snelder et al. (2022) to derive the original criteria. The GLM models were used to predict Chla92 for a wide range of concentrations for each nutrient form at up to 500 individual river locations in each Source-of-flow class. The concentrations at which the predicted biomass was 50, 120 and 200 mg m^{-2} for each location was obtained from these predictions by linear interpolation. The geometric means of the concentrations associated with each biomass target within each Source-of-flow class are the criteria.

For each biomass target, within each Source-of-flow class, Snelder and Kilroy (2023) also obtained the exponentiated standard deviation of the log of the individual nutrient concentrations as a measure of the within-class variability of the concentration criterion. This acknowledges that the derived criterion represents a mean condition for an entire REC class. Using the mean for that segment's class introduces uncertainty because the true criterion for the specific segment will differ from the mean for all segments in the class. The impact of the within-class variation on the validation can be assessed with a Monte Carlo simulation of the validation procedure, which is are explained later.

A detail of the revised criteria derived by Snelder and Kilroy (2023) was that the underlying GLM models tended to over-estimate low Chla92 values (i.e., ≤50 mg m^{-2}). Over-estimation of the low Chla92 values meant that the derived criteria for the lower biomass threshold (i.e., 50 mg m^{-2}) were too stringent (i.e., the concentrations were too low). This issue was also present in the original OLS models and criteria but was slightly more apparent for the revised criteria.

To address the issue of over-prediction of low Chla92 values, Snelder and Kilroy (2023) suggested that an alternative set of criteria for the 50 mg m^{-2} biomass threshold could be derived using quantile regression. This approach was used to derive TN and TP criteria for Otago and Southland sites from the fitting data used by Snelder and Kilroy (2023). These criteria were derived for the same levels of under-protection risk as the revised criteria. However, the quantile regression criteria are spatially uniform (i.e., one value applies to all REC Source-of-flow classes). The alternative set of spatially uniform criteria for TN and TP derived using quantile regression for the 50 mg m^{-2} threshold is provided in Appendix 1.

Validation of the revised criteria for Otago and Southland

Guidance provided by (MFE 2022) suggests that the use of the criteria, for example within a region, should be accompanied by a verification that considers whether they are reasonably consistent with local observations of relationships between periphyton (as Chla92) and nutrient concentrations. There are limited ways to assess confidence in the criteria. However, where a monitoring network for periphyton and nutrients exists within a region, a validation analysis can be performed with the following seven steps.

1. Obtain the median concentration of each nutrient and Chla92 from the observations at each monitoring site.
2. Obtain the REC source-of-flow class and shade status for each site.
3. For a fixed nutrient and level of under-protection risk, obtain the criteria from the lookup tables for the A, B and C bands for each site based on the site's REC source-of-flow class and shade status.
4. For each nutrient and site, and under-protection risk, interpolate the biomass from the criteria by:
    a. treating Chla92 for A, B and C bands of 50, 120 and 200 mg m^{-2} as the variable Y and nutrient criteria for each band as the variable X and assuming biomass is zero when nutrients are zero,
    b. use linear interpolation to estimate the Chla92 (Y values) predicted by the observed site nutrient concentrations,
    c. treating the interpolated Chla92 as a prediction.
5. Calculate, over all sites, the proportion of sites with observed values of Chla92 that exceed the above predicted values. We refer to these sites as the 'exceeding sites'.
6. Repeat this process for each nutrient and level of under-protection risk.
7. Assess whether the nutrient criteria are consistent with the observations by comparing the proportion of exceeding sites with the proportion indicated by the under-protection risk.

MFE (2022) suggests that reasonable agreement (i.e., ± 20%) between the proportion of exceeding sites and level of under-protection risk can be interpreted as evidence that the nutrient criteria are valid for the sites represented by the monitoring network. MFE (2022) notes that perfect agreement should not be expected and that divergence between the proportion of observations that exceed the predictions, and the under-protection risk can be expected to decrease as the sample size increases.

Uncertainty of the validation analysis

The above analysis is uncertain for two reasons. First, the observed values of Chla92 are imprecise (i.e., they are estimates of the population value calculated from the monthly samples). Second, as noted above, there is within-class variability in the estimates of the criteria for each site.

The first component of uncertainty is part of the more general issue that all estimates of attribute states are subject to uncertainty because of sampling error. Recent guidance (Milne *et al.* 2023) has made suggestions for accounting for this uncertainty under subclause (4) of clause 3.10 of the NPS-FM. However, Milne et al. (2023) acknowledge that robust methods for quantifying attribute state uncertainty have not been identified. Milne et al. (2023) acknowledge that standard statistical assumptions (e.g., observations are randomly varying and drawn from the same population), associated with the calculation of confidence intervals, are likely to be violated for typical NPS-FM attributes. For example, observations of chlorophyll have a seasonal component of variation and are, therefore, not entirely random. Attribute states are also assigned to sites using observations collected over time periods of up to five years. Time periods of this duration are likely to include significant changes that are due to long-term trends and inter-annual fluctuations (Snelder *et al.* 2021), which means that the sample does not represent a single population. Therefore, in this study, we ignored the uncertainty associated with observed values of Chla92 and focussed on accounting for the uncertainty associated with the within-class variability in the criteria.

The second component of uncertainty is quantified by the within-class standard deviation of the nutrient concentration criteria across river locations. A second validation analysis was undertaken that repeated the first analysis but used this standard deviation in a Monte Carlo simulation to generate 1000 “realisations” of the predicted Chla92 for each site. For each realisation, random errors were added to the criterion for each site and then this “perturbed” criterion was used to produce a realisation of the predicted Chla92. The random error was derived by drawing from a normal distribution with a standard deviation equal to the standard deviation of the log of the individual nutrient concentrations within each class. The 1000 realisations produced by the Monte Carlo analysis were summarised to provide best estimates of the proportion of exceeding sites. The uncertainty of the proportion of exceeding sies was quantified by the 95% confidence interval.

Results

The validation was performed using a dataset pertaining to 64 sites in Otago and Southland (Figure 84). The data for the Otago sites covered the period from February 2019 to March 2022. The data for the Southland sites covered the period from January 2015 to May 2022. Most of these sites were represented in the dataset used by Snelder and Kilroy (2023) to derive the nutriment concentration criteria. However, the period of record for the sites used for this validation analysis was an additional year of observations and therefore the data was semi-independent of the derivation procedure.

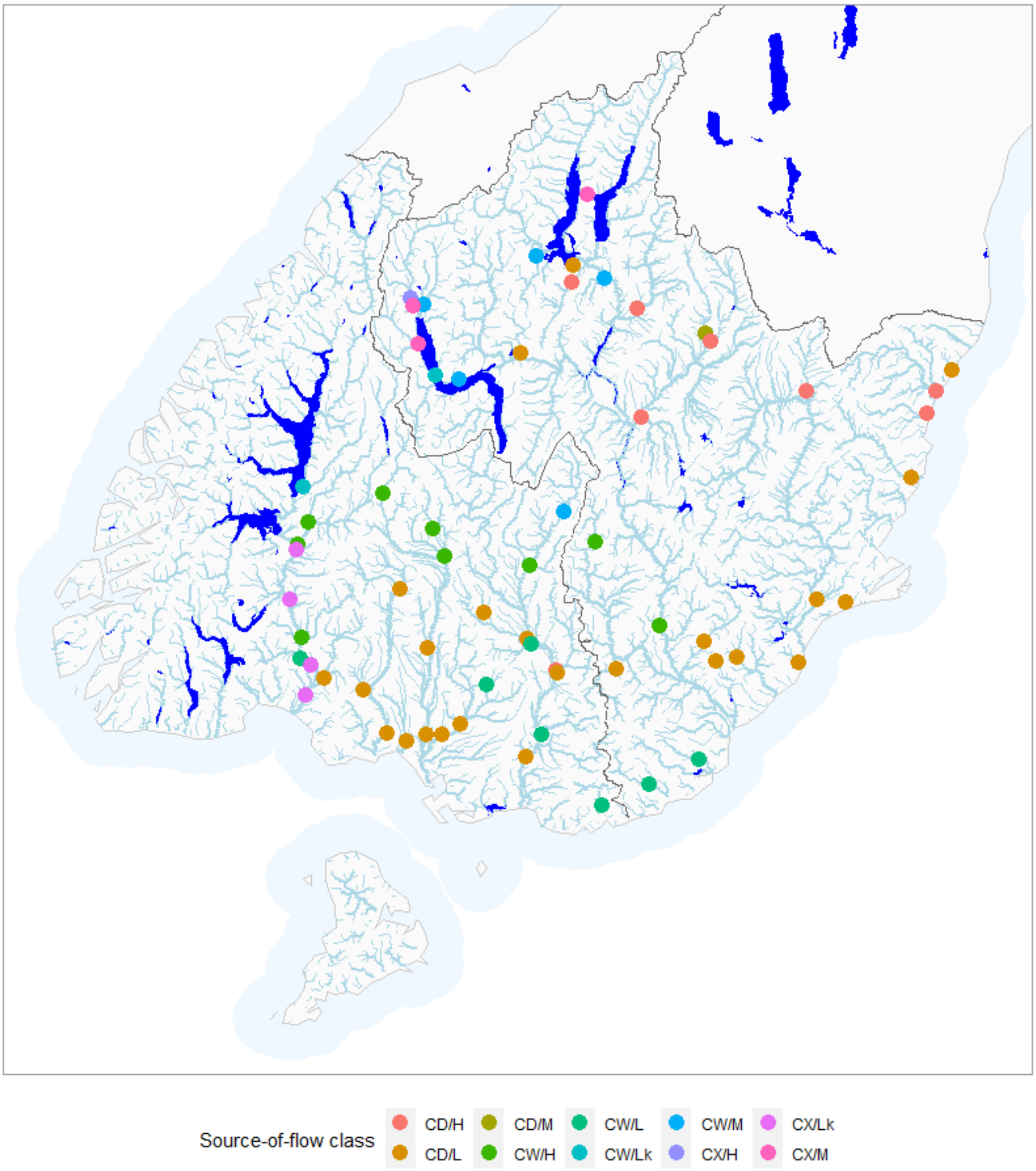

Figure 84. Map of the periphyton monitoring sites in Otago and Southland that were used in the validation process. The Source-of-flow class of each site is identified.

The observed and predicted values of Chla92 at the 64 sites in the region based on the two nutrient forms (TN and TP) are shown as scatter plots in Figure 85. Theoretically, 5%, 10%, 15%, 20%, 25%, 30% and 50% of the sites should have observed biomass that exceeds the predicted biomass when the predictions are made based on the corresponding levels of under-protection risk (i.e., should lie above the red lines on Figure 85).

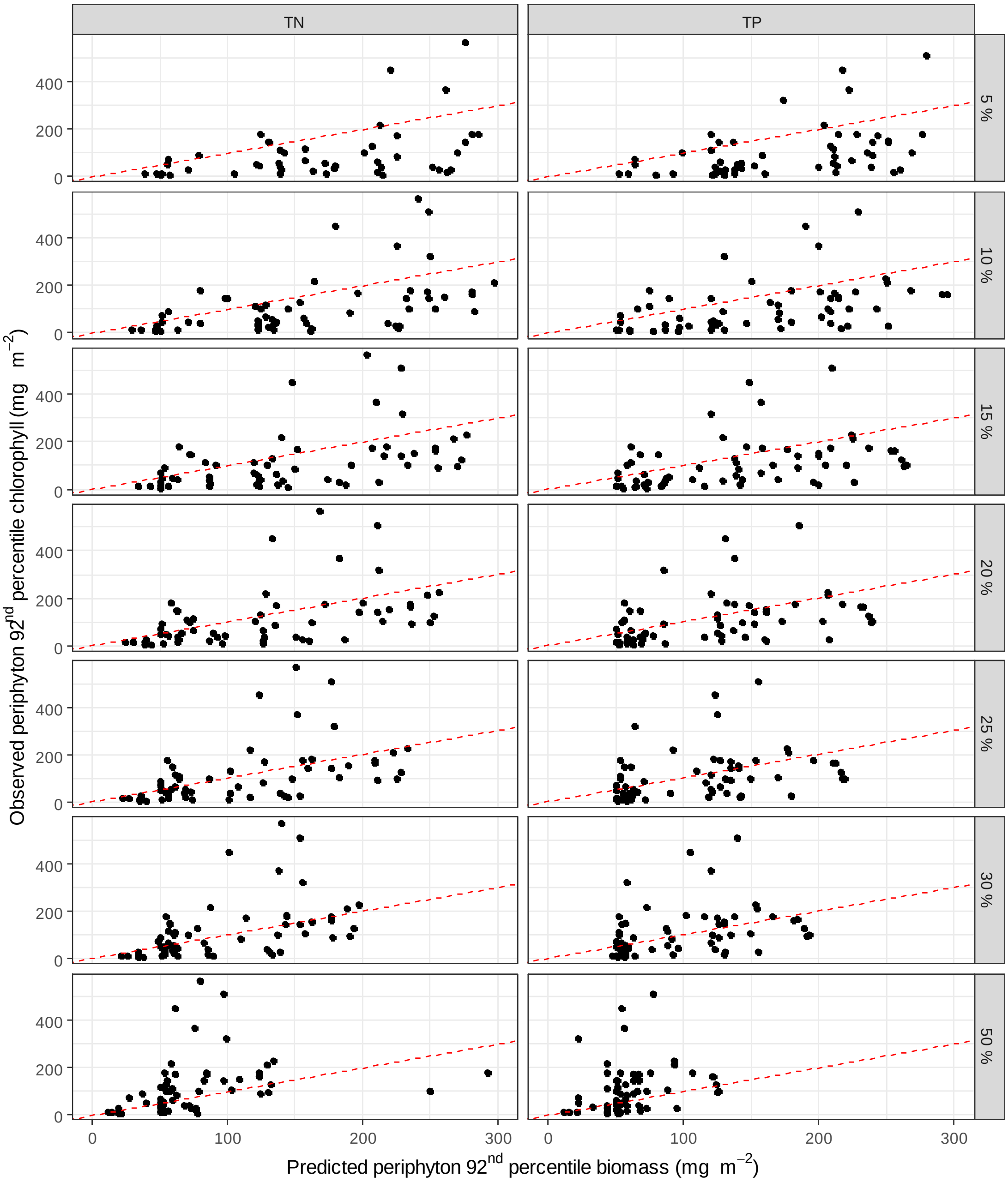

Figure 85. The observed and predicted values of Chla92 at the 64 sites in the Otago and Southland regions where predicted values are derived from the nutrient criteria for under-protection risks of 5, 10,15, 20, 25%, 30% and 50%. Panel labels indicate the under-protection risks and the nutrient form (TN and TP). The dashed red diagonal (one to one) line represents agreement between the predictions and observations. The points lying below the red line indicate 'exceeding sites' (i.e., sites for which the observed biomass was greater than the predicted).

The data shown in Figure 85 indicate that the proportions of sites for which observed Chla92 exceeds predicted Chla92 increases systematically as the under-protection risk increases for both nutrients. Table 85 indicates that the proportion of sites for which observed Chla92 exceeds the predicted is always greater than expected based on the under-protection risk for both nutrients. The column headed "discrepancy" is the difference (for each nutrient) in the under-protection risk and the observed proportion of exceeding sites. Negative values indicate that the criteria are too permissive. Discrepancies are in the range of -6 to -14%, but these discrepancies are considerably lower than those of the validation of the original criteria (-12 to -36%) reported in LWP memo to ORC dated 22 February 2023 and shown in Table 2.

Table 85. Validation results for the revised criteria. Proportion of sites (%) for which observed biomass exceeds that predicted for the seven levels of under-protection risk and two forms of nutrient (TN and TP). The discrepancy is the difference between the UPR and the observed proportion of sites exceeding the threshold (%). Negative values indicate that the criteria are too permissive.

1. **Under protection risk (%)**	2. **Proportion exceeding (%)**		3. **Discrepancy (%)**	
	4. TN	**5. TP**	**6. TN**	**7. TP**
8. 5	9. 17	10. 17	11. -12	12. -12
13. 10	14. 17	15. 20	16. -7	17. -10
18. 15	19. 22	20. 23	21. -7	22. -8
23. 20	24. 27	25. 31	26. -7	27. -11
28. 25	29. 31	30. 39	31. -6	32. -14
33. 30	34. 38	35. 42	36. -8	37. -12
38. 50	39. 58	40. 64	41. -8	42. -14

Table 86. Validation results for the original criteria. Proportion of sites (%) for which observed biomass exceeds that predicted for the six levels of under-protection risk and two forms of nutrient (TN and TP). The discrepancy is the difference between the UPR and the observed proportion of sites exceeding the threshold (%). Negative values indicate that the criteria are too permissive.

43. **Under protection risk (%)**	44. **Proportion exceeding (%)**		45. **Discrepancy (%)**	
	46. TN	**47. TP**	**48. TN**	**49. TP**
50. 5	51. 17	52. 20	53. -12	54. -15
55. 10	56. 22	57. 31	58. -12	59. -21
60. 15	61. 33	62. 42	63. -18	64. -27
65. 20	66. 45	67. 55	68. -25	69. -35
70. 30	71. 53	72. 61	73. -23	74. -31
75. 50	76. 78	77. 86	78. -28	79. -36

Figure 86 summarises the results of the Monte-Carlo procedure and shows the proportion of exceeding sites and the 95% confidence interval for each level of under-protection risk. Figure 86 is consistent with the validation results shown in *Table 85*; for all levels of under protection risk, the lower confidence limit is always above the associated level of under-protection risk (indicated by horizontal lines). This indicates that the revised criteria are too permissive and the inconsistency between the observation and predictions is larger than what can be attributed to the uncertainty of the criteria.

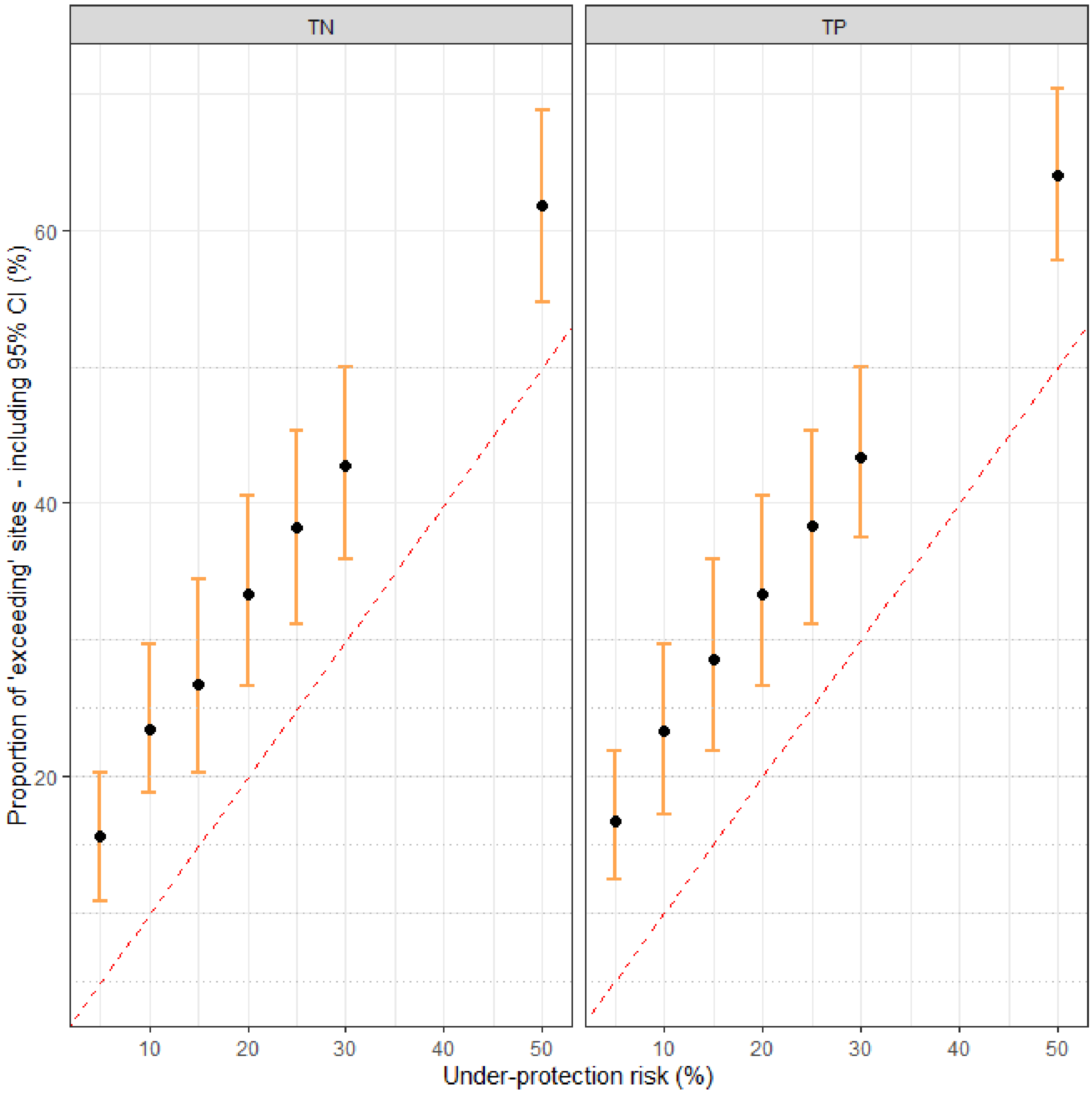

Figure 86. Proportion of "exceeding" sites (i.e., sites that are under-protected) for each level of under-protection risk (x-axis) and the two nutrients. The error bars indicate the 95% confidence interval of the observed "exceeding" sites, which was generated from a Monte Carlo analysis. The dashed red diagonal (one to one) line represents agreement between the proportion of exceeding sites and the under-protection risk.

Conclusions

This validation indicates that the revised criteria are too permissive but are an improvement over the original criteria. The analysis of Snelder and Kilroy (2023) found that, at the regional level, the revised criteria were variously too stringent or too permissive but also that they were very consistently an improvement on the original criteria. It is noted that a perfect validation may be an unrealistic goal given the inherent uncertainties and potential biases associated with several aspects of these analyses, including the small, and potentially biased, network of periphyton monitoring sites that were used in the analysis. The improved performance of the revised criteria, and the underlying technical explanation for why this was expected, is a sound basis for generally recommending the use of the revised criteria over the original criteria for Otago and Southland.

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Appendix 1. Criteria for the 50 mg m^{-2} target state

Plots of observed Chla92 values versus observed site median nutrient values were wedge-shaped (Figure 87). This indicates that there is a limiting relationship between peak biomass (i.e., Chla92) and nutrients at the regional (i.e., Otago and Southland) scale but that other factors influence the Chla92 response (Phillips *et al.* 2018; Kelly *et al.* 2022). Quantile regression models were statistically significant ($p < 0.1$) for all quantiles for TN and most quantiles for TP (*Table 87*).

Sites with Chla92 values of 50 mg m^{-2} or less occurred across a wide range of nutrient concentrations and in most Source-of-flow classes (Figure 87). This indicates that there is no obvious landscape scale spatial pattern in the low biomass sites and that, in the absence of variables that can better explain low biomass at these sites, the uniform criteria derived from the quantile regression models are a justifiable approach to defining criteria for the 50 mg m^{-2} biomass target.

Where possible, we derived alternative criteria from all QR models (*Table 87*) and used these values to replace the criteria pertaining to the 50 mg m^{-2} biomass target for the revised and original criteria.

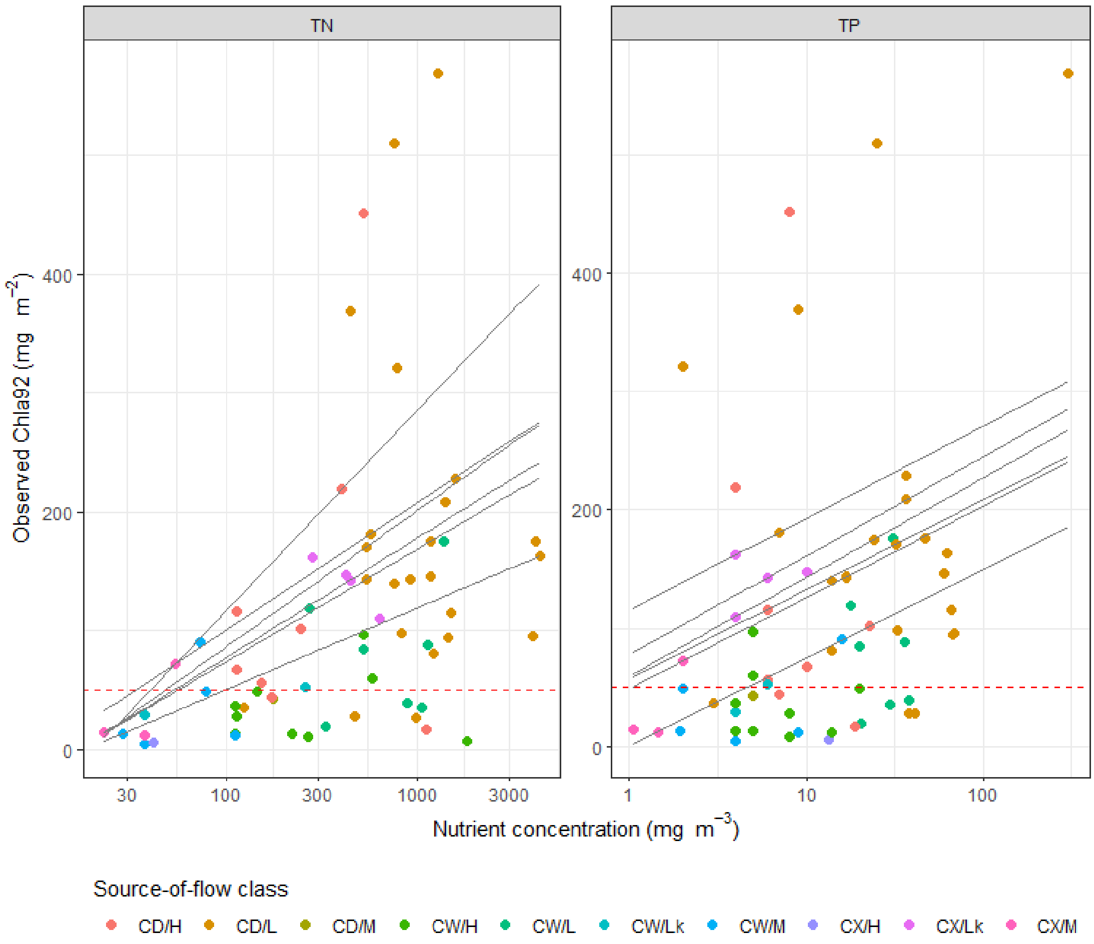

Figure 87. Relationships between Chla92 and median nutrient concentrations at the 251 monitoring sites. The grey lines are quantile regressions fitted to the 0.95, 0.9, 0.85, 0.8, 0.7 and 0.5 quantiles. Not all of these regression lines are statistically significant (see Table 3). The red dashed line indicates a biomass of 50 mg m^{-2}. Points are coloured to indicate the Source-of-flow class of the monitoring site.

Table 87. Criteria derived from the QR models for the 50 mg m-2 Chla92 target state for each nutrient form and level of under-protection risk. The P-value indicates the confidence in the regression coefficient fitted to the nutrient concentration. The criteria have units of mg m-3. NA values indicate that criteria could not be derived from the QR model.

Nutrient	Quantile	Under-protection risk (%)	P value	Criteria
TN	0.5	50	**0**	97.7
	0.7	30	**0**	55.1
	0.75	25	**0**	52.4
	0.8	20	**0**	47.6
	0.85	15	**0.047**	33.4
	0.9	10	**0.044**	39.6
	0.95	5	**0**	29.9
TP	0.5	50	**0**	4.6
	0.7	30	**0.027**	1.1
	0.75	25	**0.078**	1
	0.8	20	0.139	1
	0.85	15	0.357	0.9
	0.9	10	0.493	0.8
	0.95	5	0.451	0.3

Appendix 4

Nutrient modelling limitations for estuaries (internal memo)

Summary

The estuary modelling is highly uncertain due to uncertainty present in estimates of estuary dilution characteristics, variations in seasonal nutrient loading patterns, factors other than nutrient availability restricting macroalgal abundance at the time of survey (e.g, recent floods or scour events, lack of suitable substrate), and uncertainty in the freshwater inflow and tidal prism among other reasons as highlighted in (Plew 2021). There are other large limitations of the model for estuaries including that it does not account for legacy effects (internal loading) of N within estuaries or the absorption of N by macroalgae and denitrification. Estuaries that contain more native forest in the catchment are particularly uncertain due to limited reference data. These limitations mean the model is best interpreted by considering directionality of change opposed to likelihood of achieving an objective.

This memo is intended for internal council use to accompany the report Plew (2021) ‘’Models for evaluating impacts of nutrient and sediment loads to Otago estuaries.’’ This memo summarises additional notes prepared by Sam Thomas (ORC) to accompany the use of the estuary nutrient models in scenario testing.

It is acknowledged that these simple models were developed primarily as a screening tool to identify where management should be prioritised in the catchment. Limitations are discussed with the intent to create awareness for users applying the models and should not be construed as a critique of the approach.

Although the models have also been used to provide a high-level estimate of contaminant reductions in combination with the rivers and lakes models (Snelder & Fraser 2022), more in-depth studies will likely be needed where estuaries are prioritised for management, either because of an estuaries current state or where an estuary is driving contaminant reductions (e.g. Catlins estuary, Shag estuary, Blueskin Bay; Snelder & Fraser 2022).

NUTRIENT MODELS

BACKGROUND

The estuary nutrient models are based on the New Zealand Estuary Trophic Index (ETI) Tool 1 dilution models used to determine an estuary's response to nutrient loads (Zeldis et al., 2017; Plew, et al., 2020). In summary, the model is a single compartment model that uses the principles of dilution to calculate a potential[1] nutrient concentration in the estuary after mixing of freshwater inputs and ocean water (Figure 1; Plew 2021). The estuary is modelled in a steady-state, the tidal flow in and out of the estuary is averaged over the tidal period and the concentrations for the tracer (TN and TP) are solved for the estuary at high tide (Plew 2021). A ''tuning factor'' accounts for incomplete mixing and return flow, the tuning factor is estuary specific and is determined by monitoring salinity over a range of tidal cycles and freshwater inflows at multiple sites within an estuary. Where salinity data are not available, the tuning factor is estimated from the freshwater inflow and tidal prism (Plew et al., 2018). Plew (2021) estimated the tuning factor using a national dataset (Plew et al., 2018) including more recent data collected in Southland and Otago estuaries. The potential nutrient (TN and TP) concentrations are calculated for the estuary based on an input load scenario and compared to the relevant ETI thresholds in Table 2.1, 2.3 and Table 2.4 of Plew (2021) that meet the equivalent bandings for EQR (macroalgae attribute) and chlorophyll-a (phytoplankton attribute). The models predict the likely eutrophication response i.e. maximum chlorophyll-a concentration or mean[2] macroalgal response (Ecological Quality Rating; EQR) and the primary eutrophication indicator (macroalgae or phytoplankton) is determined by the physical characteristics of the estuary (e.g. intertidal area and flushing time).

1 Potential concentration refers to the calculated concentration based on dilution principles. It does not account for any uptake or release of nutrients through biological and chemical processes.
2 The EQR is predicted from a regression relationship and predicts mean EQR with the underlying assumption that N limiting macroalgae growth).

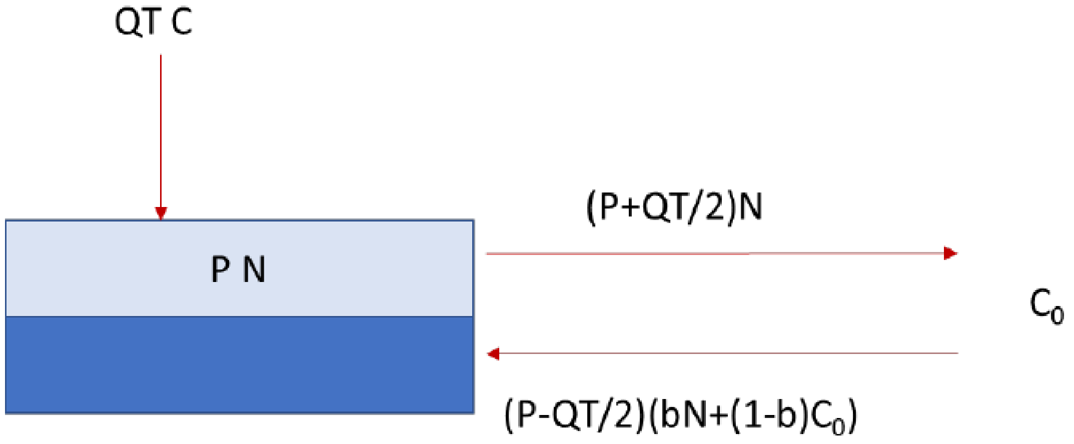

Figure 2-1: Mass balance diagram for the single-compartment estuary dilution model.

The terms in Figure 2-1 are as follows:

Q = freshwater inflow (m^3/s).

T = tidal period (12.42 x 3600 s).

P = tidal prism, difference in volume between high and low tide (m^3).

N = concentration of the tracer in the estuary (mg/m^3).

C = concentration of the tracer in the freshwater inflow (mg/m^3).

C_0 = concentration of the tracer in the ocean (mg/m^3).

b = tuning factor (-).

Figure 1. Diagram of single compartment model used to estimate potential nutrient concentrations in estuaries (sourced from Plew 2021)

The estuary nutrient models will be applied in Otago to:
1. Connect to regional river and lake models to predict nutrient loads and estuary state under different catchment use scenarios. In combination with the other regional models the estuary modelling has been used as a screening tool to identify the limiting environment (e.g. river, lake or estuary) within the catchment that is driving nutrient load reductions (e.g. periphyton in rivers or macroalgae in the estuary, for example). This will help prioritise estuaries where load reductions may be greater than required by rivers or lakes, and that potentially require more in-depth studies to aid in decision making and guide management.

2. Test load reduction scenarios. The models will provide a high-level overview of estuary state and reductions required to achieve an objective state under different nutrient load scenarios.

It is important to note that while these models can be used as a tool for understanding the magnitude of change required to move from one estuary state to another, more in-depth studies may be necessary where an estuary has been prioritised for management.

OUTPUTS

The models are briefly summarised above and described in more detail in Plew (2021). Two models have been prepared: one for phytoplankton and one for macroalgae. Although the models are based on the same principles, the key differences are listed in Table 1. Care should be taken when presenting the outputs of the two models to highlight and explain the subtle differences in the output values (for example, salinity and flushing time will differ between the phytoplankton output and the macroalgae output because the flow input is different).

Table 1. Key differences between the macroalgae and phytoplankton models.

Indicator	Macroalgae	Phytoplankton
Flow (Q; Figure 1)	Mean Annual Flow	Mean Summer Flow (February seasonality factor has been applied to mean annual flow)
Nutrient Load	Annual TN loads	Annual TN and TP loads
River Nutrient Concentration (C; Figure 1)	Annual TN load/mean annual flow	Annual TN load/mean annual flow Annual TP load/mean annual flow
Limiting Nutrient	Nitrogen	Nitrogen and/or Phosphorus
Conditions	Low salinity (<5ppt) (Macroalgal growth is limited at salinities <5ppt)	Flushing time (Estuaries with flushing times greater than ~3.4 days may support phytoplankton growth)
Phytoplankton growth model (Additional parameters are included e.g. phytoplankton growth rate, nutrient half saturation constants etc)		
Output	Macroalgal response (EQR) for the calculated potential TN concentration. Concentrations are compared to bandings in the attribute table (Appendix 1).	Maximum chlorophyll-a response for the calculated potential TP and TN concentration. Concentrations are compared to bandings in the attribute table (Appendix 1).

COMPARISON OF MODEL OUTPUT AND CURRENT STATE

Modelled and current estuary eutrophication response states are shown for macroalgae (EQR) (Table 2) and phytoplankton (chlorophyll-a; Table 3). Modelled state estimates are derived from Plew (2021) and current state from State of Environment monitoring (SoE) results. Because estuary type influences the primary eutrophication response (e.g., phytoplankton vs macroalgae) only those estuaries where the primary indicator is macroalgae are presented in Table 2, and those where phytoplankton is the primary indicator in Table 3. There is no data or monitoring occurring in the lagoons in which phytoplankton is the primary indicator and the estuaries when closed and phytoplankton is the primary indicator are predominately open so macroalgae is used as the primary indicator.

For macroalgae under a present-day scenario, the model over-predicts macroalgal growth meaning that the EQR score is lower (i.e. in a worse state) than what has been recorded in SoE monitoring (Table 2). The largest differences between predicted and measured current state are observed in Kakanui, Akatore, Tautuku, Kaikorai, Waipati, Tahakopa, Tautuku and Tokomairiro estuaries (Table 2). As a result the model provides a conservative estimate of the contaminant reductions required to meet a target objective. For example, according to the model output nutrient loads would need to decrease significantly to achieve an A-state for Akatore Estuary even though the estuary is already in an A-state. If Akatore Estuary is the waterbody within the catchment driving contaminant reductions this overestimation could lead to unnecessary contaminant reductions within the catchment. Conversely the Kakanui and Kaikorai estuaries were both monitored/sampled after large flood events and therefore, their measured state is not representative of the nutrient issues present in these systems as macroalgae blooms are known to occur in these systems.

As discussed in Roberts and Ward (2020), applying the model to test a 'reference condition' scenario also over-predicted macroalgal growth, with predicted state poorer than expected based on expert opinion. This overestimation could lead to a broader range presented for reference conditions than what would have occurred naturally.

For phytoplankton (Table 3) there is no data for the coastal lagoons or under the closed mouth scenarios in the Kaikorai and Kakanui estuaries.

Table 2. Current state in estuaries where the primary indicator of eutrophication is macroalgae, the condition rating A to D

Estuary	Otago Type	Snelder (current)	Current State	Predicts correct state band
Kakanui (open)*	SSRTRE	D	A	X
Shag river estuary	SIDE	B	A	X
Pleasant River estuary	SIDE	C	C	✓
Waikouaiti estuary	SIDE	C	B	X
Blueskin Bay	SIDE	B	A	X
Purakanui inlet*	SIDE	B	A	
Otago Harbour	DSDE	A	No data	
Papanui inlet	SIDE	A	A	✓
Hoopers inlet	SIDE	A	No data	
Kaikorai estuary (open)	SSRTRE	D	A	X
Taieri river*	SSRTRE	D	No data	
Akatore estuary	SIDE	D	A	X
Tokomairiro estuary	SSRTRE	D	B	X
Catlin's estuary	SIDE	C	B	X
Tahakopa estuary*	SSRTRE	C	A	
Tautuku	SIDE	C	A	X
Waipati/ Chaslands*	SIDE	C	A	

*Kakanui - Flooding during SOE sampling affected current state, with A not being reflective of known macroalgae issues; Purakanui inlet - During Field visits no large areas of macroalgae were present, expert observation/opinion would place the estuary in A band; Taieri river - Due to substrate availability and scouring there is unlikely to be large macroalgal growths in this estuary and state would not likely be D band; Tahakopa estuary - During Field visits no large areas of macroalgae were present, expert observation/opinion would place the estuary in A band; Waipati/Chaslands - During Field visits no large areas of macroalgae were present, expert observation/opinion would place the estuary in A band

Table 4. Current state in estuaries or Coastal lakes where the primary indicator of eutrophication is phytoplankton (chlorophyll-a), the condition rating A to D is depicted with the chlorophyll-a concentration (µg/L) represented in brackets.

Estuary	Otago Type	Limiting nutrient	Snelder/Plew (current)	Current State (2019)	Predicts correct state band
Kakanui estuary(closed)	SSRTRE	P	D	No data	
Orore Lagoon	Coastal Lake	P	D	No data	
Stony creek lagoon	Coastal Lake	P	D	No data	
Kaikorai estuary (closed)	SSRTRE	P	D	No data	
Tomahawk Lagoon	Coastal Lake	P	D	No data	

Broadly there are several reasons why the models may differ from current state measured in SoE monitoring, including, but not limited to:

- Large portions of the annual nutrient load may be delivered during a few, short duration, events (floods) and be discharged to the sea without contributing to macroalgal growth. This effect varies both between estuaries, and from year to year within an estuary.
- The models are driven with estimated annual average nutrient loads, which may differ from actual nutrient loads corresponding to periods of SoE monitoring.
- The macroalgae model does not consider seasonality in loads or flows. This seasonality may vary between estuaries, causing different responses to similar potential TN values.
- The 'tuning factor' has been estimated from the freshwater inflow and the tidal prism using a national dataset updated with Southland and Otago data. The predictions for each estuary would be improved by updating the tuning factor using real data (i.e., measuring salinity, temperature and depth over different tidal cycles and flow conditions in the field).
- Many of the physical properties of the estuary including estuary volume, tidal prism, area and fetch have been obtained from Coastal Explorer and the New Zealand Estuary Classification (see references in Plew 2021). These desktop studies calculated estuary parameters using aerial imagery and other available information, rather than field surveys, thus these parameters may not necessarily reflect true conditions in the estuary.
- The actual nutrient concentrations observed in an estuary are likely lower than the maximum potential concentration predicted by the model because the model does not account for processes including plant uptake, biogeochemical processes such as denitrification, redox processes such as phosphorus binding the sediment.
- For phytoplankton Plew (2020) refers to a study that states potential concentrations are ''directly linked to the nutrient load and has found to be a better predictor of phytoplankton biodiversity and biomass (National Research Council 2000; Ferreira, Wolff et al. 2005) than observed concentrations, particularly during nutrient limited phases of the annual cycle (Bricker et al. 2003). ''
- The model assumes that primary production is driven by nutrients in the water column. Entrained macroalgae in some parts of Catlins Estuary and Pleasant river Estuary, for example, may obtain at least some part of their nutrient requirements from the sediment. While sediment nutrients are a potentially contributor to macroalgal growth, water column concentrations of nutrients in these estuaries are elevated and unlikely to be limiting.
- Nuisance macroalgal growths in Otago are often located in the upper tidal range and therefore are only exposed to water column nutrients for part of the tidal cycle. While differences in

exposure time to nutrients over a tidal cycle are not captured in the model the model is calibrated by regressing potential TN at high tide with EQR (David Plew pers comm).

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