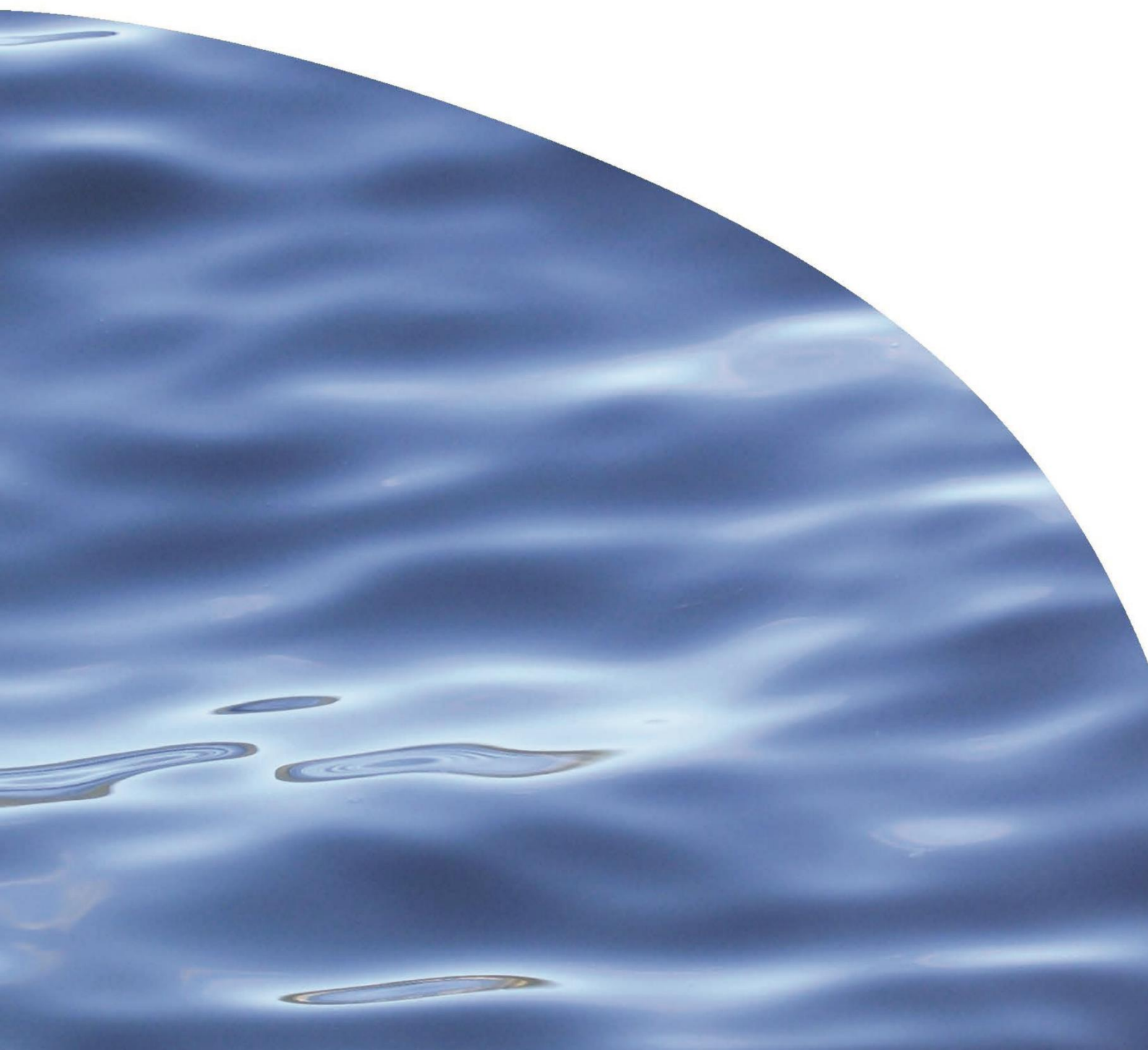


REPORT NO. 3181

**SUMMARY OF A REVIEW WORKSHOP ON THE
'NEW ZEALAND GUIDELINES FOR
CYANOBACTERIA IN RECREATIONAL FRESH
WATERS'**



SUMMARY OF A REVIEW WORKSHOP ON THE 'NEW ZEALAND GUIDELINES FOR CYANOBACTERIA IN RECREATIONAL FRESH WATERS'

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EXECUTIVE SUMMARY

The 'Interim New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters' were released by the Ministry for the Environment (MfE) and the Ministry of Health (MoH) in 2009. Knowledge on cyanotoxin-producing species, cyanotoxin production and toxicity, and methods for detection and monitoring have advanced markedly since the release. Additionally, new issues related to potentially toxic cyanobacteria have emerged that are not covered by those guidelines. Furthermore, while some aspects have been adopted nationwide, others need refining based on feedback from key stakeholders.

The Cawthron Institute, the University of Waikato, the National Institute of Water and Atmospheric Research (NIWA) and Griffith University, Australia, were contracted by MfE to undertake a review of the 2009 guidelines. An end-user workshop was held on Monday 7 May 2018 at MfE in Wellington as part of that review and is the subject of this report. In addition to the authors of this report, the workshop was attended by regional, district or city council scientists, District Health Board and MfE staff.

Based on the results of a survey prior to the workshop, the following six topics were discussed:

1. Planktonic cyanobacteria
2. Benthic cyanobacteria
3. Communicating risk
4. Emerging issues
5. New technologies
6. Appearance and functionality of guidelines

These sessions raised many ideas and opportunities that if actioned will improve cyanobacterial monitoring and management in New Zealand. The below lists recommendation that are included as part of the Guidelines Review project, and our suggested high priority recommendations that are not part of the current project.

Recommendations included as part of the Guideline Review project

- Restructuring the planktonic threshold table.
- Review of sections related to sampling planktonic cyanobacteria.
- Identify the 'next-steps' for risk modelling related to benthic cyanobacteria.
- Review the communication section of the guidelines.
- Include a section on benthic cyanobacteria in lakes.
- Include a section on the possibility of freshwater toxins affecting marine environments, strain variability and the possible impact of climate change on cyanobacterial blooms.

- Incorporate toxin gene screening as an option to guide selection of 'Situation' in alert table.
- Provide a recommendation on the layout/appearance of the new guidelines in the final report.

Not included as part of the Guideline Review project

- Update biovolume table using available data and develop an 'online biovolume calculator'.
- Review of methods for picocyanobacteria identification and enumeration.
- Develop new education and communication material.
- Include a section on emerging technologies and how these could be integrated into monitoring programmes.
- Support further research related to benthic cyanobacteria in lakes.

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1. INTRODUCTION

The 'Interim New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters' were released by the Ministry for the Environment (MfE) and the Ministry of Health (MoH) in 2009. Knowledge on cyanotoxin-producing species, cyanotoxin production and toxicity, and methods for detection and monitoring have advanced markedly in the last nine years. Additionally, new issues related to potentially toxic cyanobacteria have emerged that are not covered by the 2009 guidelines. Some aspects of the 2009 guidelines have been adopted nationwide, and others need refining based on feedback from key stakeholders.

The Cawthron Institute (Cawthron), the University of Waikato, the National Institute of Water and Atmospheric Research (NIWA) and Griffith University, Australia, were contracted by MfE to undertake a review of the current interim guidelines, to update and finalise sections where feasible, and to identify what further knowledge is required and how this can be obtained.

The guidelines review project involves five stages:

- Stage 1 – Hold an end-user workshop to gather feedback on aspects of the guidelines that are and are not working, and to identify additional areas that need to be addressed.
- Stage 2 – Conduct a review of cyanobacteria and toxin literature and data from New Zealand undertaken between 2009-2017.
- Stage 3 – Update microcystin quota values based on new data, and if appropriate use these to revise the planktonic thresholds.
- Stage 4 – Identify knowledge gaps and plan the next steps required to develop benthic cyanobacterial thresholds.
- Stage 5 – Produce a final report incorporating the finalised sections (where feasible) and provide recommendation for further work.

This report summarises Stage 1. An end-user workshop was held on Monday 7 May 2018 at MfE in Wellington. In addition to the authors of this report, the workshop was attended by 16 regional, district or city council scientists, eight District Health Board staff and two MfE staff (Appendix 1).

Prior to the workshop an online survey was conducted to identify key areas of concern for discussion at the workshop. The survey was customised for participants from either councils or district health boards. The full results of the survey are provided in Appendix 2. Based on survey results, the following seven topics were discussed during the workshop (full agenda in Appendix 3):

1. Planktonic cyanobacteria
2. Benthic cyanobacteria

3. Communicating risk
4. Emerging issues
5. New technologies
6. Appearance and functionality of guidelines.

The workshop introductory session included presentations from:

- Susie Wood (Cawthron) on cyanobacteria and background on how and why the 2009 guidelines were developed (Appendix 4),
- Jonathan Puddick and Susie Wood (Cawthron) on recent MfE-funded projects on toxic cyanobacteria (Appendix 5),
- David Hamilton (Griffith University) on the unique attributes of planktonic cyanobacteria that make sampling and monitoring their abundance challenging (Appendix 6), and
- Graham McBride on associating risk based on pathogen indicator species and how similar approaches could be used in the cyanobacterial guidelines.

Workshop sessions 1 to 3 were undertaken as 'break-out' workshops in small groups, whereas sessions 4 to 6 involved short presentations with feedback sought from everyone.

Prior to Session 1 on Planktonic Cyanobacteria, Penny Fairbrother (Greater Wellington Regional Council; GWRC) presented on the methods GWRC has used to communicate the risk related to benthic cyanobacteria in rivers (Appendix 7).

During Session 4 on Emerging Issues, some examples of benthic cyanobacteria in lake systems were presented (Appendix 8).

Session 5 on New Technologies began with a presentation from Dr Mark Heath (GWRC) on the use of drones for monitoring benthic cyanobacteria in rivers (Appendix 9) followed by summaries of other potential new technologies (Appendix 10).

Detailed notes were written following the workshop, and attendees were offered the opportunity to view and contribute to these one week after the workshop (Appendix 11).

The following sections of this report provide a brief synopsis of each workshop session and highlight the key recommendations or action points. These will be further elaborated on in the final project report (due September 2018).

2. PLANKTONIC CYANOBACTERIA

Many challenges were identified associated with monitoring and assessing planktonic cyanobacteria. These are documented in further detail in the workshop notes (Appendix 11). In this section we focus on the topics that received the greatest collective attention.

2.1. Cell biovolumes

The 2009 guidelines advocated for a shift away from the previous protocol that was based on warnings being issued when cell counts exceeded 20,000 cells mL⁻¹, to incorporating biovolumes. The rationale was that cell counts do not account for the inherent differences in the size of different species of cyanobacteria. This is particularly relevant when the cyanobacteria present are very small (i.e., picocyanobacteria; < 2 µm). In lakes dominated by picocyanobacteria, health warnings would be issued unnecessarily when there were > 20,000 cells/mL but their biovolume was small in comparison to larger species. The 2009 document provides a table of expected biovolumes for 22 species. Issues encountered with biovolumes in the last nine years include (further detail provided in Appendix 9):

- Biovolumes within a species are highly variable seasonally and can be regionally- (or lake-) specific.
- Accurate biovolumes are critical for issuing warnings when levels approach guideline limits but commonly taxa are only identified to genus level.
- Many taxa have been identified in samples but are not in the 2009 biovolume list. This has resulted in additional cost, and/or estimated biovolumes being used (which may be inaccurate).
- There is no known relationship between toxin content and biovolume of toxic cell, although research exploring these relationships is lacking.

Recommendations:

Many regional councils have determined specific biovolumes for species present in their lakes:

- A review of this data should be undertaken and an updated biovolume table provided.
- This should include interpretation on spatial and temporal variability (if possible from the datasets acquired).
- Investigate whether preserving samples using Lugol's iodine causes cell shrinkage, and determine how this might impact calculated biovolumes.
- It would be valuable if there was a mechanism for species-specific biovolumes to be updated regularly.

In view of new knowledge obtained since the draft guidelines were issued the planktonic thresholds can now be restructured. We recommend that they include a combination of cell counts (for known toxic species) and biovolumes for all other taxa. Research undertaken in New Zealand over the last 10 years has now established three planktonic taxa as toxin producers (*Microcystis* spp., *Nodularia spumigena* and *Cuspidothrix issatschenkoi*). Cell count thresholds could be developed for each of these taxa based on measured cell toxin quotas (i.e., toxin produced per cell).

A mock threshold table for planktonic cyanobacteria alerts is provided below. The values provided need further investigation and are provided as indicative only. Further discussion and refinement is required and will be on-going through this project. In particular, there is a need to stress that it is highly likely that there are other planktonic toxin producing species that have not yet been identified or tested. A strong recommendation in the new guidelines should be that toxin gene screening, or toxin testing should continue, in parallel with cell counts, until a detailed knowledge of the toxin-producing capabilities of taxa within a specific lake system has been obtained.

Decision Chart 1. Mock-up of possible modifications to the planktonic alert-level framework for planktonic cyanobacteria. The numbers here are for display purposes only and further refinement of these is required.

Alert level
<p>Surveillance (green mode)</p> <p>Situation 1: The cell concentration of total cyanobacteria does not exceed 500 cells/mL</p> <p>Situation 2: The biovolume equivalent for the combined total of all cyanobacteria does not exceed 0.5 mm³/L</p>
<p>Alert (amber mode)</p> <p>Situation 1:</p> <p><i>Microcystis</i> spp. < 19,000 cells/mL *</p> <p><i>Nodularia spumigena</i> < 15,000 cells/mL *</p> <p><i>Cuspidothrix issatschenkoi</i> < 20,000 cells/mL *</p> <p>Situation 2: 0.5 to < 10 mm³/L total biovolume of all cyanobacterial.</p>
<p>Action (red mode)</p> <p>Situation 1:</p> <p><i>Microcystis</i> spp. ≥ 19,000 cells/mL *</p> <p><i>Nodularia spumigena</i> ≥ 15,000 cells/mL *</p> <p><i>Cuspidothrix issatschenkoi</i> ≥ 20,000 cells/mL *</p> <p>Situation 2: ≥ 10 mm³/L total biovolume of all cyanobacteria; or</p> <p>Situation 3: Cyanobacterial scums consistently present.</p>

EXAMPLE ONLY

* These are indicative numbers only - further assessment is required. Consideration also needs to be given to a scenario where these taxa co-occur.

2.2. Representativeness of sampling due to large spatial and temporal variability

The design of monitoring programmes and sampling for planktonic cyanobacteria is challenging due to factors such as cyanobacteria's ability to grow in open waters, the ability of some species to regulate their buoyancy, and their ability to form scums that may be shifted and concentrated by wind and currents. However, these are long-standing and well-known issues.

Recommendations:

The current guidelines provide information on site selection and sampling, for example

...factors, monitoring programmes for planktonic cyanobacteria should be tailored to the characteristics of each water body. They also need to be flexible to take account of changes in the risk posed by rapid changes in the cyanobacterial populations with time and location...Collection of historical information on blooms and growth conditions, and the identification of patterns of cyanobacterial growth, can be used to help focus the monitoring programme on critical periods and locations in the water body of interest.

We believe the recommendations in this section are still relevant and best practice, but we suggest a detailed literature review and discussions with international colleagues to determine if alternative approaches are available.

Phycocyanin sensors and remote sensing have potential to enhance the monitoring of planktonic cyanobacteria. These are discussed further in Section 6. Considerable research and validation will be required before these can be incorporated into routine monitoring programmes. We recommend that organisations involved in monitoring or regulating cyanobacteria support research and validation into the use of phycocyanin sensors and remote sensing.

2.3. Picocyanobacteria

Picocyanobacteria (usually defined as having a cell diameter < 1-2 μm) occur in all lakes in New Zealand. They are abundant in many oligotrophic lakes (e.g., Wakatipu, Wanaka, Manapouri, Coleridge), where they form an important part of the microbial food web (Bayer 2013). More recently, picocyanobacteria have been detected in eutrophic coastal lagoons where they can reach very high concentrations, which has led to health warnings (e.g., Te Waihora, Waituna Lagoon). They also occur in lower concentrations in almost all lakes throughout New Zealand. The key concern regarding picocyanobacteria identified during the workshop were:

- accurate species identification and quantification (current results from different laboratories can vary by orders of magnitude)
- uncertainty as to whether picocyanobacteria in New Zealand produce toxins (they have been shown to overseas).

Recommendations:

A review of identification and enumeration methodologies available for picocyanobacteria should be undertaken. Further discussions are required if standard methodologies (i.e., Utermöhl chambers and light microscopy at up to 600×) are insufficient to identify these taxa. It may not be feasible to include them in the guidelines if analysis methods are inaccurate or cost prohibitive.

Further analysis using either the toxin gene screen method (see Section 6) or chemical analysis of samples with high concentrations of picocyanobacteria is required to gain a better understanding of whether picocyanobacteria in New Zealand produce toxins.

3. BENTHIC CYANOBACTERIA IN RIVERS

A number of challenges associated with monitoring benthic cyanobacteria were identified. These are documented in further detail in the workshop notes (Appendix 11). In this section we focus on the two topics that raised the greatest concern.

3.1. Relationships with cover and detaching mats, and health risk

Recommended guidelines for monitoring benthic cyanobacteria (primarily *Phormidium*) were introduced in the 2009 guidelines. To our knowledge this was the first attempt to create benthic cyanobacterial guidelines internationally. The 2009 guidelines acknowledged that the thresholds (given as percent cover) were preliminary and would require refinement.

Workshop participants found Alert and Action modes required similar responses and more clarity was needed between 20–50% cover response and the > 50% response. Alert and Action modes both require notification and consultation with public health units for ongoing assessment hence the > 50% was not seen as undertaking significantly different action than the Alert 20–50% cover response.

Cyanobacterial mats can detach from the substrate and may accumulate along river edges under certain environmental conditions. During these events the risk to human and animal health is higher due to the accessibility of the cyanobacterial mats to river users. In the 2009 guidelines the occurrence of detaching mats also triggered the highest alert level ('Action') and workshop participants found this problematic as a single detached mat could trigger an action response.

Wood et al. (2015a) also identified issues associated with the limited scientific robustness of the percentage cover thresholds, and highlighted important gaps in international knowledge on the toxicity of anatoxins (the toxins produced by *Phormidium* in New Zealand). To address these gaps MfE has funded a project to determine the acute toxicity to mice of three of the four anatoxin congeners by intraperitoneal injection, gavage and voluntary consumption. Completion date for this work is September 2018 and will provide new information on the toxicity of two anatoxin congeners which have never been assessed before. Work on assessing the toxicity of the fourth anatoxin congener abundant in New Zealand (*Phormidium*) has not yet been funded, but feasibility assessments are underway. This research is needed to understand how toxic anatoxins are (this information is not available internationally) so that acceptable exposure limits can be determined.

A project to assess the level of anatoxins released from *Phormidium* mats into river water demonstrated that release of toxins does occur and was related to the severity and amount of toxins in the *Phormidium* mats on the river bed (Wood & Puddick

2018). Further work would be required to quantify the relationship between bloom severity and the level of anatoxin released into the river water.

Stage 4 of the Guidelines Review project aims to identify what additional information is required to develop risk models and to explore whether robust thresholds can be developed for *Phormidium* in New Zealand rivers.

Recommendations:

Following the completion of the *Phormidium* Toxicity project and Stage 4 of the Guidelines Review project, we recommend that risk modelling is pursued. Any additional information required for risk modelling will be identified during Stage 4 of the Guidelines Review project. Consultation with regional council staff should also be undertaken, to ensure that new thresholds can be implemented without being time- or cost-prohibitive. Issues related to detaching mats should be discussed further and incorporated into the risk modelling, including the issue of river-specific thresholds. Therefore, they should be given consideration during Stage 4 of the Guidelines Review project.

In the interim, a review could be undertaken of *Phormidium* cover data collated as part of the MfE-funded project to develop a national model to predict susceptibility of rivers to *Phormidium* blooms (Wood et al. 2017). This data could be used to assess maximum cover in a range of rivers and might provide additional knowledge for defining suitable thresholds for *Phormidium* in rivers.

3.2. Representativeness of sampling due to large spatial and temporal variability

Phormidium mats are patchily distributed and are influenced by a wide range of factors such as: river flow, water velocity and depth, substrate size and stability and the presence of grazers. Current survey methods work well in wadable rivers if implemented at sites with known *Phormidium* blooms. They do not work well in rivers with non-wadable areas and/or if a very small stretch of a river is surveyed (usually a transect < 50 m).

Recommendations:

A compelling case was made at the workshop for the use of unmanned aerial vehicles (UAVs; commonly known as drones) which would allow a large stretch of river to be surveyed rapidly (see Section 6 and Appendix 9). However, further research is required to validate this methodology and to properly assess its limitations and the opportunities it could provide. There was strong interest in a regional council-led Envirolink Tools application to fund this work, and we support the development of an application.

4. COMMUNICATING RISK

The discussion on communicating the risk associated with cyanobacteria blooms centred on the current methods used to communicate the risk and the challenges associated with this. These are documented in further detail in the workshop notes (Appendix 11).

In the 2009 guidelines, the main recommendations on communicating the potential health risk of cyanobacteria blooms to the public were via media releases and erecting warning signs at the affected water bodies, and an example of a pamphlet on toxic cyanobacteria was also provided as an appendix. Whilst this strategy was standard practice at the time, communication strategies have evolved greatly since then and regional councils/public health units are currently using a wide range of media to communicate cyanobacterial health risks to the public:

- use of conventional media, e.g., TV, radio, newspapers
- use of social media, primarily Facebook, but also Twitter and Neighbourly
- commissioned advertising, e.g., paid advertorials in local papers, internet advertising, social media 'boosts', advertisements on council vehicles
- website information, e.g., council websites, Land, Air, Water Aotearoa (LAWA)
- bathing updates sent to representatives of wider interest groups, e.g., local iwi, clubs that use recreational bathing sites
- warning signs at bloom sites
- educational videos
- information pamphlets
- the creation of fictional characters (e.g., the use of a named dog to 'talk' to other dogs) to enhance communication and response from the public
- competitions and promotions to raise awareness.

The updated guidelines should provide end-users with more up-to-date guidance on modern-day best practice. Flexibility in the communications strategy used between the regions was desired by the workshop participants, but there was agreement that nationally-consistent terminology and wording of key phrases would be useful for avoiding confusion and mixed messages.

Education was identified as a valuable tool that can be used to increase public knowledge on cyanobacteria risk and to engage with a greater number of recreational water users. Because regional/district councils do not have the resources to monitor every waterway in their region, public education can support the safe use of waterways without requiring site-specific warnings. However, several workshop participants highlighted the need to avoid information saturation and advised that different messaging should be used throughout an educational programme, and that the overall issue should be broken down into more easily digestible bites of

information. To improve the ability of agencies to provide successful education strategies, there was support for the development of a database of educational resources such as; photos, videos, FAQs, infographics and case studies. Education could also be provided through websites such as LAWA.

Some of the challenges workshop participants faced in communicating the risk cyanobacteria blooms pose and 'closing' recreational sites were:

- the delay in being able to send out communications (i.e., confirming the transition to 'Action' or downgrading the risk) because of the time taken to get analytical results. This can lead to the public becoming desensitised to the message as they view it as ineffective when it comes too late or meaningless when it is present for too long.
- inconsistencies with risk communication strategies between regions and managing this while accounting for inter-regional variability and region-specific issues.
- managing inter-agency roles and responsibilities regarding risk communication.
- public engagement and attention to communications about cyanobacterial risks (e.g., signage erected at freshwater bloom sites) can be ineffective as it is largely ignored by the public.

In response to these issues there was general support for a national approach to communicating the risks of cyanobacterial blooms in recreational waters. Workshop participants noted how the LAWA website had facilitated a consistent national approach to communicating water quality information to the public. However, when it comes to risk communication, LAWA is not presently the ideal platform because of the time it takes for information to become visible to the public. Other ideas for a nationally coordinated approach included using GPS-based apps where health warnings were automatically issued to users in the area.

Some workshop participants indicated that there can be difficulties in coordinating the roles and responsibilities among multiple agencies involved in communicating cyanobacteria bloom events. They expressed a need for stronger guidance around how agencies in the same region might work better together and advice on the legislation that underpins each agency's legal responsibilities to partake in the assessment and communication of risk associated with cyanobacteria. A strategy used by some workshop participants was an annual pre-season meeting between all the regional agencies to agree upon who would perform each role prior to the first bloom event occurring and to ensure that there was sufficient resourcing to undertake this. Section 2.4 of the current guidelines provides a clear suggested framework of the required roles and suggestions for which agency would be most 'ideally suited' to fill each of these roles, whilst also providing flexibility to tailor the framework for each region. The current guidelines do not provide advice on any legal responsibilities of the various agencies apart from stating that: 'This protocol should be based on each agency's respective legislative functions relating to recreational water-quality

monitoring and reporting.’ The current guidelines do not acknowledge that the process of assigning roles and responsibilities needs to be conducted on a regular basis to compensate for the changes in resourcing which can occur over time and to refresh the memory of the people involved in the monitoring and communication.

Recommendations:

Formation of a working group to 1) develop guidelines on best-practice for communicating the risk of freshwater cyanobacteria and, 2) explore what a nationally-coordinated approach might look like. Group members should include those who have previously undertaken communication work on toxic cyanobacteria risk. The group would be well-positioned to develop a set of effective terminology / key phrases to include as an appendix in the guidelines and to select appropriate educational resources to include as appendices.

Examples of different communication strategies and educational material should be provided as an appendix. The updated guidelines should clearly delineate between what types of communication are required in response to reaching ‘Action’ status.

Section 2.4 of the guidelines should more clearly state the obligations of the various agencies involved in recreational water-quality monitoring and reporting, whilst still maintaining its present flexibility to allow region-specific tailoring. This section should also include advice on how regularly the delegation of roles and responsibilities should be discussed.

5. EMERGING ISSUES

Four issues were identified. The first of these (benthic mats in lakes) received the most attention.

5.1. Benthic cyanobacteria in lakes

Although toxic benthic cyanobacteria have been identified in multiple lakes (see Wood et al. 2015a for a full review), the main focus of the discussion centred on the Lake Taupō event in December 2017.

In December 2017, unusually warm water temperatures and calm conditions in Lake Taupō resulted in the mass accumulation of algal flocs in an embayment. Fortunately, this was dissipated quickly through wind movement. Some of these flocs contained cyanobacteria known to produce toxins in New Zealand, or in other countries. Consequent sampling found the remaining mat material contained a variable but generally low percentage of these cyanobacteria.

During this 2017 event, a precautionary approach was taken and many bays were 'closed' briefly for recreational activities, until the mat material could be assessed. This resulted in significant disruption to planned recreational events and economic loss to the region. The potential for future benthic cyanobacteria bloom occurrences in lakes is not covered currently in national or international guidelines describing how to monitor benthic cyanobacteria in lakes, nor is information provided on whether benthic cyanobacteria can affect the use of lakes for recreational purposes.

Recommendations:

Further research is required to fill the following knowledge gaps identified in the workshop:

1. Do the benthic cyanobacteria contain toxins, if yes, which species are the producers?
2. What methods are available to monitor benthic algae/cyanobacteria in lakes?
3. Can these methods be incorporated into routine monitoring programmes?

Further funding is required to address Question 1, and given that this event is likely to occur again, we suggest that this research is high priority. Questions 2 and 3 could be addressed by a review of survey methods that have been used in other environments or in other parts of the world, however ground-truthing of these would be required in Lake Taupō.

Until further research is undertaken, a section of the new guidelines should document the current knowledge, highlight the potential risks, and provide possible actions that

could be undertaken to refine risk assessments (e.g., toxin gene screening or toxin testing of mats).

5.2. Impact of freshwater toxins on marine environments

Many freshwater systems that contain cyanobacteria flow into estuaries or sheltered coastal environments. Examples in New Zealand include the Kaituna River which is the outflow of Lake Rotorua and Rotoiti and drains into the Maketu Estuary, and the Utaura River which is the outflow of Lake Omapere and flows into the Hokianga Harbour. International research has shown that cyanotoxins from freshwater sources can accumulate in marine organisms and pose a health risk to humans and marine organisms (e.g., Miller et al. 2010; Gibble et al. 2016).

Recommendations:

Further research is required to identify whether there is a significant risk in New Zealand from freshwater toxin transfer to marine environments. The research could include a desktop exercise to identify high risk areas, followed by sampling campaigns at these sites. It was acknowledged that because this is a food safety issue, it may need to be addressed by the Ministry for Primary Industries. Until further research is undertaken, a section of the guidelines should (based on international literature) highlight the potential risk, and suggest times when extra care might be required. It should also document how sampling could be undertaken if there was reason for concern.

5.3. High variability among cyanobacterial strains

Recent research continues to highlight high intra-species (or strain) level variability. For example, strains within the same species have different growth rates, produce different amounts of toxins, and have different cell volumes and different light and temperature optima (e.g., Wood et al. 2012; Willis et al. 2016; Xiao et al. 2017; Willis et al. 2018). This new knowledge adds to the complexity of trying to predict cyanobacterial blooms and the associated risk.

Recommendations:

A section of the new guidelines should include a summary of the latest advances in this field. Given the high variability in cell biovolumes, it may be advisable not to use this metric when defining thresholds for toxin species (see recommendations in Section 2). As toxic and non-toxic strains of the same cyanobacteria species cannot be distinguished by microscopy, the guidelines should encourage the use of toxin gene screens or toxin testing to better understand the risk.

5.4. Effect of climate change on cyanobacterial blooms

Climate change is predicted to enhance cyanobacterial blooms through many mechanisms, for example:

- increased water temperature which may selectively promote cyanobacteria as their growth rates are optimised at higher temperatures (compared to other phytoplankton e.g., Wood et al. 2015b)
- warming of surface waters will intensify vertical stratification increasing the potential for buoyant cyanobacteria to accumulate at the surface (Hamilton et al. 2013)
- increased storm events will result in greater nutrient and sediment run-off into lakes (Wood et al. 2017)
- hydrological change may result in longer periods of stable flows leading to more prolific benthic cyanobacterial blooms in rivers.

Recommendations:

A section of the guidelines should include a summary on the potential impacts of climate change on cyanobacteria in New Zealand. If possible, recommendations to mitigate these effects, such as destratification of lakes and engineered flushing flows in rivers should be included.

6. NEW TECHNOLOGIES

Six technologies that could assist in cyanobacterial or cyanotoxin monitoring were presented (Appendices 9-10). There was support from the workshop participants for an emerging technology toolbox approach to be included in the guidelines, where information would be provided on the developing technologies along with guidance on how they might be integrated into cyanobacteria monitoring programmes.

Workshop participants suggested that of the methods presented, only cyanotoxin gene screening was potentially ready to be incorporated into the guidelines. This testing method has been validated and a commercial service is available through Cawthron. Alternatively, users can purchase commercial kits (excluding a screen for genes involved in anatoxin production) and run the assays themselves, although some capital expenditure on equipment is required. The toxin gene screen provides a relatively affordable and rapid method to determine whether toxin production genes are present in a sample and this could be used to inform which 'Situation' from the alert level framework is required; i.e., toxic or non-toxic cyanobacteria. It also overcomes other challenges such as ascertaining the inherent risk during previously un-encountered situations (such as the presence of benthic mats in Lake Taupō; see Section 5.1).

As noted in Section 3.2, UAVs or drones have the potential to assess percent cover of benthic cyanobacteria on large spatial scales and in areas that could not be surveyed using the current approach. Further research is required to assess the limitations and opportunities that UAVs offer. There was strong interest in a regional council-led Envirolink Tools application to investigate the feasibility of this technology further and to develop its potential.

Numerous studies have highlighted the benefits and limitations of phycocyanin sensors (e.g., Brient et al. 2008; Bastien et al. 2011; Hodges et al. 2016). Phycocyanin sensors are now deployed on many monitoring buoys throughout New Zealand. However, there is still some uncertainty on the robustness of the data and how best to utilise it. Further work to evaluate the data generated by *in situ* phycocyanin sensors is planned for the 2018/2019 summer, as part of the MBIE-funded Lakes Resilience programme (led by the University of Waikato).

Remote sensing has the potential to be used to assess cyanobacterial blooms at a regional or national scale. For example, it could be used to identify lakes with potential blooms, or at specific sites within larger lakes. Presently remote sensing can only detect chlorophyll (i.e., detects all phytoplankton, not specifically cyanobacteria), but the new Sentinel-3 satellite has the potential to measure phycocyanin. There are limitations that can restrict the usability of the technique (e.g., only assesses the top layer of the water, cloud cover and turbidity affect the signal), but it would allow

councils to target monitoring to the most relevant sites. The technique also requires further validation and if funded a MBIE Smart Ideas proposal (led by Waikato University) will further develop this technique.

Site-specific models that predict *Phormidium* cover are presently being developed. Two different approaches have been used to date and these will be documented in greater detail in upcoming reports (Thomson-Laing et al., in prep; Wood et al., in prep). Whilst further validation of these models is required, if they prove reliable, this may reduce the monitoring requirements in rivers until certain thresholds are predicted to be exceeded.

Models to simulate the occurrence of cyanobacteria blooms and toxin production have the potential to be extremely useful to authorities for providing predictions of risk, instead of assessments based on past measurements. The models require a major investment of personnel time, however, to collect flow, climate and water quality (e.g., nutrient) data, as well as to calibrate the model. Coupled hydrodynamic-biogeochemical models have been applied to individual lakes and have previously successfully simulated changes in lake phycocyanin concentrations associated with cyanobacteria blooms (Hamilton et al. 2014), but have yet to be used in a predictive or operational mode. Simpler models for predicting blooms can involve statistical or Bayesian modelling (Rigosi et al. 2015) which may include expert knowledge on bloom behaviour. Each of these approaches could be validated with *in situ* phycocyanin sensors that provide continuous real-time data suitable to sequentially tune the model to observations over time scales on which long-range weather forecasts are made (e.g., 7-10 days).

Using antibody-based 'dipstick' tests, real-time toxin results can be acquired in the field. Commercial kits are available for microcystin/nodularin, anatoxins, cylindrospermopsin and saxitoxins. Robust validation of these kits has not been undertaken in New Zealand, but if their detection limits prove reasonable then they could offer a method to rapidly determine which 'Situation' from the Alert level framework should be used (i.e., toxic or non-toxic cyanobacteria are present).

Recommendations:

There was support from the workshop participants for an 'emerging technology toolbox' approach to be included in the guidelines. This would include information on developing technologies, guidance on how they might be integrated into monitoring programmes, and how this could help guide decision making. The new guidelines should include the use of gene screening as a method for determining which 'Situation' in the Alert level frameworks should be used, and as a tool to assess the toxin-potential of samples. For example, if cells count exceeds defined thresholds, and the cyanotoxin gene test is negative, no toxin testing is required and the Alert level could be downgraded. Support should be given to endeavours to further develop and validate these new technologies.

7. APPEARANCE AND FUNCTIONALITY OF GUIDELINES

Although there were no issues identified with the overall structure of the 2009 guidelines, over 30 suggestions for improvements or additional sections/appendices were provided in the workshop. These were wide-ranging and included ideas such as additional fact sheets, an online biovolume calculator, a photograph database, and advice on the expected health symptoms following contact with cyanobacteria. Full details are provided in Appendix 11. We have undertaken a preliminary prioritisation of suggestions to highlight which are covered under the Guideline Review project (Appendix 12).

There was general support for an online 'living' document that would allow for specific sections to be updated as required. There were requests that sections and the entire guidelines document should also be 'printable' and available as a PDF. Workshop participants suggested that if updates were made to the document, that these would need to be dated and that the users should be notified. A mechanism to achieve this could be an online database identifying interested persons who would receive notifications on the guidelines document.

Recommendations:

Many of the recommendations for new sections are beyond the scope of the currently-funded project (e.g., the development of an online biovolume calculator). In many instances, the requested resources already exist regionally (e.g., information pamphlets for pet owners have been developed by GRWC and Nelson City Council / Tasman District Council) and only small modifications would be required to make them nationally applicable. In certain instances, the information is provided in the present guidelines document (e.g., guidance surrounding site selection). To better evaluate the merit of each suggestion we recommend that, in concert with MfE and MoH, the potential impact of each suggestion is evaluated in relation to the expected cost of implementing it so that the list can be further prioritised.

The next version of the guidelines should be web-based but with the ability to generate the full guidelines as a PDF. At the end of the current project we anticipate that new planktonic guidelines will be available, however work on the benthic thresholds will be on-going. This mode of presentation would allow the new benthic thresholds to be easily incorporated at a later stage.

8. CONCLUSIONS AND SUMMARY OF RECOMMENDATIONS

The workshop raised many ideas and opportunities that if actioned will improve cyanobacterial monitoring and management in New Zealand. We had anticipated some of these and they are included as part of the Guidelines Review project. However, many of them are outside the scope of the Guideline Review project and we recommend MfE and MoH, in concert with stakeholders, prioritise these. The list below includes the recommendations that will be addressed in the Guidelines Review project, and partly prioritises the remainder.

8.1. Recommendations included as part of the Guideline Review project

- Restructuring the planktonic threshold table
- Review of sections related to sampling planktonic cyanobacteria
- Identify the 'next-steps' for risk modelling related to benthic cyanobacteria and if available incorporate data from the *Phormidium* Toxicity project
- Review the communication section of the guidelines and update text (but not resources – see high priority below)
- Include a section on the visual appearance and potential risk of benthic cyanobacteria in lakes
- Include a section on the possibility of freshwater toxins affecting marine environments, strain variability and the possible impact of climate change on cyanobacterial blooms
- Incorporate toxin gene screening as an option to guide selection of 'Situation' in alert table
- Provide a recommendation on the layout/appearance of the new guidelines in the final report.

8.2. Not included as part of the Guideline Review project

We have partially prioritised these recommendations based on our opinions, but these may not necessarily represent those of stakeholders.

High Priority

- Update biovolume table using available data and develop an 'online biovolume calculator'.
- Review of methods for picocyanobacteria identification and enumeration, reconsider whether picocyanobacteria should be included in guidelines, and undertaken further testing to ascertain their toxicity in New Zealand.

- Develop communication materials, e.g., pamphlets, information signs, photos, videos, which can be used to educate the public on what to look for and potential risks. Workshop participants were open to providing their specific knowledge and the resources they had produced on cyanobacteria (e.g., data sets, images, information resources), and this may rapidly advance developing these resources.
- Support further research to fill knowledge gaps related to benthic cyanobacteria in lakes.
- Review the merit of each recommendation made by workshop participants regarding improvements to guidelines (Section 7). We have undertaken a preliminary prioritisation of these to show which are covered under the Guideline Review project (Appendix 12).

Medium

- Review *Phormidium* coverage data. This may help provide guidance on appropriate threshold (i.e., if 50% is very rarely reached this level may be too high).

8.3. Beyond funding scope of Ministry for Health/Ministry of Health but recommend they support

- Support a regional council-led Envirolink Tools application to investigate the feasibility of using UAVs (drones) for surveying rivers to determine *Phormidium* cover.
- Support endeavours to further validate new monitoring or detection technologies, such as phycocyanin sensors, predictive models, *in-situ* toxin tests and remote sensing.

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APPENDICES

Appendix 1. Workshop participants

	Name	Organisation
Workshop Organising Team	Susie Wood	Cawthron
	Jonathan Puddick	Cawthron
	Georgia Thomson-Laing	Cawthron
	Graham McBride	NIWA
	Karl Safi	NIWA
	Ian Hawes	Waikato University
	David Hamilton	Griffith University, Australia
Regional Council Representatives	James Dare	Bay of Plenty Regional Council
	Graeme Clarke	Environment Canterbury
	Shirley Hayward	Environment Canterbury
	Kate Sykes	Gisborne District Council
	Mark Heath	Greater Wellington Regional Council
	Penny Fairbrother	Greater Wellington Regional Council
	Anna Madarasz-Smith	Hawke's Bay Regional Council
	Janine Kamke	Horizons Regional Council
	Michael Patterson	Horizons Regional Council
	Steffi Henkel	Marlborough District Council
	Paul Fisher	Nelson City Council
	Alison McHugh	Northland Regional Council
	Roger Hodson	Southland Regional Council
	Darin Sutherland	Taranaki Regional Council
Deniz Ozkundakci	Waikato Regional Council	
Eloise Ryan	Waikato Regional Council	
District Health Board / Public Health Unit Representatives	Angela Sheat	Canterbury DHB
	Peter Wood	MidCentral DHB
	Andrew Watt	MidCentral DHB
	Gavin De Klerk	Northland DHB
	Jan Powell	Northland DHB
	Simone Jeffery	Public Health South (Southern DHB)
	Neil de Wet	Toi Te Ora Public Health (Bay of Plenty and Lakes DHBs)
	Jill McKenzie	Wellington Regional Public Health
MfE	Isaac Bain	Ministry for the Environment
	Kirsten Forsyth	Ministry for the Environment

Appendix 2. Results of a pre-workshop survey summarised by Regional Councils and District Health Boards / Public Health Units participants.

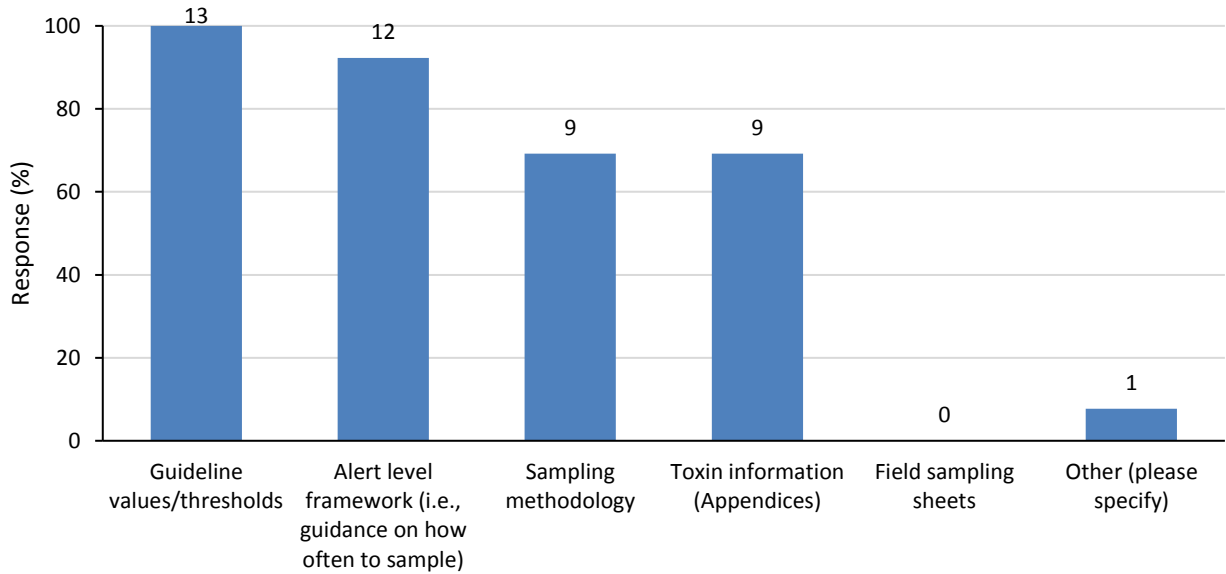
Pre-workshop survey responses from Regional Council participants

Does your council monitor planktonic and/or benthic cyanobacteria?

Benthic cyanobacteria only = 3
 Benthic and Planktonic cyanobacteria = 9
 Planktonic cyanobacteria only = 2
 Neither = 1

Planktonic Cyanobacteria

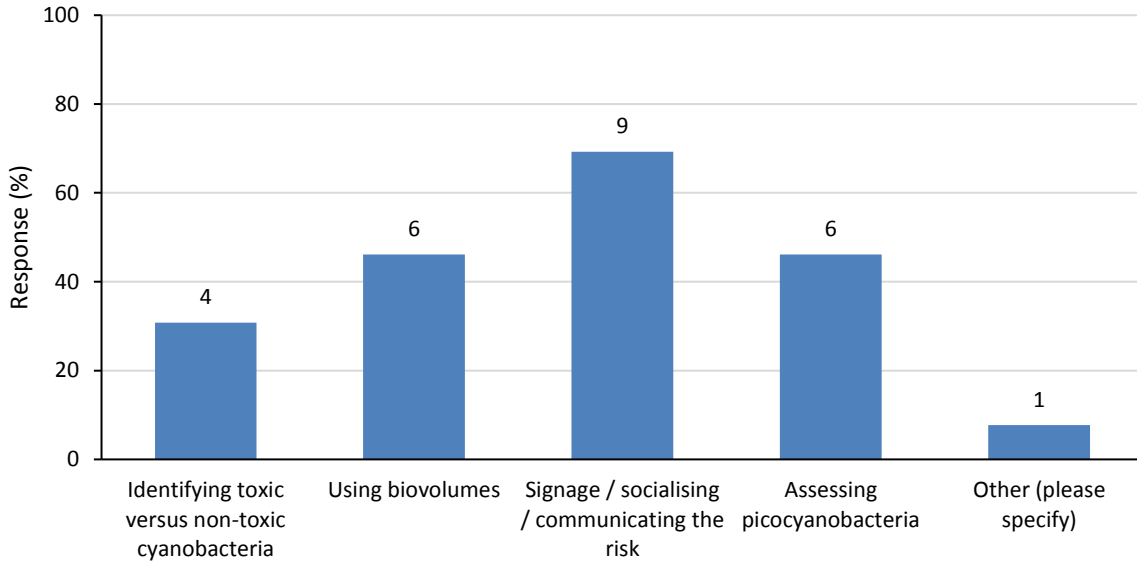
Which parts of the current guidelines do your council utilise for planktonic cyanobacteria?



Other:

- Use in house field sheets. Report based on Cawthron results

What are the biggest challenges your council encounters when using the guidelines and/or when managing planktonic cyanobacteria?

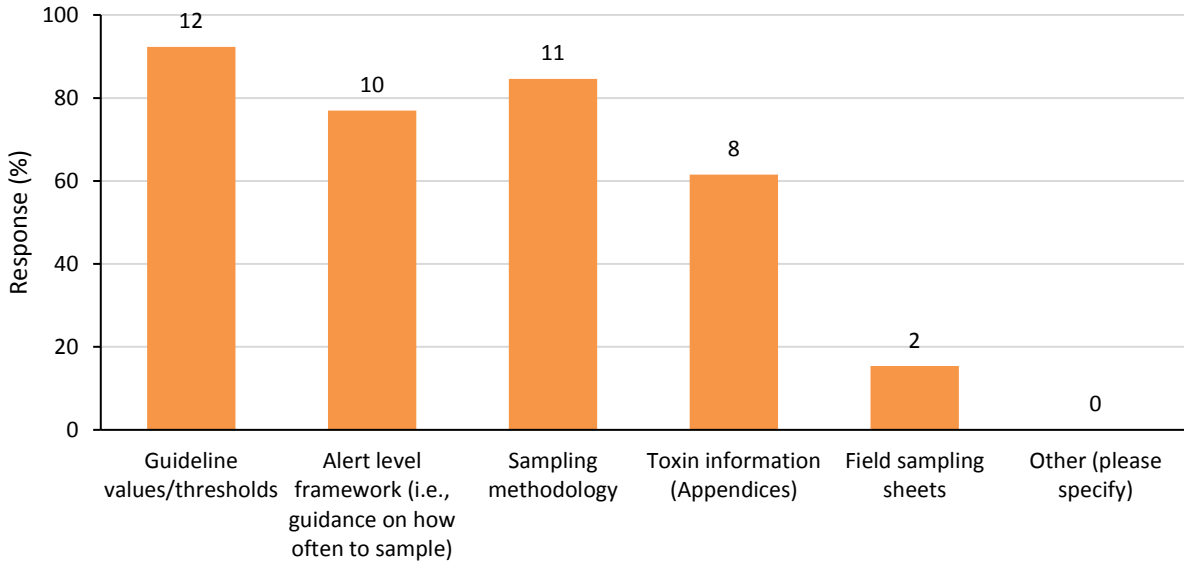


Other Challenges:

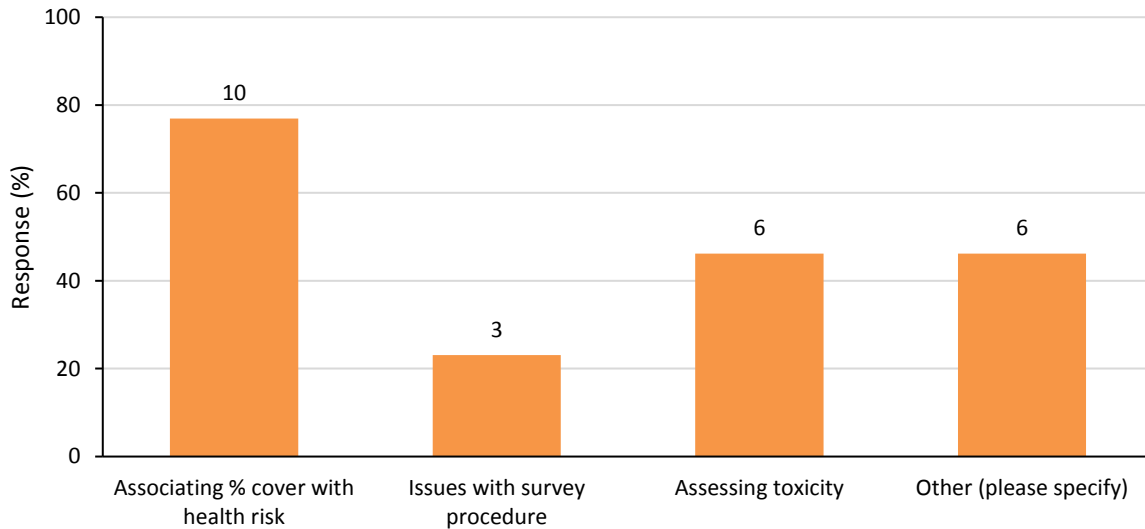
- Setting to a red alert when detaching or exposed mats are present but coverage is low, e.g. 2%. Not well received by the public. Warning loses its effect.

Benthic Cyanobacteria

Which parts of the current guidelines do your council utilise for benthic cyanobacteria?



What are the biggest challenges your council encounters when using the guidelines for benthic cyanobacteria?



Other Challenges:

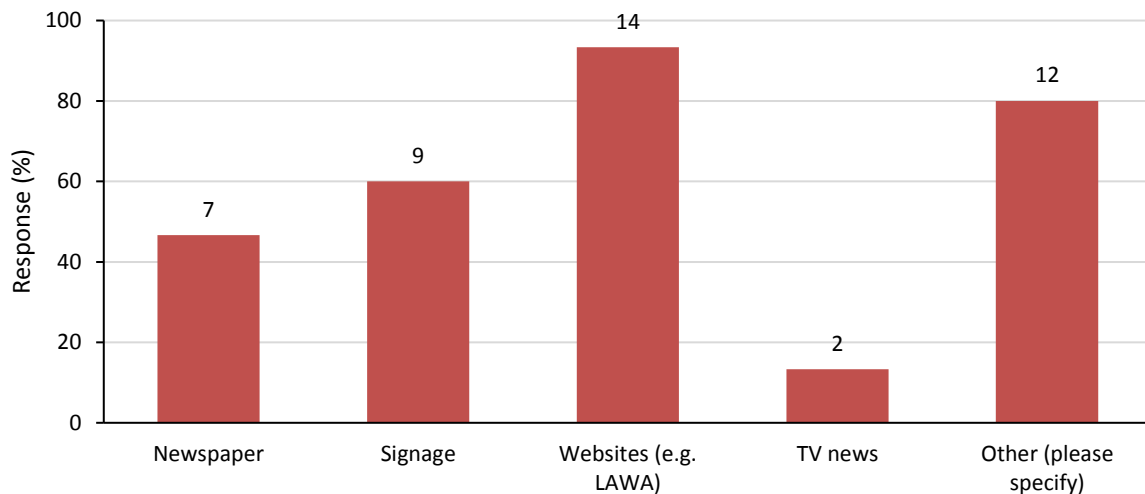
- signage, and timeframes regarding change in site status
- Associating detaching with health risk. Currently any level of detaching mat results in a red alert level for public health (i.e., advise people not to use the waterway). There can be less than 1% coverage, and only a single bit of mat that is detaching over the 20 views but that holds the maximum level of risk. This is clearly conservative but not sure this is appropriate.
- Associating detaching and exposed mats with health risk. Currently no guidance as to how much detaching mats or exposed mats needs to be present at a site to warrant Action level. We have modified the framework to have an Alert level for detaching and exposed mats if minor levels are present but we feel this does not warrant going to Action mode and closing a waterway to recreational users
- Constraining values around recreation with limited correlation between coverage and risk.
- Scale of potential issue - most Otago rivers may have benthic cyanos at some time. Local sampling site vs. risk from elsewhere in the catchment. Sampling at a site isn't necessarily representative of actual risk.
- We have had dogs die or nearly die with < 5% *Phormidium* cover. Cost of assessing toxicity means we don't do it.
- Questions related to human/animal consumption of fish, stock drinking water

Does your council alert the public when action levels for bloom events are reached?

Yes = 15 RCs

No = 1 RC

If yes, how does your council alert the public when action levels are reached?



Other:

- Social media
- Also, CPH. But we have not gone over 20%, so theoretical at this stage in terms of following through guidelines. We have made public statements when dogs have died, although the river in question was not over 20%.
- Close collaboration with public health as well. They advertise via radio etc. though this is more general (i.e., the fact that the risk exists).
- Lake warnings are also produced on BoPRC webpage
- Council newsletter
- We notify district council
- Signage is put up but this is done by the district council on advice from the district health board which receives information regarding cyanobacteria levels from TRC.
- Social media (Tank the Pug; google it)
- Signage is TAs except for at sites owned by us
- Media release
- Depending on the risk there are various communication plans.
- Facebook, media release, email to bathing governance group

Respondents were asked to specify any emerging issues with cyanobacteria in NZ that they had identified:

- The use of lookup tables for calculating biovolume is an outdated method. A more modern approach should consider seasonal variation of cell size and intra-specific trait variation. Site selection process can be biased and influences results.
- The use of standard species biovolumes for calculating total biovolume. Concerned about the possible variation in seasonal variability.
- Cyanobacterial mats in close proximity to (immediately upstream or in fact on) water intake structures for public drinking supplies. To the best of our knowledge there is no research that identifies the risk of cyanotoxins being released into the water column and its attenuation through a water treatment system.

Pre-workshop survey results from District Health Board / Public Health Unit participants**Does your District Health Board deal with planktonic and/or benthic cyanobacteria?**

Benthic cyanobacteria only = 1

Benthic and Planktonic cyanobacteria = 7

Planktonic cyanobacteria only = 1

Does your DHB alert the public when action levels for bloom events are reached?

Yes = 7 DHBs

No = 2 DHBs

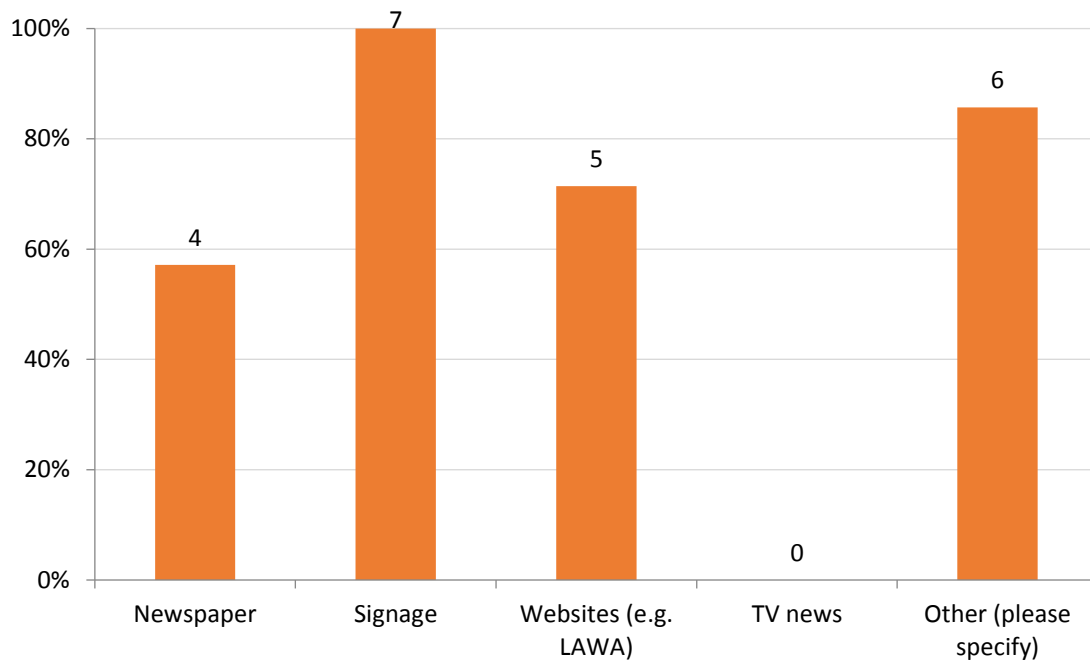
How often (per summer) does your DHB issue warnings for bloom events?

- 2-4
- 3-5
- Last summer (8), this summer (13)
- Highly Variable. This summer (50), ~ 20-40
- Warnings are issued in conjunction with partner councils and not independently. Summers are very variable from 0-1x up to several times
- Over the last few years no work has been undertaken in this area. The regional council and local councils are working together with the DHB to develop a regional approach to this work. So, for this most recent summer season, one warning was issued. It is envisaged that once the roles and responsibilities have been better defined/accepted by the agencies that communicating warnings will improve.

How many lakes and/or rivers are warnings issued for in your area?

- 2-6
- Approx. 3 - 5 different sites. Some sites may reach alert or action levels multiple times in a season.
- 9 rivers and 4 lakes warnings this year. Last summer 3 lakes and 5 river warnings
- Approximately 10, multiple sites on some rivers. ~10-15
- Variable but usually 1 lake and 1-6 rivers depending on the season
- One this past summer season 2017/2018

How does your District Health Board alert the public when action levels are reached?

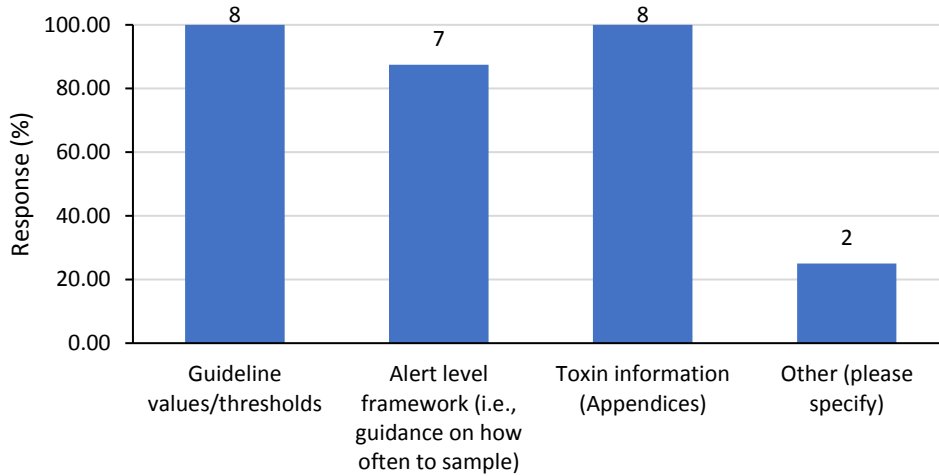


Other:

- Media release (which is variably reported by different media), social media, website, local signage
- the DHB website, not the LAWA website (could be an option though). Warning signs would be at the request of the DHB but undertaken by the TA.
- Our CPH website and the CDHB website. The local newspapers will put in articles about warnings and the Medical Officer of Health is sometimes interviewed by the local TV station.
- Some radio and contact with some newspapers.
- All done in conjunction with partner councils. Also, social media and DHB/Public Health Unit websites, Council websites ("is it safe to swim"); information signage vs warning signage; health practitioners' info alerts; TV news only if significant media interest; radio ads; texts to dog owners
- Social Media through TLAs, community groups, Iwi, hapu

Planktonic Cyanobacteria

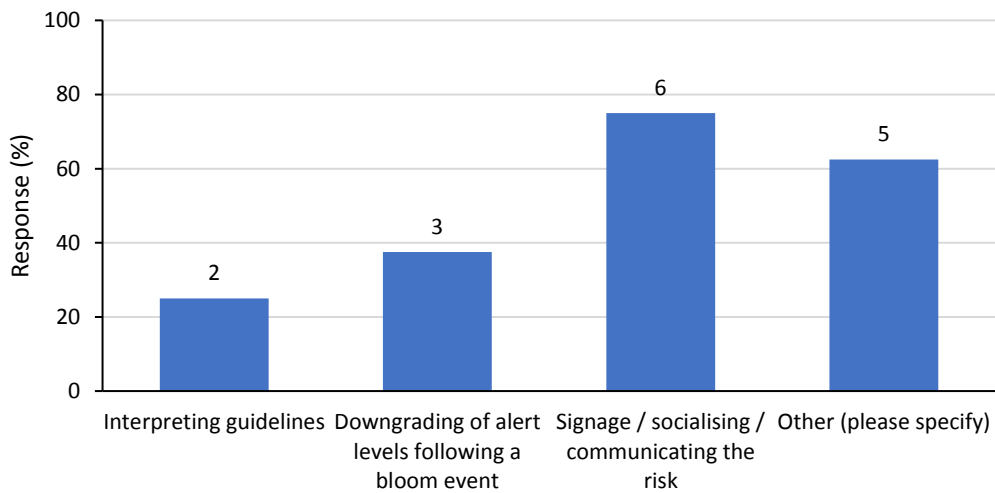
Which parts of the current guidelines do your District Health Board utilise for planktonic cyanobacteria?



Other:

- Adapted examples of media release and warning signage from guidelines

What are the biggest challenges your District Health Board encounters when using the guidelines for planktonic cyanobacteria?

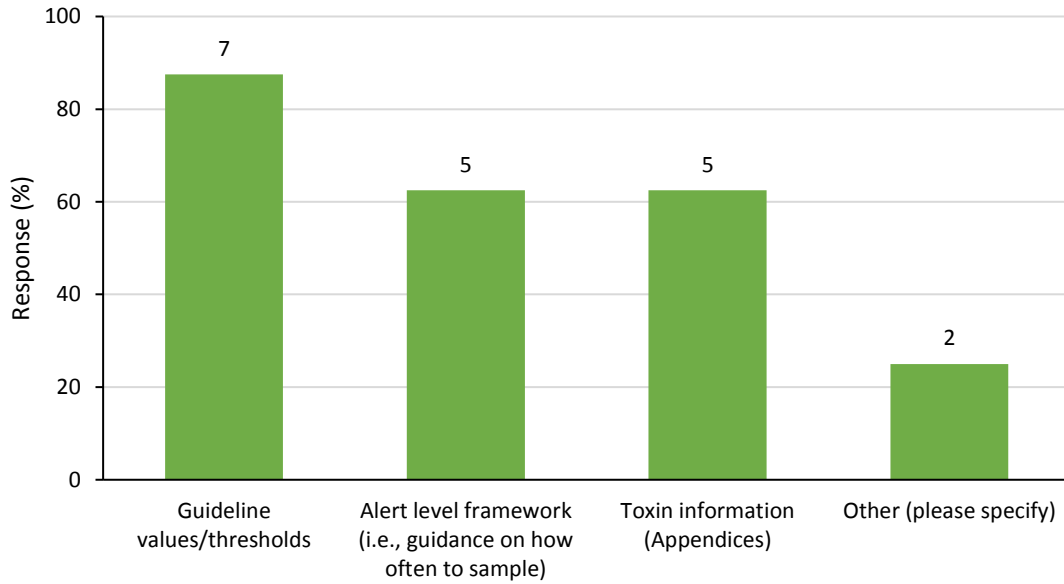


Other Challenges:

- Working with other partners (regional & district council) to determine public health risk based on sampling results.
- Assessing a mixed planktonic and benthic bloom in Lake Taupo
- Responses are delayed and often based on test results that don't represent the current situation as things change so quickly
- Benthic responses are the most challenging and decisions are made in conjunction with our council partners
- Lack of risk assessment tools, protocols in guidelines

Benthic Cyanobacteria

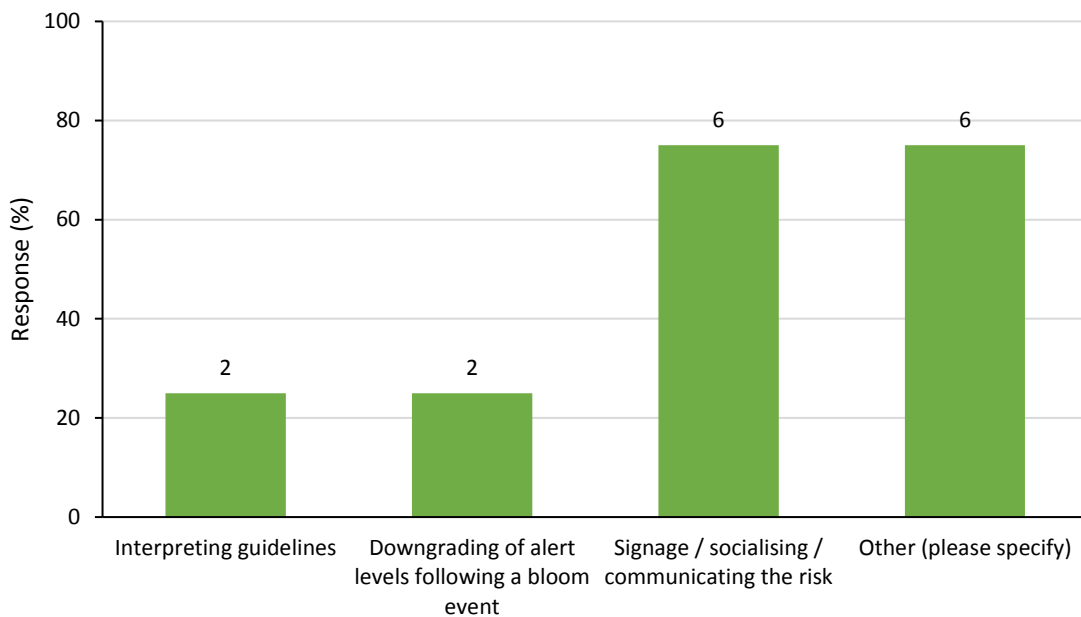
Which parts of the current guidelines do your District Health Board utilise for benthic cyanobacteria?



Other

- We use our Wellington Regional Response guidelines which align with the national guidelines.
- Note: The DHB does not undertake any of the sampling but will become involved once Alert and Action levels are reached and then provide public health advice where necessary
- Internal Health Protection Officer Procedure.

What are the biggest challenges your District Health Board encounter when using the guidelines for benthic cyanobacteria?



Other Challenges

- Working with other partners (regional & district council) to determine public health risk based on sampling results.
- Assessing a mixed planktonic and benthic bloom in Lake Taupo
- Again, response is always delayed by the time results are available.
- Managing a very dynamic situation that changes rapidly. A lot more focus has gone onto trying to increase public understanding/literacy on knowing what to look for; signs don't work for a river with wide access.
- Lack of risk assessment in guidelines, rationale for warnings in some circumstances
- Issues primarily driven by Councils who keep PHS in the loop

Respondents were asked to specify any emerging issues with cyanobacteria in NZ that they had identified:

- Non-toxic? cyanobacteria in Lake Ellesmere for a long period resulting in a warning from 2014-2017, more non-monitored site blooms being notified and sorting out the appropriate action for these.
- Benthic mats in rivers.

Appendix 3. Workshop agenda

NZ Guidelines for Cyanobacteria - Review workshop
 Ministry for the Environment - Environment House, 23 Kate Sheppard Pl, Pipitea,
 Wellington

Monday 7 May 2018

From 8.30	Coffee and tea
9.00 – 9.30	Welcome and introductions
9.30 – 10.15	Aims for the day, background on the guidelines, what the guidelines do and don't cover (i.e., risks to animals and accumulation of toxins in aquatic animals) Update on relevant projects in progress

Two questions to ponder during the day:

1. What should the guidelines look like and what information should they include?
2. What would the ultimate sampling/monitoring programme look like?

10.15 – 10.35 Morning tea

10.35 – 10.50	Learning from experiences - Successfully communicating cyanobacterial risk – lesson from GWRC (Penny Fairbrother) –10 min talk
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10.50 – 12.00 Gathering everyone's input – Session 1 - What works, and current challenges

Split into three groups. Leader will remain at each table, and groups will move every 15 mins (first 2) then 10 mins. Aim is for leader to document (large A1 piece of paper) what is and isn't working and suggestions for improvements.

Facilitator	Ian Hawes & Karl Safi	David Hamilton & Graham McBride
Topics	Assessing benthic cyanobacteria (or other issues related to benthic cyanos) <ul style="list-style-type: none"> • Associating % cover with health risk • Associating detaching/exposed mats with health risk • Site selection • Assessing toxicity of cyanobacteria 	Assessing planktonic cyanobacteria (or other issues related to planktonic cyanos) <ul style="list-style-type: none"> • Biovolumes • Assessing picocyanobacteria • Downgrading warnings • Toxic vs. non-toxic

Facilitator/s	Jonathan Puddick & Georgia Thomson-Laing
Topics	<p style="text-align: center;">Communicating risks</p> <ul style="list-style-type: none"> • Timeframes regarding change in site status • Responses are delayed based on test results • Different communication strategies to alert public • Websites vs LAWA • National standardised sign

Report back from leader of successes and challenges.

12.00– 12.45 Lunch

12.45- 1.15 **Gathering everyone's input – Session 2 - Emerging issues** (session chaired by Karl Safi/Ian Hawes)

- Brain storming on key new issues. Areas identified to date – benthic mats in lakes
- What are the critical knowledge gaps
- How can these be addressed (i.e., research, learning from other environments/countries)
- How/can we incorporate these into the guidelines in the future

1.15 – 2.15 **Gathering everyone's input – Session 3 - New technologies** (session chaired by David Hamilton/Jonathan Puddick)

1.15–1.25	Learning from experiences – Drones in action and potential for monitoring (Dr Mark Heath) –10 min talk
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New methods that will be discussed. These will be 2-3 min presentations from project team followed by discussion. Consider which are ready to be included and which need further research

- Molecular tools (toxin production)
- Predictive models (lakes and river)
- Sensors (Phycocyanin/ Phycoerythrin)
- Remote Sensing
- Rapid in-situ kits for toxins
- Other ideas?

2.15 – 3.00 **Gathering everyone's input – Session 4 – How should the new guidelines look** (session chaired by Jonathan Puddick/Georgia Thomson-Laing)

List what section we want to keep/remove, what is missing that is needed, web based or paper etc.

Review of thoughts on ultimate sampling/monitoring plan

3.00 – 3.30 **Wrap up and next steps**

Appendix 4. Presentation given by Susie Wood (Cawthron) on cyanobacteria and background on the 2009 guidelines for cyanobacteria in recreational waters



The top section of the slide features a horizontal strip of four microscopic images showing various cyanobacteria. From left to right: a cluster of small, spherical cells; a long, thin, filamentous chain; a network of branching filaments; and a chain of larger, oval-shaped cells.

Monitoring cyanobacteria in recreational waters

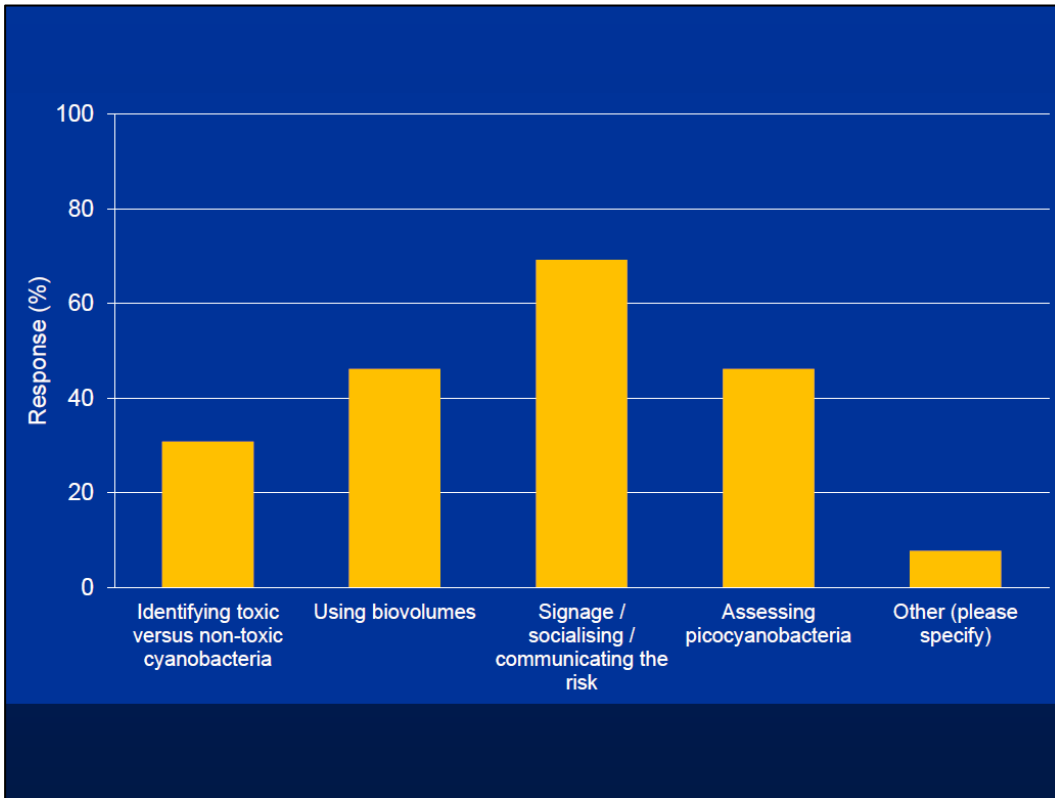
REVIEW WORKSHOP 2018



The middle section of the slide shows a photograph of a pond with a thick green algal bloom (cyanobacteria) covering the water surface. In the foreground, there are green reeds or grasses growing out of the water.

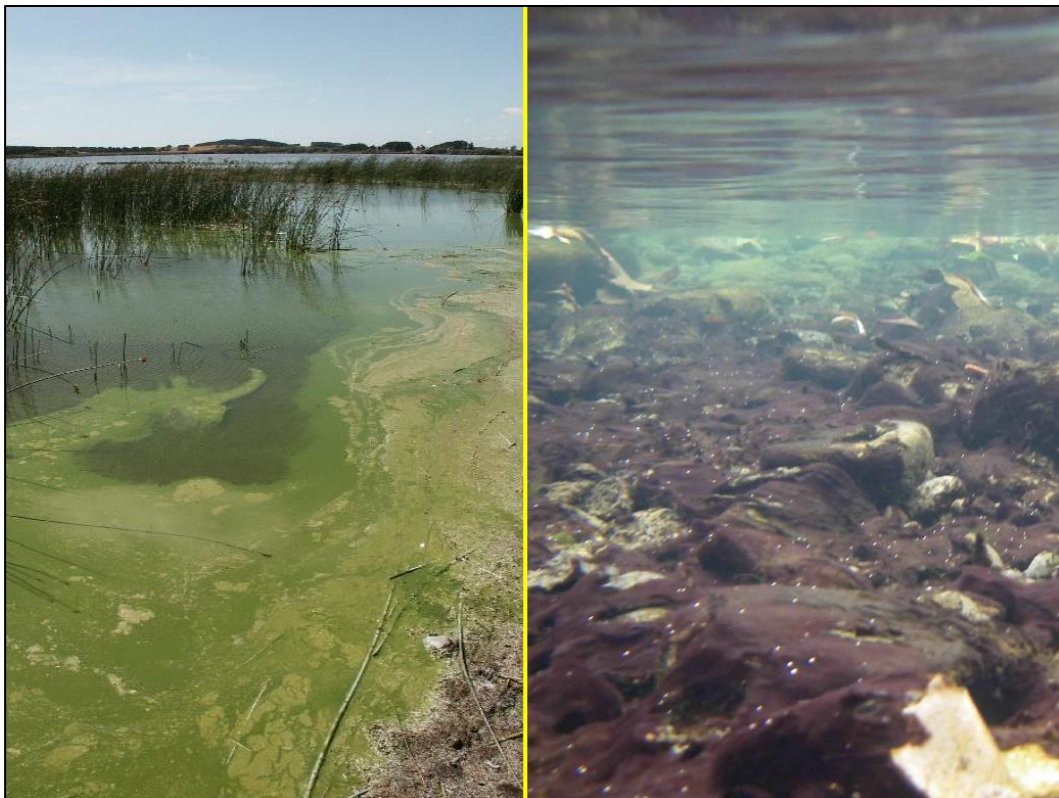
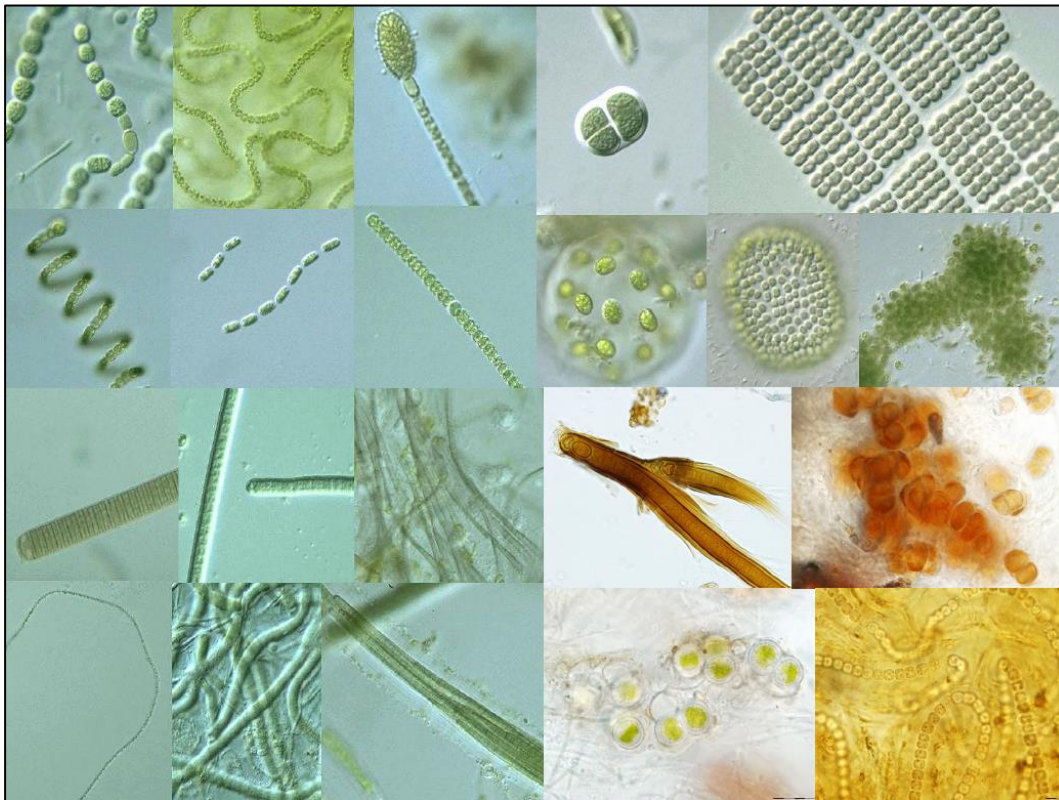
Agenda

- Aims for day
- Intro to cyanobacteria
- Background on guidelines
- MfE cyano project updates
- **Gathering input**
 - **Benthic**
 - **Planktonic**
 - **Communicating risk**
- Emerging issues
- New technologies
- How the new GL should look & function
- Next steps



Review of guidelines

1.
 - Workshop (aims)
 - Report on feedback
2.
 - Literature review
 - Update relevant GL sections
3.
 - Review toxicology
 - Update toxin quotas
4.
 - Risk modeling – gap identification
 - Identifying next steps
5.
 - Reporting back
 - Updating appropriate sections



Unique adaptations

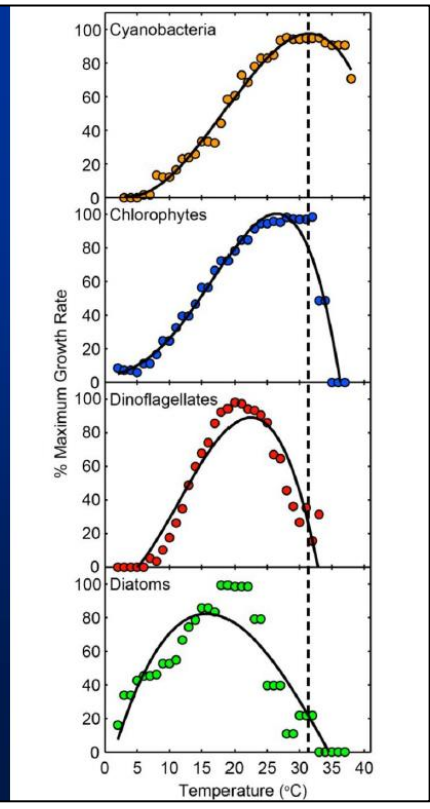
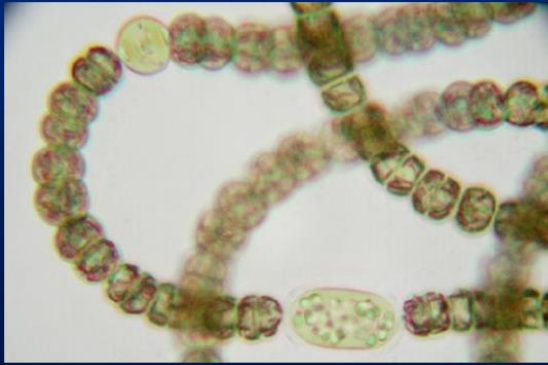
Example:

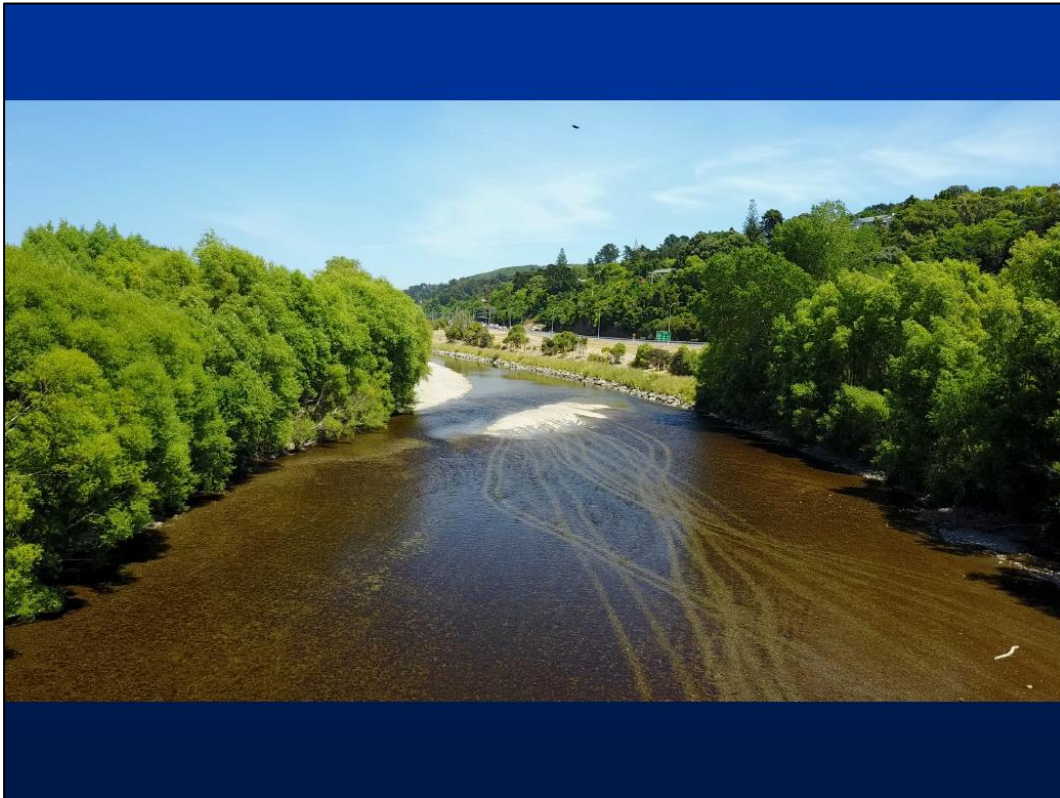
Akinetes - resting cell

Heterocytes - N₂ fixation

Buoyancy regulation

High temp growth optima/s





Cyanotoxins

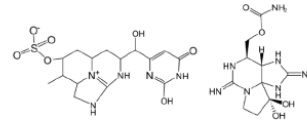


Cyanotoxins

Cyanotoxins fall into three broad classes;

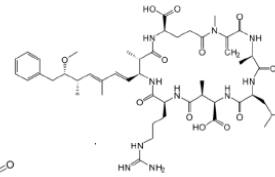
Hepatotoxins

- Microcystin eg: *Microcystis*, *Anabaena*, *Planktothrix*
- Nodularin eg: *Nodularia*
- Cylindrospermopsin eg: *Cylindrospermopsis*



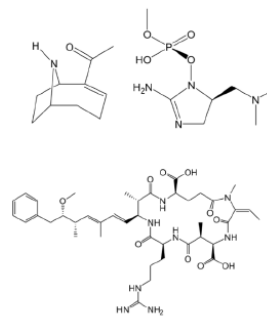
Neurotoxins

- Anatoxin-a eg: *Aphanizomenon*, *Anabaena*
- Saxitoxin eg: *Lyngbya*, *Anabaena*



Dermatotoxins

- Lyngbyatoxin-a eg: *Lyngbya*, *Anabaena*
- Aplysiatoxins
- Lipopolysaccharides eg: most spp

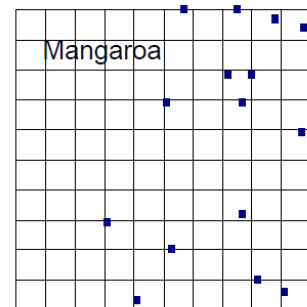
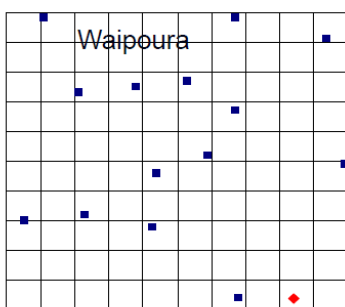
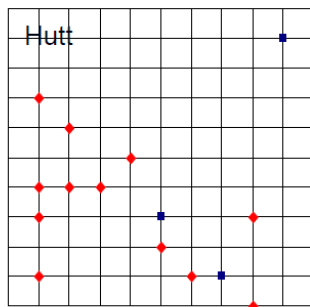
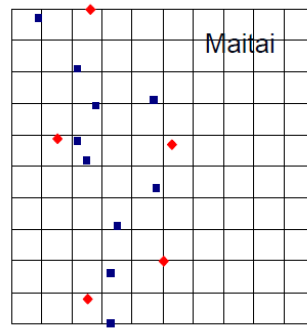
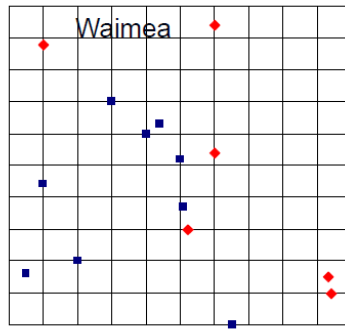
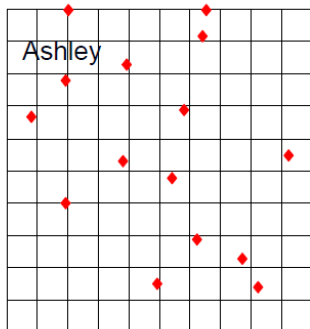
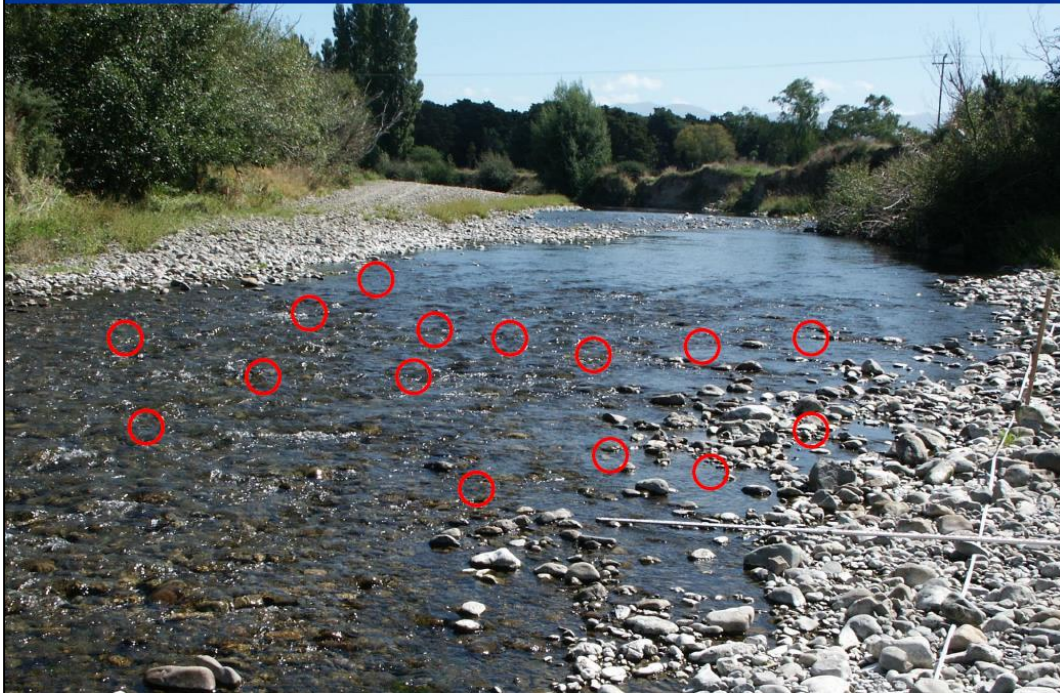


Cyanotoxins – how toxic?

IP LD₅₀ (ug/kg)

Saxitoxin	= 20	Ricin	= 22
Microcystin-LR	= 50	(castor oil plant)	
Cylindrospermopsin	= 64	Cobra venom	= 185
Anatoxin-a	= 200	Sarin	= 218
		(nerve gas)	
		Curare	= 500
		(poison arrows)	

Variability – Spatial & Temporal



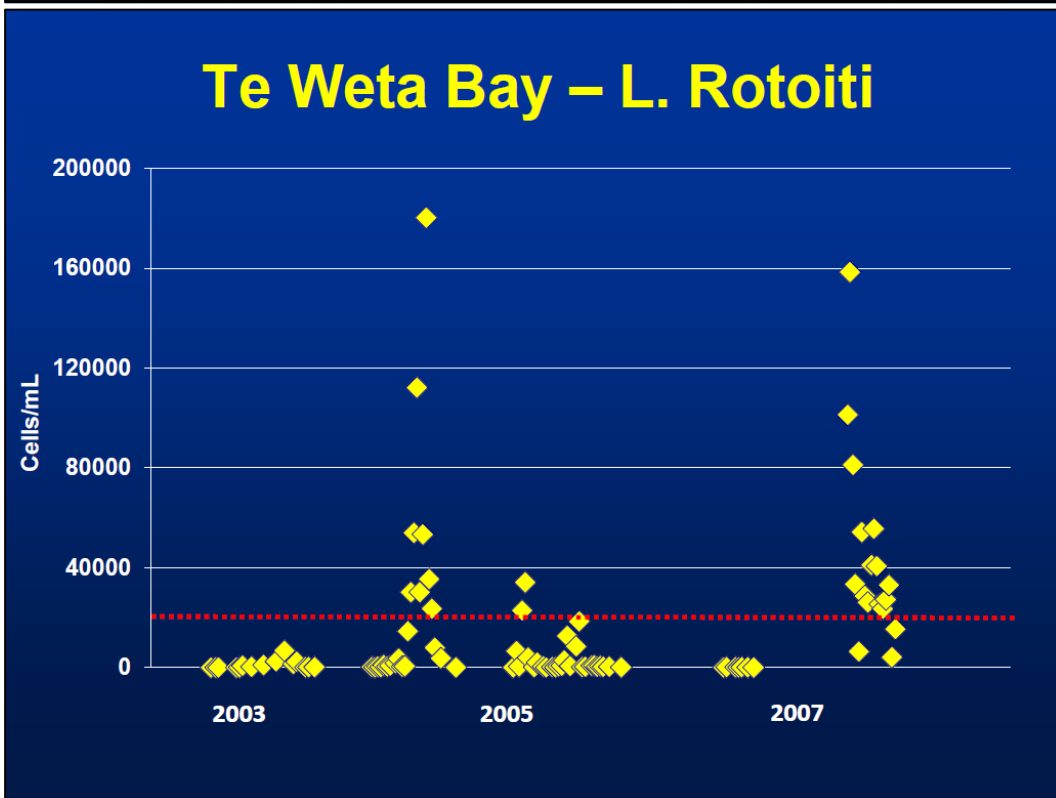
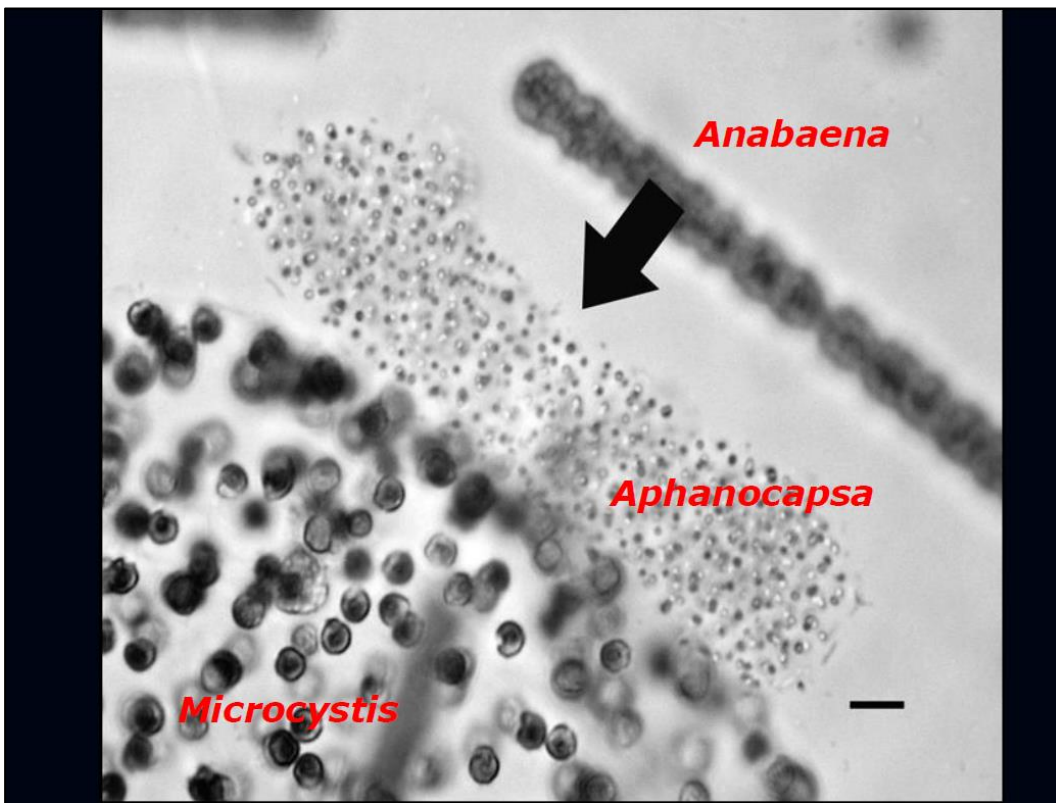
Recreational-Water Guidelines

- Up-to-date knowledge
- Approaches to sampling/monitoring
- Nationally unified approach
- Monitoring framework

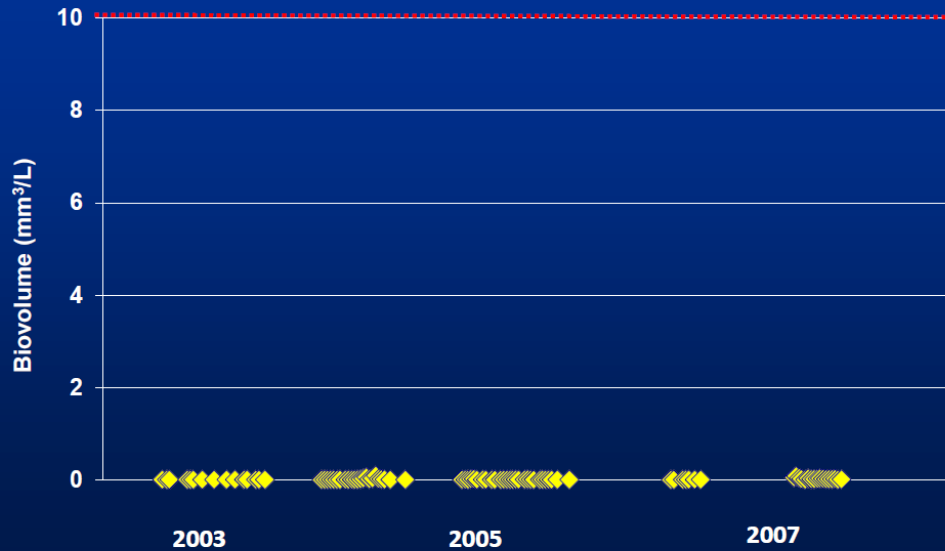


Planktonic cyanobacteria

Alert level	Actions
Surveillance (green mode) <ul style="list-style-type: none"> • Cell concentration < 500 cells/mL • Total biovolume < 0.5 mm³/L 	<ul style="list-style-type: none"> • Weekly or fortnightly visual inspection and sampling
Alert (amber mode) <ul style="list-style-type: none"> • Biovolume of potentially toxic cyanobacteria • Biovolume of cyanobacteria 	<div style="background-color: red; color: white; padding: 10px; text-align: center;"> <p>-Three measurements</p> <p>-Biovolumes</p> </div>
Action (red mode) <ul style="list-style-type: none"> • ≥ 12 µg/L total microcystins; • Biovolume ≥ 1.8 mm³/L of potentially toxic cyanobacteria • ≥ 10 mm³/L biovolume all cyanobacterial • cyanobacterial scums consistently present. 	<ul style="list-style-type: none"> • Continue monitoring as for alert (amber) mode • If potentially toxic taxa are present, then consider testing samples for cyanotoxins.^f • Notify the public of a potential risk to health.

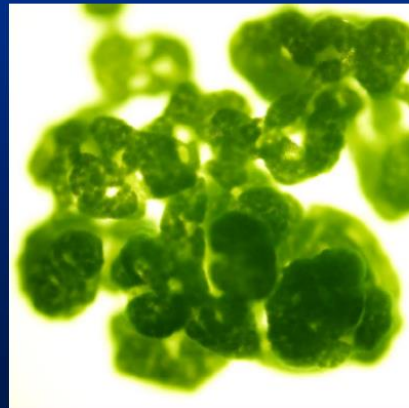


Te Weta Bay – L. Rotoiti

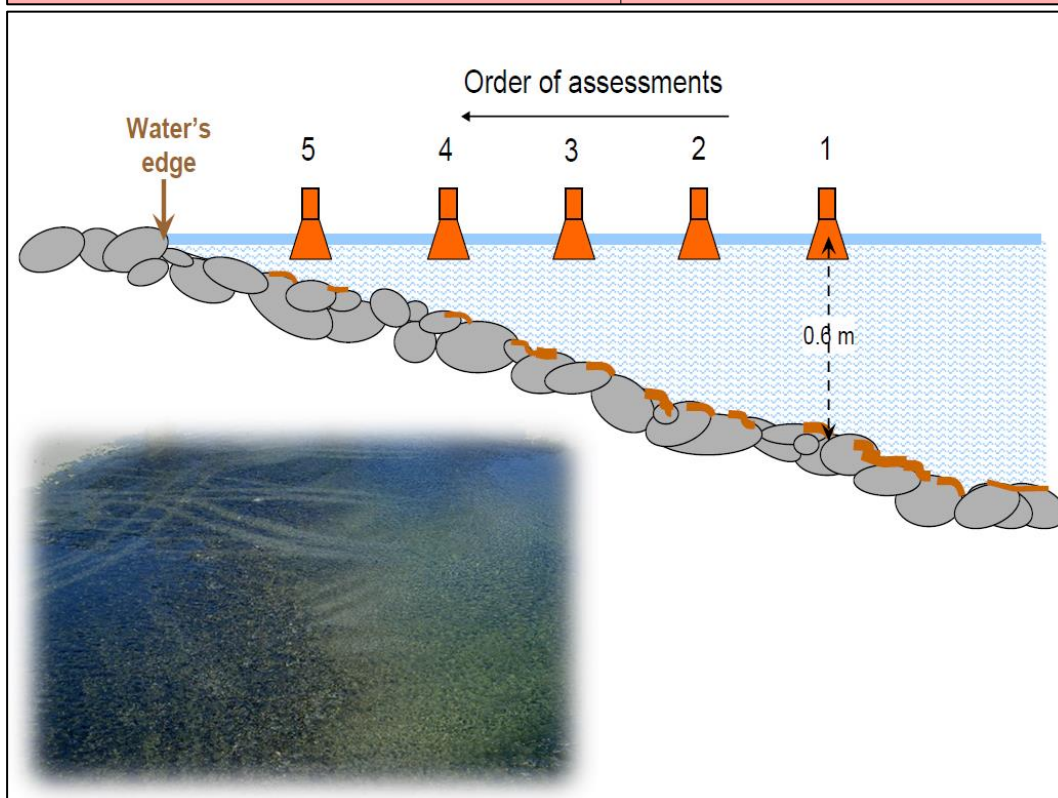


How thresholds calculated

- International toxicology data = microcystins
- Calculate MAV (15 kg)
- Derive cell concentration
= five cultured samples
- Convert to biovolumes



<h1>Benthic cyanobacteria</h1>	
Alert level	Actions
<p>Surveillance (green mode)</p> <ul style="list-style-type: none"> Up to 20% coverage 	<ul style="list-style-type: none"> Undertake fortnightly surveys
<p>Alert (amber mode)</p> <ul style="list-style-type: none"> 20-50% coverage 	<ul style="list-style-type: none"> Increase sampling frequency to at least weekly. Notify the public health unit. Multiple sites should be inspected and sampled
<p>Action (red mode)</p> <ul style="list-style-type: none"> > 50% coverage Up to 50% where mats are detaching 	<ul style="list-style-type: none"> Continue monitoring as for alert (amber) mode If potentially toxic taxa are present, then consider testing samples for cyanotoxins. Notify the public of a potential risk to health.



<h1>Benthic cyanobacteria</h1>	
Alert level	Actions
<p>Surveillance (green mode)</p> <ul style="list-style-type: none"> Up to 20% coverage 	<ul style="list-style-type: none"> Undertake fortnightly surveys
<p>Alert (amber mode)</p> <ul style="list-style-type: none"> 20-50% coverage 	<ul style="list-style-type: none"> Increase sampling frequency to at least weekly. Notify the public health unit. Multiple sites should be inspected and sampled
<p>Action (red mode)</p> <ul style="list-style-type: none"> > 50% coverage Up to 50% where mats are detaching 	<ul style="list-style-type: none"> Continue monitoring as for alert (amber) mode If potentially toxic taxa are present, then consider testing samples for cyanotoxins. Notify the public of a potential risk to health.

What don't the guidelines cover?

- Drinking-Water Standards and Guidelines 2005
 - 7 cyanotoxins assigned PMAVs







Links to NOF & water quality targets

Band	Planktonic
A	Total cyano < 0.5 mm ³ /L <u>or</u> < 500 cells/mL
B/C	Toxic cyano 0.5 to < 1.8 mm³/L <u>or</u> Total cyano 0.5 to < 10 mm³/L
D	Toxic cyano ≥ 1.8 mm³/L <u>or</u> Toxic cyano ≥ 10 mm³/L



Toxic Species

<i>Anabaena lemmermannii</i>	Microcystins (genes but no toxin)
<i>Aphanizomenon issatschenkoi</i>	Anatoxin-a
<i>Cylindrospermopsis raciborskii</i>	Cylindrospermopsin, DeoxyCYN
<i>Microcystis</i> spp.	Microcystins
<i>Nodularia spumigena</i>	Nodularin
<i>Nostoc commune</i>	Microcystins
<i>Phormidium autumnale</i>	Anatoxin-a, homoanatoxin-a
<i>Planktothrix</i> sp.	Microcystins
<i>Scytonema</i> cf. <i>crispum</i>	Saxitoxins



Appendix 5. Presentation given by Jonathan Puddick and Susie Wood (Cawthron) on recent research and MfE-funded projects on toxic cyanobacteria.

Research to Develop a NOF Attribute for Benthic Cyanobacteria in NZ Rivers

Susie Wood, Jonathan Puddick, Roel van Ginkel, Andy Selwood, Javier Atalah, Hayden Rabel, Annika Wagenhoff, Graham McBride, Daniel Dietrich, Ian Hawes, Penelope Truman, Sarah Munday, Rex Munday

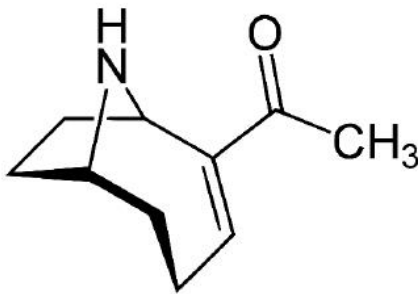
Benthic Cyanobacteria in NZ

- Report commissioned in 2015 to summarise:
 - The risk posed by benthic cyanobacteria in NZ.
 - The state of knowledge on toxic benthic cyanobacteria in NZ.
 - The research required to develop a NOF attribute for benthic cyanobacteria.



REPORT NO. 2752

ADVICE TO INFORM THE DEVELOPMENT OF A
BENTHIC CYANOBACTERIA ATTRIBUTE



Toxic algae may have killed three Hutt dogs

Algae can be deadly

Dog killed by toxic algae in Hutt River

Council looks into dog 'poisonings' from river visits

Fears killer algae may flare up in other areas

algae have killed dog

PHORMIDIUM toxin is a potent neurotoxin that causes paralysis and death in many animals. It is produced by the cyanobacterium Phormidium, which is commonly found in freshwater environments. The toxin is highly stable and can persist in the environment for long periods of time.

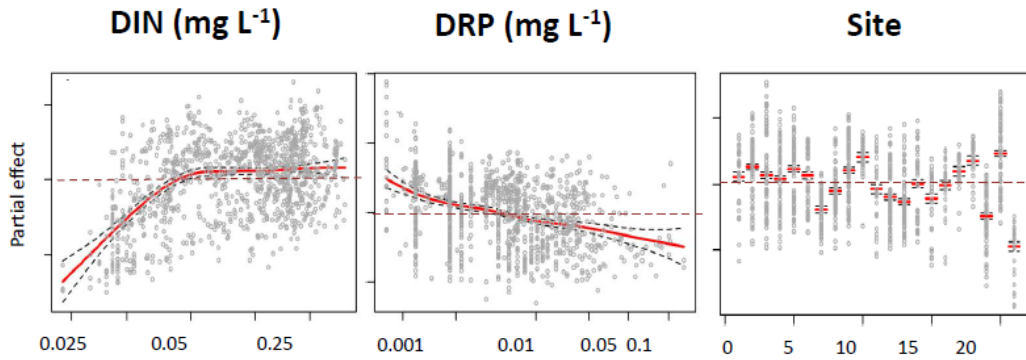
PHORMIDIUM toxin is a potent neurotoxin that causes paralysis and death in many animals. It is produced by the cyanobacterium Phormidium, which is commonly found in freshwater environments. The toxin is highly stable and can persist in the environment for long periods of time.

Identified Knowledge Gaps

- Environmental drivers of *Phormidium*.
- Toxicity of anatoxin congeners in *Phormidium*.
- How much toxin to expect in the environment.
- Assess *in situ* methods to assess toxicity.
- Risk modelling using generated data.
- Effect of repeated exposure to toxins.
- Additional recommendations also provided.



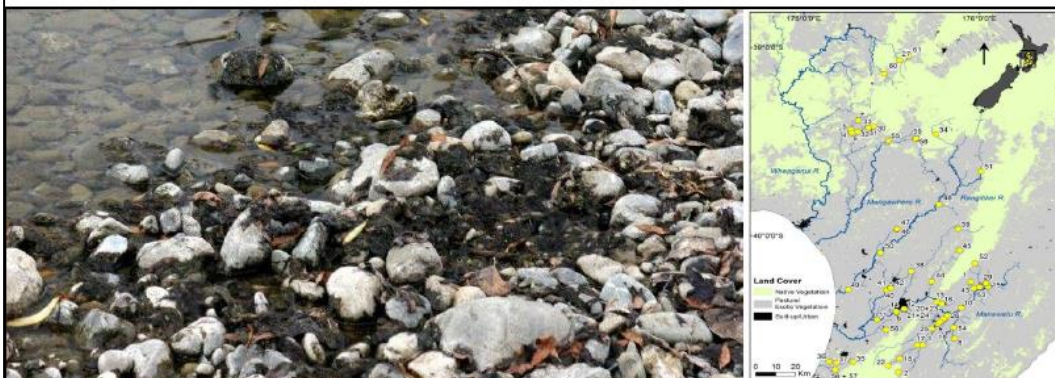
Phormidium Drivers - River Scale Weekly Sampling

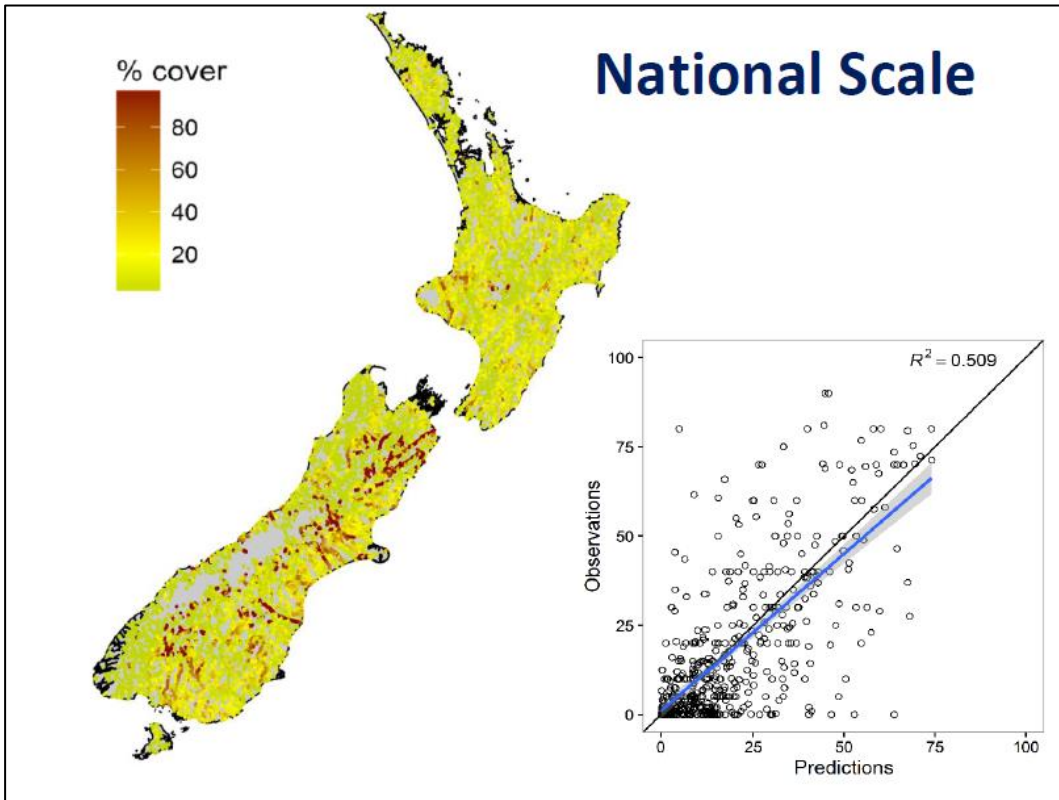


Strong patterns - DRP (<0.01 mg L⁻¹)
Generalities - DIN
Site specificity - hierarchies of importance

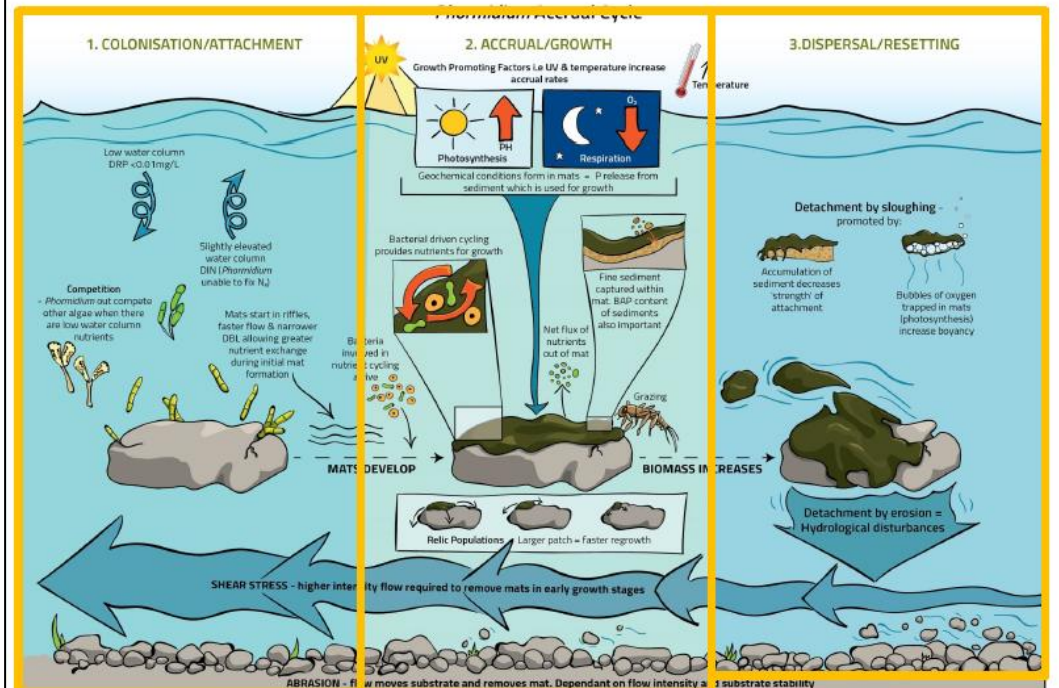
Phormidium Drivers - Regional Scale

- Relationship between *Phormidium* & pastoral land use
- Same pattern not observed in all regions
- The BRT model suggests
- More frequent flushes
- Increased with rising DIN

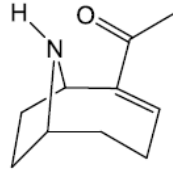




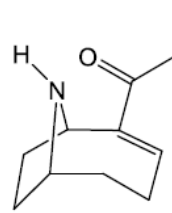
Linking It All Together....



Toxicity of Anatoxin Congeners

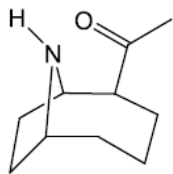


Anatoxin-a (ATX)

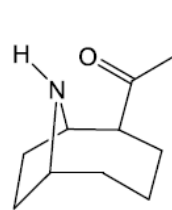


Homoanatoxin-a (HTX)

LD_{50} 200-400 $\mu\text{g}/\text{kg}$ (i.p.)
Ave \approx 260 $\mu\text{g}/\text{kg}$



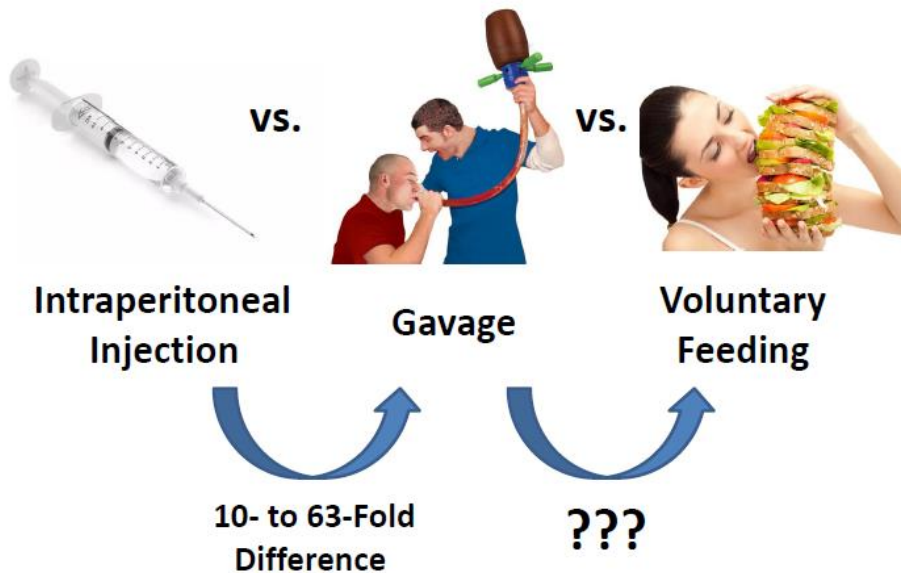
Dihydro-anatoxin-a (dhATX)



Dihydro-homoanatoxin-a (dhHTX)

LD_{50} = ???

Method of Administration

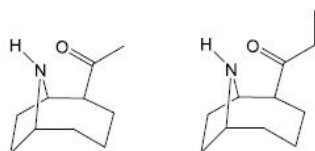


***Phormidium* Toxicity Project**

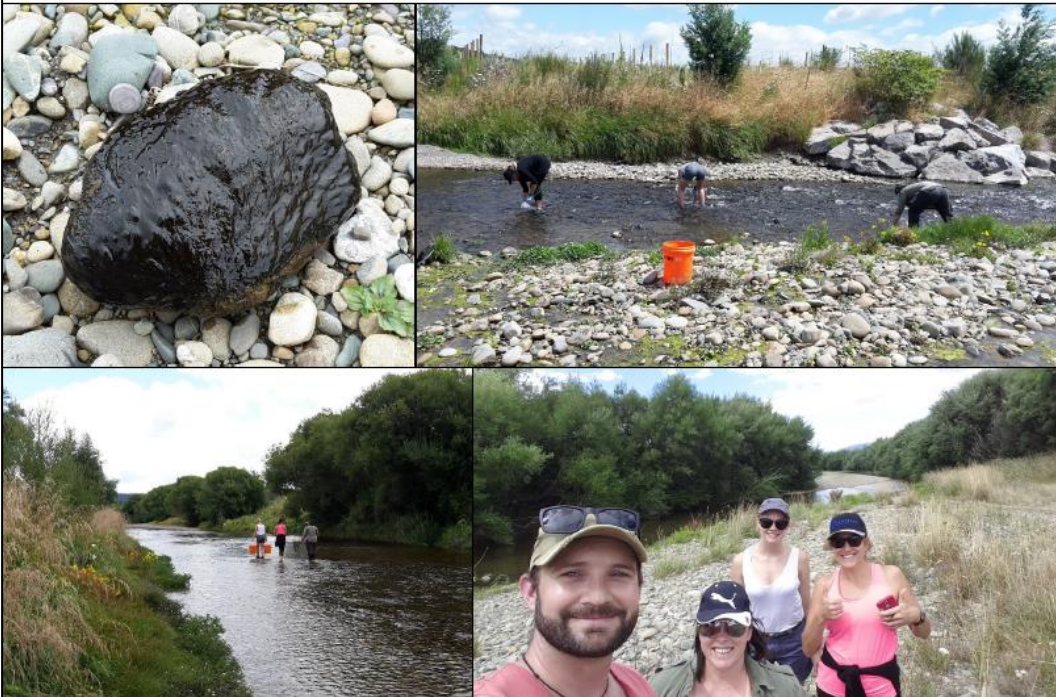
- **Determine accurate acute toxicity values for:**
 - ATX
 - HTX
 - dhATX
 - dhHTX
- **Three methods of administration:**
 - Intraperitoneal (i.p.) injection
 - Gavage
 - Voluntary Feeding
- **Assess biochemical options to evaluate *Phormidium* toxicity**

Range-Finding on Anatoxin Toxicity

- Estimate the toxicity of the dihydro-anatoxins.
- Estimate the difference in toxicity via different routes of administration.
- Using environment *Phormidium* bloom extracts
 - Low level anatoxin sample
 - 2 × dihydro-anatoxin samples



Environmental *Phormidium* Extracts



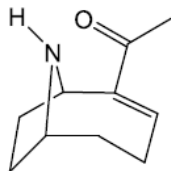
Environmental *Phormidium* Extracts



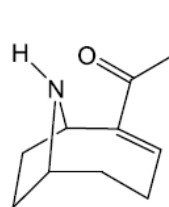
Preparation of Extracts for Toxicology



Toxicity Estimate for Dihydro-Congeners

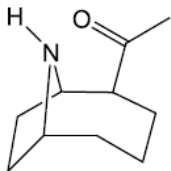


Anatoxin-a (ATX)

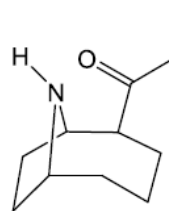


Homoanatoxin-a (HTX)

LD₅₀ 200-400 µg/kg (i.p.)
Ave ≈ 260 µg/kg



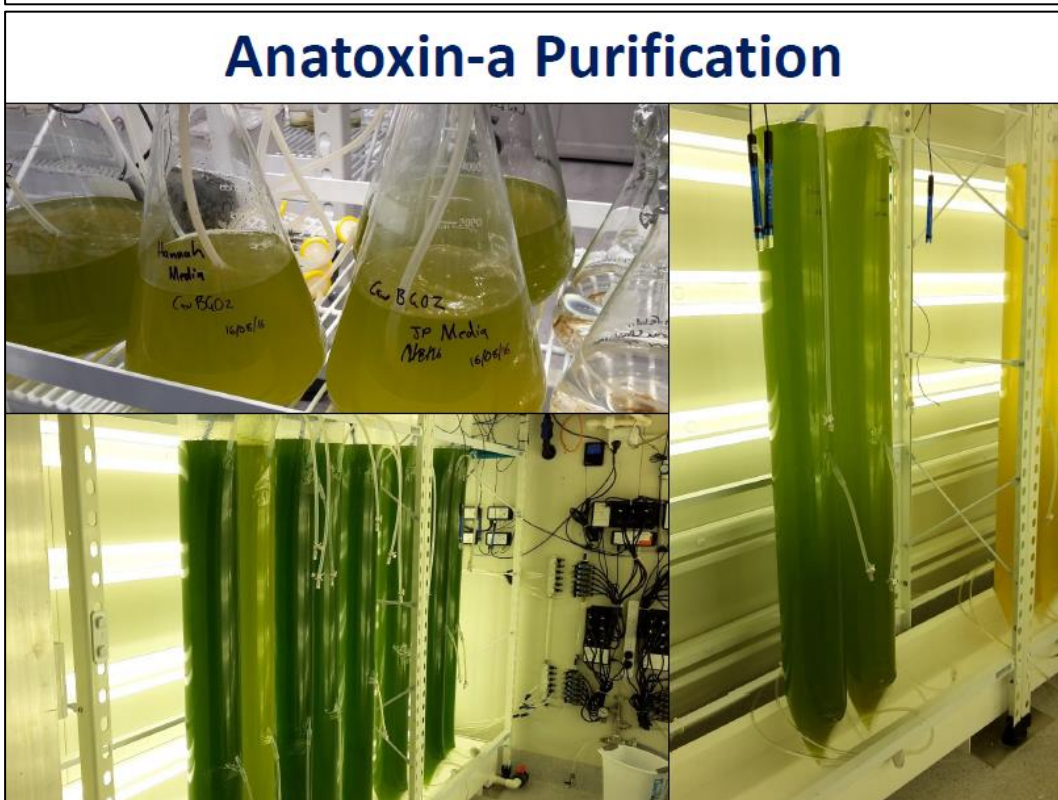
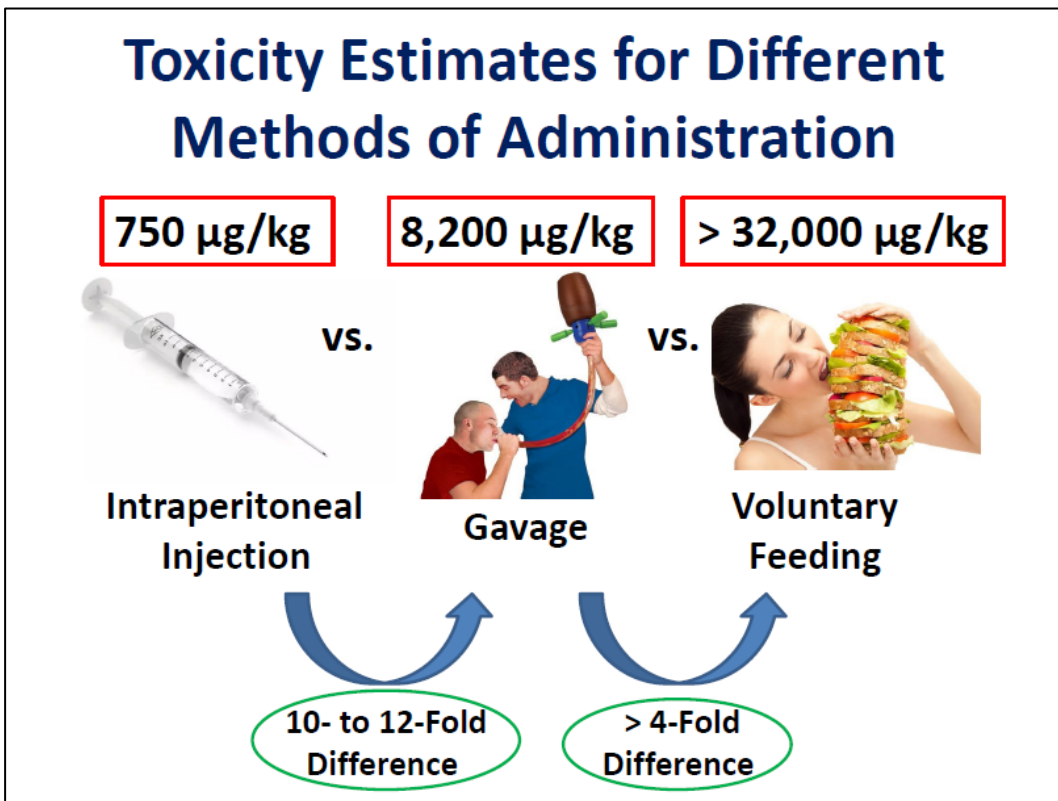
Dihydro-anatoxin-a (dhATX)



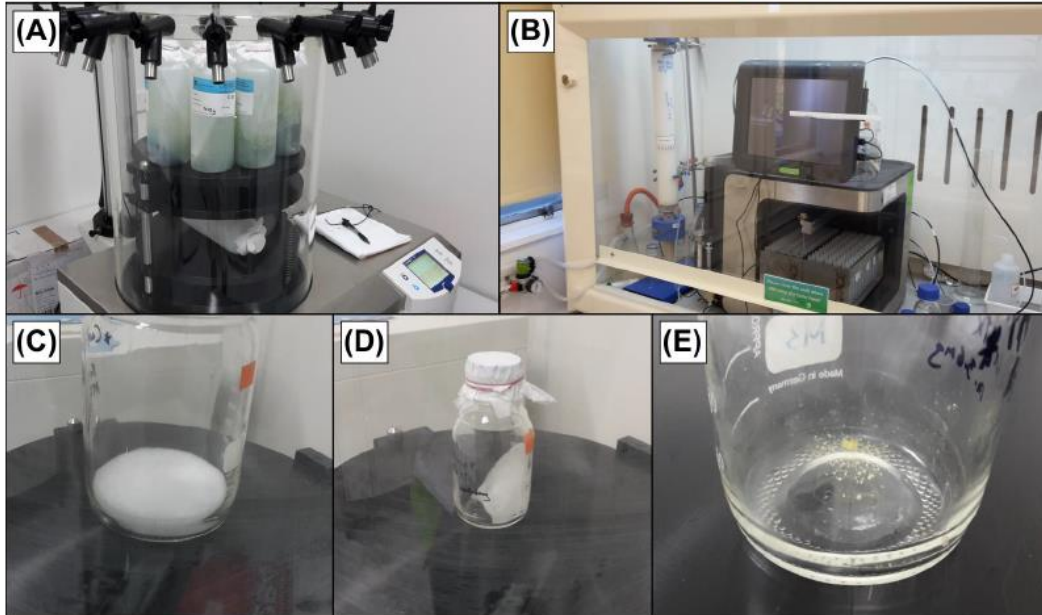
Dihydro-homoanatoxin-a (dhHTX)

LD₅₀ 680-820 µg/kg (i.p.)
Ave ≈ 750 µg/kg

ca. 3-times less toxic by i.p.

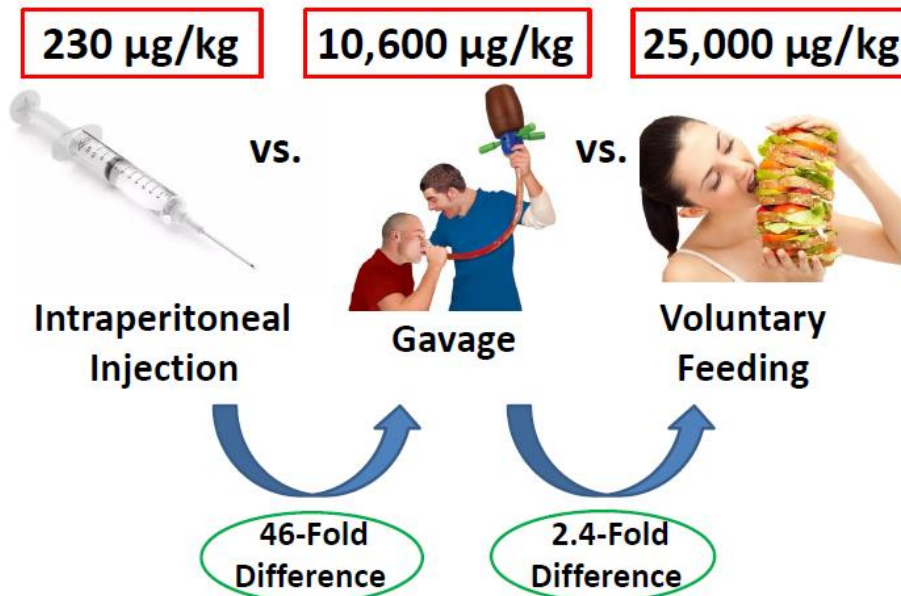


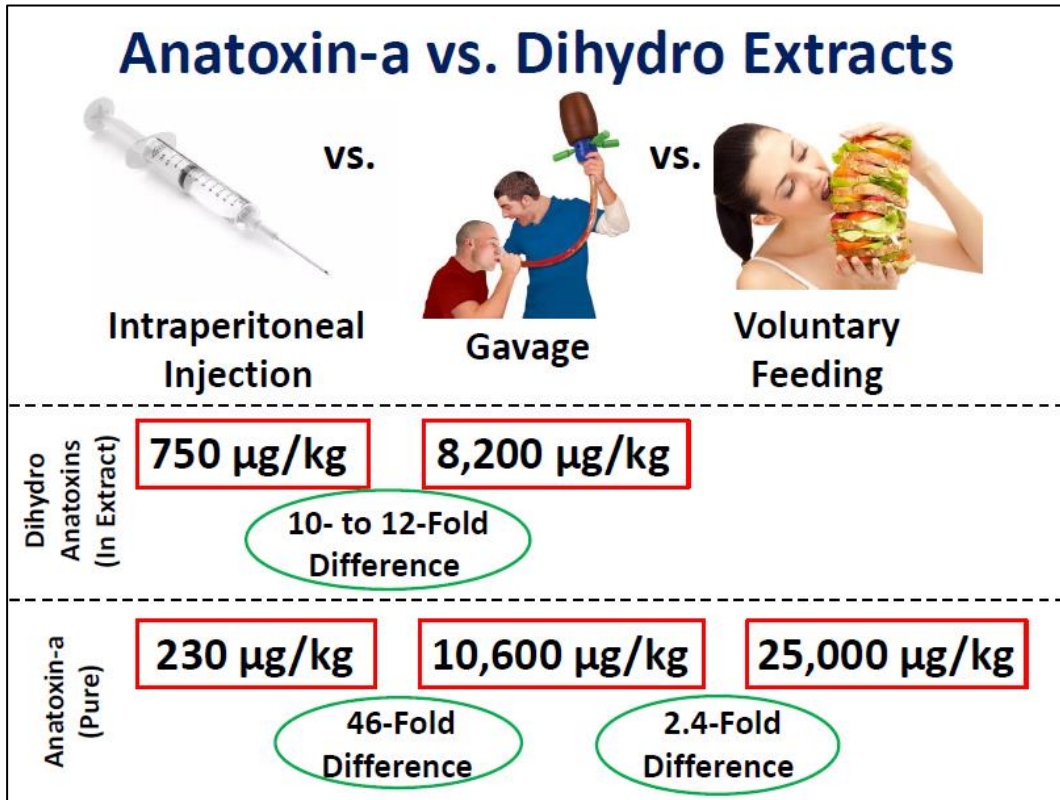
Anatoxin-a Purification



▪ 6 mg of anatoxin-a purified for toxicology work

Anatoxin-a Toxicity Results





Dihydro-Anatoxin Purification

CC12C3CC4C(C1)C(=O)N(C2)C3

Dihydro-anatoxin-a (dhATX)

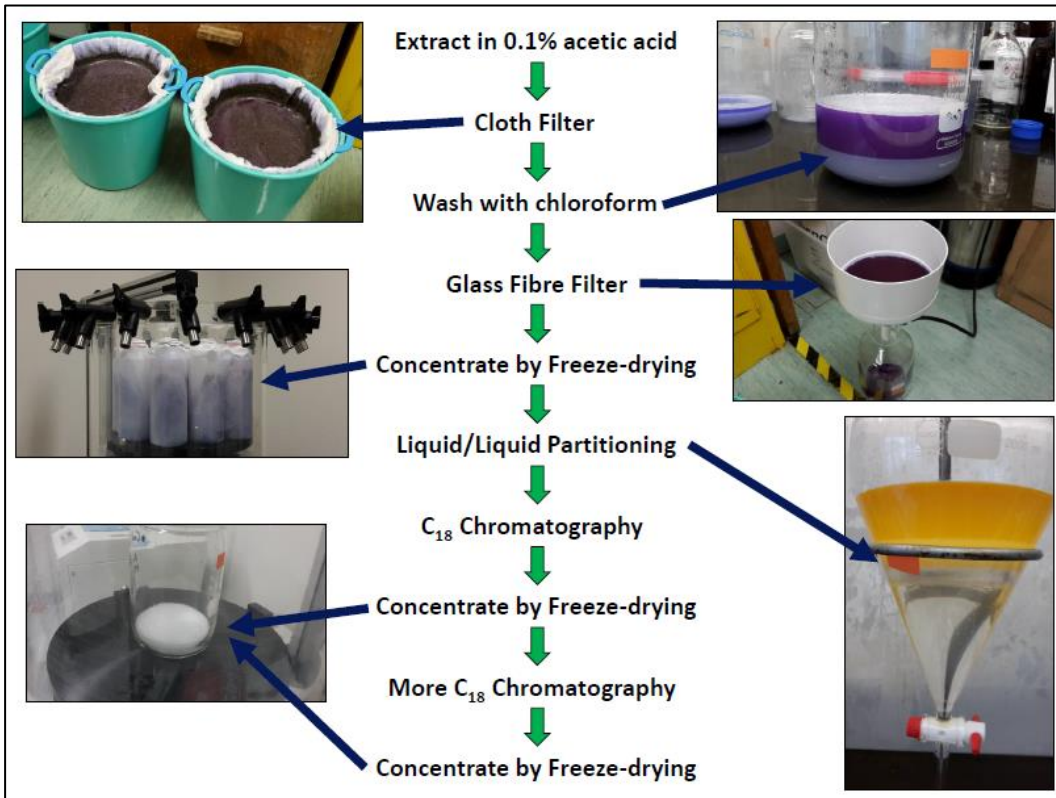
CC12C3CC4C(C1)C(=O)N(C2)C3

Dihydro-homoanatoxin-a (dhHTX)









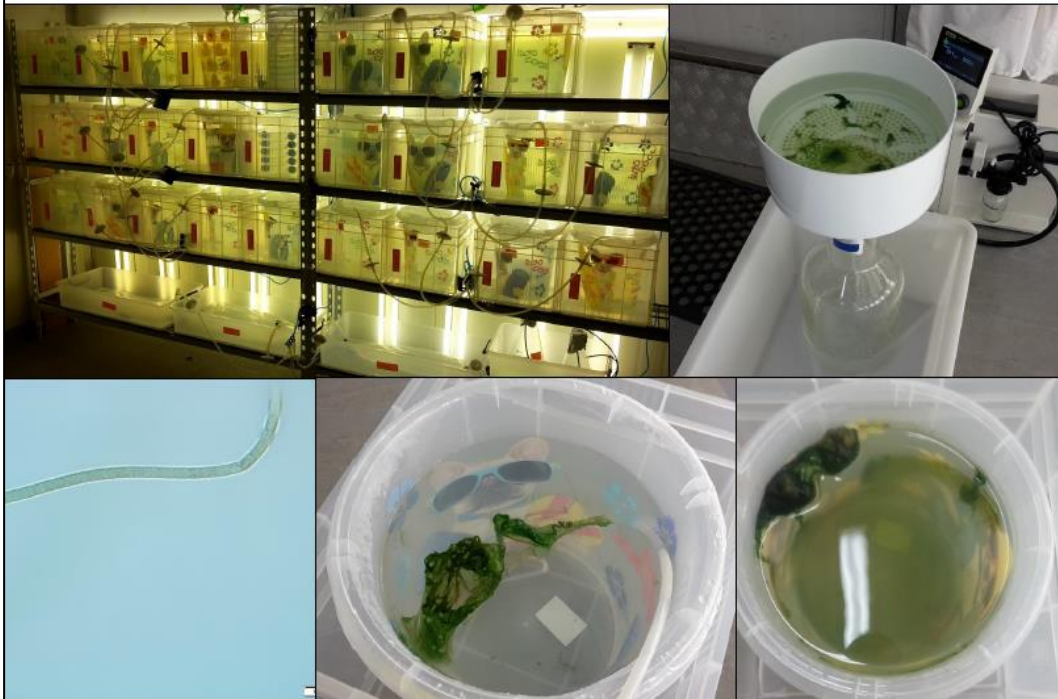
HTX-Producing Cyanobacteria Strains

Imported Strains

Isolate NZ *Phormidium* Strains



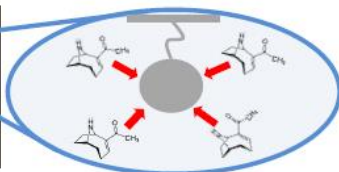
Bulk Culturing of *Oscillatoria*



Bulk Culturing of *Phormidium*



Anatoxin Release into River Water

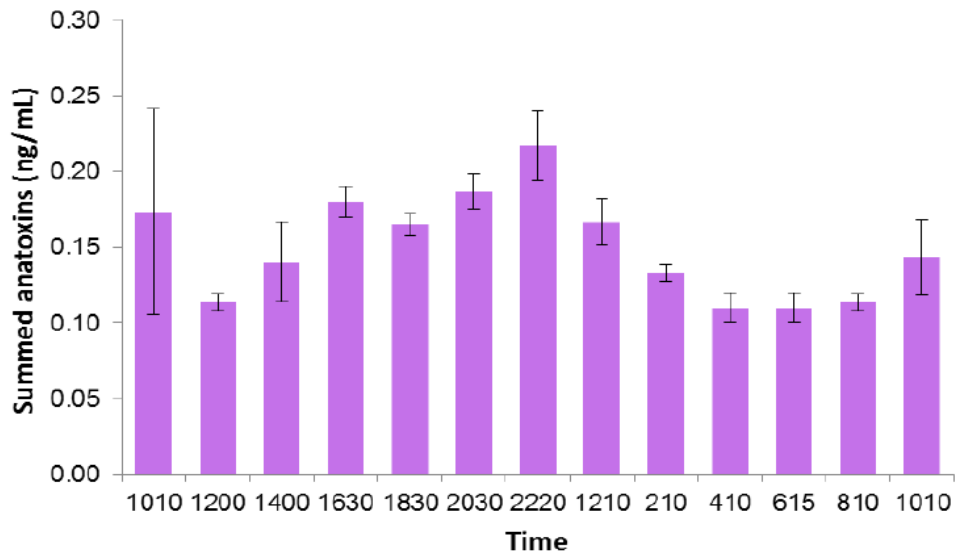


Overcomes Sampling Challenges:

- Pulses of toxin release
- Low levels of dissolved toxins

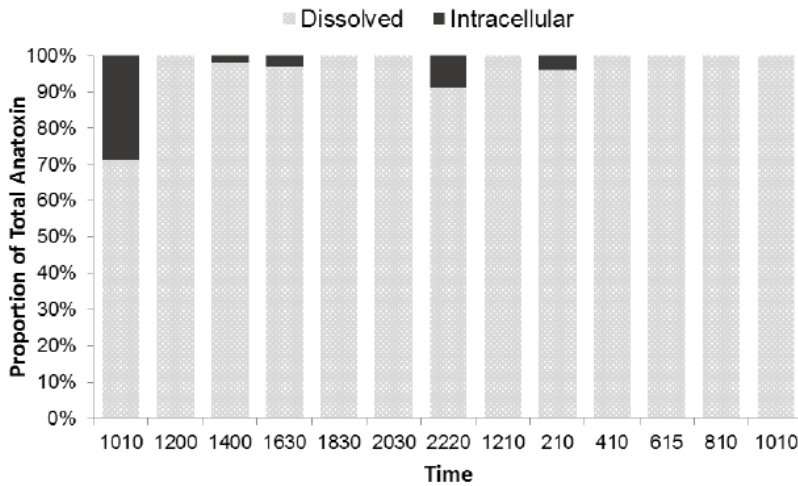
Hutt River Water Samples

- Anatoxin concentrations below drinking water PMAV.
- Possible pattern to toxin concentrations observed.



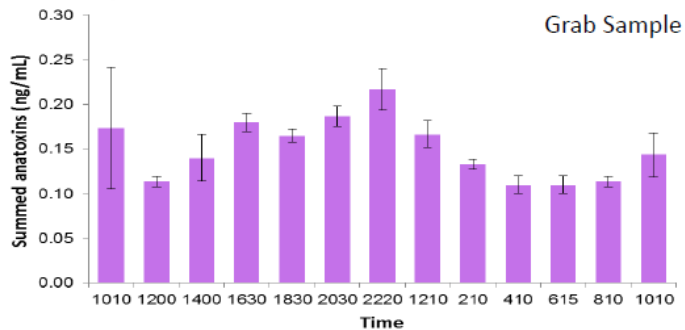
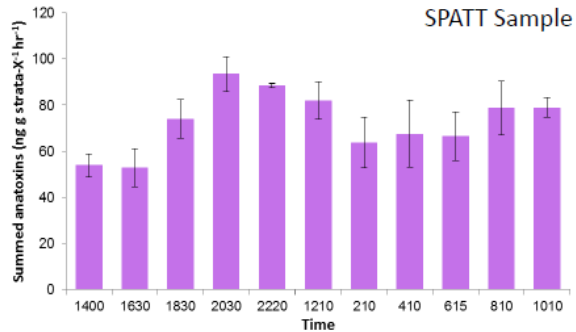
Dissolved vs Cell-Bound?

- The majority of toxins were dissolved, with few ‘free-floating’ *Phormidium* cells in the water.
- The method of toxin release from mats is not understood.

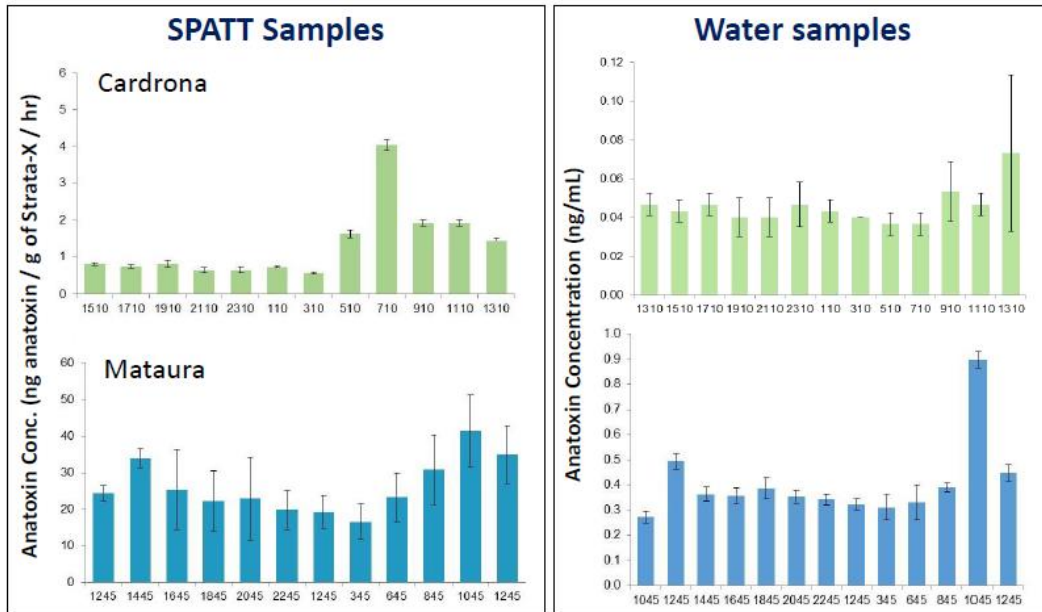


SPATT Samples vs. Grab Samples

- Good relationship between SPATT samples and grab samples.
- In Cardrona River allowed better detection of toxins



Cardrona and Mataura Rivers



Summary – Anatoxins in River Water

- When *Phormidium* mats are present, there are also toxins found in the water.
- Higher anatoxin concentrations in water were associated with more severe *Phormidium* blooms.
- Data from a wider range of sites required to properly understand relationship between released toxin and bloom severity.



Anticipated Work in the Near Future

- Acute toxicity of dhHTX and HTX
- Risk Assessment:
 - Toxicologist to check safety factors and calculations to determine lethal dose.
 - How much toxin do we expect in mats?
 - How much toxin will be in the river water?
 - Risk model development.



Appendix 6. Presentation given by David Hamilton (Griffith University) on the attributes and monitoring methods of planktonic cyanobacteria.

New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters

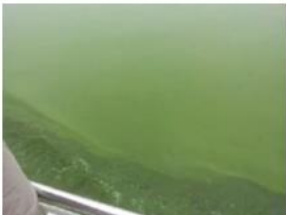

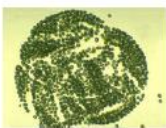
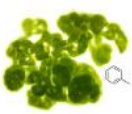
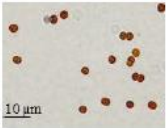
Review workshop

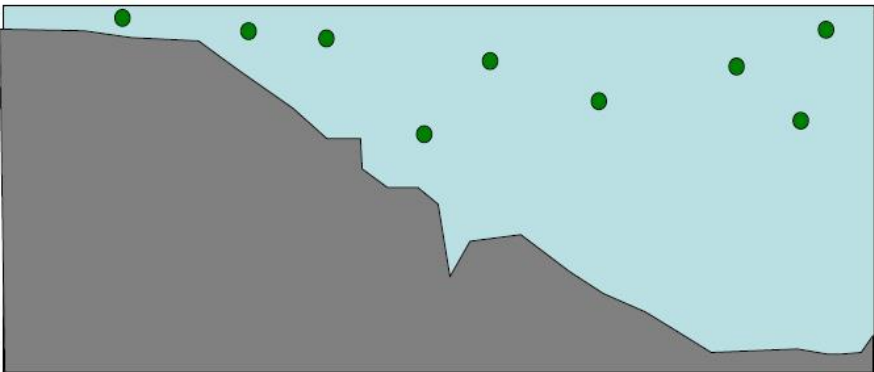
**Ministry for the Environment - Environment House
23 Kate Sheppard Pl, Pipitea, Wellington
7th May 2018**

**Overview of planktonic cyanobacteria
David Hamilton**



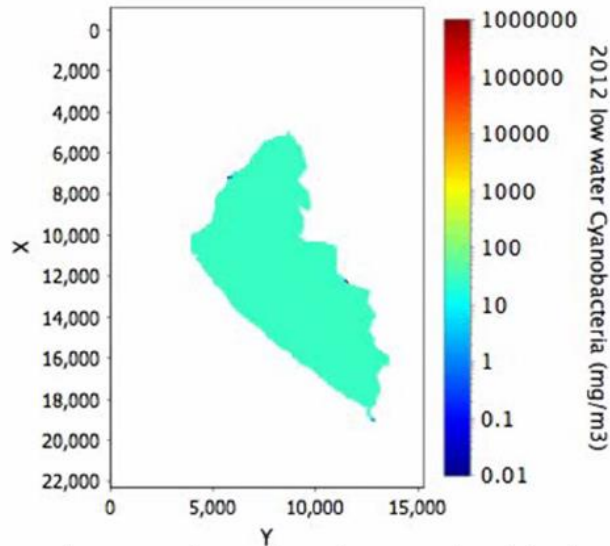
Temporal and spatial variability of cyanobacteria





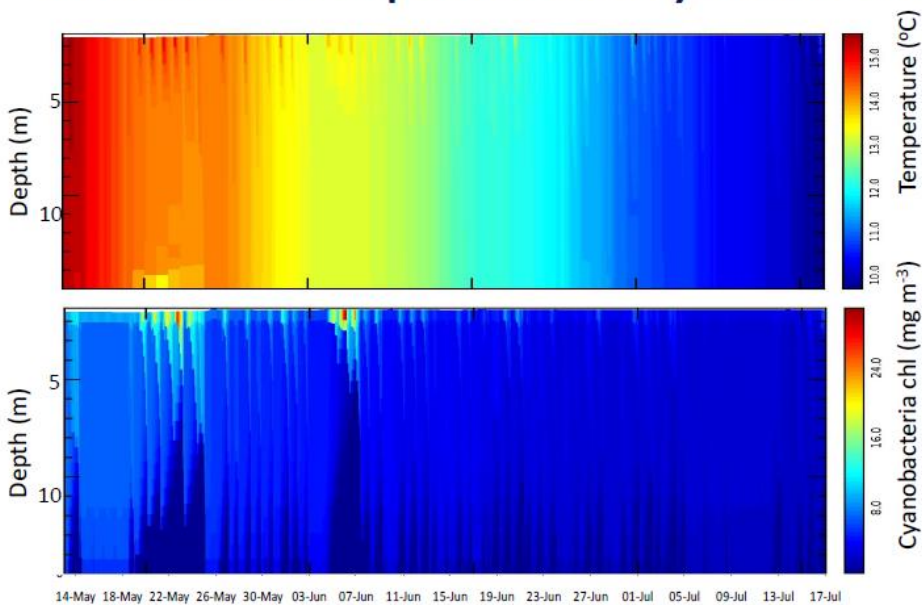
This slide (and animation) is to highlight the importance of buoyancy in bloom formation and the enabling role of gas vesicles and colony formation.

Cyanobacteria surface concentrations Lake Ypacarai, Uruguay

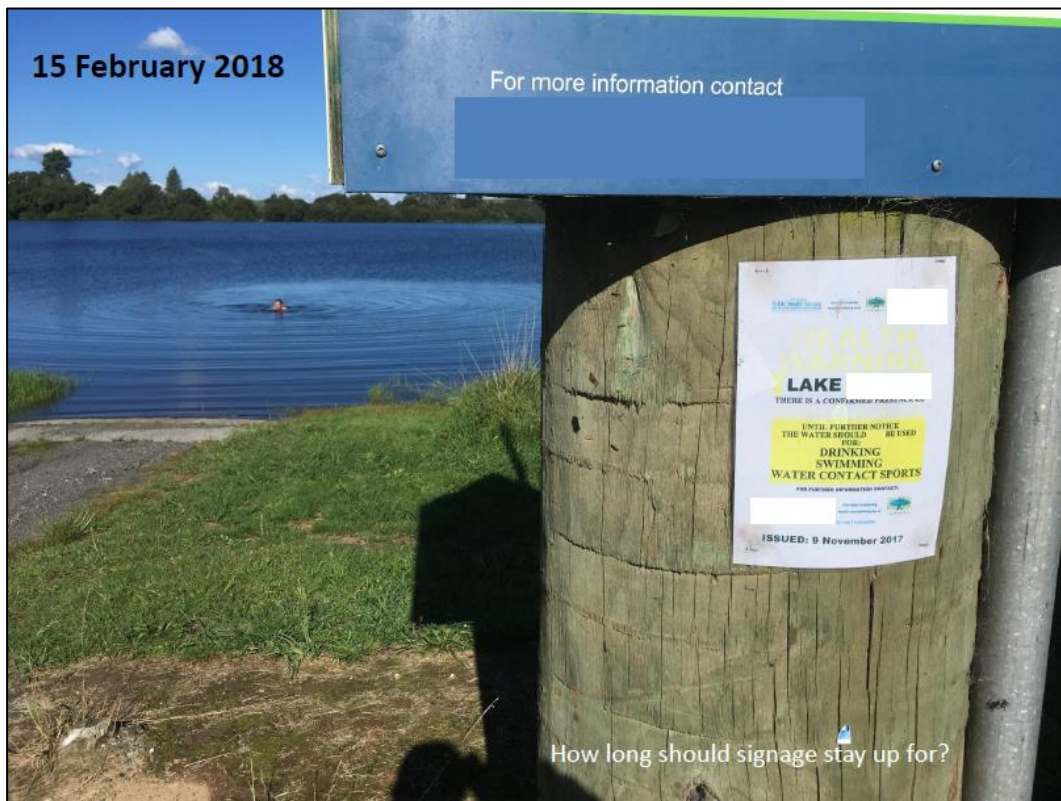


This slide (and animation) is output from a three-dimensional model. The animation shows the exceptionally high levels of horizontal variability of cyanobacteria in the lake.

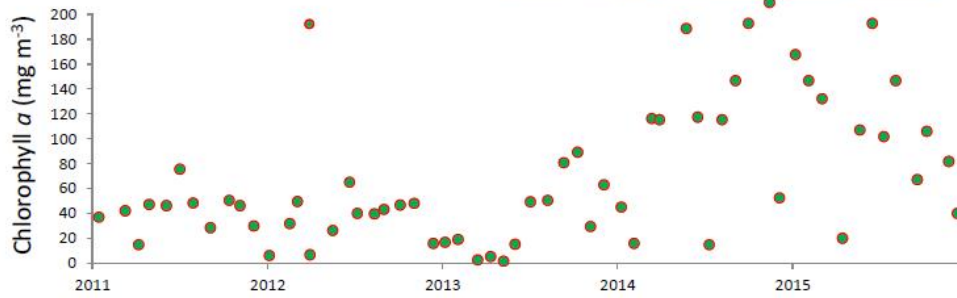
Simulation of temperature and cyanobacteria



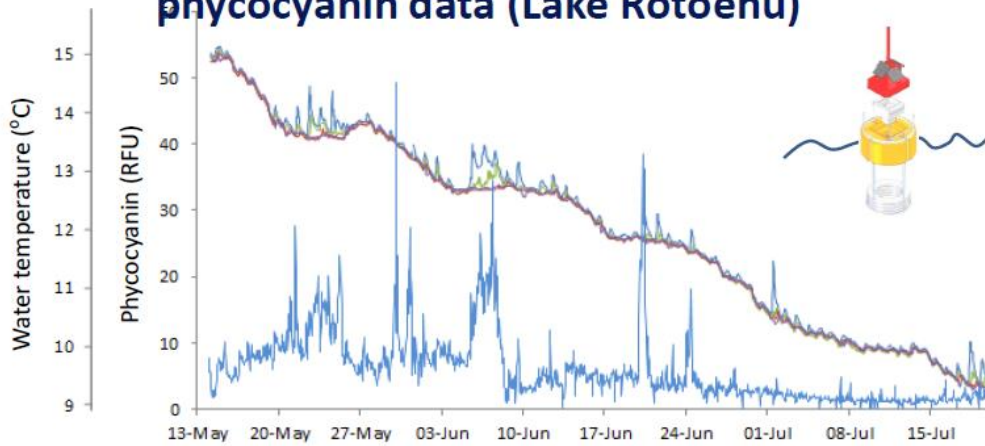
This slide is output from a one-dimensional model. It shows the exceptionally high levels of vertical variability of cyanobacteria in a lake associated with periods of daytime stratification (from surface heating) in the lake.



Increases in chlorophyll *a* mostly due to picocyanobacteria (especially 2014-15) in Lake Ellesmere / Te Waihora



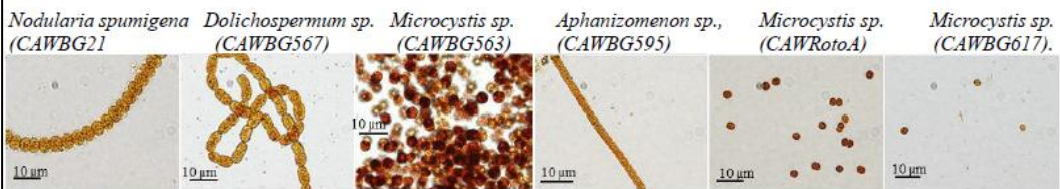
New technologies Opportunities for real-time acquisition of phycocyanin data (Lake Rotoehu)



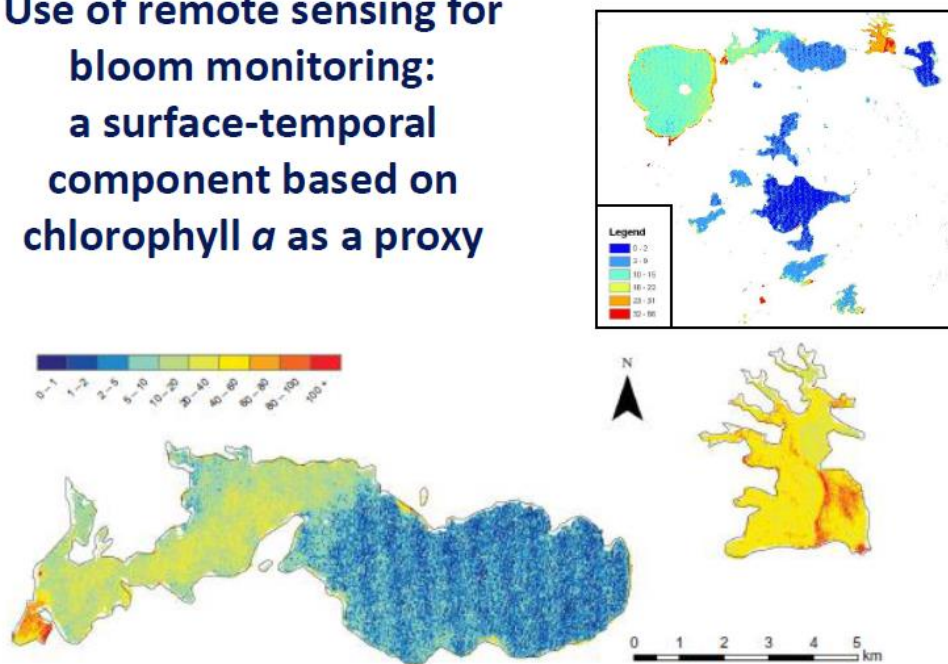
Phycocyanin (a pigment in cyanobacteria that fluoresces) can be monitored with sensors to allow semi-continuous real-time monitoring of cyanobacteria but require a comprehensive calibration schedule (e.g., against cell biovolumes)

How well do phycocyanin sensors perform (R²)?

	YSI	Manta	T928	Sea-point	TriLux
Single celled					
<i>Microcystis</i> sp. (CAWBG617)	0.96	0.97	0.97	0.92	0.92
<i>Microcystis</i> sp. (CAWRotoA)	0.96	0.85	0.91	0.92	0.95
Colonial					
<i>Microcystis</i> sp. CAWBG563)	<0.01	<0.01	0.34	0.16	0.68
Filamentous					
<i>Nodularia spumigena</i> (CAWBG21)	0.11	<0.01	0.95	0.63	0.62



Use of remote sensing for bloom monitoring: a surface-temporal component based on chlorophyll *a* as a proxy



Allan, M.G., Hamilton, D.P., Hicks, B.J. and Brabyn, L. 2011: Landsat remote sensing of chlorophyll *a* concentrations in central North Island lakes of New Zealand. *International Journal of 32*(7): 2037-2055

Appendix 7. Presentation given by Penny Fairbrother (Greater Wellington Regional Council) on methods used to communicate the risk of benthic cyanobacteria.

Toxic algae may have killed three Hutt dogs

Algae can be deadly

From pg 4. The potentially toxic cyanobacteria (blue-green algae) has been detected in high abundance and is thought to be the same species which was responsible for five deaths in the Waikato River in the summer of 2009.

One Council GWRC pollution control officer, says the water is becoming more concentrated they create more perfect conditions for the algae to grow. Algal blooms are a natural occurrence and not all algae are toxic.

The valley's two city councils have erected signs to warn people of the potential danger. Environmental Inspector Alan Pope says it is bright yellow warning signs have been put up on both sides of the river, between Porere estuary and Silverstream.

Annexure Walker suggested that if there's a river sign on the Hutt River at times of low flow/high temperatures, warning signs should be put up every two weeks in the spring/summer. After all, she says, a goodly number of people that are a water skier or dog walking. But city council environmental enforcement officer Steve McCarthy does not agree. The current

reached home but within an hour they were dead. The woman said an autopsy was being done to confirm if the toxic algae from the river had caused the deaths. The deaths occurred on Tuesday.

THE HUTT NEWS, 22 NOVEMBER, 2008

DOG KILLED BY TOXIC ALGAE IN HUTT RIVER

COLIN PATTERSON

A DISTRAUGHT Wellington dog owner performed cardiac massage on his dog in a desperate attempt to revive the animal when it collapsed after a swim in the Hutt River.

Despite his efforts, Richard Nicholls' six-year-old Labrador cross, Maggie, died after a dip in the river on Sunday.

Dog owners had been warned to keep their animals out of the water after tests revealed high levels of a bacterial algae.

Nicholls said neither he or his wife were aware of the warning signs until the dog went into the river. "We wouldn't have known she had been in the water until she came home and started coughing and vomiting," he said.

Both Mr Nicholls and his wife were still upset at the loss of their pet.

Warning too late: Labrador cross Maggie died after swimming in the Hutt River last Sunday. Owner Richard Nicholls saw no warnings.

while his wife drove to a vet. The vet put Maggie into an incubator and gave her adrenaline.

However, efforts to revive the dog failed.

Both Mr Nicholls and his wife were still upset at the loss of their pet.

Council looks into dog 'poisonings' from river visits

BY SIMON EDWARDS

HUTT CITY Council is looking into a claim that three dogs have been poisoned whilst swimming in the Hutt River.

Louise Pierce from Taita says she took her dog Max for a swim near the dog exercise area north of Fraser Park on Sunday.

Her dog got sick shortly afterwards and had to be taken to the After Hours vet.

The vet told her that she was the third person to bring in a dog that appeared to have been poisoned during a visit to the river.

Max was induced by a vet and treated her as poisoned with 1080.

"If I had not got I would have died," Louise said.

Whilst Max made it home, Louise was told that three other dogs had died.

Council animal officer Dalton told the *Hutt* "we went to press you would look into it if there is any water, he says the council will put up a sign warning dog owners."

THE HUTT NEWS, 22 NOVEMBER, 2008

Fears killer algae may flare up in other areas

LANE NICHOLS

AUTHORITIES fear a toxic algal bloom in the Hutt River that has killed at least two dogs will flare up in other Hutt Valley waterways.

It has brought a warning to keep children and pets away from shallow water. Hutt City Council is urging residents to be vigilant around streams, ponds and drainage ditches as warm weather and low rainfall increase the risk of the algae polluting rural water supplies.

Greater Wellington regional council issued a warning last week about high toxin levels in the Hutt River.

Lower Hutt environmental health officer Dean Bentley said the toxin was likely to be the same algae that killed dogs at Waikato five years ago.

The council advised rural land owners with private water supplies to check for the algae. It is described as a thick,

black-green slimy mat. Anyone with concerns should use an alternative source of water.

Hutt and Upper Hutt city councils have erected signs along rivers and stream banks advising of potential dangers from swimming or walking dogs.

The algal bloom will remain a threat until it is washed away by a heavy downpour.

Be warned: Parks and Reserves cader David Leahy with a sign at Moonshine Park.



Phase 1 – Agencies collaborate



UPPER HUTT CITY
UPPER HUTT CITY COUNCIL



Metron District Council



greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao



HUTT CITY
TE AWA KAIRANGI

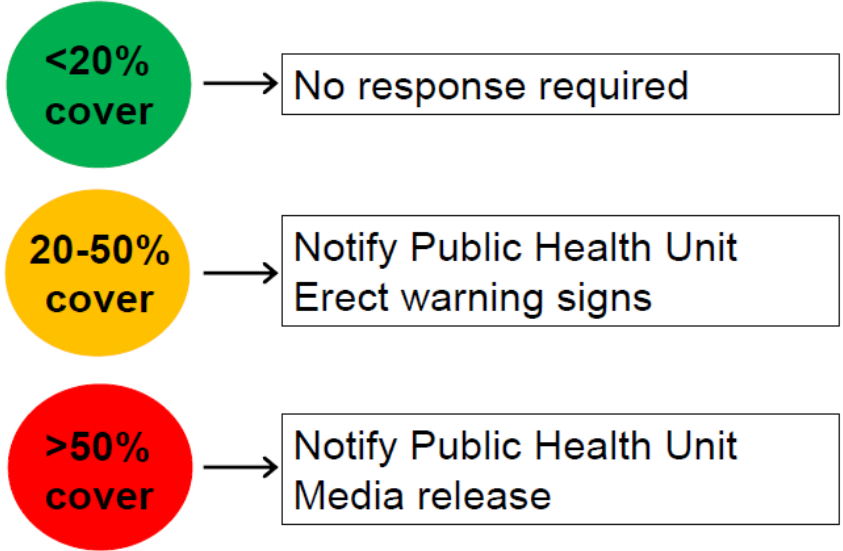


Kapiti Coast
DISTRICT COUNCIL
Me Huri Whakamuri, Ka Titiro Whakamua



Regional Public Health
Better Health For The Greater Wellington Region

Phase 2 – Response protocol



WARNING

TOXIC ALGAE MAY BE IN THIS RIVER

IT CAN MAKE PEOPLE SICK AND KILL DOGS






DON'T swim near or touch the algae



DON'T let dogs near the algae

If you or your dog get sick after being in or near the river, contact your doctor or vet **immediately**.

For more information: gw.govt.nz/toxic-algae
Hutt City Council – 04 570 6666





Blue-green algae warning for Hutt River

LARGE mats of toxic blue-green algae are washing up along the Hutt River, prompting health officials to warn the public to keep away.

Warm weather and low river levels have created perfect conditions for the algae, which are fatal to dogs and can cause severe reactions in humans – rashes, skin and eye irritation, and stomach upsets.

Summer Warr, a senior environmental scientist for Greater Wellington regional council, said high-risk warnings were in place between Silverstream and the Ava rail bridge near Strand Park.

She said algae washed up on the river's edge and very accessible to

people of particular concern, and that people should stay away from the river and not walk their dogs there.

Warning signs had been put up at five public access points, and dogs were also medium-risk in places north of Silverstream and south of Ava.

There had been less algae growth this summer, but a late-summer weather had brought it back. She hoped the next flood or rain on the river would clear it.

Algal mats flushed out

■ Heavy rain this week appears to have cleared the Hutt River of toxic algal mats, which killed two dogs last week. Greater Wellington regional council inspections of popular swimming spots found most of the algal buildups appeared to have flushed away. However, the council says that, with warm weather likely in the coming weeks, algal mats could return, so river users should thoroughly check the water before swimming or letting their dogs in. Staff reporters and NZPA



Deadly algae flares up yet again in Hutt River

Dead pup's owner upset at lack of toxic algae warnings

Matt Stewart and Blair Ensor

A WELLINGTON woman whose dog died after eating toxic algae in the Hutt River plans to complain to the council about its lack of warning about the deadly weed.

Kath McGuinness, 40, from Kelson, saw her 3-month-old border collie puppy, Taco, eating the algae on the banks of the river, between Melling and Ewen bridges, about 6.40pm on Monday.

"I saw him take a little nibble... we ran back to the car. Within 10 to 15 minutes his eyes were really funny, then he threw up and then he couldn't walk," Miss McGuinness said through tears last night.

Taco was taken to the vet, but within two hours he was dead. "He



Another victim Taco, a border collie puppy that died on Monday after eating algae on the banks of the Hutt River.

warn dog owners about the algae. "I'm really angry. [Hutt City] Council are useless."

Warning signs needed to be more visible and letters sent to all regis-

Canine-killing algae return to Hutt River

KATE CHAPMAN



Phase 3 – Comms strategy



greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

WARNING
TOXIC ALGAE MAY BE IN THIS RIVER
IT CAN MAKE PEOPLE SICK AND KILL DOGS

DON'T swim near or touch the algae

DON'T let dogs near the algae

If you or your dog get sick after being in or near the river, contact your doctor or vet **immediately**.
For more information: gw.govt.nz/toxic-algae
Hutt City Council – 04 570 6666

HUTT CITY
Regional Public Health
greater WELLINGTON REGIONAL COUNCIL

IS IT SAFE TO SWIM?
greater WELLINGTON REGIONAL COUNCIL
Te Pane Matua Taiao

CHECK FOR TOXIC ALGAE

Look out for black / brown leathery-looking mats growing on the rocks. Detached mats form 'floating rafts' in the shallows. It's got a distinctive musty smell dogs love. Keep your precious pets safe - don't let them eat anything suspicious.

For the latest toxic algae warnings www.gw.govt.nz

HUTT CITY
Regional Public Health

Phase 4 – Going digital and “show me the money”

Phase 5 – Embracing social media



Phase 6 – Information vs Infotainment

Greater Wellington Regional Council
January 27

My fellow canines,
My human informant tells me that most of the algae in the Waipoua River has been washed away by the heavy rains earlier this week. Much of this algae was a harmless species of diatom, but it was interspersed with patches of toxic algae – which as you know us canines have to be very careful around. The weather's looking pretty nice this weekend, so why don't you get your human to take you for a nice walk down by the river.

Woof.
Tank.



Greater Wellington Regional Council
March 9

Me and my mate Rhino (the little fluffy dude) sure have been feeling the heat this week! If you're keen for a swim on the weekend my human informant tells me the water quality around the region is looking pretty good – the only warning is for Henley Lake which currently has high levels of toxic algae. So keep out of there and don't drink the water!

Also, there's a spot of rain forecast for tomorrow. Remind your humans of the golden rule – wait two days after rain before you swim again. And don't forget, for the latest water quality warnings go to <http://bit.ly/WaterQualityMap>

Woof, Tank

For more information on toxic algae in Henley Lake check out <https://www.msn.govt.nz/news-images/algae-schigh.jpg> and <https://www.msn.govt.nz/healthbro.../HenleyLakebrochure.pdf>

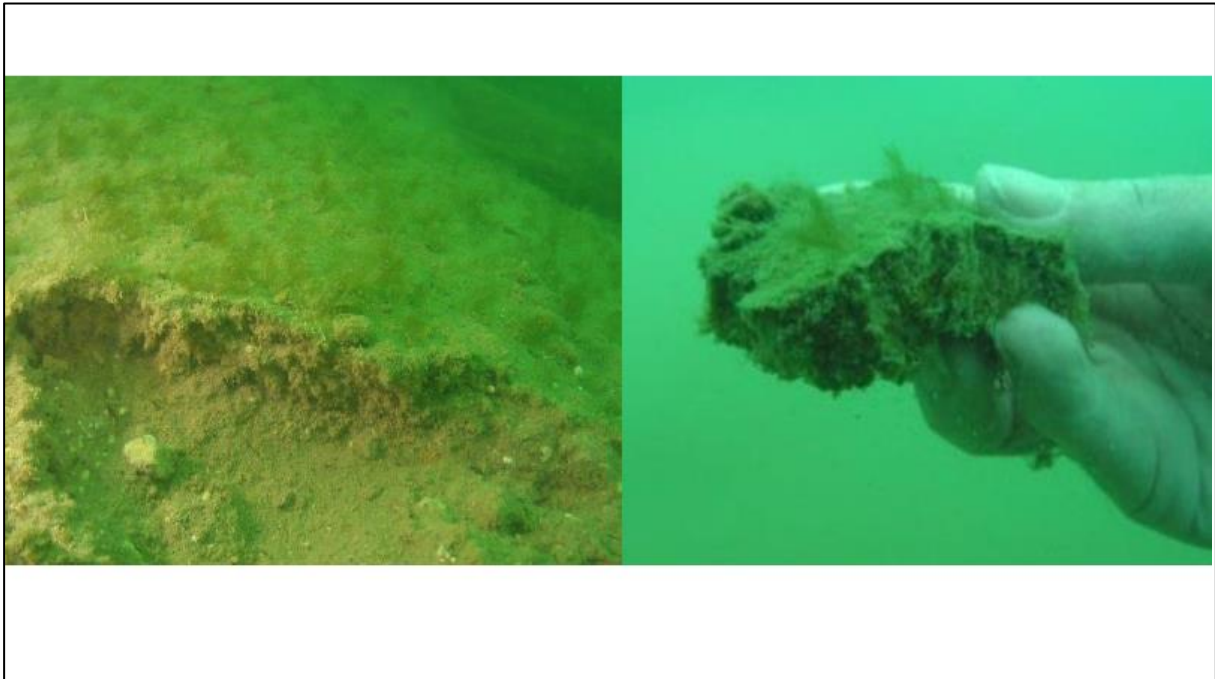


Key lessons learned

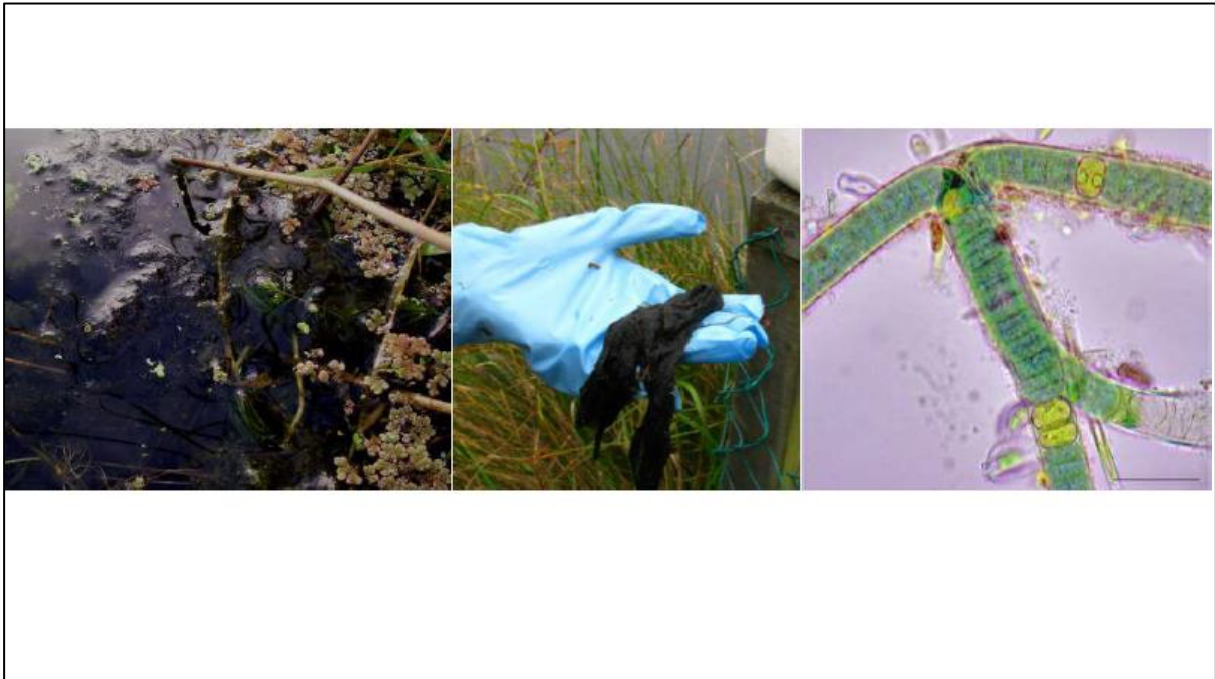
1. Agencies – Collaborate, cooperate, coordinate
2. There's a fine line between "warning" and scaring
3. Educate!
4. Comms staff involvement is crucial
5. Put your money where your mouth is
6. Use multiple avenues to communicate
7. Social media is key
8. Don't be afraid to be creative – think "infotainment"

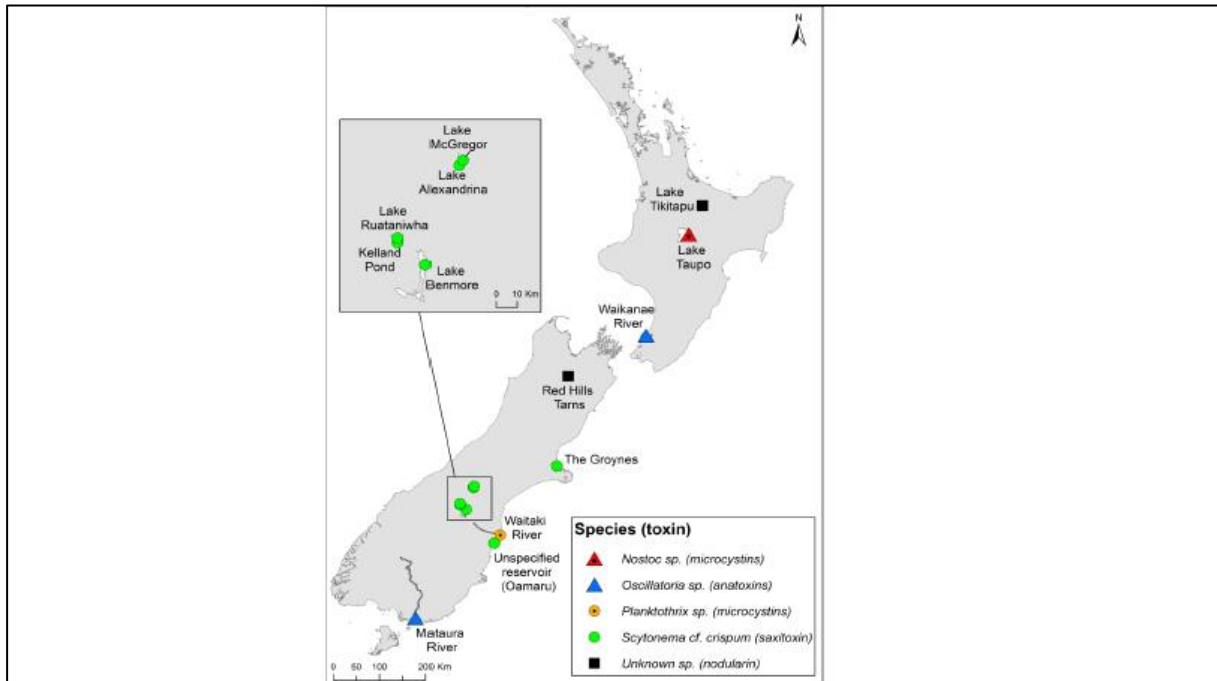
Appendix 8. Presentation given showing examples of benthic cyanobacteria in lake systems as an emerging issue.





Flotation – requires gas bubbles – shallow only due to hydrostatic pressure





Appendix 9. Presentation given by Dr Mark Heath (Greater Wellington Regional Council) on the use of drones for monitoring benthic cyanobacteria in rivers.



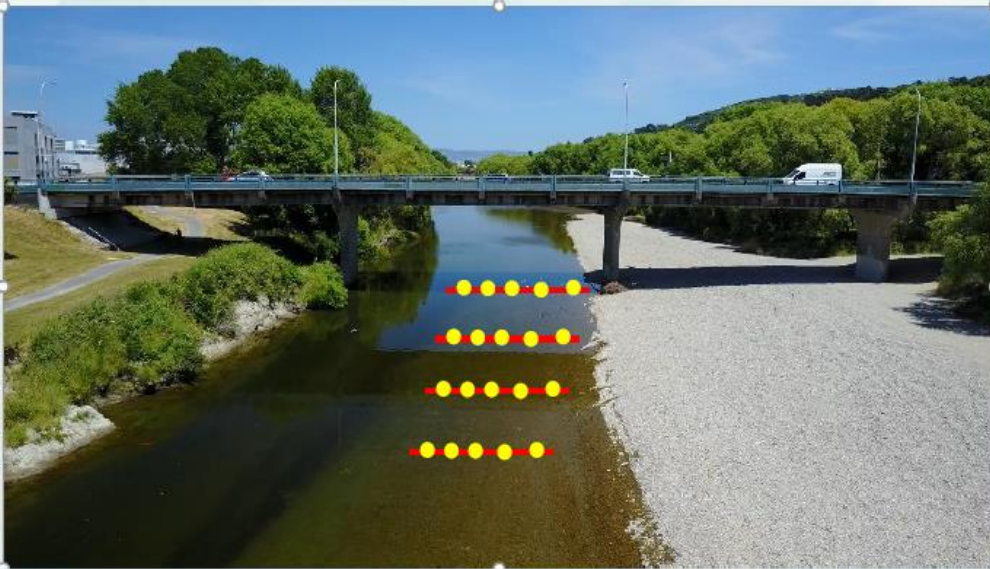
Learning from experiences – drones in action and potential for monitoring



Mark Heath - Senior Environmental Scientist



Gaps/limitations identified





Lessons learnt?

- Semi-quantitative method not fit for purpose
 - bankside assessments
- Drones are superior for assessment of human health risk
- Accurate coverage assessments
- Large spatial scales (500m)
- Site selection tool

Continued...

- Science tool (greater understanding of drivers)
- QC/QA
- Trust (models and investigation of drivers)
- Quick, low cost and easy to use
- Communication/education




greater WELLINGTON
REGIONAL COUNCIL
Te Pone Matua Talao

Collaboration with VUW

- Infrared and multispectral cameras
- Image processing software




greater WELLINGTON
REGIONAL COUNCIL
Te Pone Matua Talao

The future...



BAY OF PLENTY
REGIONAL COUNCIL
Te Pone Matua Talao

Appendix 10. Presentation of new technologies for monitoring / analysing cyanobacteria.

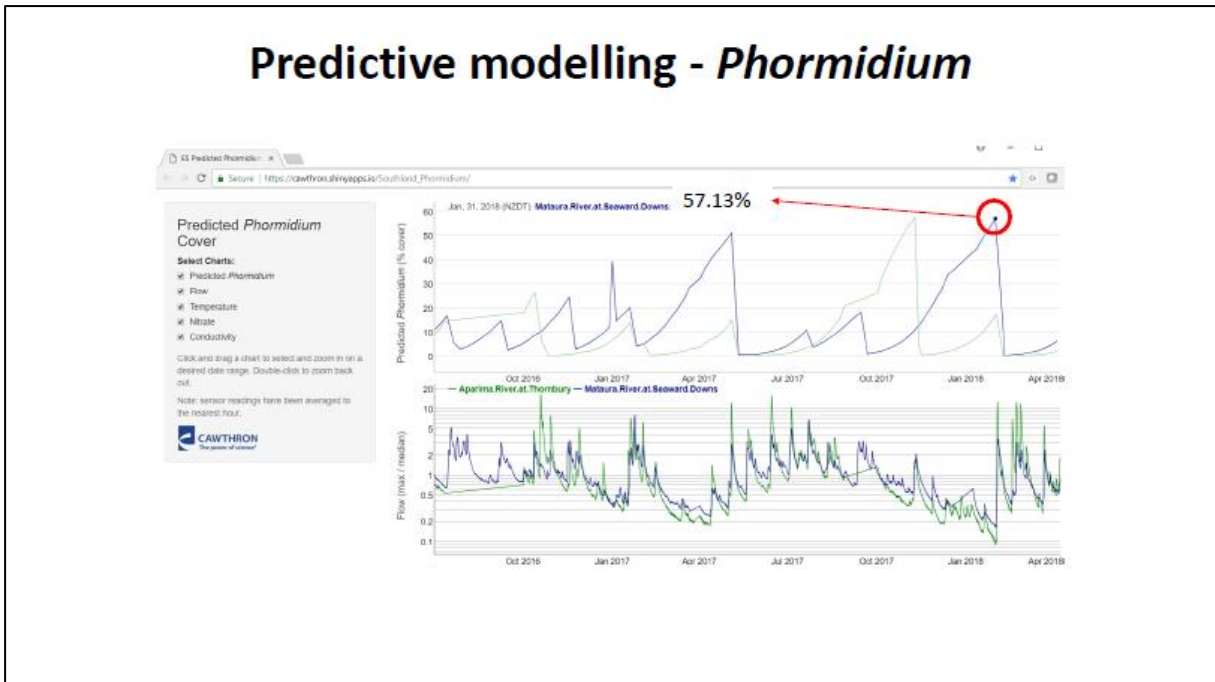
DNA-based toxin screening tool

Microcystis

mcyJ mcyI mcyH mcyG mcyF mcyE mcyD mcyA mcyB mcyC

- Targets toxin genes (MC/NOD/CYN/STX)
- Quantifies total cyanobacteria
- Turnaround >8 hours
- Scalable & cost effective (c. \$200/sample)
- Internal controls

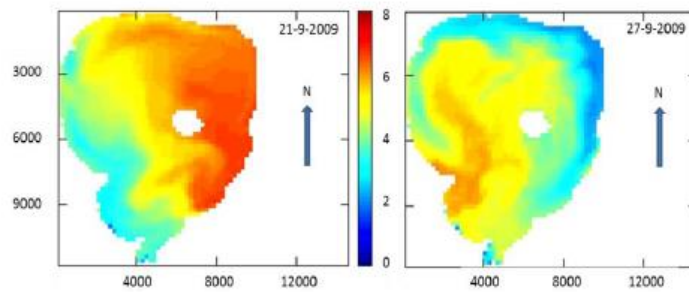
-> Ready to go



Predictive modelling - *Phormidium*



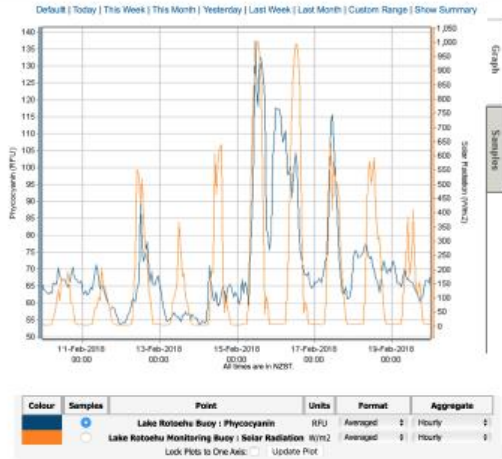
Predictive modelling - Lakes



Sensors



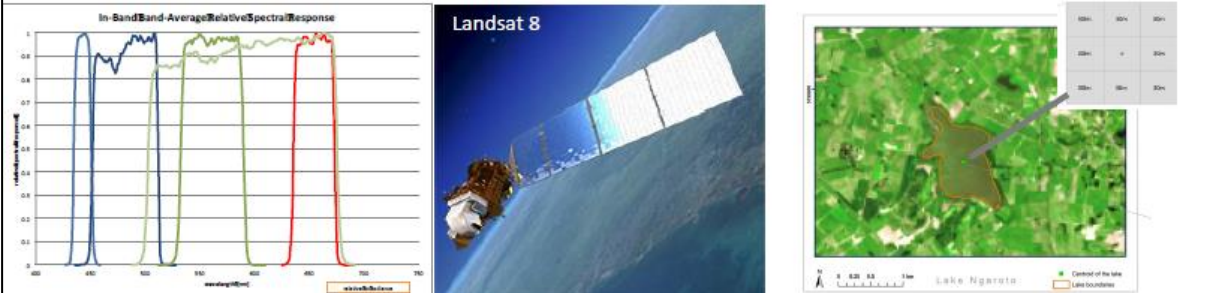
Lake Rotoehu Monitoring Buoy: Phycocyanin



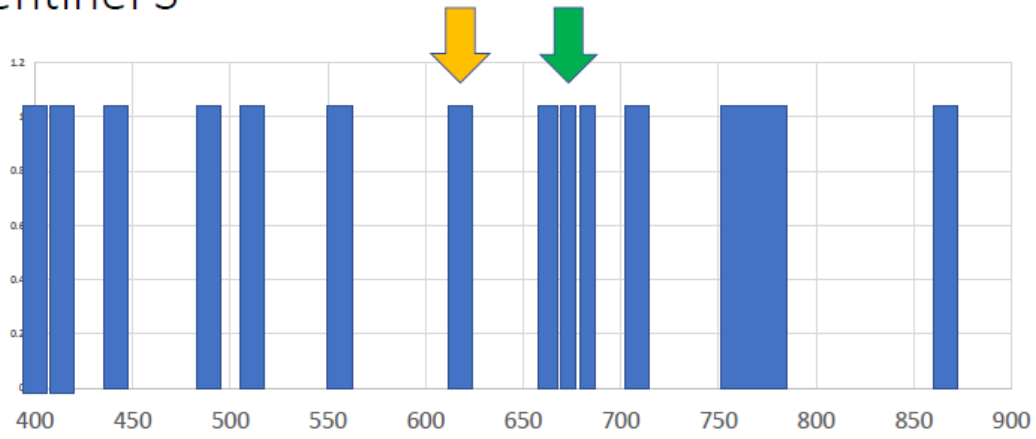
Can RS provide data to support monitoring requirements?

How often are NZ lakes observed?
 What are their optical characteristics?

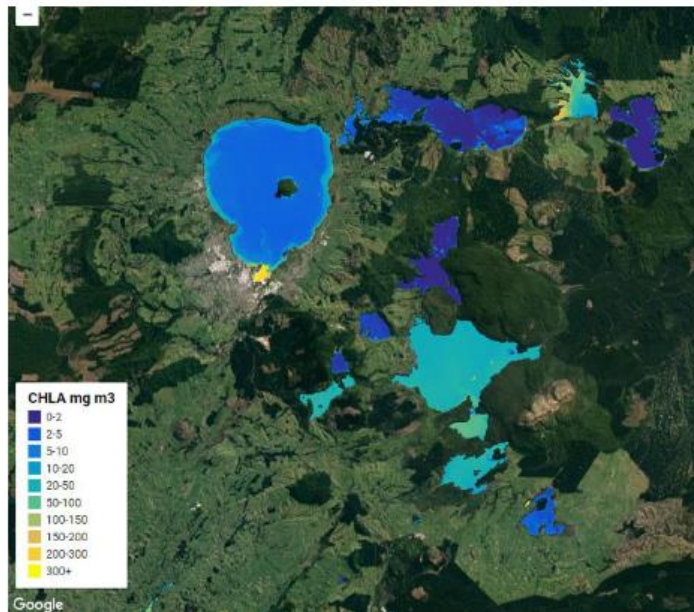
- Landsat 8 radiances and reflectances of 3-by-3 pixels in lake centre



Sentinel 3



Remote sensing



Rapid *in situ* Detection of Cyanotoxins

Abraxis Dipsticks

Per Test = \$40-50 NZ
 Reader = \$3,500 NZ
 Anatoxin, Cylindro, MC/Nod

Creative Diagnostics Dipsticks

Per Test = \$65 NZ
 Reader = \$?? NZ
 Anatoxin

Jellett Rapid Test Kit

Per Test = \$40 NZ
 Saxitoxin

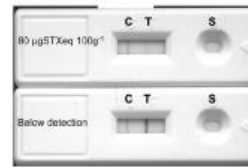
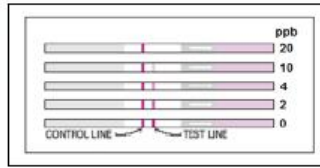
Beacon MC Tube Kit

Per Test = \$15 NZ
 Reader = \$800 NZ
 MC/Nod



Work to be done

Assess Sensitivity??
 Validate Performance



Appendix 11. Detailed workshop summary notes

Summary of discussions from the New Zealand Guidelines for Cyanobacteria - review workshop

Ministry for the Environment, 7 May 2018, Wellington

1. Planktonic cyanobacteria

1.1. General challenges when dealing with planktonic cyanobacteria

- Issues associated with assessing picocyanobacteria:
 - Accurate species identification and quantification.
 - Consistency between laboratories and methods.
 - A lack of information on picocyanobacterial toxicity in New Zealand.
 - A lack of biovolume information for some picocyanobacteria.
- The representativeness of sampling due to large spatial and temporal variability:
 - How to deal with variability (vertically, temporally, horizontally). There is a need to revisit current recommendations regarding how to deal with variability.
 - Improved guidance is needed for sampling methodology (i.e., councils currently use variable techniques; some still use grab samples others tube samples, some sample downwind vs fixed location)
- Issues associated with biovolumes:
 - Currently the guidelines suggest using species-specific single values, yet research suggests these can be highly variable and regionally- (or lake-) specific.
 - Lookup tables need to be kept active, renewed and continually updated.
 - Accurate biovolumes are critical for issuing warnings but commonly taxa are only identified to genus level and biovolumes can be lake- or regionally-specific.
 - A suggested remedy was to use standard biovolume values when cyanobacteria levels were below a threshold and to use site-specific values when a threshold was being approached. Site-specific values should also be used when there are higher levels of consequence, e.g., a very popular site with high usage vs a site that restrictions of usage will have small impacts.
 - Is there a relationship between toxicity and biovolume?
- Consistency of laboratory methods related to toxin testing – e.g. lysing vs testing whole sampling (e.g., filtered/pre-filtered/non-filtered; recreational vs drinking water).
- Are we assessing the toxin content with high enough frequency to actually understand which samples are toxic, and how can we incorporate into routine monitoring given the high testing costs?
- Dealing with non-monitored water bodies (e.g., camps, new lakes, artificial lakes and when environmental health funds can't be used).
- When to lift health warning? How many samples/times until health warning lifted? Are there other proxies that would be used (e.g., chlorophyll)?
- Frequency of monitoring and risk assessment:
 - Equating risk to monitoring frequency at a national scale (e.g., MPI interest as recreational harvest sites in difficult monitoring areas).

- Timeframe; i.e., fortnightly or monthly?
- Levels of risk; i.e., recreational use vs frequency of monitoring.
- Understanding the relationships between driving variables and planktonic cyanobacteria.

1.2. Suggestions for addressing challenges with planktonic cyanobacteria

- Methods to cope with variability - Include guidance around the use of phycocyanin sensors as an early warning system (i.e., show wind effects).
- Integrating monitoring buoys (phycocyanin sensors) and temperature to indicate stratification effects on bloom formation.
- Employ remote sensing as an initial screening method to help cope with variability and spatial scale limitations.
- Propose guidelines for artificial lakes including roles and responsibilities as well as simple and practical risk management strategies for artificial lakes.
- Monitoring needs be practical, cost effective and balanced with ownership and level of risk.

2. Benthic Cyanobacteria

2.1 General challenges when dealing with benthic cyanobacteria

- Site selection – Issues surrounding site selection and subsequent effectiveness:
 - Percentage cover of benthic cyanobacteria is variable and both site and reach specific.
 - Site selection in relation to different recreational activities and the relative importance (low to high use) of different recreational activities regarding risk and site selection (e.g., contact recreation, swimming vs dog walking, kayaking vs fishing, school camps).
 - Sites are selected based on monitoring limitations or past knowledge; i.e., depth (wading limitations on site selection), access, history of recreational monitoring, substrate, which might interfere with the representativeness of site.
- Downstream effects of river cyanobacteria – it would be useful to have further advice of the possible effects on downstream sites/environments:
 - Toxins in river water.
 - Detachment of mats.
 - Should an upstream bloom trigger downstream warning?
- Defining risk effectively. Need more guidance and justification of how percent cover relates to risk. Currently the system is essentially binary with > 20% leading to the same management action as the > 50% threshold. 50% was questioned as being too high as high cover levels do not necessarily relate to the risk of detaching mats - which is a greater risk? There needs to be a better link of cover to risk and how to assess the risk. Risk assessment needs to address the risk of exposure alongside using coverage to assess risk.
- Defining the risk of detaching mats: Any detachment is high risk regardless of percent cover and this can lead to public confusion.
- Species identification - Correctly identifying *Phormidium* in multispecies mats (e.g., diatoms plus *Phormidium*) that is then assumed as *Phormidium* which could lead to conservative results and a precautionary approach.

- Testing cyanobacterial samples for toxins:
 - Percentage cover of cyanobacteria vs toxins in mat (or water) is not known, which makes practical implementation of toxin testing difficult. Information such as how much to sample, how many samples are required, where to sample, to what extent is sampling required. Also require information regarding mat vs water sampling for toxins.
 - Limitations to toxin testing include time taken for toxin testing to occur (delay in response time) as well as cost of toxin testing.
- Downgrading response from red (action mode) to orange or green modes. Need to consider whether it makes sense that two surveys are needed to downgrade risk. Benthic cyanobacteria growth is a dynamic issue (changes quickly).
- Should a large flushing event lead to an immediate downgrade from red action mode if the benthic cyanobacterial cover has been removed?
- Issues were raised about guidance associated with streams that are used as drinking water supplies as well as food chain accumulation of toxins in rivers.
- There is vagueness when reporting on human effects and there needs to be more information on health impacts.
- Benthic mats in lakes (see Section 4, Emerging Issues).

2.2 Suggestions for addressing challenges with benthic cyanobacteria

- Site selection needs to be regionally or river specific - due to huge variability and site specificities.
- Multiple phase sampling – surveillance and then sampling (e.g., drones).
- Combine monitoring programmes; i.e., micro-biological and cyanobacteria monitoring, site selection for recreational sites could aligned with SOE sites. Sometimes this is not helpful – microbiological sites are often not suitable for cyanobacterial monitoring.
- Guidance on site selection.
- River specific forecasting – Develop forecasting models as predictive tools: can these lead to more accurate prediction of risk areas.
- Identified the potential of molecular tools, specifically in relation to analysis on genes/toxins/species. This requires more resourcing for complex analysis and includes the issue of repeatability and variability.

3. Communicating the risk

3.1 Current methods of communicating risk

- **Media:** TV, Radio (e.g., Morning report), Newspapers (these involved pre-season warnings as well as reports of bloom events).
- **Commissioned Advertising:** Internet (pay for appropriate messaging and aim for high-exposure sites (e.g., banner advertising on MetService which was related to the greatest risks according to the weather; i.e., recent rain in the region = *E. coli* warnings, warm conditions with no rain for a period of time = *Phormidium* warnings), paying to boost social media presence, promotional advertisements on council cars, advertorials in local papers.
- **Warning signs at sites**

- **Social Media:** Facebook (most popular), Twitter, Neighbourly, a suggestion that the Red Cross Hazard app could possibly be used.
- **Websites:**
 - LAWA (in particular the “can I swim here” component)
 - Overall feeling was that a national approach to communicating water quality was good, but it needs to have more flexibility (e.g., LAWA has combined risk but there is a need to delineate the risk so that people don’t get confused about why they can’t swim and start ignoring warnings).
 - Difficult to use for one off bloom events as fact checking is required prior to uploading of water quality data, an option to expediate certain data would be useful.
 - More education – could there be an expediated LAWA update?
 - Local sites (e.g., own council sites): often link to LAWA from own site but retain regional specific information internally.
 - YouTube for hosting of video content.
- **Bathing Updates:** Sent out to representatives of interest groups as well as to internal communications.
- **Promotions:** To increase interest and awareness (e.g., ‘Spruce your spot’, photo competitions).
- **Education and risk communication to the public**
 - Seminars, pamphlets, Tank the Pug (Social Media), Enviro-Schools (teaching in primary schools).
 - Use/educate contact centre staff to free up monitoring staff.
 - There is a requirement for consistent terminology – e.g., (potentially) toxic algae or toxic cyanobacteria.

3.2 Issues associated with communicating risks

- Signage at sites is not very effective as it is largely ignored by public.
- Delays in communications because of testing times (planktonic).
- Permanent health warnings lose effect.
- Variability and region-specific issues, for example internet availability – not all regions have 100% internet users, especially in rural regions. Quick Response codes might work in urban areas but not in rural areas. Demographic differences (e.g. social media vs radio/newspaper).
- Understanding and communicating ‘real risk’ levels with confidence (e.g., stretches of whole rivers, lakes with buoyant blooms).
- Reach vs site – monitoring location bloom vs reach risk can lead to misinterpretation of risks by public (e.g. media release misinterpretation of location vs risk).
- Anxieties about programs at schools – cancelling river field trips (e.g., Enviro-Schools).
- Inconsistent messaging across and within regions.

3.3 Suggestions for improvements and resources required to better communicate the risk

- Alternative/improved communication strategies

- App development – educational, GPS coordinated. e.g., LAWA app, regional QR codes on the signs in Wellington link to the correct location on the “can I swim here” map.
- Combine online approaches – e.g. link LAWA/local sites to big tourism apps (i.e., camper apps) or Met Service etc.
- National standardised sign (logo changeable).
- Other platforms – Instagram? Snapchat?
- Not just informing about bad news but also good news – e.g., when blooms are gone and it’s safe to swim again.
- Professional guidance on the communications strategies used could be a useful investment.
- Communication strategies need to be always evolving and need to consider regional variation/flexibility (e.g., foreign visitors vs locals).
- Stronger guidance on how agencies in the same region might work together better:
 - Guidance on the legislation which underpins each agency’s legal responsibilities to partake in the assessment and communication.
 - Guidance on communicating cyanobacterial risk in recreational waters should mirror the same guidance used for microbiological risk communication.
- Education:
 - Alternative education strategies – e.g. Myth busters (GWRC willing to contribute), facts, FAQs, factoids, debunking urban legends (consistent message across the country) - educate before questions are asked by the public.
 - Nationally coordinated education (e.g., television advertisements).
 - Wider variety of messages - including awareness between bloom events.
 - Infographics – easily digestible packets of information.
 - Case studies – humans and dogs.
 - Production of a summary of technical reports for educating internal staff on the latest research/data – to help with contact centre staff education.
- Alert effectiveness and coordination:
 - Coordination with water suppliers – communication coordination.
 - Geographic text alerts – i.e., how the civil defence text system works.
 - Directly accessing user groups in regions (e.g., iwi, fishers, duck hunters, etc.)
 - Distribution of health messages could utilize national telehealth service for public concerns such as Healthline or National Poisons Centre.
- Photos of blooms – need a database and perhaps drone footage. Suggestion for public engagement – gather photo database with “find the bloom”.

4. Emerging Issues

4.1 Benthic cyanobacteria in lakes

- **Example of a bloom of benthic, flocculent mats in Lake Taupo**
 - Concern – the Taupo bloom was a one-off event but need guidance in the future if the bloom event is more long-term.

- Guidance on how to assess risk with low- or medium-level blooms, consideration of high contact points (e.g. swimming/contact).
 - Guidance on when a health warning should be maintained
- Taupo – *Nostoc* accumulates around the edge of the lake year-round – how to cope with this as part of a monitoring programme as they will always be present.
- Consideration: Should the guidelines provide advice for specific events or for long-term surveillance of lake benthic mats?
- Proposed: Guidelines should highlight what to look for and where to seek advice, observational guides, potential species, when and where to monitor for this phenomenon.
 - There is a lack of knowledge on which species are present and related toxin production and a need for guidance on how to interpret this information.
 - Guidance on how to assess risk, considering high contact points (e.g., swimming).
 - Need guidance on sound sampling methods – flocculent benthic mats lift up and are very easily disturbed when sampler steps into the water, the structure of lake benthic algae is variable (range of species) which provides challenges for monitoring.
 - Biovolume? (may be not suitable), maybe alternative measurement is needed for benthic cyanobacteria in lakes (e.g., cover, visual surveillance).
 - Guidelines could provide a baseline knowledge of benthic cyanobacteria in high risk areas.
 - Guidelines could provide direction (in response to historical event) but can give justification for future resourcing

4.2 Impact of freshwater toxins on marine environments

- Should the guidelines address the river-estuary interface?
 - Risk of *Phormidium* downstream impacts (i.e., mat and toxin drift).
 - Kaituna River given as an example of a river with high cyanobacteria (planktonic) that discharges into an estuary as an example of high risk of anatoxin exposure.
- Guidelines should provide guidance on knowledge of cyanobacteria in estuaries and tidal zones:
 - A potential strategy to meet needs would be to draw on international literature, highlight knowledge gaps.

Strains vs 'species'

- Issues raised:
 - Taxonomy and toxins – difficult to identify strains (e.g. numerous *Microcystis* strains – both toxic and non-toxic).
 - Validity of culture-based toxicity studies vs field sample results.
- Potential for qPCR to identify toxin genes (toxic vs non-toxic).

4.3 Climate change: Guidelines should comment on this and highlight potential risks and changes – Provides justification of a need for the guidelines to be a 'living document'.

5. New Technologies

5.1 Drones

Future potential of drones for monitoring of benthic cyanobacteria in rivers

- Drones footage can show percent cover over large spatial scale – shows variability along entire river (can access non-wadable areas) vs the more limited in-stream site assessment.
- Drone footage can identify limitations/gaps in site coverage/representativeness – Is a very useful tool for site selection.
- Could be used as a science tool to greater understand the drivers of benthic cyanobacteria.
- Potential to use infrared/hyperspectral cameras for detecting *Phormidium* and image analysis software for automatically assessing percent cover.
- Quick, low cost (small capital cost; \$2-3k), easy to use.
- Footage can be used as material for communication strategies.
- Limitations of drones (at this point in time):
 - Lack of confidence in *Phormidium* identification vs other periphyton.
 - Recognising detaching mats in waterway.
 - Drone regulations mean that there are additional permits required when they are to be used in a professional situation.
 - Drones can only fly under certain conditions.
 - Semi-quantitative, so they may need additional assessments (e.g., bankside assessment).
 - Need more information on effects of mixed assemblages, turbidity, riffles/rapids, glare, shading.
- Considerations – How would drone monitoring be integrated into current monitoring plans; i.e., the merit of monitoring replication (e.g., bankside assessments and in-stream monitoring).

5.2 Molecular tools: DNA-based toxin screening

- Has potential to be used as an initial toxin screening tool. Assays can detect the genes involved in the production of saxitoxins, cylindrospermopsins, anatoxins, nodularins and microcystins.
- Benefits:
 - For planktonic cyanobacteria could identify non-toxic/toxic and therefore enable the 2nd (i.e., non-toxic) threshold to be used.
 - Minimise analytical toxin testing as only positive samples are tested by LC-MS.
 - Can be used in unknown situations to quickly assess the potential risk.
 - No additional sampling required - sample material can be used for both DNA screening and toxin testing.
 - Extremely sensitive.
 - Results can be obtained within 1 day.
- Limitations:
 - Not quantitative but could be developed to be semi-quantitative (i.e., low, medium, high).
 - The presence of toxin production genes does not provide an indication of the amount of toxin present.
- Positive feedback was received from the workshop participants to include molecular tools in the new technologies toolbox and to provide guidance of the specific situations where the technique would prove useful.

5.3 Predictive modelling

- Models for both benthic and planktonic bloom formation were highlighted.
- Benthic models are site specific and have the potential to be used as a preliminary warning tool which when certain cover thresholds are reached may trigger actual monitoring:
 - Could be used to focus monitoring efforts to sites of greatest risk.
 - Opportunity to retrain models with additional data collected through monitoring programmes.
 - Future development – could include using forecasting of rainfall/flow so that it can be used as a forecasting model.
- Limitations of the benthic model:
 - The better the data available for a site (needs to be weekly) the more accurate the models are likely to be.
 - Models need further validation.

5.4 Phycocyanin sensors

- Detection of the fluorescence signal of the cyanobacterial pigment phycocyanin can provide a proxy for cyanobacterial biomass:
 - Can be attached to in-lake buoys or used as a hand-held device. Could work best where it is possible to develop up a time series of phycocyanin readings on a lake.
 - Many different manufacturers of sensors which vary in quality and specific cyanobacterial sensitivity.
 - Has the potential to be a relatively rapid method to assess cyanobacterial biomass.
 - Maybe possible to relate phycocyanin thresholds in the mid-lake to the start of accumulation on shoreline (when linked to other parameters; e.g., wind).
 - Should calibrate sensor as the calibration can vary between manufacturer and with species present, so this is necessary to maintain confidence in the data over time.
 - May be useful for ground trothing of remote sensing for cyanobacteria
- Limitations:
 - Not 100% specific as some green algal species also emit same wavelength of light.
 - Some challenges related to different species having different levels of phycocyanin and measuring colonial cyanobacteria.
 - Need to have some understanding of species in lake to relate phycocyanin signal to biomass.
 - Advice on good sensors should be sought, as many manufacturers can ‘promise the world’ but not deliver the performance.

5.5 Remote Sensing

- Has potential to be used to assess cyanobacterial bloom at a regional or national scale. Could be used to identify lakes with potential blooms, or specific sites within larger lakes. Presently remote sensing can only detect chlorophyll (i.e., detects all phytoplankton, not specifically cyanobacteria). Sentinel 3 Satellite has potential to measure phycocyanin (between 600 – 650 nm absorbance) but has a large (300 m) footprint:

- Provides potential to look at a wider number of lakes: increased coverage and spatial surveillance ability.
- Can focus monitoring efforts on lakes with cyanobacteria present (i.e., could be used to exclude low-risk lakes).
- Faster turn-around times – results within hours.
- Good tool for site selection.
- Limitations:
 - Requires validation (Ian Hawes has a MBIE Smart Ideas proposal in the second round to do this work and he is seeking expressions of support from end-users interested in using this technology).
 - Only assesses the top layer of water in the lake.
 - Turbidity and weather conditions (e.g., clouds) can affect the signal.
 - Pixel size of the satellite camera determines the size of lake which can be assessed (i.e., smaller pixel size = smaller lakes can be assessed otherwise effects from land-based signals become evident). Sentinel 3's pixel size is quite large, but the data quality will get better with time and development in the validation of this technology will be transferable.
 - Need to calibrate form other materials in different water bodies (i.e., CDOM)
- Potential to combine remote sensing and phycocyanin sensor data.

5.5 Rapid *in situ* toxin testing kits

- Realtime toxin results can be acquired in the field using dipstick tests:
 - Kits are available for microcystin/nodularin, anatoxins, cylindrospermopsin and saxitoxins.
 - Cost can be up to \$50 per test.
 - Could provide preliminary information on the potential risk.
- Limitations:
 - Tests are mostly designed for water samples, however, cell lysis kits are available (their effectiveness with benthic cyanobacteria is probably not well tested).
 - Not quantitative but could be used as an initial screen before LC-MS testing.
 - Assessment of the sensitivity would be required.
 - Some assessment of robustness should be performed before incorporating into a monitoring programme.

There was support from the workshop participants for an emerging technology toolbox approach to be included in the guidelines where information would be provided on developing technologies with guidance of how they might be used and integrated into monitoring programmes. This is highlighted further in Section 7 (comprehensive monitoring programme).

6. How should the guidelines look?

6.1 Combination of feedback from question sheets and session

There were no issues found with the general structure of the Guidelines document. There were several proposed sections that may be added to the appendix. The main addition that was widely proposed was a toolbox of approaches, including new technologies with guidance about how to use and integrate into monitoring programs. Also, there were improvements/changes that were proposed to be made to sections of the interim Guidelines. Regarding the document access, both pdf/printed and web-based versions were determined to be valuable. There was also support for an online living document that would allow for specific sections to be updated more frequently as required. Changes to the document would have to be transparent and dated and the users notified.

6.1 Additions to Guidelines:

- Toolbox of new/alternative technologies – how to use and integrate into monitoring programmes.
- Examples of effective communication strategies (e.g., case studies from various regions).
- Guide to field sampling methods (i.e., a simplified field sampling sheet that can be used by many, including students).
- Health and Safety information – including cyanobacteria specific health and safety.
- A look-up biovolumes tables or alternatively a biovolume calculator.
- Include a factsheet for vets.
- Include a factsheet for dog owners.
- Health risks of toxic vs non-toxic species of cyanobacteria (still risk of skin irritation with non-toxic) in addition to more defined health risks (e.g., to humans, toxic food consumption, dog health).
- More defined legal responsibilities for different agencies involved in cyanobacteria monitoring for the purpose of protecting human health.
- ‘Executive summary’ for media people: e.g., what are cyanobacteria, what does sampling involve, etc.
- Contacts page for who agencies can contact; e.g., MfE, MoH.
- Section on lake fringe sampling.
- Photo database.
- Links to standard national communication resources that can be locally adapted (i.e., signage, FAQs and quick forms, visual aids – photos, videos).
- Guidance on potential downstream effects of benthic cyanobacteria in rivers.
- Estuaries – include recommendations on the extended impacts from freshwater cyanobacteria (e.g., expected dilution rates that might enter marine environment).
- Decision tree diagrams.
- Best practice scenarios (flowcharts).
- Downgrading template for the MoH after event.
- Include the science behind sampling different areas in relation to sample results – i.e., sampling in proximity to rocks with cyanobacteria and sampling in passing/surrounding water.
- Guidance surrounding recreational sites that are co-located with drinking water sources – if recreational water warning is issued then water supplier must be informed.
- NOF / NZ drinking water standards / attribute cyanobacteria / recreational guidelines all need to align.

- Overall latest scientific knowledge – online so it can be updated, list of current species and associated toxin production identified to date in NZ.

6.2 Improvements/changes to current interim Guidelines

- Biovolumes – site specificities (related risk communication), expanded species list, include variability data, provide advice on targets that might indicate that total biovolumes should be calculated (make effort/resources targeted).
- Updated list of potentially toxic / non-toxic species in New Zealand.
- More guidance around the risk of toxin bioaccumulation in the food chain.
- Re-evaluate the two-weeks monitoring to go back from red alert to amber/green - Defined alert levels and procedures for warnings that are practical and do not restrict access to waterways unnecessarily.
- Guidance on issuing and lifting health warning and how to appropriately communicate risk to public – simplicity is key regarding risk response.
- Guidance surrounding site selection.
- Provide alternative communication strategies for areas with no cell phone or internet coverage.
- Requirement for the validation of information regarding toxin production and health risk.
- Mechanisms for lifting health warnings – confidence that bloom won't re-occur.
- Need a better understanding of risk of cover & detaching/exposed mats – Low level coverage (benthic alert and action levels) that are more defined than 0-50% and need some sort of actual level (%) and detaching/exposed mats.
- Risk assessment tools - need sections on assessing decrease/resolution of risk when blooms subside and communication for benthic/planktonic blooms/mats in lakes/ivers.
- Plain English where possible so it can be more widely used.
- Updated biosecurity section – this is out of date.
- Standardised sampling approaches.
- Toxin monitoring – power analysis (requires study), optimum number of samples to detect toxin presence (include percent mat and river cross section), quantify cell size/toxin production.
- Guidance for DHBs about toxin symptoms & framework to record potential human health toxin incidences.
- Need to consider what to include in specific guidelines vs what is included in the document as advice (i.e., what are considerations vs what are prescriptions - flexibility is required for advice on the communication of bloom events).

6.3 How should the guidelines be accessed?

- Support for continuing the current PDF version of the entire Guidelines document, although a useful addition would be linking of the contents page to the various sections

(and also linking throughout the document when sections or appendices are mentioned) so that the section required can be accessed more easily.

- Also support for a web-based living document so long as changes are widely announced and a full version of the guidelines can be generated: certain sections might merit updating more frequently; e.g., emerging technologies, timeframes around development and integration, detections/species/toxins in NZ- what is happening in NZ, evolving communication strategies, photo database.

7. What would a comprehensive sampling/monitoring programme look like?

Main points:

- A lot of interest in utilizing a large toolkit with multiple monitoring techniques/approaches. Using different technologies to develop a tiered approach with an initial screening/visualisation tool (e.g., Drone survey along rivers, Sentinel satellite remote sensing for lakes, phycocyanin sensors, DNA-based toxin gene screening, bankside assessments) followed by subsequent sampling/monitoring/risk assessment options based on the situation. Ideally, specialised optics (such a drone hyperspectral cameras) could be employed to specifically detect cyanobacteria cover and provide an automatic calculation. This toolkit should still be tailored to prioritise risk of human health and understand what can be done to reduce bloom frequency, and take into consideration differences in the available resourcing between regions.
- There were considerations to this toolkit framework. For example, there was not unanimous interest in drones with issues such as effectiveness in riffles/rapids being raised. In addition, cost benefits of methods must be considered for these technologies. Also, methods need to be practical and able to work in rural areas and large catchments. One opinion was that the guidelines should not include upcoming techniques (i.e., changing technologies) and should exclusively focus on only the currently available methods.
- Acquisition of real-time results was desirable (e.g., *in situ* lakeside/streamside toxin testing and remote sensing of cyanobacteria).
- Approaches described need to be multi-agency.
- Sufficient monitoring frequency (e.g., weekly site monitoring) and robust sampling programme to deal with spatial heterogeneity (lakes and rivers) – many councils struggle to do weekly monitoring and once warning is in place, repeated monitoring is primarily undertaken to downgrade an alert.
- Determination of strains that have toxin production gene – enables refinement of risk assessment/communication.
- Risk model that could be developed to support sampling/monitoring programme.
- Predictive modelling for key recreational sites – e.g. meteorological-linked model (or stratification model) as a bloom forecasting tool.

Appendix 12. Prioritised list of suggested amendments or new areas to include in guidelines.

Recommendations for improvements to the guidelines as suggested by workshop participants

1. Suggestions for improvements to guidelines that are included as part of the scope of the Guideline Review project

1.1. Recommendations for refinement / improvement of sections that are already included in the Interim Guidelines

Major refinements / improvements

1. Include the latest scientific knowledge, i.e., an updated list of potentially toxic / non-toxic species and associated toxin production in New Zealand.
2. Include the science behind sampling different areas in relation to sample results, i.e., sampling in proximity to rocks with cyanobacteria and sampling in passing/surrounding water. *This is partly present in the Interim Guidelines. There is potential to review the benthic sampling section.*
3. Re-evaluate the current protocol of undertaking two-weeks of monitoring to downgrade risk from red alert to amber/green. This requires defined alert levels and procedures for warnings that are practical and do not restrict access to waterways unnecessarily.
4. Provide greater understanding of risk of cover & detaching / exposed mats. Low coverage levels need to be more defined than just a range from 0-50% (benthic action level) and need to include detaching/exposed mats information alongside a percent level of coverage to inform alert/action levels. *This is work/research in progress*
5. Provide risk assessment tools and related communication strategies, i.e., guidance on assessing decrease/resolution of risk when blooms subside and communication for benthic/planktonic blooms/mats in lakes/ivers.
 - (a) Guidance on issuing/lifting health warnings and how to appropriately communicate risk to the public when considering that simplicity is key to risk response.
 - (b) Guidance on lifting health warnings that provides confidence that blooms will not re-occur.
 - (c) Consideration on what to include in specific guidelines vs what is included in the document as advice (i.e., what are considerations vs what are prescriptions of the Guidelines. This specifically relates to flexibility around advice on the communication of bloom events).
6. Validation of information regarding toxin production and health risk.
7. A standardised sampling approach.

Minor refinements / improvements

8. Field sampling method guide, i.e., a simplified field sampling sheet that can be used by a range of cyanobacterial site monitors, including students
9. Contacts page for who agencies can contact; e.g., MfE, MoH.
10. Plain English where possible so it can be more widely used.
11. Guidance surrounding site selection.
12. Update biosecurity section.

1.2. Recommendations for additions to Guidelines

1. Include recommendations on the extended impacts of estuaries from freshwater cyanobacteria (e.g., expected dilution rates that might enter and impact on the marine environment).

2. Provide guidelines around toxin monitoring i.e., power analysis (requires further research), optimum number of samples required to detect toxin presence (include percent mat and river cross section), quantify cell size/toxin production.
3. Examples of effective communication strategies (e.g., case studies from various regions).
4. More guidance around the risk of toxin bioaccumulation in the food chain.
5. Include a factsheet for dog owners.

2. Suggestions for improvements to guidelines that are beyond the scope of the Guideline Review project

1. Provide a toolbox of new / alternative technologies with information on how to use and integrate technologies into current monitoring programmes.
2. Include a section on lake fringe sampling of cyanobacteria.
3. Provide more information about biovolumes, e.g., site specificities (and related risk assessment and communication), expanded species list, variability data, provide advice on targets that might indicate that total biovolumes should be calculated to make effort/resources more targeted).
4. Define legal responsibilities for different agencies involved in cyanobacteria monitoring to protect human health. *Agency responsibility is outlined in the Interim Guidelines. This section may be refined however legal responsibilities are beyond the scope of this project.*
5. Health and Safety information including cyanobacteria specific health and safety. *Some health and safety information is present in the Interim Guidelines but there was a suggestion for a more comprehensive section in the appendix.*
6. Include a factsheet for vets.
7. Guidance of protocol surrounding recreational sites that are co-located with drinking water sources. For example, if a recreational water warning is issued then water supplier must be informed.
8. Alignment of the NOF / NZ drinking water standards / attribute cyanobacteria / recreational guidelines.
9. Guidance on potential downstream effects of benthic cyanobacteria in rivers. *Requires the development of research questions as there is a lack of data to provide adequate guidance.*

Communication resources database

1. Provide an 'Executive summary' of cyanobacterial risk assessment and monitoring for media / communication people working at agencies: e.g., what are cyanobacteria, what does sampling involve, etc.
2. Photo database. *The Interim Guidelines provide a limited number of cyanobacteria photos. The development of a larger photo database is beyond the scope of this project.*
3. Links to standard national communication resources that can be locally adapted (i.e., signage, FAQs and quick forms, visual aids, e.g., photos, videos).
4. Decision tree diagrams and best practice scenarios (flowcharts).
5. Provide alternative communication strategies for areas with no cell phone or internet coverage.
6. Provide a downgrading risk template for the MoH after an event.

Information about cyanobacterial health risks

1. Provide information on the health risks of toxic versus non-toxic species of cyanobacteria, (e.g. non-toxic cyanobacteria may still pose a risk of skin irritation) in addition to more defined health risks of toxic cyanobacteria (e.g., to humans, toxic food consumption, dog health).
2. Guidance for DHBs about toxin symptoms & framework to enable potential human health toxin incidences to be recorded.