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Dear Katie

Review of proposed lake monitoring programme for the Taranaki Region

Thank you for the opportunity to review Taranaki Regional Council's draft proposal to establish a new regional lake monitoring programme. By way of background, we understand that:

- Current monitoring is focussed on Lake Rotorangi, an artificial lake used for hydro-electric generation, with limited recreational water quality monitoring carried out in some lakes during summer.
- Ecological health using the LakeSPI (submerged plant indicator) method has been assessed in three lakes (Lakes Kaikura, Mangawhio and Rotokare in 2021).
- Sediment cores were collected and analysed in at least two lakes (Lakes Rotokare and Waikare) as part of the national Lakes 380 MBIE Endeavour Research Programme.
- The key objectives of the proposed new regional programme will be to inform catchment management, implement and fulfil the requirements of the National Policy Statement for Freshwater Management 2020 (NPS-FM), including informing the development of action plans to maintain and improve lake water quality and ecosystem health.
- TRC is currently working with iwi/hapū partners to inform site selection and alternative/additional lakes may be included in future as conversations progress.
- Any cultural monitoring, including monitoring of mahinga kai and threatened species, will be developed with iwi/hapū partners through TRC's NPS-FM implementation programme.

Below we have responded to each of the nine areas of guidance sought through MBIE Envirolink Small Advice Grant TRC001/2236. Our responses follow a review of the following documents:

- FRODO-#2910341-v2-Proposed lake monitoring programme
- FRODO-#2887094-v1-Recommendations of lakes suitable for inclusion in a long term monitoring programme
- FRODO-#2917887-v1-Lakes baseline survey July-Oct 2021 (landowner contacts removed)
- FRODO-#2525572-v1-A review of regional lakes monitoring.

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For clarity, the focus of our review is on water quality and ecological monitoring to support lake ecosystem health; monitoring of lakes for the mandatory national freshwater values of human health for recreation, mahinga kai and threatened species is out of scope.

1. Representativeness

   The representativeness of lakes proposed in terms of: spatial distribution, taking into consideration Council's proposed Freshwater Management Units (FMUs); lake type; depth; and hydrogeological characteristics, surrounding land use, and other potential drivers of lake health.

   Our impression is that the six lakes identified by TRC are a good cross sample representative of the range of lake types in the Taranaki Region, although we do not have information regarding the above mentioned hydrogeological characteristics and surrounding land use, so cannot comment on those aspects.

   The Taranaki Region has 89 lakes over 1 ha in size according to the Freshwater Ecosystems of New Zealand (FENZ) geo-database[1]. Discussions with TRC confirm that a ground truth of waterbodies was undertaken, which excluded a number as candidate lakes for monitoring due to infilling, classification as wetland or modifications such as weirs. Representation across the draft FMUs and geographic distribution was considered in TRC's selection process and appears sound. The initial lake selection may benefit from a cross-comparison with the primary lake types (5 groups) identified by FENZ. The representation of coastal waterbodies (two currently proposed) might also be worth increasing, given the large number of such waterbodies in the region. Additionally, a significant hydrological event at Lake Mangawhio in 2015[2] when the outlet stream blew out, might mean this waterbody has not yet stabilised following the new, lower lake level. The implications for long-term monitoring of this waterbody should be considered.

2. Physico-chemical monitoring

   Physico-chemical monitoring, including the appropriateness of sampling methodology selected.

   The proposed sampling is appropriate: monthly casts to record vertical profiles of water temperature, dissolved oxygen (DO) and conductivity at minimum, and potentially also pH, and turbidity. We note that conductivity, pH and turbidity measurements are also mentioned in Table 2 of FRODO #2910341 at 3 to 4 different depths. This appears to duplicate the vertical profiler measurements (temperature is not mentioned in Table 2).

   The proposed laboratory test methods (and method detection limits) should be checked against the NEMS Discrete Water Quality (Part 3, Lakes).[3] It appears from the Excel spreadsheet of baseline survey results (FRODO-#2917887) that total nitrogen was probably calculated from the sum of TKN and NNN, rather than measured directly. While the NEMS doesn't preclude the use of this indirect method (and it is preferable for sediment-laden lake water samples (i.e., a Total Suspended Solids concentration > 20 g/m^3)), the APHA 4500-NO3 I method provides a direct measurement and offers a much lower detection limit that is desirable for long-term monitoring programmes of low nutrient waters.

3. Ecosystem health monitoring

   Ecosystem health monitoring, including the appropriateness of sampling methodology selected.

   The proposed monitoring is appropriate. We appreciate that there are costs associated with automated DO and water temperature sensor deployment, but relying on monthly sampling

[1] *Freshwater Ecosystems of New Zealand: Freshwater (doc.govt.nz)*

[2] *Page, M.J., Rosser, B.J., Townsend, D.B., Carey, J.M., Ries, W.F. (2015) Reconnaissance report on landsliding caused by the 19-20 June 2015 rainstorm in the Taranaki-Wanganui-Manawatu region. GNS Science Report 2015/47.*

[3] https://www.nems.org.nz/documents/water-quality-part-3-lakes/

alone could miss mixing/stratification events and their impact on bottom water oxygen in polymictic lakes. While for temperature, ideally a string with multiple sensors is used throughout the water column, this is not really necessary for DO. The most important depth for an oxygen sensor is near the lake bottom, around 1 m above the bottom (i.e., one sensor per lake would be sufficient). To just establish in general what the potential is for each lake to mix/stratify and deoxygenate (as opposed to capturing every hypoxia event), then automatic monitoring equipment could be rotated between lakes. For instance, if TRC has two sets of instruments two lakes could be monitored for a year and then instrumentation rotated to the next two lakes and so on, to establish how frequently lakes mix/stratify.

The proposed sampling includes LakeSPI surveys every five years (FRODO #2887094) for the required NPS-FM NOF attributes of Native Condition Index and Invasive Impact Index. While this is a departure from the minimum three-yearly frequency specified in the NPS-FM 2020 (Appendix 2B, Tables 11 and 12), we note that the LakeSPI user manual[4] states that frequency of survey might be 10 years for stable lakes that are isolated from disturbance, with surveys three-yearly or less for ecologically valuable lakes that are vulnerable to change. Consequently, recommendations for frequency of re-survey have varied. NIWA has generally recommended five-yearly surveys, with more frequent surveys suggested if large changes in ecological condition are detected (e.g., pressure from land-use intensification or new invasive weed species incursions).

The six waterbodies selected for monitoring (FRODO #2887094) appear to be suitable for LakeSPI assessment. LakeSPI is not an appropriate method where natural conditions substantially limit the development and diversity of submerged vegetation, such as in coastal lagoons that experience high salinity, lakes with extremes of pH, strongly geothermally influenced waters, and high-altitude lakes (>c. 1,300 m asl). Under the NOF, there is also provision to set a target attribute state below the national bottom line (i.e., the D-band) for lakes that fall into the D-band due to natural processes (e.g., naturally non-vegetated geothermal or peat lakes).

4. Additional or alternative parameters, methods or approaches
Additional or alternative parameters, methods or approaches that would increase the value of the information obtained, including building our understanding of the current and future state of lake health, and any pressures and/or drivers of change.

We recommend that TRC considers the inclusion of dissolved oxygen and water temperature sensors if budget allows.

In addition to cyanobacteria biovolume, TRC should receive – or request – cyanobacterial species composition and cell counts per species. This information is more informative than total biovolume alone (e.g., for lakes seasonal dominance of cyanobacteria, including potentially toxic species, might be a concern) and we understand it will be a requirement of the NEMS Cyanobacteria (in preparation).

Species composition, cell counts and biovolume can also be recorded for non-cyanobacteria phytoplankton species.

5. Water sampling depth
A key issue that should be addressed relating to sampling methodology is the selection of sampling depth. For stratified lakes, a recommendation as to whether sampling should be [within the] epilimnion/hypolimnion based on the thermocline location at the time of sampling, or whether sampling depths should be stationary throughout time.

[4] https://niwa.co.nz/sites/niwa.co.nz/files/import/attachments/lakespi_manual.pdf

The proposed sampling depths and test suites (outlined in Table 2 in FRODO #2910341) are appropriate, except for chlorophyll and nutrients (see response under 6 below). Water samples for both nutrient and chlorophyll analysis should be taken from the epilimnion. Ideally the epilimnion depth should be determined first from in situ measurements followed by sampling within it, for instance at half the epilimnion depth. However, typically 2 m depth will likely fall within the epilimnion. If time constraints limit looking at water temperature profiles before sampling then we recommend taking the epilimnion sample at 2 m depth (note that in the shallowest lakes (around 5 m deep), 1 m sampling depth may be better than 2 m). Since the epilimnion is in theory a "mixed layer" in general it should not matter much where in the epilimnion sampling occurs, as long as the sample is not taken too close to the water's surface or too close to the upper boundary of the thermocline. When the lake is fully mixed using ¼ and ¾ sampling depths is fine. When a lake is fully mixed and <10 m deep the deeper sample may be omitted.

6. Chlorophyll-*a* sampling depth
   Chlorophyll-a sampling depths – should these be calculated from Secchi depth or the same as the epilimnion depth, or calculated from vertical profiles?

   We note that both cyanobacteria biovolume and chlorophyll *a* are proposed to be monitored by integrated depth sampling (Table 2 in FRODO #2910341), while nutrients are to be monitored from a fixed depth water sample. We would advise to measure chlorophyll *a* on a water sample taken from the same sample depth as the sample used to measure nutrients. As noted in our response under 5 above, sampling should occur within the epilimnion.

7. Utility of bottom water and sediment sampling
   Collection of water samples from near the bottom of the water column to assess potential nutrient release and how much additional insight is gained compared to purely assessing oxygen levels at the lakebed. Also, consideration of whether directly assessing nutrient levels in the sediment would provide more useful information.

   We do not consider that collection of water samples just above the lakebed will provide much additional information to that obtained from epilimnion and hypolimnion sampling. Nutrient concentrations near the lakebed will likely be higher than at the depth of the mid hypolimnion but the difference will depend on turbulence, not just on sediment release rates. We consider that oxygen concentrations just above the sediment are more informative. Assessing nutrient concentrations in the bottom sediments would mainly be useful if TRC was considering an application such as sediment capping to prevent release of phosphorus.

8. Complementary monitoring
   Complementary monitoring that should be considered on a one-off or infrequent basis. For example, this could include techniques such as groundwater flow pathway assessments, sediment core analysis, bathymetry, and/or remote sensing. Prioritisation of these from a management perspective?

   One-off groundwater flow pathway assessments, sediment core analysis, bathymetry, and/or remote sensing can all be useful in some way. Bathymetric information is probably the highest priority from a management perspective as it is important in lake management scenarios and is used to estimate lake volume, a key metric needed when putting nutrient budgets together (it could also assist with confirming where the deepest point in the lake is for TRC's regular water quality monitoring). The lake volume divided by lake area gives mean depth, a more useful metric than maximum depth, and used in nutrient budget modelling. If lake outflow rates are measured, or automatically monitored, the lake hydraulic residence time can be calculated, which is also useful in nutrient budget models.

As discussed with you on 4 May, hydro-acoustically derived bathymetry at the accuracy sufficient for ecological purposes is now an easy and cheap survey method. Hydroacoustic survey can be easily integrated with other vessel-based activities, such as LakeSPI surveys or water quality sampling. Relative sediment hardness and vegetation biovolume (occupation of the water column) are other strands of hydroacoustic data that may be recorded and mapped simultaneously with bathymetry. Calculation of waterbody volume is an automated process with some mapping services (e.g., BioBase).

Groundwater flow pathway assessments could be prioritised for coastal dune lakes where the 'catchment' is poorly defined.

Remote sensing may detect algal blooms between monthly sampling events. We suggest it would be useful to see what initial water sampling reveals about algal biomass before considering the potential to use of remote sensing.

Sediment core analysis (N and P), in combination with information on nutrient loads to the lake, can indicate the magnitude of sediment burial and denitrification occurring (if the outflow rate is known). Again, we suggest waiting to see what initial water column sampling reveals about lake condition before considering any sediment sampling.

Analysis of water samples for eDNA may reveal information about current lake ecology, although the detection limitations of the method (especially for biosecurity[5]), missing species in reference sequence databases and issues with interpretation of results (especially indicated abundance) should be understood. However, we consider it a relatively low priority.

9. Other considerations
Any further considerations that could assist the Council in the design and implementation of a lakes monitoring programme.

We have not seen contour maps of the proposed sampling lakes but one central/deep sampling site is generally sufficient for small lakes with a reasonably 'uniform' shape. Multiple monitoring sites and the choice of their locations is more important when the shape of a lake is complex, dendritic (i.e., branch-like) or elongated with bays and side-arms.

We note that TRC's preliminary lake water quality surveys were done in the wintertime. It is possible that nutrient concentrations are quite different in summer (e.g., lakes with high macrophyte biomass can experience macrophyte die-off in winter, resulting in release of nutrients into the water column). Therefore, the actual annual mean trophic level index and NOF attribute states might be better in such lakes than found in the preliminary surveys.

Water quality of shallow lakes where aquatic weeds occupy a large proportion of the water column may show reduced symptoms of eutrophication (e.g., measurements of phytoplankton abundance, and suspended solids and nutrient concentrations in the water may be depressed in the presence of weed beds).[6] Weed beds can also cause strong diurnal patterns in DO concentrations and accentuate temperature gradients. On the other hand, dense stands of macrophytes often drive up the pH during summer to levels where it can result in enhanced release of phosphorus from the sediment.

Conducting exploratory investigations in a wider number of lakes and lagoons across the region would complement the long-term monitoring programme by confirming lake types and values represented. For example, data-deficient lake investigations have been conducted by Waikato Regional Council and reconnaissance lake surveys undertaken by Northland Regional Council.

Biosecurity surveillance activities are recommended, which would be compatible with the long-term lake monitoring and any wider investigations. While the current Regional Pest

[5] Distinguishing dreams from reality when using eDNA to detect aquatic invasive plants in lakes | WALPA

[6] Nezbrytska et al. (2022) Potential use of aquatic vascular plants to control cyanobacterial blooms: A review. *Water, 14*(11), 1727. Full text available at: https://www.mdpi.com/2073-4441/14/11/1727

Management Plan for Taranaki does not list any submerged weeds or pest fish, we would recommend that surveillance focuses on known environmental aquatic pests (Pest species of NZ_master file.indd (niwa.co.nz)), particularly those designated in adjacent regions. A site prioritisation process for surveillance intensity should be guided by a risk analysis for pest pathways and vectors.

Lastly, as an additional note with regard to LakeSPI attributes, shallow lakes that are heavily infested by hornwort *(Ceratophyllum demersum)* to the point of excluding all other vegetation may score an Invasive Impact Index >90%,which does not meet the NOF national bottom line for this attribute. Based on descriptions of hornwort at Lake Herengawe, this lake may fail to attain an acceptable condition under the NOF.

Please do not hesitate to contact us if you wish to discuss any aspects of this review.

Yours sincerely

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