Nuisance Macroalgae in Estuaries

Ministry for the Environment Attribute Stocktake

Ngā Kapoke Moroiti Riha i ngā Wahapū

Whakarārangi Āhuatanga a Te Manatū mō te Taiao

Ministry for the Environment
Manatū Mō Te Taiao

Te Kāwanatanga o Aotearoa
New Zealand Government

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Acknowledgements

This publication may be cited as: Jones H (Ministry for the Environment), Roberts K (Salt Ecology), Stevens L (Salt Ecology). 2025. *Nuisance Macroalgae in Estuaries: Ministry for the Environment Attribute Stocktake*. Ministry for the Environment, Wellington.

Published in July 2025 by the
Ministry for the Environment
Manatū mō te Taiao
PO Box 10362, Wellington 6143, New Zealand
environment.govt.nz

ISBN: 978-1-991140-98-2 (online)

Publication number: ME 1906

Contents

Introduction

This document collates existing information and has been produced by the Ministry for the Environment. It complements the Ministry's commissioned stocktake of 55 environmental attributes. The stocktake involved 43 researchers from NIWA, Manaaki Whenua Landcare Research, Cawthron Institute and Environet Limited (Lohrer et al, 2024a). The attributes covered by the stocktake are in air, terrestrial, soil, freshwater, and estuaries and coastal waters domains.

'Nuisance' macroalgae blooms in estuaries generally arise where opportunistic species respond to surplus nutrients and reach levels that are detrimental to estuary functioning. Common nuisance species in Aotearoa New Zealand estuaries are the native red seaweed *Agarophyton* spp. (formerly *Gracilaria* spp.) and the bright green seaweed *Ulva* spp., commonly known as 'sea lettuce' (Nelson et al, 2015).

State of knowledge conclusion

- State of knowledge of nuisance macroalgae attribute: **Good/established but incomplete** – general agreement, but limited data/studies.

Overall, the state of knowledge for the nuisance macroalgae attribute is 'good/established but incomplete' for estuarine ecosystems in New Zealand. Good evidence links nuisance macroalgal growth to ecological integrity, and New Zealand–specific data quantifies the link between macroalgae growth and total nitrogen loads to estuaries.

Management interventions to reduce nutrient loads to estuaries are well understood, but implementation is likely insufficient, given recent rapid increases in nuisance macroalgae in some places.

Monitoring of estuarine macroalgae is feasible and there are well-established methods, but (as for many other estuarine attributes) monitoring coverage is insufficient – both for properly understanding the scale of the problem and for linking management interventions to the response.

Part A – Attribute and method

A1: How does the attribute relate to ecological integrity or human health?

Macroalgae are an important natural feature of estuaries and contribute to their high productivity and biodiversity. However, when high nutrient inputs combine with suitable growing conditions, nuisance growth of rapidly growing species can adversely affect estuarine ecosystems. Nuisance macroalgae can be a key indicator of eutrophication in estuaries (Sutula et al, 2011).

Excessive growth of nuisance macroalgae and their subsequent decomposition can create degraded sediment conditions (such as sediment anoxia), reduce benthic diversity, and contribute to the decline of seagrass (eg, Lyons et al, 2012; Scanlan et al, 2007; WFD-UKTAG, 2014). Other adverse effects that can directly impact humans include odour associated with deposition of drift algae on shorelines, and interference in water-based activities.

Persistent beds of entrained macroalgae (ie, macroalgae growing into seabed sediments) typically become dominated by soft, muddy sediments because near-bed current velocities decrease as cover of macroalgae increases, promoting sediment deposition (Romano et al, 2003). The co-accrual of fine, muddy sediments together with the nuisance macroalgae can exacerbate adverse effects, including changes in sediment nutrient and oxygen fluxes, decreased water clarity, further smothering of seagrass beds, and impacts to benthic macroinvertebrates (Thrush et al, 2004 and references therein).

Nuisance macroalgae in estuaries therefore have a direct, clear relationship to ecological integrity, influencing ecological representation, composition, structure and function. Also note the indirect relationship to human health and wellbeing via impacts on recreational, cultural and economic values.

A2: What is the evidence of impact on (a) ecological integrity or (b) human health? What is the spatial extent and magnitude of degradation?

Where nuisance macroalgae comprise the primary eutrophication response in an estuary, nutrient loads are strongly correlated with the proliferation of macroalgae (WFD-UKTAG, 2014; Sutula et al, 2014; Robertson et al, 2017; Plew et al, 2020; Stevens et al, 2022). In New Zealand, it is well established that nutrient loads to the coastal zone have increased significantly over the past 50 years or so (eg, Snelder et al, 2018). Many estuaries – particularly those that are shallow or have large intertidal areas – are highly susceptible to excessive macroalgae growth due to nutrient pollution (Plew et al, 2020). Consequently, nuisance macroalgae blooms have been observed in recent years in many places, including New River Estuary, Southland (Stevens et al, 2022), Hutt Estuary, Wellington (Stevens and Forrest, 2020), Tauranga Harbour, Bay of Plenty (Crawshaw, 2021) and Avon-Heathcote Estuary, Christchurch (Barr et al, 2020).

In some places, the magnitude of degradation, as exhibited by nuisance macroalgae blooms, is severe. For example, in the New River Estuary in Southland, nuisance macroalgae cover increased 40-fold between 2001 and 2021, and some parts of the estuary are often now completely covered by nuisance macroalgae, with significant effects on ecological integrity (Stevens et al, 2022).

A3: What has been the pace and trajectory of change in this attribute, and what do we expect in the future 10–30 years under the status quo? Are impacts reversible or irreversible (within a generation)?

As described above, there have been relatively rapid and recent changes in nuisance macroalgae cover and biomass in some estuaries in New Zealand, which coincide with an increase in nitrogen loads to estuaries from land via freshwater (eg, Snelder et al, 2018; Dudley et al, 2020; Stevens et al, 2022). Under the status quo, nuisance macroalgae blooms in estuaries are expected to worsen in the future as nutrient-laden freshwater travels into downstream-receiving environments. Warming temperatures due to climate change may exacerbate eutrophication symptoms.

It may be possible to reverse the impacts by reducing nutrient loads, although the timescale for recovery will be affected by other factors, such as internal nutrient sources (nutrients stored in estuary sediments) and the presence of other stressors in estuaries, such as sedimentation. In the Avon-Heathcote Estuary, after nutrient pollution was reduced due to wastewater diversion, there was a significant reduction in macroalgal biomass, as well as improvements in ecological condition (Barr et al, 2020; Zeldis et al, 2020). While improvements in terms of a decrease in macroalgae cover and biomass have been observed following nutrient load reductions, the timescales are uncertain for recovery of sensitive habitats displaced by macroalgae (such as seagrass beds and macroinvertebrate communities).

A4: What monitoring is currently done and how is it reported (eg, is there a standard, and how consistently is it used; who is monitoring for what purpose)? Is there a consensus on the most appropriate measurement method?

The Opportunistic Macroalgal Blooming Tool (OMBT) was developed for the European Water Framework Directive as a multi-metric indicator that incorporates macroalgal per cent cover, biomass, and level of entrainment (ie, macroalgae growth within the sediment) (WFD-UKTAG, 2014). The components are combined to produce an overall Ecological Quality Rating (EQR) ranging from 0 (severe disturbance) to 1 (undisturbed, reference conditions).

The OMBT was adopted in the New Zealand Estuary Trophic Index (ETI) as the recommended rating tool for nuisance macroalgae (Robertson et al, 2016). Since then, improvements to the method have been made specifically for New Zealand estuaries, including updated biomass thresholds, as outlined by Plew et al (2020), and better characterisation of estuaries with low macroalgal cover, as outlined by Stevens et al (2022).

At least eight regional councils already map and monitor nuisance macroalgae using the OMBT method (Roberts and Stevens, 2023), and the methodology is to be included in an update to the National Estuary Monitoring Protocol (Stevens et al, in prep). Results are reported by the councils via state-of-the-environment reporting.

A4(i): Are there any implementation issues such as accessing privately owned land to collect repeat samples for regulatory informing purposes?

Accessing intertidal estuarine sites for macroalgae surveys may require permission to cross private land, or the use of a boat when access from the shore may not be possible or practical. Some parts of estuaries or surrounding shorelines can be wāhi tapu (sites of significance) and so may be off limits for monitoring, or else monitoring may need to be conducted in partnership with iwi.

Health and safety also need to be considered for fieldwork in estuaries. Using boats and kayaks requires relevant training and qualifications. Fieldwork also requires hazard identification and risk management (eg, identifying and avoiding areas of deep mud, fast-flowing tidal channels).

A4(ii): What are the costs associated with monitoring the attribute? This includes up-front costs to set up for monitoring (eg, purchase of equipment) and ongoing operational costs (eg, analysis of samples).

The OMBT relies on measuring the spatial extent of nuisance macroalgae in an estuary, and then measuring or estimating per cent cover, biomass and entrainment within each macroalgal patch. Surveys should be undertaken during the peak growing season (generally late spring or summer). The spatial extent of macroalgae can be mapped on the ground with a handheld GPS unit, or by using aerial/remotely sensed imagery with ground truthing at representative locations, as per the broad-scale mapping described in the National Estuary Monitoring Protocol and the ETI (Robertson et al, 2002a, 2002b, 2002c; Robertson et al, 2016). The per cent cover, biomass and degree of entrainment is then estimated for each discrete macroalgae patch. The method does not require very specialised equipment or laboratory services, so most of the cost will be associated with fieldwork.

The cost of undertaking nuisance macroalgae monitoring is therefore highly dependent on the size of the estuary and the extent of the problem. Small estuaries (< c. 50 ha) with relatively little macroalgae can generally be easily assessed by two experienced people on a single tide. Large estuaries with significant problems (like the 4,600 ha New River Estuary) will require at least four to six people over four to six tides to assess. However, the level of effort is scalable based on the degree of confidence required. It may be possible to classify an estuary into a broad, narrative band with relatively limited sampling effort if a high degree of confidence is not required. Alternatively, an estuary may be so degraded that additional sampling effort to confirm what is already known is unwarranted.

A5: Are there examples of this being monitored by iwi/Māori? If so, by whom and how?

The authors are not aware of nuisance macroalgae specifically being monitored by iwi/Māori, but tohu (cultural health indicators) have been developed and used for estuarine monitoring and management at a local level (eg, Lang et al, 2012; Bamford et al, 2022). Tohu include taonga species, mahinga kai and kai moana (eg, pāua, kina, tuna), as well as measures of hauora (health) and mauri (life force), and are used to monitor estuarine health from a te ao Māori perspective.[1] The presence, type and abundance of nuisance macroalgae is likely to influence cultural health indicators, for example, by affecting the abundance and quality of kai moana and indigenous species.

Ngā Waihotanga Iho (The Estuary Monitoring Toolkit)[2] was developed by NIWA and iwi partners to provide guidance on estuarine monitoring for tangata whenua. The tools are science based and are intended to complement traditional knowledge and kaitiakitanga. The toolkit provides guidance on habitat mapping, which could include mapping of macroalgae beds if they are present in an estuary. It is unclear how often the toolkit has been implemented around New Zealand, but Dodson and Miru (2021) document the use of the toolkit by a Kaipara hapū as a mechanism for enabling kaitiakitanga and indigenous-led environmental education.

A6: Are there known correlations or relationships between this attribute and other attribute(s), and what is the nature of these relationships?

Nuisance macroalgae in estuaries is likely to be correlated with nutrient (especially nitrogen) concentrations and/or loads in freshwater inputs, because excessive nutrients are a key driver of nuisance macroalgae growth.

Nuisance macroalgae may also be correlated with other indicators of eutrophication in the estuary, such as water column nitrogen and phosphorus concentrations, sediment oxygen depletion, sediment total nitrogen, and sediment total organic carbon. However, these relationships are not straightforward. For example, water column nitrogen and phosphorus concentrations can be low if these nutrients have been taken up by phytoplankton, macroalgae or other plants. Sediment total nitrogen may be elevated from catchment inputs or internal nutrient cycling and breakdown of plant material. It is also possible for estuaries to have low sediment organic content but be affected by excessive growth of nuisance macroalgae if the estuary has high nutrient loading and naturally coarse, well-irrigated sediments (Zeldis et al, 2020).

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[1] Tangaroa Tohu Mana, Tangaroa Tohu Mauri | Marine Cultural Health Programme. *Monitoring*. Retrieved 27 May 2025 from https://marineculturalhealth.co.nz/

[2] National Institute of Water and Atmospheric Research (NIWA) | Taihoro Nukurangi. *Ngā Waihotanga Iho – The Estuary Monitoring Toolkit*. Retrieved 27 May

Conversely, nuisance macroalgae are likely to be negatively correlated with biodiversity indicators/attributes that are impacted by excessive macroalgal growth, such as seagrass extent and quality, and estuarine macroinvertebrate diversity (eg, reviewed by Nelson et al, 2015).

Note that excessive growth of nuisance macroalgae is likely to be the primary eutrophication response in most shallow intertidal-dominated estuaries, and in intertidal areas of other types of estuaries where suitable growing conditions exist (Plew et al, 2020). In contrast, excessive growth of phytoplankton is likely to be the primary eutrophication response in deeper or poorly flushed estuaries (or parts of estuaries).

Part B – Current state and allocation options

B1: What is the current state of the attribute?

The current state of nuisance macroalgae growth is well understood in estuaries that are regularly monitored, but it is not well documented elsewhere. It is not reported at a national level – for example, nuisance macroalgae is not currently included in the estuary health module on LAWA,[3] or on the Department of Conservation's *Our Estuaries* hub.[4] Nuisance macroalgae growth has not yet been assessed at regional or national scales via remote sensing, although remote-sensing methods are currently being explored in an Envirolink Tools project that could lead to larger-scale assessment.[5] As such, our understanding of current state comes from field-based monitoring of individual estuaries, usually conducted by regional councils and unitary authorities. The results are often reported on an estuary-by-estuary basis, and these indicate that nuisance macroalgae problems, particularly of *Ulva* and *Gracilaria* species, are present in many estuaries throughout New Zealand (eg, Nelson et al, 2015; Stevens et al, 2022; Stevens and Forrest, 2020; Crawshaw, 2021; Barr et al, 2020).

B2: Are there known natural reference states described for New Zealand that could inform management or allocation options?

The natural reference state for New Zealand estuaries is largely unknown, as most estuaries have been impacted by human activities in the catchment and/or in the estuary (eg, changes in land use and intensification causing increases in nutrient and sediment inputs, reclamation, dredging). Place-based knowledge and mātauranga Māori may be useful, however, for providing qualitative descriptions of natural reference states. The few remaining estuaries that are close to a natural or unimpacted state (eg, Freshwater Estuary, Stewart Island) are not likely to be suitable reference cases for all New Zealand estuaries (eg, due to differences in climate, estuary morphology, catchment characteristics), but they can be used in a local context to inform management.

To our knowledge, monitoring has been undertaken in five near pristine ('reference') estuaries on the South Island (ie, Freshwater, Tautuku, Waipati, Whangarae and Whanganui estuaries), but there appear to be no suitable reference estuaries in the North Island. The reference estuaries monitored in the South Island comprise catchments with > 90 per cent native scrub/forest (either natural or regenerating), and minimal anthropogenic influences in the estuary or catchment. No nuisance macroalgal issues have been recorded in these estuaries, which all scored > 0.8 (ie, very good) for the OMBT-EQR (Roberts et al, 2022c; Forrest et al,

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[3] Land, Air, Water Aotearoa (LAWA). *Estuary Health*. Retrieved 27 May 2025 from https://www.lawa.org.nz/explore-data/estuaries

[4] Department of Conservation. *Estuaries spatial database*. Retrieved 27 May 2025 from https://www.doc.govt.nz/nature/habitats/estuaries/estuaries-spatial-database/

[5] Envirolink. *All tools*. Retrieved 27 May from https://www.envirolink.govt.nz/envirolink-tools/all/

2023; Roberts, 2023c). In Europe, low levels of nuisance macroalgae cover (< 5 per cent cover across available habitat) and biomass were considered the 'reference' state (WFD-UKTAG, 2014). This threshold is consistent with the data collected in New Zealand estuaries.

Modelling approaches have been used to predict OMBT-EQRs under different catchment nutrient inputs scenarios (eg, natural land use – see Plew et al, 2020), and this type of information has been combined with contemporary monitoring data to estimate reference states for Southland estuaries (Roberts and Ward, 2020). Where available, historic imagery can also be used to assess macroalgal conditions before catchment development. For example, in the Catlins Estuary (Otago), historic imagery shows that despite over 50 years of catchment development, macroalgal issues did not appear until 2010 following large increases in nutrient inputs (Roberts et al, 2024). As such, the best available information can likely be used to estimate natural reference states.

B3: Are there any existing numeric or narrative bands described for this attribute? Are there any levels used in other jurisdictions that could inform bands (eg, US EPA, Biodiversity Convention, ANZECC, regional council set limit)?

Numeric and narrative bands for nuisance macroalgae have recently been proposed by Stevens et al (2024). The numeric thresholds are set for the OMBT score and are primarily based on the bands outlined by WFD-UKTAG (2014), although the biomass sub-metric thresholds have been lowered based on the levels at which ecological impacts are expected for New Zealand estuaries (Plew et al, 2020). These updated thresholds have been used in estuary reporting since 2022, with historic data also able to be recalculated (eg, Stevens et al, 2022; Plew, 2023).

The 2016 Estuary Trophic Index adopted a similar banding system, albeit without the improvements described above, and these bands have often been used in reporting of monitoring results (eg, Stevens and Forrest, 2020; Roberts et al, 2022a). They were also adopted in Environment Southland's objective-setting process (Ward and Roberts, 2021).

B4: Are there any known thresholds or tipping points that relate to specific effects on ecological integrity or human health?

Persistent, high biomass blooms of nuisance macroalgae that are entrained in the sediment pose a high risk of a permanent regime shift to a degraded state (Lyons et al, 2012). This excessive algal growth is likely to significantly affect sediment biology and chemistry, and sediment-water interaction. For example, persistent, dense macroalgae cover and biomass will smother the sediment, causing sediment anoxia and mortality of benthic macroinvertebrates (Norkko and Bonsdorff, 1996; Marsden and Bressington, 2009).

Within the bands described in Stevens et al (2024), the 'fair' to 'poor' threshold represents a point where risk of undergoing a regime shift is high (eg, Robertson et al, 2017; Roberts et al, 2022b; Roberts et al, 2023). The ‘poor’ to ‘very poor’ threshold represents excessive algal growth and the point at which a regime shift is already likely to have already occurred.

B5: Are there lag times and legacy effects? What is the nature of these, and how do they impact state and trend assessment? Further, are there any naturally occurring processes, including long-term cycles, that may influence the state and trend assessments?

Expression of macroalgae problems in estuaries can be complex, as it can be influenced by lag times related to changes in nutrient availability – particularly if there are sediment-bound nutrient issues, or the macroalgae species is able to store and use nutrients over prolonged periods (eg, Robertson and Savage, 2018; Dudley et al, 2022). This means that, for some systems, improvements in ecological condition may take some time, even if external nutrient inputs are quickly reduced.

Other factors influencing macroalgae growth include nutrient-rich water that comes from offshore (via ocean upwelling) and non-nutrient-related changes (eg, macroalgal losses through flood scouring, channel flushing, wind-driven waves, temperature). These non-nutrient-related macroalgal reductions tend to lead to only temporary changes, however, so where input of excess nutrients is ongoing, nuisance macroalgal growth is likely to re-establish.

B6: What tikanga Māori and mātauranga Māori could inform bands or allocation options and how (eg, by contributing to defining minimally disturbed conditions, or unacceptable degradation)?

Nuisance macroalgae are likely to impact on kaitiakitanga, manaakitanga, tikanga, taonga species and mahinga kai, as well as iwi/Māori connection to the environment. Mātauranga Māori could help to define natural reference states, which (as described above) are not well understood. Mātauranga Māori is inherently place based, however, so the definition of natural reference states and/or unacceptable degradation is likely to vary from place to place (especially given the variety of estuaries, issues and historical contexts around New Zealand).

The Sustainable Seas National Science Challenge collaborated with iwi partners, the Our Land and Water National Science Challenge, and the Ministry for the Environment to produce guidance on integrated estuarine management reflecting ki uta ki tai (mountains to the sea) concepts, and on improving connectivity between mātauranga Māori and western science (Lohrer et al, 2024b). The guidance highlights the need to engage at the local level, with face-to-face communication, to achieve meaningful co-development of policies and management interventions. A combination of mātauranga Māori and environmental science was used to inform objective setting for freshwater ecosystems, including estuaries, in Murihiku Southland (Bartlett et al, 2020).

Part C – Management levers and context

C1: What is the relationship between the state of the environment and stresses on that state? Can this relationship be quantified?

Data from New Zealand and overseas indicate a strong correlation between nutrient loads and the proliferation of macroalgae in estuaries (WFD-UKTAG, 2014; Sutula et al, 2014; Robertson et al, 2017; Plew et al, 2020; Stevens et al, 2022; Roberts et al, 2022b). The relationship between total nitrogen (TN) catchment load and nuisance macroalgae has been quantified using data from 37 New Zealand estuaries (Plew, 2023). Plew's (2023) study showed that nuisance macroalgae, measured using OMBT-EQR, were predominantly absent unless the potential TN concentration exceeded 230 mg/m^3. While there is some variation in the response caused by estuary-specific factors – including internal nitrogen sources and sinks in the estuary, and physical characteristics that influence dilution and water residence time – the OMBT-EQR decreases (worsens) approximately linearly at TN concentrations > 230 mg/m^3. Where enough data are available, this relationship can also be applied to specific estuaries – for example in New River Estuary, Southland (eg, fig 13 in Roberts et al, 2022b).

Other studies have found similar trends of increasing macroalgae with TN load. For example, Robertson and Savage (2021) found a relationship between TN load and percentage intertidal area of nuisance macroalgae in 26 New Zealand estuaries. In that study, when the TN load exceeded c. 50 mg N m^{-2} d^{-1}, macroalgae cover increased in extent in an approximately linear fashion.

C2: Are there interventions/mechanisms being used to affect this attribute? What evidence is there to show that they are/are not being implemented and being effective?

Multiple types of activities may need to be managed to influence the state of this attribute, especially those associated with point-source and diffuse pollution causing nutrient runoff into rivers, streams and estuaries. National-scale analysis of estuarine and coastal water quality indicates that a large proportion of nutrients in estuaries come from land via freshwater (Dudley et al, 2020), so managing activities on land, and discharges to freshwater, is highly relevant for this attribute.

Existing legislation, such as the Resource Management Act 1991 and associated national direction (including the National Policy Statement for Freshwater Management 2020 (NPS-FM) and New Zealand Coastal Policy Statement 2010 (NZCPS)), contain relevant land and freshwater management policies and requirements to avoid significant adverse effects of activities on estuary habitats. Current regulations (eg, regional and coastal plan rules) and catchment management activities already attempt to either reduce nutrients generated from various catchment activities or intercept them before they reach waterways (eg, via constructed wetlands and/or riparian planting), and/or set limits on point-source inputs, such as wastewater treatment facilities. Given the eutrophication problems observed in estuaries in many regions, however, it seems current management interventions have not been effective. Possible reasons for this could be inconsistent or insufficient regulation, lack of enforcement and monitoring, and the consequences of cumulative and legacy effects (eg, Ministry for the Environment and Stats NZ, 2023; Joy and Canning, 2020).

Potential active intervention actions include physical removal of accumulations of nuisance macroalgae, which is sometimes carried out by councils when it impacts public recreational or amenity areas such as beaches and boat ramps.[6] For the highly impacted New River Estuary in Southland, it was considered unfeasible to physically remove established, heavy growths of nuisance macroalgae, but possible to remove incipient or overwintering macroalgae in otherwise healthy parts of the estuary before they develop into persistent eutrophic areas (Roberts and Stevens, 2021; Zeldis et al, 2019). Although commercial harvesting may be a mechanism for achieving this, at present there is a moratorium (through Schedule 4C of the Fisheries Act 1996) on new permits for the commercial harvest of seaweeds including *Gracilaria chilensis* (now known as *Agarophyton chilense*) and *Ulva* spp. (White and White, 2020).

All interventions (including those listed in more detail below) would require monitoring of nuisance macroalgae growth, nutrient loads to estuaries, and specific actions made in catchments to reduce nutrient runoff, to evaluate whether management is being effective. However, regular, repeated monitoring of nuisance macroalgae in estuaries is only carried out in a few places and is often not well aligned with monitoring of management interventions. As such, evaluation of the efficacy of estuarine management is difficult, which is also the case for freshwater management (eg, Westerhoff et al, 2022; McDowell et al, 2024).

C2(i): Local government driven

The NPS-FM requires councils to consider effects on sensitive receiving environments, such as estuaries, in freshwater planning processes. However, the inclusion of estuaries in Freshwater Management Units (FMUs) and the objective-setting process is not mandatory, and the National Objectives Framework (NOF) contains no estuarine attributes. Consequently, some councils include estuaries in their NPS-FM implementation process, and some do not. The NOF specifies compulsory attributes that relate to nutrients or trophic state for rivers and lakes, but it is unknown whether managing these attributes in freshwater will protect estuaries from adverse effects associated with eutrophication (ie, whether estuaries are more or less sensitive to eutrophication than upstream environments).

Effective integrated management is challenging, partly because regional coastal plans are generally separate from regional land and water plans, and land use is controlled by territorial authorities under district plans. A report by the Parliamentary Commissioner for the Environment (2020) highlighted the complex legislation and difficulties associated with managing estuaries and called for the mandatory inclusion of estuaries in the NPS-FM and within FMUs.

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[6] Bay of Plenty Regional Council. *Sea lettuce*. Retrieved 27 May 2025 from https://cdn.boprc.govt.nz/media/374297/boprc-thfs1-sea-lettuce-web.pdf

Aside from regulation, many councils also support and provide funding to catchment or harbour care groups (see sections below). These groups often undertake riparian fencing, planting and wetland restoration that may reduce nutrient loads to freshwater and estuaries (eg, Sinner et al, 2022).

C2(ii): Central government driven

As noted above, central government policies that would affect this attribute include the management of nutrients in freshwater under the NPS-FM, and policies relating to water quality and integrated management under the NZCPS. The implementation of these policies largely occurs at regional council and unitary authority level (see above).

Central government agencies also support and provide funding to catchment and estuary management initiatives at regional or local levels, such as the Kaipara Moana Remediation Programme[7] and the Wai Connection – Tatai Ki Te Wai project.[8] The Ministry for the Environment and Department of Conservation have also supported and (co-)funded science and research that aim to inform more effective monitoring and management of estuaries. The Ministry for the Environment projects include the 'Managing Upstream' project (eg, Cornelisen et al, 2017), the review and update of the National Estuary Monitoring Protocol (Roberts and Stevens, 2023; Stevens et al, 2024, in prep), and involvement in the Sustainable Seas ki uta ki tai project (Lohrer et al, 2024). The Department of Conservation's *Our Estuaries* hub provides information on estuarine monitoring and restoration for interested community groups.[9]

C2(iii): Iwi/hapū driven

Relevant iwi/hapū-driven initiatives include Māori-led projects for catchment management, river and estuary care, which aim to improve water quality and protect taonga species and mahinga kai. These inherently place-based projects often incorporate mātauranga Māori. Iwi environmental management plans may also address issues associated with eutrophication in freshwater and estuaries. Some projects are partnerships between iwi and other organisations. For example, the Kaipara Moana Remediation Programme[10] is a partnership between iwi, and central and local government.

C2(iv): NGO, community driven

There are hundreds of catchment and community groups across New Zealand, which may also include iwi/hapū. These groups are often supported by non-governmental organisations (NGOs) like the NZ Landcare Trust and The Nature Conservancy, and by central or local government. Much of the work done by these catchment and community groups – such as riparian planting, pest control, wetland protection and restoration – will indirectly affect nutrient loads to estuaries, and therefore potentially nuisance macroalgae growth. Further,

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7 Kaipara Moana Remediation. *Kaipara Moana Remediation*. Retrieved 27 May 2025 from https://kmr.org.nz/

8 Mountains to Sea Conservation Trust. *Wai Connection – Tatai Ki Te Wai*. Retrieved 27 May 2025 from https://www.waiconnection.nz/

9 Department of Conservation. *Our Estuaries*. Retrieved 27 May 2025 from https://www.doc.govt.nz/nature/habitats/estuaries/our-estuaries/

10 Kaipara Moana Remediation. *Kaipara Moana Remediation*. Retrieved 27 May 2025 from https://kmr.org.nz/

attempts at within-estuary restoration are becoming increasingly common (eg, saltmarsh planting and improvements in tidal flushing), which will also indirectly affect nutrient availability and therefore nuisance macroalgae growth.

C2(v): Internationally driven

As a signatory to international conventions, New Zealand has obligations relating to managing estuarine pollution and eutrophication. For example, there are several designated Ramsar sites in and around estuaries, including the Firth of Thames, Awarua Waituna Lagoon and Manawatū River estuary.[11] The Kunming-Montreal Global Biodiversity Framework contains a target relating to reducing pollution – including reducing excess nutrients lost to the environment by at least half, by 2030 – which is relevant to this attribute.

[11] Department of Conservation. *Ramsar Convention on Wetlands*. Retrieved 27 May 2025 from https://www.doc.govt.nz/about-us/international-agreements/ecosystems/ramsar-convention-on-wetlands/

Part D – Impact analysis

D1: What would be the environmental/human health impacts of not managing this attribute?

Excessive growth of nuisance macroalgae affects environmental health by contributing to sediment anoxia, loss and degradation of seagrass and shellfish beds, and impacts on estuarine food webs, as described in Part A. Where nuisance macroalgae growth is very severe, it can also affect human health due to the production of hydrogen sulphide gas from the decomposition of macroalgae, as well as aesthetic and amenity impacts (Nelson et al, 2015). Not managing this attribute will likely lead to more widespread and/or severe nuisance macroalgae growth and further environmental degradation.

D2: Where and by whom would the economic impacts likely be felt (eg, horticulture in Hawke's Bay, Electricity generation, housing availability and supply in Auckland)?

Costs to reduce nuisance macroalgae growth and manage eutrophication in estuaries will vary depending on the scale of the current issue, and the human activities that contribute to it. Costs to reduce nutrient loads may be substantial in many developed catchments where large reductions in nutrient inputs might be required (eg, Stevens et al, 2022).

However, given that the major pressures contributing to nuisance macroalgae issues are already being managed or just need to be managed more effectively to give effect to current national direction, the extra costs to councils will mostly be for improved monitoring, risk assessments and research to determine effective management (eg, via catchment nutrient load modelling), and for restoration interventions (eg, catchment management, wetland restoration, active removal of macroalgae).

Costs arising from nutrient management may include lower agricultural productivity, and increased compliance and operational costs for commercial users and land owners, who may also be less likely to invest in long-term growth strategies. However, a range of environmental, social and cultural benefits will likely result from actions to reduce nuisance macroalgae growth in estuaries. Reduced nutrient and sediment loads will improve water quality, benefitting the aquaculture and fisheries sectors. Reducing nuisance macroalgae growth can also enhance recreation, amenity values and tourism potential. In the long term, it could support the preservation (and potentially the regeneration) of culturally significant resources and practices, mahinga kai and associated mātauranga.

D3: How will this attribute be affected by climate change? What will mitigating that require in terms of management response?

Nuisance macroalgae growth is influenced by light, temperature and salinity, as well as nutrient supply (eg, Howarth and Marino, 2006; Nelson et al, 2015; Dudley et al, 2022). However, the complex interactions between climate variables and conditions in the estuary make it difficult to predict exactly how climate change will influence nuisance macroalgae growth (Crawshaw, 2021). For example, increased rainfall, storm intensity or frequency may drive increases in nutrient loads to estuaries, which would in turn drive increases in macroalgal growth. Conversely, these events may also increase sediment supply, potentially increasing turbidity and decreasing light levels, which would decrease macroalgae growth. Increasing temperature will likely increase nuisance macroalgae growth, up to an optimum – after which growth rates may then decrease. Sea-level rise may increase water depths, which would decrease light levels near the seabed, but may also create new intertidal, shallow habitat suitable for nuisance macroalgae growth. Regardless of the exact response to climate change, effective management of nutrient loads to estuaries will be required, to manage eutrophication symptoms such as nuisance macroalgae growth.

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