9.18 Cyanobacteria in water

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Preamble: There are three different concerns related to cyanobacteria in coastal waters.

- Planktonic cyanobacteria (PC) that live in the water column of estuaries/coastal waters.
- Benthic cyanobacterial mats (BCM) that live on substrates (i.e., mud, other organisms) in estuaries/coastal ecosystems.
- Freshwater cyanobacteria (FW) that live in upstream rivers or lakes, which flow into estuaries/coastal ecosystems. These freshwater species can survive some exposure to saline conditions. Additionally, the toxins produced by freshwater species, also flow into coastal waters and can accumulate in marine species.

There are different degrees of knowledge for each of the above and different response and mitigation actions are required. In each question below we will note how the answer/s related to each "type" of cyanobacteria.

State of knowledge of the "Cyanobacteria in coastal waters" attribute: Poor / inconclusive – based on a suggestion or speculation; no or limited evidence

Part A—Attribute and method

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

Ecological integrity (PC, BCM)**.** Marine cyanobacteria can be beneficial with some species forming symbiotic relationships with other micro- and macro-eukaryotes. They can also play vital roles in the biogeochemical cycle of carbon and nitrogen and represent the primary nitrogen-fixing microorganisms in marine environments [1]. However, cyanobacterial blooms and proliferations of benthic mats can also alter trophic structure and functionality, and in the case of planktonic species, can also causes water column deoxygenation, leading to fish mortalities and decreasing water quality [2].

PC blooms can cause light limitation and the death of competing phytoplankton species and rooted aquatic vegetation. Cyanobacteria are often of low food preference for herbivores when compared to other phytoplankton [3, 4]. Planktonic cyanobacterial blooms are relatively common in estuaries and brackish waters in Aotearoa New Zealand. For example, there is a long history of planktonic cyanobacterial blooms in Te Roto o Wairewa / Lake Forsyth and Te Waihora /Lake Ellesmere [5].

BMC blooms can smother the underlying aquatic system, resulting in food web changes and in some cases killing the underlying substrate (i.e., sponges and corals; [6]). Once formed, the mats can impact the recruitment of corals and other benthic taxa, impacting food webs. For example, data from overseas indicates there can be shifts in reef fish communities [7].

Ecological integrity (FW). FW species and their toxins can have profound impacts on coastal ecosystems. Internationally freshwater cyanotoxins (see below) have been responsible for the death of marine mammals and have been detected in a range of other marine organisms [8].

Human health (PC, BCM, FW). Cyanobacteria can be hazardous to aquatic and terrestrial organisms, as some species produce highly toxic secondary metabolites, known as cyanotoxins that have killed numerous animals worldwide and endanger human health [9]. Exposure to cyanotoxins can occur in various ways, however, the oral route is the most important. In the marine environment, the most likely exposure route is though the consumption of contaminated seafood (e.g., [10]). Dermic exposure and inhalation are also possible especially during proliferations of BCM. Some species of BCMs, including those in Aotearoa New Zealand, produce lyngbyatoxin-a, a cyanotoxin that can cause acute dermatitis as well as eyes and throat irritation and respiratory issues [11].

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

Internationally, data and publications on cyanobacteria in coastal waters is relative limited, especially compared to their freshwater counterparts.

PC – Internationally, there is considerable evidence to show that PC blooms and the toxins they produce can have negative ecosystem effects. For example, the toxins commonly produced by the cyanobacteria in estuaries in Aotearoa New Zealand have been shown to affect the reproduction and survival or aquatic organisms (e.g., [12]) and when blooms are severe, they can create water quality issues such as low dissolved oxygen. These cyanobacteria also pose a health risk to human through exposure via by ingestion of containment seafood or water, inhalation of aerosolised cells or toxins, or dermal contact with cells / toxins. To date these blooms are constrained to a small number of brackish water lakes / estuaries in Aotearoa New Zealand

BMC – There is limited data from Aotearoa New Zealand, but there is an increasing body of international literature that has highlighted a range of negative ecological impacts from smothering other organisms to changing food webs [6]. Studies on the ecological impact of BCM have not been undertaken in Aotearoa New Zealand. There is strong evidence from international studies that shows a detrimental impact of aerosols from BCM [13], and some evidence from anecdotal reports in Auckland that this may also be an issue in Aotearoa New Zealand. Recently the toxins produced by BCM mats have been detected in shellfish but the toxicity to humans via shellfish consumption is unknown (Biessy L, in prep).

FW - There is evidence that some freshwater cyanobacteria can survive at different salinity levels in estuaries [14, 15]. As noted above, the main impact of FW species on coastal waters is likely through the contamination of organisms that ingest the toxins through contaminated food or water. The extent of the problem is unknown in Aotearoa New Zealand.

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)?

We anticipate that the frequency and severity of all three cyanobacterial types will increase over the next 10-30 years with rising eutrophication and sea temperatures [2]. However, assessing these changes will be challenging as currently very little data is collected on cyanobacteria in coastal waters. BCM are known to bloom seasonally, but the prevalence and duration of BCM blooms are increasing at an accelerating rate worldwide [6]. In Aotearoa New Zealand, there are records of blooms of the filamentous marine cyanobacterium, identified at the time as *Lyngbya majuscule* (now reclassified as species of *Lyngbya*, *Moorea*, *Okeania*, *Dapis* and others) in the Hauraki Gulf [16]. Blooms of benthic marine cyanobacteria at sites in eastern Auckland in the Hauraki Gulf as well as sites in the Manukau Harbour and Waitematā Harbour were reported with large rafts of this species washed ashore during warm summers in the years 1999-2001, 2003 and 2005 [17], with over 100 tonnes washing up on the beach for the 2005 event. For the last two summers (2022 and 2023), over 400 tonnes of BCM, identified as *Okeania* sp. (previously classified as *L. majuscula*), have washed up on Waiheke Island, affecting local communities and the environment.

The impacts of cyanobacteria in coastal waters should be reversible but these will take considerable catchment wide restoration. If the drivers / stressors were removed or reduced over time, we anticipate that cyanobacterial blooms / proliferations will decrease in severity. However, effects from cyanobacteria might not be reduced if these blooms were caused by larger scale climatic drivers, but due to the lack of research, this is unknown.

A4-(i) What monitoring is currently done and how is it reported? (e.g., 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?

To our knowledge, there is no current monitoring for any of the cyanobacterial types in coastal waters.

Auckland Council monitored BCM between 1999 and 2007 at selected sites. They used a graduated approach that included; (1) a regular assessments of algal mat build-up through the summer months, (2) working closely with the public health services regarding public health risks posed and the level of public nuisance, and (3) monthly sampling of the location of interest using a systematic grid and quadrats [18].

Australia, in particular the Queensland Region, has experienced frequent BCM proliferations over the last decade. The Moreton Bay Regional Council published a Harmful Algal Bloom Response Plan in 2018 including monthly monitoring (i.e., visual inspections from boats, combined with shore-based inspections) and a three-level response plan shown in Table 1 [19].

Table 1. Three-level response plan for marine benthic cyanobacterial blooms in Moreton Bay, Australia [19].

Alert level	Detection	Response
1	Small to moderate bloom material at locations away from developed areas	No action required to remove material, but signs to inform the public of the presence of a potentially

		harmful algal bloom may be appropriate. Activate stakeholder communications.
2	Large quantities of bloom material washing ashore or forming rafts adjacent to developed areas or areas of high public use	Activate or install signs immediately. Issue media release. Physically remove material from foreshores.
3	Very large quantities of material washed ashore or beginning to form large rafts adjacent to developed areas or areas of high public use	Same response as for Level 2, but closure of beaches may also be required, particularly where large amounts of blooms are growing close to the water's edge.

The Cawthron Institute, alongside Health New Zealand | Te Whatu Ora and the New Zealand Ministry of Health | Manatū Hauora, is currently working on a project titled "Managing marine harmful algal blooms (HABs) in recreational settings" [20]. This is a review of international material on recreational management of marine HABs (bathing, water sports and aerosols) to determine the feasibility of developing guidelines for Aotearoa New Zealand. The project is also identifying knowledge gaps required to form robust risk management approaches and including for BCM.

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

We do not envision significant barriers or issues related to implement monitoring for this attribute, although as noted above, there is a need to develop appropriate monitoring protocols. Most estuaries/ coastal waters are not on privately owned land, but access across private land might be required to reach suitable boat launching or monitoring sites. Iwi and hapū should be kept informed of any work and sample collection being undertaken in their rohe.

A4-(iii) What are the costs associated with monitoring the attribute? This includes up-front costs to set up for monitoring (e.g., purchase of equipment) and on-going operational costs (e.g., analysis of samples).

Field work would be required to monitor all types of cyanobacteria in coastal waters (PC, BCM, FW). As noted above, there are currently no national (or regional) monitoring protocols for any of the types of cyanobacteria in coastal waters and these need to be developed.

PC and FW. Sampling could be undertaken using similar approaches to those used to monitor lakes. This would likely involve travelling to the site(s), taking a boat to the sampling site(s), and taking grab or depth integrated water sample. The samples then need to be sent to a laboratory with algal identification expertise. The species and concentrations of cyanobacteria need to be determined using microscopy and this usually costs about $150 per sample. In addition to the above, there would be initial set up costs such as staff time to design monitoring programme and select high-risk sites.

BCM. Monitoring protocols still need to be developed. It is likely that they will involve diver surveys as well as assessments of beaches. Initially, the causative/dominant species needs to be identified using microscopy or genetic testing. Thereafter, it may be possible to use macroscopic surveys to assess the abundance of BCM.

A5. Are there examples of this being monitored by Iwi/Māori? If so, by who and how?

We are not aware of any monitoring of PC, BCM, or FW being undertaken by representatives of iwi/hapū/rūnanga. However, it is worth noting that Ngāti Paoa iwi and whānau have been severely impacted by recent BCM events on Waiheke Island over the last two summers. Restrictions on place (i.e., rāhui or temporary closures) are generally applied by iwi and hapū to ensure the safety of whānau and the wider community.

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

There are possible links to coastal water nutrient and sediment attributes (PC/ BCM). However, because there is insufficient data on the causes of increases in cyanobacteria in coastal waters in Aotearoa New Zealand, we are currently unable to establish this. If cyanobacteria in freshwater systems increase, this will impact on the occurrence of FW species and their toxins in coastal waters. There are well established links between cyanobacterial blooms in lakes and total nitrogen and total phosphorus levels. It would be reasonable to assume a relationship between FW cyanobacteria in coastal waters and the lake ecosystem attributes of total nitrogen and total phosphorus [21].

Part B—Current state and allocation options

B1. What is the current state of the attribute?

There is almost no information on the current state and distribution of marine cyanobacteria in Aotearoa New Zealand. A few small studies have characterised cyanobacteria communities in coastal waters (e.g., [22]) and work is currently underway on BCM in the Auckland / Waiheke Island region. These studies have primarily focused on biodiversity or identification of causative toxin-producing/bloom forming species and did not focus on studying spatial or temporal patterns.

As noted above, there is a long history of cyanobacterial blooms in Te Roto o Wairewa / Lake Forsyth and Te Waihora / Lake Ellesmere – which are often classified as estuaries or as Intermittently Closing and Opening Lakes and Lagoons [5]. More recent studies have explored bloom dynamics and the accumulation of cyanotoxins in tuna (eels; [23]) and the causes of these blooms [24].

We assume that all cyanobacterial types described here will become more problematic with increasing eutrophication and climate change. There is some evidence to suggest this in Aotearoa New Zealand with an increase over the last two summers in BCM the Auckland region / Waiheke Island and more frequent and intensive cyanobacterial blooms in freshwater bodies that flow into coastal systems.

We believe that there is **currently insufficient information** for marine cyanobacteria in coastal waters to be used as an indicator.

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

There is no information on natural reference states for cyanobacteria in coastal waters. Paleolimnological studies have been undertaken in lakes [25, 26] in Aotearoa New Zealand, and this approach might be useful to estimate the natural reference state of FW cyanobacteria in marine systems. To date, the areas where paleolimnology studies of cyanobacterial communities have been undertaken are not lakes which flow directly into coastal systems. Paleolimnological studies could also be undertaken in estuaries, and this might help establish natural reference states for BMC and PC.

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? (e.g., US EPA, Biodiversity Convention, ANZECC, Regional Council set limit)

We are unaware of any existing numeric or narrative bands for marine cyanobacteria. There are National Objective Frameworks for freshwater cyanobacteria, but these are not relevant for cyanobacteria in coastal waters.

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

We are unaware of any specific thresholds or tipping points that relate to specific effects on ecological integrity or human health for cyanobacteria in coastal waters. Internationally, there has been some work undertaken to explore safe levels of cyanotoxin consumption in seafood (e.g.,[27]).

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

There is insufficient data on cyanobacteria in coastal waters in Aotearoa New Zealand to assess any potential lag times, legacy effects, or natural oscillations.

B6. What tikanga Māori and mātauranga Māori could inform bands or allocation options? How? For example, by contributing to defining minimally disturbed conditions, or unacceptable degradation.

A high standard of water and sediment quality is an outcome sought by iwi/hapū/rūnanga. There is tikanga and mātauranga Māori relevant to informing bands, allocation options, minimally disturbed conditions and/or unacceptable degradation residing in treaty settlements, catchment/species restoration strategies, cultural impact assessments, environment court submissions, iwi environmental management plans, reports, etc.

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?

There are insufficient data on all cyanobacterial types (PC, BCM, FW) in coastal waters in Aotearoa New Zealand to determine this. However, based on our expert opinions and work on cyanobacteria in freshwater systems, we suggest that it is highly likely that increases in all types of cyanobacteria in coastal waters will occur with increasing nutrients, sediment and other contaminates, as well as warming sea temperatures.

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?

- **C2-(i). Local government driven**
- **C2-(ii). Central government driven**
- **C2-(iii). Iwi/hapū driven**
- **C2-(iv). NGO, community driven**
- **C2-(v). Internationally driven**

At present, we do not know of any interventions/mechanisms being used to affect this attribute, other than general freshwater and marine water and sediment quality management activities (which are covered by discussions of other attributes). Although cyanobacteria in coastal waters are becoming an increasing problem, data is so deficient that we are currently a long way from been able to implement interventions. However, as noted above, because of the likely close relationship with blooms / mat proliferation and eutrophication, any measures taken to reduce the input of nutrients and contaminants into coastal waters will likely also reduce cyanobacteria in coastal waters.

Part D—Impact analysis

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

This is unknown because sufficient data and information on cyanobacteria in coastal water in Aotearoa New Zealand is lacking. Based on the limited international research, we assume that if this attribute is not managed in the future, all three types (PC, BCM, FW) of cyanobacterial in coastal waters will increase in severity and frequency. This could have wide-reaching environmental, economic, and social impacts. For example, it could result in harvesting of seafood being restricted over certain periods and closure of beaches for recreational activities, and BCM mats could smother or impact important marine ecosystems (e.g., when tons of BCM mats were removed from Waiheke Island beaches, most of the shellfish beds that are necessary to feed colonies of native birds, were removed at the same time, impacting the food web).

D2. Where and on who would the economic impacts likely be felt? (e.g., Horticulture in Hawke's Bay, Electricity generation, Housing availability and supply in Auckland)

There is insufficient data on all cyanobacterial types (PC, BCM, FW) in coastal waters in Aotearoa New Zealand to determine this. However, given the recent issues in Auckland, we highlight this region where blooms of BCM have had a significant impact. BCM can wash up on the beach which results in access being restricted, impacting locals and tourism. The toxin detected in shellfish may impact the aquaculture industry. For example, the harvest and consumption of shellfish was prohibited by the Ministry for Primary Industries during the 2023 bloom (https://www.mpi.govt.nz/news/media- releases/public-health-warning-shellfish-biotoxin-alert-for-waiheke-island/). Removal of the BCM bloom from beaches on Waiheke Island cost approximately $250k in 2022 and $450k in 2023. An example of where FW bloom have had an impact on coastal waters occurred in 2004 in the Hokianga Harbour. Lake Omapere experienced severe cyanobacterial blooms, and these reached the Hokianga Harbour via the Utakura River. Cyanotoxins were then detected in oysters in the harbour prohibiting harvesting for a significant period [22, 28].

D3. How will this attribute be affected by climate change? What will that require in terms of management response to mitigate this?

Given the limited knowledge on cyanobacteria in coastal waters in Aotearoa New Zealand, we are unable to comment on this with any certainty. There is strong evidence that climate change will impact cyanobacteria in freshwater in Aotearoa New Zealand [29]. If freshwater blooms increase, then it is likely that the effect of FW cyanobacteria on coastal waters will also intensify. International studies suggest that climate change will increase the occurrence of BMC [6].

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