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Dear Andy

Survey design and laboratory analyses for the monitoring of lake sediment quality (Envirolink 1830-HBRC230)

Cawthron has been requested to provide advice regarding the assessment and monitoring of sediment quality in lakes in the Hawke's Bay Region. This letter presents recommendations regarding survey design and protocols for sediment sampling and analysis which is intended to:

- provide a baseline for the organic and nutrient status of the sediments
- investigate how nutrients are bound in and released from, the sediment
- compare and contrast sediment composition between different lake systems.

It is understood by us that this programme will provide the data to inform a wider project which aims to understand how lake sediments affect the Hawke's Bay Regional Council's (HBRC) ability to meet water quality targets under the National Objective Framework.

These recommendations are targeted at sampling within eight Hawkes Bay lakes (three deep [lakes Tutira, Waikopiro and Opouahi] and five shallow [lakes Whatuma, Poukawa, Oinga, Runanga and Whakaki]) however, it is envisaged that the protocols and procedures developed under this programme could provide the basis for a nationally-applicable lake sediment sampling and analysis methodology.

Sediment analysis can help lake managers gain a better understanding of the risk of internal nutrient loading as well as the likely and actual effects of management interventions. A standardised suite of sediment analyses can provide a snapshot of current concentrations of organic material, nutrients and nutrient-binding phases, while analysis of phosphorus fractionation and release rates provides an indication of the potential for phosphorus to become bioavailable and hence support excessive primary productivity. Comparisons between lake catchments may highlight catchment-specific issues and help targeted interventions. Ongoing monitoring of these sediment characteristics may then provide a gauge of management effectiveness.

It should be noted that we are in the early stages of a research programme (Lakes380) that is undertaking sediment analyses on a nationwide set of lakes with some similar aims to that addressed in this letter. Interpretation of the data obtained from the HBRC lakes (or any

lakes nationwide on which sedimentary analysis is being undertaken) would be easier and more robust, in the comparative context of a larger nationwide dataset. For this reason, the protocols recommended here are similar to those intended to be utilised on the Lakes380 programme. Should these change (we are in the early, protocol development stage), we undertake to advise HBRC of these changes and any revised recommendations.

Sample sites and sediment collection

In general, it is recommended that a single monitoring site should be established in the main basin of each lake. Where possible this should be at the deepest point, but if this is deemed to be unrepresentative of the lake basin, then a more representative site may be selected. Where the lake is large and/or has complex bathymetry with multiple arms/basins, several monitoring sites may be required. In the eight HBRC lakes I reviewed (see Appendix 1) a single site should suffice for monitoring purposes. However, in the initial sampling effort it is recommended that additional sites be sampled in order to assess spatial variability and help inform any development of a nutrient budget for each lake. The number of sites considered appropriate for each of the eight HBRC lakes are included in Appendix 1; however, the actual number of sites may be determined by budgetary constraints.

Lake sediment samples should be collected by coring and it is recommended that a gravity corer with a barrel of known area is used for this purpose. This allows the calculation of bulk density and hence areal calculations which can be used to inform nutrient budgets. We recommend that the upper 0-4 cm layer of the sediment core is sampled. This reduces the variability in bulk density calculations usually associated with shallower layers (eg: 0-1cm), but keeps the portion of the sediment which is likely to be in intimate contact with the water column with respect to nutrient fluxes. Two core samples should be taken and combined in a single sample container to give a composite sample for analyses.

Another option for sampling is the use of a ponar grab type sampler—however, these are likely to disturb lower-density surface sediment, particularly in lakes with high-organic ‘floc’ layers at the sediment/water interface. I believe that the peaty lakes such as Poukawa and Hatuma are especially likely to present this problem. In these types of soft, organic sediments defining the ‘top’ of the sediment pile is also a challenge when using a gravity corer. Nonetheless, the corer method provides better consistency (than the ponar grab) between sampling occasions, and between operators. It is recommended that a standard approach to defining the ‘top’ of the sediment is documented (and photographed) for each lake.

I recommend that sampling be conducted annually although the suite of analyses may vary from year to year depending on budget. It is strongly recommended that a ‘full suite’ of analyses (as described in the analysis section below) is undertaken on the first sampling occasion and, if budget is limited, this should be repeated every five years. In the intervening years a more ‘limited suite’ (see analysis section) of analyses could be undertaken. If a more rapid accumulation of data is required for management purposes (e.g. trend monitoring for management outcomes), it is recommended that sampling be undertaken six-monthly with the ‘full suite’ of analyses conducted annually. The timing of annual sampling should be

standardised and is recommended to be undertaken pre-stratification (August-September) in deep lakes and in early summer (November-December) for shallow lakes.

Where sedimentation rates are slow, bed sediment sampling may not pick up subtle changes in organic matter/nutrients due to the dilution effect of sampling a 0 to 4 cm layer of the sediment. In order to understand the effectiveness of management interventions on the organic and nutrient loads of the deep lakes we recommend the use of duplicate sediment traps suspended 1 m above the lake bottom. These can be easily and cheaply constructed and would provide a targeted assessment of sedimentation rates, organic loads and nutrient accumulation rates.

Details of sampling protocols are presented in Appendix 2.

Sample analysis

The full suite of analyses should include:

- grain size analysis
- sediment characterisation (bulk density, organic matter content, carbonate content, total organic carbon, total phosphorus, total nitrogen, total organic carbon, total metals [Fe, Mn, Al, Ca,], total sulphur, total biological oxygen demand)
- phosphorus fractionation
- phosphorus release under anoxic conditions
- phosphorus release under high pH conditions (recommended for shallow lakes only, if high pH (> 9) is evident in monitoring data)
- equilibrium phosphorus dynamic concentration (recommended for shallow lakes only, where sediment resuspension is an issue).

If utilised, the 'limited suite' of analyses should include:

- total phosphorus, total nitrogen, total organic carbon.

Where sediment traps are utilised to analyse recent sediment accumulations, analyses should include;

- sediment mass, total suspended solids, volatile suspended solids
- total phosphorus, total nitrogen, total organic carbon

Compound specific stable isotopic analysis may also be considered for these samples and could potentially be used to distinguish in-lake (autochthonous) from catchment-derived (allochthonous) organic material in the sediments. This may enhance the detection of effects on in-lake productivity resulting from management interventions. Costs for these analyses are not included in the budget presented below.

Additional investigations to enhance interpretation of sediment data

If they are not already utilised, it is strongly recommended that thermistor chains (a chain of temperature loggers) with surface and bottom-water dissolved oxygen (DO) loggers be deployed in the deep lakes. These will provide an understanding of stratification dynamics and the depth and duration of any deoxygenation which occurs. This understanding is critical to interpreting the sediment data with respect to the internal nutrient loading risk in these lakes. In addition, this may provide the most direct evidence of the effectiveness of the proposed 'bubblers'. In lieu of deploying DO loggers, monthly water column profiles of temperature and DO should be obtained.

It is also suggested that surface and bottom-water temperature and dissolved oxygen loggers be deployed at 2-3 locations per lake in the shallow lakes. Again, this will provide data on the occurrence of any deoxygenation events and provide critical context to interpreting the sediment data with respect to internal loading risks. Such events in shallow lakes may be strong drivers of internal nutrient loading but tend to be short-lived and may be spatially limited and hence easily missed without continuous logger data. Placement of these instruments in locations where water-column stabilisation may be suspected (eg; inside macrophyte beds or sheltered bays) could provide useful information on the likelihood of these environments contributing to internal loading.

Estimated summary budget

The summary budget presented in the table below is based on a single monitoring site for each lake. A final budget will be dependent on decisions regarding the number of sites per lake.

	'Full suite' cost per sample	'limited suite' cost per sample
Deep lakes	*$1082.00*	*$75.28*
Total for 3 deep lakes	*$3246.00*	*$225.84*

	'Full suite' cost per sample	'limited suite' cost per sample
Shallow lakes	*$1974.00*	*$75.28*
Total for 5 shallow lakes	*$9870.00*	*$376.40*

The shallow 'full suite' cost assumes that pH release and EPC experiments are included. More detailed budget figures are provided in Appendix 4.

Summary

In summary we recommend the establishment of a single sediment monitoring site in all of the eight Hawkes Bay lakes. Additional sites may be selected as budget allows, to provide insight into spatial variability. The monitoring sites should be sampled at least annually. Two cores should be collected from each site and the upper 0-4 cm layer of the sediment pile retained and combined into one composite sample. These samples should then be analysed for a comprehensive suite of sediment and nutrient characteristics as detailed in the letter above. It is recommended that a 'full suite' of analyses should be performed at the first sampling in order to provide baseline data and that this suite of analyses should be repeated

at least every five years. A 'limited suite' of analyses could be conducted in the intervening years if budget dictates. In addition, sediment traps should be deployed in the deep lakes, and temperature and oxygen loggers should be deployed in all lakes.
I trust this information will be of assistance to you in planning your monitoring.

Yours sincerely

Scientist

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Reviewed by

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Appendix 1. Recommended numbers of sample sites in the 8 x HBRC lakes.

Lake	Deep/shallow	Lake area (ha)[1]	Recommended number of sampling site to capture spatial variability
Tutira	deep	174	4
Waikopiro	deep	11	2 (deep and littoral sites)
Opouahi	deep	6	2 (deep and littoral sites)
Whatuma	shallow	152	3
Poukawa	shallow	103	3
Oingo	shallow	85	3
Rununga	shallow	110	5
Whakaki	shallow ICOLL	475	7

1. Lake areas obtained from LAWA or Takiwa Lakes

Appendix 2. Sampling protocols and processing

2 x 0-4cm core section to be accurately collected using a gravity corer. Samples should be combined into a new, pre-weighed (to 2 decimal places), 500 ml plastic container with screw lid. If this container is not laboratory-supplied, and/or is not new it should be acid washed.

The composite sample should be transported on ice to Cawthron within 48 hours. The sample will then be weighed, homogenised and sub-sampled into four 50-ml falcon tubes. The sub-sample will be weighed prior to centrifuging at 3900 rpm/40 minutes. Separated pore water will be removed, filtered (0.45µm) and frozen for DRP and TDP analysis. The sediment sub-sample will then be reweighed and frozen for storage prior to P fractionation and release analysis. The remaining original sample will be couriered away for TBOD and sediment characterisation analysis.

Appendix 3. Sediment analysis details

- Sediment characterisation analyses (as detailed in the sample analysis section of the above letter) will be conducted at an accredited laboratory according to standard methods.
- Phosphorus fractionation will be conducted at Cawthron by a 'Psenner type' chemical sequential extraction. This will provide the following phosphorus (P) fractions
    - Exchangeable phosphorus (Ex-P) is considered to be very loosely bound and soluble phosphorus.
    - Redox sensitive P (P Red-P) is considered to be the phosphorus which may be mobilised by low dissolved oxygen in the surrounding water-column- it is commonly associated with reducible mineral phases such as Fe and Mn (hydr)oxides,
    - pH sensitive phosphorus (pH-P) is considered to extract phosphorus which may be mobilised by high pH in the surrounding water-column. It is commonly bound to the surfaces of mineral phases such as Al (hydr)oxides as well as the less reactive Fe and Mn (hydr)oxides, clays and organic particulates.
    - Organic phosphorus (Org-P) is considered to be the easily degradable organic fraction.
    - Calcium associated phosphorus (Ca-P) considered to be the phosphorus fraction associated with Ca minerals including apatite and carbonates as well as the phosphorus associated with refractory metal oxides.
    - Residual-phosphorus (Res-P) is considered to consist of largely refractory organic material.
- Phosphorus release experiments will be undertaken in the Cawthron laboratory utilising slurry type experiments whereby small sediment sub-samples are exposed to anoxia or high pH condition in controlled conditions.
- Equilibrium phosphorus concentrations will be conducted in the Cawthron laboratory utilising slurry type experiments whereby small sediment sub-samples are exposed to spiked phosphorus solutions of various concentrations. A water concentration is obtained which is the concentration above and below which the sediment adsorbs or releases phosphorus respectively.

Appendix 4. Estimated budget

The following budget is an estimate of the per-sample analysis costs associated with this proposed programme. It does not include the cost of in-field sampling, sample couriering or purchase of sampling equipment. All figures are ex GST. Please note these are cost estimates only and are subject to change. Any further work will be costed on a formal quote.

1. Full suite analysis

	Deep lakes–Cost per sample	*Shallow lakes–cost per sample*
Sediment characterisation		
As detailed in the sample analysis section of the main letter (+ grain size + sample processing + pore water analysis)	*$425.00*	*$425.00*
Phosphorus fractionation		
6 step sequential extraction	*$471.00*	*$471.00*
Anoxic release experiment		
Release rate under anoxia	*$186.00*	*$186.00*
High-pH release experiment		
Release rate under pH= 9 and pH=10	*-*	*$503.00*
EPC experiment		
Concentration of equilibrium release	*-*	*$389.00*
Total per sample (ex GST)	*$1082.00*	*$1974.00*

2. Limited suite analysis

	Deep lakes-Cost per sample	*Shallow lakes- cost per sample*
Sediment characterisation		
Total N, Total P, Total organic carbon	*$75.28*	*$75.28*
Total (ex GST)	*$75.28*	*$75.28*