Taranaki Regional Council

# AGENDA
# Policy & Planning

Tuesday 23 November 2021, 10.30am

# Policy and Planning Committee

23 November 2021 10:30 AM

## Agenda Topic — Page


| Agenda Topic | | Page |
|---|---|---|
| Apologies | | |
| Notification of Late Items | | |
| Purpose of Committee and Health and Safety | | 3 |
| 1. | Confirmation of Minutes | 4 |
| 2. | Freshwater Update | 9 |
| 3. | Submission on Draft Emissions Reduction Plan Discussion Document | 17 |
| 4. | Recreational Use of Coast, Rivers and Lakes in Taranak - SEM Report 2019-2020 | 27 |
| 5. | Lake Rotorangi SEM Annual Monitoring Reports | 156 |
| 6. | Natural and Built Environments Bill Select Committee Report | 385 |
| 7. | Te Kāhui o Taranaki Trust Taiao Briefing | 390 |
| 8. | Predator Free Quarterly Report | 394 |
| Closing Karakia and Karakia for kai | | 404 |

Taranaki Regional Council

# AGENDA
# Policy & Planning

**Purpose of Policy and Planning Committee meeting**

This committee attends to all matters of resource management, biosecurity and related environment policy.

**Responsibilities**

Prepare and review regional policy statements, plans and strategies and convene as a Hearing Committee as and when required for the hearing of submissions.

Monitor plan and policy implementation.

Develop biosecurity policy.

Advocate, as appropriate, for the Taranaki region.

Other policy initiatives.

Endorse submissions prepared in response to the policy initiatives of organisations.

**Membership of Policy and Planning Committee**

Councillor C L Littlewood (Chairperson)
Councillor M G Davey
Councillor D H McIntyre
Councillor E D Van Der Leden
Councillor M P Joyce (ex officio)
Councillor N W Walker (Deputy Chairperson)
Councillor M J McDonald
Councillor C S Williamson
Councillor D N MacLeod (ex officio)

**Representative Members**

Councillor C Young (STDC)
Councillor G Boyde (SDC)
Ms B Bigham (Iwi Representative)
Mr P Muir (Federated Farmers Representative)
Councillor S Hitchcock (NPDC)
Mr P Moeahu (Iwi Representative)
Ms L Tester (Iwi Representative)

**Health and Safety Message**

**Emergency Procedure**

In the event of an emergency, please exit through the emergency door in the committee room by the kitchen.

If you require assistance to exit please see a staff member.

Once you reach the bottom of the stairs make your way to the assembly point at the birdcage. Staff will guide you to an alternative route if necessary.

**Earthquake**

If there is an earthquake - drop, cover and hold where possible.

Please remain where you are until further instruction is given.

MEMORANDUM
Policy & Planning

| | |
|---|---|
| **Date** | 23 November 2021 |
| **Subject:** | **Confirmation of Minutes - 12 October 2021** |
| **Approved by:** | A D McLay, Director - Resource Management |
| | S J Ruru, Chief Executive |
| **Document:** | 2914849 |

## Recommendations

That the Policy and Planning Committee of the Taranaki Regional Council:

a) takes as read and confirms the minutes and resolutions of the Policy and Planning Committee of the Taranaki Regional Council held in the Taranaki Regional Council Boardroom, 47 Cloten Road, Stratford on Tuesday 12 October 2021 at 10.30am

b) notes the recommendations therein were adopted by the Taranaki Regional Council on Tuesday 12 October 2021.

## Matters arising

## Appendices/Attachments

Document 2886981: Minutes Policy and Planning Committee - 12 October 2021

# MINUTES
# Policy & Planning

**Date** 12 October 2021, 10.30am

**Venue:** Taranaki Regional Council Boardroom, 47 Cloten Road, Stratford

**Document:** 2886981

| | | | |
|---|---|---|---|
| **Members** | Councillor | C L Littlewood | Committee Chairperson |
| | Councillor | N W Walker | Committee Deputy Chairperson |
| | Councillor | M G Davey | |
| | Councillor | M J McDonald | *via zoom* |
| | Councillor | D H McIntyre | |
| | Councillor | C S Williamson | *via zoom* |
| | Councillor | E D Van Der Leden | *via zoom* |
| | Councillor | M P Joyce | ex officio |
| | Councillor | D N MacLeod | ex officio |
| **Representative Members** | Councillor | G Boyde | Stratford District Council |
| | Councillor | S Hitchcock | New Plymouth District Council |
| | Councillor | C Young | South Taranaki District Council |
| | Ms | L Tester | Iwi Representative |
| | Ms | B Bigham | Iwi Representative |
| | Mr | P Moeahu | Iwi Representative |
| | Mr | P Muir | Federated Farmers Representative *via zoom* |
| **Attending** | Councillor | D L Lean | |
| | Mr | S J Ruru | Chief Executive |
| | Mr | M J Nield | Director – Corporate Services |
| | Mr | A D McLay | Director - Resource Management |
| | Ms | A J Matthews | Director – Environment Quality |
| | Mr | D R Harrison | Director - Operations |
| | Mr | C Spurdle | Planning Manager |
| | Ms | K Langton | Policy Analyst |
| | Ms | B Mestrom | Policy Analyst |
| | Mr | C Wadsworth | Strategy Lead |
| | Miss | L Davidson | Committee Administrator |
| | Mr | K Holswich | *via zoom* |
| | Ms | E Bailey | *via zoom* |
| | One member of the public. | | |

**Apologies** There were no apologies received.

**Notification of Late Items** Due to illness Te Kāhui o Taranaki Trust Taiao Briefing was postponed.

**1. Confirmation of Minutes – 31 August 2021**

**Resolved**

That the Policy and Planning Committee of the Taranaki Regional Council:

a) takes as read and confirms the minutes and resolutions of the Policy and Planning Committee of the Taranaki Regional Council held via audio-visual link on Tuesday 31 August 2021 at 10.30am

b) notes the recommendations therein were adopted by the Taranaki Regional Council on Tuesday 21 September 2021.

Joyce/Boyde

**Matters arising**

Progress on working with Iwi leaders will be covered in the workshop.

**2. Submission on Proposed Regulations to Support the Crown Minerals (Decommissioning and Other Materials) Amendment Bill 2021**

2.1 Mr C Wadsworth, Strategy Lead, spoke to the memorandum informing Members of the submission made on the Proposed Regulations to Support the Crown Minerals (Decommissioning and Other Matters) Amendment Bill 2021 ("the Bill") and answered questions arising.

2.2 It was suggested that there is potential for more collaboration with Iwi and hapū, especially, in regards to regional concerns. The Council shares its submissions, where there is sufficient time to do so given the Governments rapid reform agenda.

2.3 Officers were commended on the circulation of submissions to the Committee earlier for feedback.

**Recommended**

That the Taranaki Regional Council:

a) receives this memorandum *Submission on Proposed Regulations to Support the Crown Minerals (Decommissioning and Other Matters) Amendments Bill 2021*

b) adopts the submission on the Proposed Regulations.

Joyce/Young

**3. Submission on Managing Intensive Winter Grazing**

3.1 Mr C Wadsworth spoke to the memorandum informing Members of the submission made on the Managing Intensive Winter Grazing discussion document ("Discussion Document").

**Recommended**

That the Taranaki Regional Council:

a) receives this memorandum *Submission on Managing Intensive Winter Grazing*

b) adopts (alternatively amends) the submission on the Discussion Document.

MacLeod/Walker

**4. Te Kāhui o Taranaki Trust Taiao Briefing**

4.1 Due to presenter illness this item was deferred to the next meeting.

**5. Freshwater Farm Plan Regulations Discussion Document**

5.1 Mr D R Harrison, Director – Operations, spoke to the memorandum presenting for Members' consideration the submission for the Ministry for the Environment's (MfE) *Freshwater Farm Plan Regulations Discussion Document* (Discussion Document).

5.2 It was suggested that Iwi could audit the farm plans and refer any non-compliance to the appropriate authority. It was noted that these regulations are based on Central Government considerations and frameworks, so Council had to work within those regulations.

**Recommended**

That the Taranaki Regional Council:

a) receives the memorandum *Submission on Freshwater Farm Plan Regulations Discussion Document* and the submission appended to this item

b) endorses the submission appended to this item.

Boyde/Young

**6. Stock Exclusion Regulations: Proposed Changes to the Low Slope Map Discussion Document**

6.1 Mr D R Harrison, Director – Operations, spoke to the memorandum seeking Members' endorsement of a submission to the Ministry for the Environment's (MfE) discussion document *Stock Exclusion Regulations: Proposed Changes to the Low Slope Map.*

**Recommended**

That the Taranaki Regional Council:

a) receives the memorandum *Stock Exclusion Regulations: Proposed Changes to the Low Slope Map* and submission appended to this item

b) endorses the *Submission on Stock Exclusion Regulations: Proposed Changes to the Low Slope Map.*

MacLeod/Bigham

**7. Draft Submission on the Proposed Changes to Wetland Regulations**

7.1 Mr D R Harrison, Director – Operations, spoke to the memorandum presenting for Members' consideration a draft submission to the Ministry for the Environment (MfE) on the '*Managing our wetlands: A discussion document on proposed changes to the wetland regulations*' (Discussion Document) and answered questions arising.

7.2 The proposed changes to wetland regulations was a result of sector wide negative feedback about the operability of the regulations. Extra land management officers have been employed, under the Freshwater Implementation programme, to implement the regulations and continue to use non regulatory methods, particularly for wetland enhancement.

7.3 Officers were congratulated on the way they have navigated a particularly difficult pathway over the last year. The submissions that have been written have had an impact on decisions by the Government.

**Recommended**

That the Taranaki Regional Council:

a) receives this Memorandum *Draft Submission on the proposed changes to the wetland regulation* and the attached draft submission

b) adopts (*alternatively* amends) the draft submission.

Walker/Hitchcock

**8. Freshwater Management Unit Review**

8.1 Mr A D McLay, Director – Resource Management, spoke to the memorandum and introduced Ms K Langton, Policy Analyst, who gave a presentation on the findings of an internal review of Freshwater Management Units (FMUs).

**Recommended**

That the Taranaki Regional Council:

a) receives this memo *Freshwater Management Unit Review*

b) notes the internal recommendations for an FMU approach and that work will soon commence to liaise with Council's tangata whenua partners and establish Proposed FMUs for Taranaki.

Joyce/Young

It was noted that there were some significant environmental issues raised in the Te Kāhui o Taranaki Trust Taiao Briefing paper and it was requested that Officers look in to these and provide an update at the next meeting.

There being no further business the Committee Chairman, Councillor C L Littlewood, declared the meeting of the Policy and Planning Committee closed at 11.40am. The meeting closed with a karakia.

**Confirmed**

**Policy and Planning**

**Chairperson:** ________________________________________

**C L Littlewood**

**23 November 2021**

MEMORANDUM
Policy & Planning

Taranaki Regional Council

| | |
|---|---|
| **Date** | 23 November 2021 |
| **Subject:** | **Freshwater Programme Update** |
| **Approved by:** | A D McLay, Director - Resource Management |
| | S J Ruru, Chief Executive |
| **Document:** | 2917137 |

## Purpose

1. The purpose of this memorandum is to provide the Committee with a Freshwater implementation project update.

## Recommendations

That the Taranaki Regional Council:

a) receives the update on Freshwater implementation programme.

## Background

2. The Council has prepared an implementation programme of the Government's Freshwater programme. The purpose of this memorandum is to update Members on progress in implementing the project. The implementation programme has previously been presented to, and approved by, the Committee.

## Financial considerations—LTP/Annual Plan

3. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

## Policy considerations

4. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

## Iwi considerations

5. This memorandum and the associated recommendations are consistent with the Council’s policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

## Community considerations

6. This memorandum and the associated recommendations have considered the views of the community, interested and affected parties and those views have been recognised in the preparation of this memorandum.

## Legal considerations

7. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

## Appendices/Attachments

Document 2913695 - Freshwater Implementation Project - Report to Policy & Planning Committee (November 2021)

Taranaki Regional Council

# Freshwater Implementation Project Report to Policy & Planning Committee

## 23 November 2021

Document Number: 2913695

**Executive Summary**

In September, the project team conducted the first of the planned six monthly reviews of the project – taking detailed looks at progress, project plan structure, internal governance and impacts of external factors.

Key observations and points of discussion in that review were:

- As the project began implementation, a better picture of the true implementation tasks and timelines has emerged – which shows a potentially more complex and slower pace than the original schedules predicted.
- Staff resource limitations have negatively impacted the deliverables for Policy & Planning and Communications (including tasks around engagement).
  Recent appointments have begun to reverse those impacts and show potential to make good progress from this point forward.
- Lack of clear direction and provision of information from MfE has created uncertainty that prevents some key tasks being completed. Specifically, issues are around:
  - Changes in Intensive Winter Grazing direction (required reversing drafting work) and Farm Plans (progress on rules delayed while awaiting clarity)
  - Indications that the directions on allocation may be changed – but no clear timing or details provided
- Continued consultation and changing of timelines from MfE has meant that staff resources have been diverted from progressing the project to responding to those processes.
- Increasing collaboration across the teams is positive and is leading to strong outcomes – particularly in the Science and Policy & Planning spaces.
- Operational activities are progressing well – but are also impacted by MfE changing requirements and dates.

As a result of that review, the following significant changes were made to the project plan:

- The plan format was reviewed to provide a clearer picture of key tasks and deliverables by month (over the next six months) and per six month period (over the longer term).
- There was a commitment to revisit the plan every six months to both flesh out the detail for the six month period ahead and to confirm the achievability and priority of activities and deliverables.
- Significant attention was given to developing a more detailed engagement plan – which also highlighted capacity and capability gaps within the Council. The focus on engagement in Essential Freshwater is a step-change in complexity and detail from the previous expectations on planning processes.
- Revised the internal governance structure by refocusing and changing the scheduling of key project meetings.
  The Internal Steering Committee membership was revised to include the CEO and Directors from Resource Management, Environment Quality and Operations.
- Endorsement of the continued approach of reporting to this Committee each meeting as an external governance update.

Importantly, as a result of this review and the resulting amendments to plans, the project team and the Internal Steering Committee have revised the date for notification of a draft plan from December 2023 to June 2024. Officers believe that this date is more achievable in the current environment and would still see the Council as one of the earlier notifiers of their plan.

| Project Programme |
|---|
| **Key project achievements during the last reporting period**<br>• Specific implementation activities:<br>  o Project plan review – as discussed above.<br>  o Engagement plan in development – providing a detailed view of stakeholders (mapped by "interest-influence") and key topic areas for engagement.<br>  o Drafting has resumed on the plan, with attention to defining Freshwater Management Units ("FMU") and drafting the sections, including rules, on water allocation and structures.<br>  o Baselining work on the water quality measures required under NPS-FM<br>  o Modelling via Sednet to obtain a better picture of conditions across the Region.<br>  o Participation in consultation/submissions processes on Intensive Winter Grazing, wetlands definitions and Freshwater Farm Plans.<br>  o Participation in the national level regional sector groups on INFDP (farm plans) and synthetic nitrogen recording systems.<br>  o Work beginning on developing a framework for partnering with iwi on key elements of plan drafting. |
| **Key upcoming activities and milestones in the next reporting period**<br>• Continue roll out of tangata whenua partnership model development.<br>• Continue science services modelling of key parameters.<br>• Continue engagement with sector and central government working groups.<br>• Initial engagement sessions per the engagement plan, focusing on iwi engagement and engaging agricultural interest groups (eg., TCC, Beef & Lamb)<br>• Begin managing against the revised plan and new reporting structure. |
| **HSE Updates** |
| Nothing significant to report |

| Workstream Status Summary | | |
|---|---|---|
| **Workstream** | **Tracking** | **Comments/Clarifications** |
| Tangata whenua partnerships |  | • Scoping out structures and processes (including resourcing issues) to enable iwi environmental officers and TRC staff to collaborate on technical and policy issue development. |
| Policy and Planning |  | • Completed definitions of Freshwater Management Units – paper presented to this Committee at October meeting.<br>• On-going work preparing submissions on Freshwater Farm Plans, Intensive Winter Grazing rules, low slope mapping and wetlands definitions. (All submissions have been presented to this Committee.) |
| Science Services |  | • Undertaken spatial modelling of regional water quality state, as measured against NPS attribute standards.<br>• Specific work on *E.coli* has been commissioned to assess load reductions required to meet various target attribute states and 'swimmability' standards across the region.<br>• Commissioning work to assess projected climate change impacts for Taranaki which will help inform future pressures on freshwater.<br>• SoE synthesis report is underway and due to be delivered in 2022. This will provide an up to date reference for community based discussions around freshwater state and trends. |
| Consents |  | • No noticeable increase in consent applications related to FW Implementation.<br>• New Consents Manager and Consents Officer appointments started. |
| Inspections |  | • Limited activity at present, due to government postponing/delaying implementation timelines of key elements |
| Operations |  | • Continued work on roll out of hill country plans.<br>• Beginning audit round of riparian programme properties. |
| Communications |  | • Freshwater Implementation communications plan being implemented – including media articles, Council website and direct communication with stakeholders.<br>• Drafting a detailed engagement plan that will meet the requirements of the NPS-FM and will enable effective community consultation and input to the Plan. |

## Project Risk/Opportunity Management

| Description | Effect | Mitigation Strategy | Risk Rating (unmitigated) | Actions currently being taken |
|---|---|---|---|---|
| Lack of a clear strategy and timeline for engagement on key strategic issues. | Engagement in this sense is the two way discussions needed to obtain external stakeholder input on key FW programme and FW Plan elements.<br><br>Engagement requirements for FW are significantly higher than previous TRC experience (due to NPS-FW requirements). Experience from other RC's is that the process can be long and involved.<br><br>Lack of dedicated engagement (as opposed to comms) resources to manage this process. | Build greater alignment around the nature and timing of the engagement that is needed.<br><br>Develop specific strategies and plans to undertake the focused engagement.<br><br>Consider ways to address Council's current gaps in capacity and capability to lead engagement processes. | High | Developing a detailed engagement plan that is based on a combination of:<br>• Ten key topic areas where engagement is needed or beneficial<br>• Three phases of engagement – general introduction; consultation to gather input/views; review of specific implementation proposals<br>• Identifying engagement parties by "interest-influence" and defining actions accordingly across each phase.<br><br>Discussion is underway on how the Council can effectively resource the required engagement activities. |

| Description | Effect | Mitigation Strategy | Risk Rating (unmitigated) | Actions currently being taken |
|---|---|---|---|---|
| Lack of clarity and guidance due to gaps in key Government advice or changes in the policy/legal framework | Some FW Implementation elements need to be developed in the absence of clear guidance – which may result in changes later if Government position changes. This lack of guidance also increases risks of a need for rework.<br><br>Examples of areas where there are gaps in clear guidance include:<br>• Managing diffuse nitrogen loss risks (including the applicability of Overseer)<br>• Managing climate change impacts on freshwater. | Recognise that some level of risk is unavoidable.<br><br>Maintain strong presence on Government (especially MfE) and sector working groups.<br><br>Maintain contacts with other regional council *Essential Freshwater* teams.<br><br>Develop tools and processes that based on established or determined best practice. | High | Risk has impacted delivery and is a factor behind the revised project timeline.<br><br>Officers are progressing activities to the extent that they can – with a constant attempt to balance between maintaining progress and minimising the risk of potential rework. Policy & Planning and Science Services activities are the most impacted.<br><br>Risk is expected to remain high for the duration of the project. |

Taranaki Regional Council

MEMORANDUM
Policy & Planning

| | |
|---|---|
| **Date** | 23 November 2021 |
| **Subject:** | **Submission on Draft Emissions Reduction Plan Discussion Document** |
| **Approved by:** | A D McLay, Director - Resource Management |
| | S J Ruru, Chief Executive |
| **Document:** | 2914460 |

## Purpose

1. The purpose of this memorandum is to inform the Committee of the Taranaki Mayoral Forum's submission on the Draft Emissions Reduction Plan Discussion Document ("ERP").

## Executive summary

2. The Climate Change Response Act 2002 sets up a system of emissions budgets and emissions reduction plans to meet those budgets. Those plans and budgets are independent from, but appear to be strongly informed by the recent Climate Change Commission Advice ("CCC" and "Advice") to government.
3. The ERP is a discussion document that is designed to enable interested parties to input into the development of the plan for the first budget period (2022-2025). The plan itself will not be developed until some stage in the new year, in order to meet the statutorily mandated end of May 2022 target.
4. The ERP very closely follows the Advice, with the only major changes being a relaxation of the position against exotic forestry for carbon sinks and a recognition that the initially proposed timetable for zero carbon light vehicles was unrealistic. Overall, the document is very light on detail and is essentially asking submitters to provide the detail input that a plan could be built around. Disappointingly, the main role seen for local government is planning and roading provision, rather than as a facilitator or catalyst for actions by local communities.

## Recommendation

That the Taranaki Regional Council:

a) receives the Memorandum *Submission on Draft Emissions and Reduction plan Discussion Document*.

## Background

5. The Climate Change Response Act 2002 ("CCRA") sets up a system of emissions budgets and emissions reduction plans to meet those budgets. Those plans and budgets are set in up to five year intervals, covering the periods to 2025, 2030 and 2035 respectively. The budgets are all designed to be steps on New Zealand's path to meet the government's 2050 emissions target. The budgets are to be set by the Minister of Climate Change and must follow the CCRA requirements.

6. Alongside this process has been the CCC work preparing the Advice. As Members will be aware from the March meeting agenda item, the CCC was established as an independent advisory body, in part to analyse and report on possible pathways to achieve the 2050 targets. Those pathways would then inform policy, including the budgets and ERP's. CCC released its Advice in May 2021, and the Government is currently considering how to implement it. The ERP forms a part of that implementation.

## Emissions Reduction Plan Discussion Document

7. The ERP consists of three main sections:
   7.1. Describing the transition pathway and discussing key design elements and principles;
   7.2. Discussing various options and tools that could help to achieve the pathway results (e.g. programme funding, emissions pricing, research); and
   7.3. A sector by sector description of the considerations applying to the required transitions in key emitting sectors.

8. It is important to note that the ERP is not the emissions reduction plan itself. It is merely a discussion document to provide interested parties an opportunity to comment on particular aspects that Ministry for the Environment (“MfE”) may then consider as it develops the plan. To that end, there are some 113 specific questions that MfE are seeking input on.

9. The ERP lists five main principles that MfE believes should guide the plan, namely:
   9.1. Fair, equitable and inclusive transition – with includes incorporating a te ao Māori lens to transition planning;
   9.2. An evidence based approach;
   9.3. Environmental and social benefits beyond emissions reductions;
   9.4. Upholding the Treaty of Waitangi; and
   9.5. A clear, ambitious and affordable path.

10. Notable amongst those principles are the repeated weightings of social and environmental factors, alongside a lack of a clear consideration of the economic impacts of any strategy (affordability is at most a narrow subset of economics). The lack of the economic considerations in particular are concerning, especially as the plan is expected to kick in from 2022 in an economy that is already seeing significant and uneven impacts from covid response strategies.

11. In terms of the sector specific strategies, the ERP largely echoes the position taken in the Advice. The only major areas of change are:

11.1. A greater recognition of a potential role for exotic forestry in carbon sequestration; and

11.2. A recognition that the proposed timelines for converting the vehicle fleet to EV's were unrealistic. Consequentially, the target is somewhat relaxed and there are now calls for the government to work in concert with the motor vehicle importers to bring in more lower carbon vehicles.

12. Overall, the ERP is very light on detail and doesn't give any real indication of options and preferred pathways on any of the key pathway tools or sector specific strategies. Instead, these parts of the ERP are characterised by "motherhood and apple pie" comments and very generalised lists of current or proposed strategies (with no indications of priorities or their feasibility).

13. Where there are specific options discussed, they are not always clear or realistic. For example, the discussions on transport call for extensive electrification of the rail network. However, as the plan will only cover the period from 2022 – 2025, the extent of electrification proposed is unrealistic. Similar challenges exist with coastal shipping and the proposals for extensive use of wood-based biofuels to displace coal.

14. The ERP is disappointing for its lack of recognition of a role for local government outside of traditional areas of land use planning and transport planning. In fact, in the section on cross-government coordination, the "working together in new ways" paragraph that details who government expects to partner with on mission oriented innovation and innovation across systems is noticeable for excluding local government. As with the CCC Advice, there appears to be no recognition of the benefits from (or need for) regionally developed strategies and plans to support overall emission reductions.

15. Some of the proposed research, science and innovation activities (which largely centres on funding programmes) are more positive. For example, there are a number of opportunities that could support programmes such as Council's engagement with the Taranaki Catchment Communities or the agricultural energy work that we are engaged with Venture Taranaki and Federated Farmers on. Other Taranaki programmes, such as some of the waste-to-energy work that South Taranaki District Council is investigating could also benefit from this funding.

16. Lastly, there is an indication of support for using "large-scale pest management" as a tool to support climate outcomes, although there is no detail on what is proposed.

## Combined Taranaki Mayoral Forum Submission

17. Against the background of little change since the CCC Advice, limited detail in the ERP to comment on and the value of a "single Taranaki voice" on climate issues, officers recommended that Council's best avenue for a submission was via the Taranaki Mayoral Forum. As the three territorial authorities agreed, this approach was taken.

18. Highlights of the combined submission are:

18.1. Concerns at the lack of detail in the ERP, which limited the ability for fully informed submissions;

18.2. Concerns that the centralised approach would fail to address the need for regionally specific strategies and programmes;

18.3. Noting that the current volume of reform and general change will require "transparent communication and well-planned action" from government;

18.4. General support for the need to transition to lower emissions, with more qualified support for sector specific transitions, namely:

18.4.1. Ensuring that there are economically and technically viable solutions for currently fossil fuel dependent sectors;

18.4.2. Supporting agricultural communities through their transitions;

18.4.3. Recognising the limited transportation opportunities in rural communities;

18.4.4. Ensuring that there is adequate resourcing for partnering and recognition of the current consultation demands on Māori ; and

18.4.5. Highlighting the need to manage the negative employment, social and (if not intensively managed) environmental impacts of carbon forestry.

18.5. Calling for a greater role for local government as a partner in developing and implementing the plan (including providing appropriate funding); and

18.6. Concern at the levels of centralisation, including the drafting of 16 separate strategies to support the ERP, especially without a clear level of cross-departmental coordination in central government.

19. The submission was given to the respective CEO's and Mayors/Chair on 16 November, with feedback still being called at the time that this Memorandum was drafted.

## Financial considerations—LTP/Annual Plan

20. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

## Policy considerations

21. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

## Iwi considerations

22. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

## Community considerations

23. This memorandum and the associated recommendations have considered the views of the community, interested and affected parties and those views have been recognised in the preparation of this memorandum.

## Legal considerations

24. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

## Appendices/Attachments

Combined Taranaki Councils' Submission on Te hau mārohi ki anamata, Transitioning to a low-emissions and climate-resilient future, draft Emissions Reduction Plan (Final Draft)

24 November 2021

Emissions Reduction Plan consultation,
Ministry for the Environment,
PO Box 10362,
Wellington 6143

**Submitted by email to: climateconsultation2021@mfe.govt.nz**

Dear Sir/Madam,

**Combined Taranaki Councils' Submission on Te hau mārohi ki anamata, Transitioning to a low-emissions and climate-resilient future, draft Emissions Reduction Plan**

We thank the Ministry for the Environment (the Ministry) for the opportunity to comment on Te hau mārohi ki anamata.

As the three territorial authorities and the regional council (the Councils) responsible for implementing a large part of Taranaki's transition to a low-emissions future, we have particular interest in the consultation process informing Aotearoa New Zealand's National Emissions Reduction Plan. We recognise our role in leading, supporting and coordinating Taranaki's just transition to a low-emissions economy through our regulatory and non-regulatory functions. We also recognise the unique relationships the Councils have with their local communities, businesses, tangata whenua and iwi and hapū partners. These relationships will be essential if our transition is to be a just one for all our communities.

The Councils continue to work collaboratively on a number of the key reforms facing the sector and the region, including climate change, future of local government, resource management reform and three waters. We have prepared this combined submission on some high-level points in response to Te hau mārohi ki anamata to speak with a single "Taranaki Voice" that we feel better represents and promotes the interests of the communities and the region we serve. We trust that the Ministry also recognises the strength of this unity.

The Ministry should note that New Plymouth District Council (NPDC) has also submitted an individual submission on more detailed matters of concern to their council. In addition, our Regional Economic Development Agency Te Puna Umanga Venture Taranaki have also submitted on matters relating to how the ERP addresses wider economic development for the Taranaki region. While we are collectively not signatories to those documents, we support both organizations intent in making their submission.

We offer a qualified support for Te hau mārohi ki anamata and the direction that government is proposing, subject to the specific comments contained below. Many of these points were points that we already raised in each Council's submissions to the Climate Change Commission on their "Climate action for Aotearoa" draft advice package. We attach those original submissions again to this submission for MFE's reference and integration into the finalised ERP.

For the people of Taranaki, there are some important considerations below that we would like the Ministry to consider and incorporate as part of this opportunity for consultation and feedback, and we wish to emphasise the following key points:

- The need for clarity around Aotearoa New Zealand's plans to reduce emissions
- Concerns around a one-size fits all approach to emissions reductions
- Ongoing reforms and Covid19
- General support for plans to reduce emissions
- The need for greater clarity on local government's role.
- Centralisation without clear co-ordination

**The need for clarity around Aotearoa's plans to reduce emissions**
The Council's express disappointment that Te hau mārohi ki anamata does not provide the necessary clarity and direction for how New Zealand will reduce emissions to further inform our submission.

Te hau mārohi ki anamata is not a draft National Emissions Reduction Plan, but a list of current actions, policies and potential options being explored by government, many of which have been consulted on by other agencies. There is also a distinct lack of information about how the potential actions will be implemented, or indeed prioritised.

It is a missed opportunity that we are not able to feedback on the specific issues that are important to Taranaki. This is particularly disappointing due to the disproportionate impact Taranaki will feel in the transition compared to other regions.

**Concerns around the one-size fits all approach to emissions reductions**
Te hau mārohi ki anamata takes a one-size fits all approach to reducing emissions, and largely disregards the disproportionately high impacts to regions like Taranaki, compared to other regions with lower per-capita emissions profiles.

Transitioning to a new environmental limits regime will be a significant issue for Taranaki, so realistic regional planning to enable this needs to be implemented with support from central government. We therefore submit that, when finalised, the National Emission Reduction Plan should consider detailed regional effects of emissions targets, economic impacts and social impacts.

Finally, the Councils are disappointed to see that the "working together in new ways" section (p 34) does not include local government as a part of the proposed partnership. We feel that this omission is a significant oversight.

**Ongoing reforms and COVID-19**
It is of note that our communities are both directly and indirectly impacted by the scale and breadth of the reforms which are afoot at present. The COVID-19 pandemic remains a source of instability while the forthcoming National Emissions Reduction Plan sits alongside major reforms in health, three waters, local government and the Resource Management Act.

Both these reforms and the pandemic necessarily create uncertainty and instability for people as residents, employees and investors in our region. It is requested that this uncertainty and its impacts be acknowledged and minimised by transparent communication and well-planned action from government.

**General support for plans to reduce emissions**

Reducing emissions in Taranaki means transitioning our economy and the way we do things across our communities. The local economy in Taranaki is predominantly comprised of industrial manufacturing, oil and gas, and primary industries, all of which will be affected by emissions reductions targets, carbon pricing and any future biogenic methane pricing.

The shifts required of the region are well documented through Taranaki 2050 and Tapuae Roa. These need adequate support to ensure the region transitions to a low-emissions economy while keeping the things that are great about Taranaki, and planning for inclusive growth.

The Council's offer general support for emission reduction options and initiatives across different sectors, and note the following:

- Energy
  We support, in principle, the decarbonisation of the energy sector and the renewable targets set out in Te hau mārohi ki anamata. However, we caution the phase out of fossil fuels prior to available, economically viable technology alternatives (especially for the hard to abate manufacturing and commercial transport sectors).

  We agree with the need for an Energy Strategy, but this must be co-designed and developed in collaboration with all affected parties. In particular, this strategy needs a clearly articulated plan on how to meet the energy trilemma: affordability, access and energy security.

  We acknowledge the importance of the Emissions Trading Scheme to achieving emissions budgets and support recommendations from the Climate Change Commission to review industrial allocation of New Zealand Units to ensure that emissions intensive and trade exposed industries, such as the Taranaki petrochemical sector, does not drive emissions leakage offshore.

- Agriculture
  The Councils support the general intention of Te hau mārohi ki anamata's proposal to support a lower carbon agricultural sector. However, Taranaki farming communities will need to be provided with comprehensive support and training and be enabled to invest in real-world on-farm technology and initiatives to enable them to successfully transition to low-carbon farming methodologies.

- Transport
  The Councils acknowledge that centres with large populations will be advanced a greater and earlier share of investment in low carbon options. However, in order not to exacerbate equity issues, Taranaki requires support as we pursue the required innovative thinking to resolve our transport challenges.

  Taranaki is a predominantly rural region, with a mid-sized city and several smaller urban areas dispersed over a large geographic area. Our rural economy and communities' mobility and connectivity are heavily road and vehicle dependent, with few alternative transport options available. Our rural areas have a low level of public transport options when compared with more urbanised districts or regions, with low patronage and limited electric vehicle infrastructure.

  Councils will need significant funding to incentivise active/shared transport options everywhere, including small rural towns. Regional communities will be significantly impacted if the government activates levers to deter the use of Internal Combustion Engine cars while not providing suitable alternatives, creating barriers for accessing employment, education, health and social infrastructure in Taranaki.

- Tangata whenua partnerships
  The Councils support the Ministry's commitment to a greater role for tangata whenua to partner, be included in planning and help implement the initiatives proposed in Te hau mārohi ki anamata. Based on our experience in working with Taranaki iwi, the strongest partnerships and best results for all parties come when that relationship recognises the high resource demands being placed on tangata whenua by a range of policy measures.

Ensuring that adequate funding and resourcing be made available for tangata whenua to engage in planning, decision-making and implementation of emissions reduction and climate change adaptation work programmes will therefore be key. Partnering with tangata whenua to determine both the areas and approaches that best suit them (at both national and regional levels) is also a measure that the Councils would strongly encourage government to follow.

- Waste, circular economy
  We support the package of measures for the waste sector, and the circular economy approach. We believe that these measures will also have large knock-on positive impacts for improving many of our other environmental problems.

  Taranaki works regionally on waste minimisation and there is considerable expertise in waste prevention, management and minimisation. The region is in a strong position to contribute more directly to central government decision- and policy-making in this area.

- Forestry, native planting
  We are supportive of the proposal within Te hau mārohi ki anamata of increasing the focus on balancing planting of both native forests and plantation forestry. The region has invested significantly in riparian planting and recently committed to reaching its 10% biodiversity target in New Plymouth City.

  We are supportive of any recommendations to extend grant schemes such as One Billion Trees (or an equivalent scheme), or to create ecosystems payments. We would like further clarity on how this could be enabled and aligned with the Emissions Trading Scheme.

  However, we note there are demonstrable negative economic effects from large-scale replacement of farms with forestry in the Taranaki eastern hill country. We submit that the government needs to include large-scale land use change and its socioeconomic and environmental impacts in any transition planning for rural communities.

  We submit that government enables measuring the carbon capture of small-scale native planting blocks, which are often individually small but cumulatively large and offer co-benefits to sequestration such as biodiversity and landscape-scale vegetation corridors.

**The need for greater clarity on local government's role**
Local government plays a key role in reducing emissions through decarbonising our own operations and advocating for our communities to lower their emissions. Many of the proposed recommendations to lower emissions in Te hau mārohi ki anamata rely on local government implementation. To achieve the pace and scale of transition proposed by the Ministry, a coordinated and aligned effort will be needed between local and central government.

References to local government partnerships are unclear within Te hau mārohi ki anamata. Te hau mārohi ki anamata provides little detail on funding for key proposals and policies suggested to help reduce emissions. The Councils submit that the National Emissions Reduction Plan detail how local government will be supported to help deliver emissions reduction activities across key regulatory and non-regulatory functions.

**Centralisation without clear co-ordination**
Allied to the need for clarity on local government's role in this transition is a concern at the proposed level of centralisation and lack of clarity in Te hau mārohi ki anamata on how cross-government collaboration will be achieved.

The Councils note the proposal to generate 16 strategy documents to support the National Emissions Reduction Plan, which alongside the ongoing reform, has potential to create further complexity in an already complex landscape. The Councils support the calls for greater cross-government coordination and accountability in Te hau mārohi ki anamata. However, references to departmental accountability and cross department groups need greater detail in the final plan to provide assurance of their effectiveness.

We submit that Government should be providing clear guidance to local communities, and empowering them to develop solutions that can roll up to national level solutions. Taranaki's experience with Taranaki 2050, Tapuae Roa and current agricultural energy and waste-to-energy projects could be instructive in this capacity.

**Conclusion**

The Councils request that in finalising the National Emissions Reduction Plan, particular emphasis be placed on unique regional perspectives and positioning, such as the disproportionately large impact emissions reduction activities will have on Taranaki.

Transitioning to new environmental limits regime will be a significant issue for this region, so realistic regional approaches will need to be adopted, with support packages from central government partnering with local government. The significant regional impacts of this transition require further consideration, funding and place-based planning and implementation to ensure the region can successfully and equitably transition to a low-emissions economy.

We submit that in order to successfully implement the National Emissions Reductions Plan, maximising the emissions reduced and ensuring a just transition, partnership between central government and local government is required. Taranaki Councils welcome working with central government and our Taranaki iwi partners to develop a transition programme that is achievable and fit for purpose for Taranaki. In doing so, the Councils will continue to broaden and strengthen our efforts to speak with our single "Taranaki Voice" as we advocate for the cultural, social, environmental and economic well-being of our region.

Yours sincerely,

Mayor Phil Nixon
**South Taranaki District Council**

Mayor Neil Volzke
**Stratford District Council**

Mayor Neil Holdom
**New Plymouth District Council**

David MacLeod
**Taranaki Regional Council Chair**

Taranaki Regional Council

**MEMORANDUM**
**Policy & Planning**

| | |
|---|---|
| **Date** | 23 November 2021 |
| **Subject:** | **Recreational Use of Coast, Rivers and Lakes in Taranaki. SEM Report 2019-2020** |
| **Approved by:** | AJ Matthews, Director - Environment Quality |
| | S J Ruru, Chief Executive |
| **Document:** | 2916042 |

## Purpose

1. The purpose of this memorandum is to provide the Council with a report on the state of recreational use of Taranaki's coast, rivers and lakes.
2. A summary of the results of public surveys, undertaken in 2019-2020 is provided, along with associated recommendations. A copy of the full technical report is attached, and will also be made available via the Taranaki Regional Council (TRC) website.
3. A presentation will be provided on the report.

## Executive summary

4. Taranaki Regional Council is required under the Resource Management Act 1991 (RMA) to recognise and provide for the maintenance and enhancement of public access to and along the region's rivers, lakes and coast. In addition, the council must have particular regard for the maintenance and enhancement of the region's amenity values, including recreational attributes.
5. To help inform whether the above requirements are being me, Council periodically undertakes public surveys to look at the use and access of the region's recreational waters. Previous such reports have been published in 1984 and 2008.
6. The current report provides an up-to-date picture of the state of, and pressures on, the regions recreational water resources, while also documenting factors that influence where and how people use the region's coast, rivers and lakes.
7. The survey consists of two main components:
   - A web-based questionnaire aimed at gathering information and views from the public on the use and access of Taranaki's recreational waters; and
   - Observational counts of recreational users, undertaken over the summer period at water recreation sites around the region.
8. Recreational sites central to New Plymouth were found to be the most frequented sites regionally, with Fitzroy Beach and the Coastal Walkway the most popular sites across

both components of the survey. In general, beach sites were found to be more popular than either river or lake sites for recreation.

9. Travel distance and proximity to home are the most important factors determining where people go for their water recreation while time constraints due to family and work commitments are the primary factors limiting the frequency of people's water recreation.

10. Access for water recreation across the region is deemed to be relatively good, with 87% of questionnaire respondents saying they have been able to access the sites they wanted, and 85% rating overall levels of access as being good or excellent.

11. There has been a marked decline in the public's perception of recreational water quality in Taranaki since the previous use and access report in 2008. The public view on water quality is shown to be in-line with the results of Council's recreational water quality testing, and suggests that improving recreational water quality regionally will be a key focus for Council's implementation of the *National Policy Statement for Freshwater Management 2020* (NPS-FM).

12. Only a third of questionnaire respondents check on state of recreational water quality prior to visiting a site. There is thus room for improvement in the Council's communication and publicising of recreational water quality results for the public's use. Potential changes to the communication of TRC's recreational bathing programme are currently being explored.

## Recommendations

That the Taranaki Regional Council:

a) receives the memorandum noting the preparation of a report into the state of the recreational use of coast, rivers and lakes in Taranaki.

b) notes the recommendations contained therein.

## Background

13. The Resource Management Act 1991 requires the Council to promote the sustainable management of natural and physical resources, including water. In promoting sustainable management, TRC is required to recognise and provide for the maintenance and enhancement of public spaces with regards to coastal marine areas, lakes and rivers. This is seen as a matter of national importance under Section 6(d) of the RMA 1991. In particular, regard is to be given to the maintenance and enhancement of the quality of the environment, and of amenity values. The recreational attributes of an area are one such amenity value.

14. The Regional Policy Statement for Taranaki 2010 (RPS) specifically outlines the need to maintain and enhance public access along the region's rivers, lakes and coastal environment, as well as containing policy pertaining to the maintenance and enhancement of regional amenity values. The relevant policies include:

Policy 6.7 Maintaining and enhancing public access to and along rivers and lakes.

Policy 8.3 Maintaining and enhancing public access to and along the coastal environment.

Policy 10.3 Maintaining and enhancing amenity values.

15. Council periodically undertakes a public survey of water recreational access and use in order to help inform whether TRC is meeting the above requirements, as set out under the RMA and RPS. The survey provides insights into the public's perception and use of the region's water-based recreational resources.
16. The results of an initial survey were published in 1984 as a part of the Taranaki Catchment Commission's report, "*Recreation: Taranaki Ring Plain Water Resources Survey 1984*", with a second survey completed in 2007-2008. The initial 1984 survey helped inform and establish the majority of the long-term monitoring sites in the Council's recreational water quality monitoring programme.
17. The water recreational access and use survey forms a part of TRC's state of environment monitoring (SoE) programme, with the results of the current report to be included in the next five-yearly SoE report which is next due to be published in early-mid 2022.

## Discussion

18. The recreational use and access survey consists of two main components:
    - A web-based questionnaire aimed at gathering information and views from the public on the use and access of Taranaki's recreational waters. This was undertaken in April 2019, with 524 complete and independent responses received; and
    - Observational counts of users, undertaken at 46 different recreational sites around the region throughout the summer of 2019-2020.
19. Recreational sites central to New Plymouth were found to be the most frequented sites regionally, with Fitzroy Beach and the Coastal Walkway found to be the most popular recreational sites across both components of the survey. Pukekura Park, Ōakura Beach, Back Beach, Ngāmotu Beach and East Beach were also highly popular.
20. In general, beach sites were more popular than either river or lake sites for recreation. Corbett Park, at the mouth of the Ōakura, and Merrilands Domain, on the Waiwhakaiho, are the two most popular river sites across the region. Meanwhile, lake sites such as Lake Rotokare, Rotorangi and Ratapiko remain popular for particular activities, including boating, jet skiing and camping.
21. Walking and swimming were the two most popular recreational activities at sites across the region. Fitzroy, Ngāmotu and Ōakura beaches were noted as the most popular swimming spots, while the Coastal Walkway and Pukekura Park were most popular for walkers.
22. Access for water recreation across the region is deemed to be relatively good, with 87% of questionnaire respondents saying that they have been able to access the sites they wanted, and 85% of respondents rating overall levels of access as being good or excellent. Only 1% of respondents had experienced being denied access to water recreation sites by landowners.
23. The main factor determining which sites people frequent for recreation is the distance of the site from home. This importance of having easy to access recreational sites close to home is seen in the spatial distribution of sites most often frequented by residents of the region's three districts. For New Plymouth and South Taranaki residents in particular, these sites are clustered around the main population centres of the respective districts.
24. Of the questionnaire respondents, 56% indicated that they do not visit beaches, rivers and lakes as often as they would like, with the primary reason for this being time constraints due to work and family commitments.

25. In general, the most popular recreational sites in the region, and the reasons why people visit particular sites, have remained relatively unchanged since the last recreational use report was published in 2008.
26. There has been a marked decline in the public's perception of recreational water quality in Taranaki since the previous use and access report in 2008. In the current study, 51% and 41% of questionnaire respondents deemed lake and river water quality, respectively, to only be fair or poor. These perceptions are in-line with the results of the 2019-2020 bathing water quality monitoring programme, where 21.3% of lake site samples and 40.9% of river site samples had *Escherichia coli* (*E. Coli*) levels at Alert or Action level.
27. Managing the pressure on water resources from agricultural and industrial uses in order to maintain and enhance the recreational attributes of a waterbody can be a tricky equation. However, the findings of this survey emphasise that there is need for Council to increase its efforts in this area in order to meet its requirements and goals under the RMA and Policy 10.3 of the RPS to maintain and enhance water quality.
28. Only a third of questionnaire respondents said that they check the status of recreational water quality prior to visiting sites, with the use of both local authorities' websites or LAWA to check conditions being very low. There is a significant gap between the 56% of people checking water quality conditions and the 77% of people surveyed who said they would not enter the water if a water quality warning were in place. Simple improvements such as more prominent signage at water recreation sites, more prominent placement of recreational water quality status' on the Council's website, and a more extensive use of different media channels for communicating results, would help raise public awareness in this regard.
29. The results of the recreational use survey show that there are a select number of sites in the region that are highly popular, yet either do not have recreational bathing water quality monitoring undertaken at them, or are only monitored every third summer. In particular, the Waiwhakaiho River at Meeting of the Waters, Lake Rotorangi, and Tongaporutu are three heavily frequented sites with no current water quality monitoring, while Waiinu and Wai-iti Beaches are listed among the 20 most popular sites in the observational count survey, yet are only monitored on a three year rotation. It is recommended that recreational water quality monitoring is undertaken at these sites in the next monitoring summer.
30. Recommendations set out in the 2019-2020 recreational use of coast, rivers and lakes report include:
    a) THAT a review is undertaken of how the results of bathing water quality monitoring results are communicated to the public, in order to increase the distribution and understanding of the results.
    b) THAT five additional sites are monitored for bathing water quality over the next summer season, given their high usage as recorded in the observational count survey. These include Waiwhakaiho River at Meeting of the Waters, Lake Rotorangi, Tongaporutu, Waiinu and Wai-iti beaches.
    c) THAT the Council increase its efforts to maintain and enhance the recreational water quality of the region's coast, rivers and lakes.
    d) THAT the water recreational access and use survey be repeated in approximately three years.

e) THAT Mātauranga Māori concepts and values are incorporated into the next recreational access and use survey.

## Financial considerations—LTP/Annual Plan

31. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

## Policy considerations

32. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

## Iwi considerations

33. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

## Community considerations

34. This memorandum and the associated recommendations have considered the views of the community, interested and affected parties and those views have been recognised in the preparation of this memorandum.

## Legal considerations

35. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

## Appendices/Attachments

Document 2841687: Recreational Use of Coast, Rivers and Lakes in Taranaki. State of Environment Monitoring Report 2019-2020. Technical Report 2021-46

# Recreational Use of Coast, Rivers and Lakes in Taranaki

State of the Environment Monitoring Report
2019-2020

Technical Report 2021-46

Working with people | caring for Taranaki

Taranaki Regional Council

Taranaki Regional Council
Private Bag 713
Stratford

ISSN: 1178-1467 (Online)
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November 2021

# Recreational Use of Coast, Rivers and Lakes in Taranaki

State of the Environment Monitoring Report
2019-2020

Technical Report 2021-46

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## Technical Report 2021-46

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# Executive summary

The Taranaki Regional Council is required under the Resource Management Act 1991 to recognise and provide for the maintenance and enhancement of public access to and along the region's rivers, lakes and coast. In addition, the council must have particular regard for the maintenance and enhancement of the region's amenity values, including recreational attributes. To this effect, the Council periodically undertakes public surveys to look at the use and access of the region's water recreational resources. This report presents the findings of the Council's third such survey, completed over the period April 2019 to March 2020.

While modernised, the methods used in the current recreational use and access survey are modelled on those used in both the 1980-1982 and 2007 versions of the survey. This allows the results of the three surveys to be compared and insights gained into how recreational habits and access have evolved over the last three decades.

The current survey was undertaken in two parts. Firstly, a web-based questionnaire was conducted to gather information and views from the public on the level of use and access to Taranaki's recreational waters. Secondly, to validate and supplement the results of the questionnaire, physical counts of users were undertaken at recreational sites around the region throughout the summer of 2019-2020.

As in the 1980-1982 and 2007 surveys, recreational sites central to New Plymouth were found to be the most frequented sites regionally. Fitzroy Beach and the Coastal Walkway were found to be the most popular recreational sites across both aspects of the survey, while Pukekura Park, Ōakura Beach, Back Beach, Ngāmotu Beach and East Beach also proved highly popular. Tongaporutu proved highly popular in the observational count survey, but not with questionnaire respondents, likely due to a large fraction of its users being out-of-region tourists.

In general, beach sites were found to be more popular than either river or lake sites for recreation. Corbett Park, at the mouth of the Ōakura, and Merrilands Domain, on the Waiwhakaiho, were the two most popular river sites across the survey. Meanwhile, lake sites such as Lake Rotokare, Rotorangi and Ratapiko remain popular for particular activities, including boating, jet skiing and camping.

Access to water recreational sites across the region was deemed to be relatively good, with 87% of questionnaire respondents saying they had been able to access the sites they wanted, and 85% rating overall levels of access as being good or excellent. The main factor determining which sites people frequented was the distance of the site from home, a result which is reflected in the spatial distribution of the most popular sites in the region. Of the survey respondents, 56% indicated that they do not visit beaches, rivers and lakes as often as they would like, with the primary reason for this being time constraints due to work and family commitments.

A comparison of the results from the 2007 and current survey show the decline in people's perception of recreational water quality in Taranaki, with 51% and 41% of questionnaire respondents in the current survey deeming lake and river water quality, respectively, to only be fair or poor. Despite this result, only a third of respondents checked on recreational water quality state prior to visiting sites. These results suggest that the Council needs to put increased focus on improving recreational water quality regionally, as well as improving the communication and publicising of recreational water quality results for the public's use.

# Table of contents


| | | |
|---|---|---|
| 1 | Introduction | 1 |
| 2 | Background | 2 |
| 2.1 | Resource Management Act 1991 | 2 |
| 2.2 | Regional Policy Statement for Taranaki 2010 | 2 |
| 2.3 | Recreational water quality monitoring | 3 |
| 3 | Survey methodology and design | 4 |
| 3.1 | Public questionnaire | 4 |
| 3.2 | Observational count | 4 |
| 3.3 | Limitations of methods used | 5 |
| 4 | Survey results | 7 |
| 4.1 | Respondent profile | 7 |
| 4.2 | Site Popularity | 9 |
| 4.3 | Activities at Sites | 15 |
| 4.4 | Reasons for visiting sites | 15 |
| 4.5 | Factors discouraging visits | 16 |
| 4.6 | Public access | 19 |
| 4.7 | Water quality | 20 |
| 4.8 | Site Conditions | 22 |
| 5 | Observational count results | 25 |
| 5.1 | Site Popularity | 25 |
| 5.2 | Activities at Sites | 26 |
| 5.3 | Temporal Patterns | 28 |
| 5.4 | Events | 29 |
| 5.5 | Activities not captured by Observational Count | 29 |
| 6 | Comparison with previous access surveys | 31 |
| 6.1 | Site Popularity | 31 |
| 6.2 | Activities at Sites | 33 |
| 6.3 | Reasons for visiting sites | 33 |
| 6.4 | Public Access | 35 |
| 6.5 | Water Quality | 35 |
| 7 | Discussion | 37 |
| 8 | Recommendations | 39 |
| Bibliography and references | | 40 |
| Appendix I | Recreational use online questionnaire | |

Appendix II How to interpret a boxplot

Appendix III Ranking of all sites visited within the last year by questionnaire respondents

Appendix IV Site usage on weekdays vs weekends from observational count

Appendix V Individual site summaries from observational count results

Appendix VI Comparison of popularity of activities between 2007 and 2019 recreational questionnaires

# List of tables

Table 1 Top 20 most popular sites as per recreational use questionnaire and observational count 11

Table 2 Perceived water quality at Taranaki beaches, lakes and rivers, 2007 vs 2019 (percentage of respondents) 36

# List of figures

Figure 1 Comparison of respondent demographics between the recreational use questionnaires of 2019 and 2007, and Taranaki census data from 2018 8

Figure 2 Distribution of respondent ethnicities, by district, for the 2019 questionnaire 9

Figure 3 Age distribution of 2019 questionnaire respondents, by gender 9

Figure 4 Boxplots of the number of days per year respondents visit beach, lake and river sites. (See Appendix II for an introduction to interpreting boxplots) 10

Figure 5 Examples of the range of recreational activities catered for by the Coastal Walkway 13

Figure 6 Top 10 most popular recreation sites for residents of each district, based off the number of respondents who had visited each site within the last 12-months 14

Figure 7 Activities undertaken by survey respondents at Beach, Lake and River sites 15

Figure 8 Survey respondents' top three reasons for visiting their favorite recreational sites, split by district residency 17

Figure 9 If residents of Taranaki's three districts visit recreational sites as often as desired (Respondents who didn't name their district of residence are not included) 18

Figure 10 Survey respondents' top three reasons for not visiting recreational sites as often as they would like 18

Figure 11 Left: Proportion of survey respondents who could gain access to their desired recreational sites in the past year. Right: Reasons given when access was not able to be gained 19

Figure 12 Perceived level of access to recreational sites in Taranaki by survey participants 20

Figure 13 Perceived level of water quality at recreational sites in Taranaki 20

Figure 14 Number of *E.coli*/Enterococci samples falling in each band of the MfE contact recreation guidelines over the 2018-2019 bathing season 21

Figure 15 Do questionnaire respondents check conditions prior to visiting a recreational site? 22

| | | |
|---|---|---|
| Figure 16 | Conditions checked by survey respondents prior to visiting a site | 22 |
| Figure 17 | Websites used when checking site conditions prior to a visit | 23 |
| Figure 18 | If questionnaire respondents would still visit a recreational site when a water quality warning is in place | 24 |
| Figure 19 | If respondents would still use the water when a water quality warning sign is in place | 24 |
| Figure 20 | Reasons for still visiting a site despite a water quality warning being in place | 24 |
| Figure 21 | Boxplots of total number of users counted at beach sites throughout the observational count survey | 25 |
| Figure 22 | Boxplots of total number of users counted at river sites throughout the observational count survey | 26 |
| Figure 23 | Boxplots of total number of users counted at lake sites throughout the observational count survey | 26 |
| Figure 24 | Mean number of swimmers recorded at sites during the observational count survey | 27 |
| Figure 25 | Mean number of walkers recorded at sites during the observational count survey | 28 |
| Figure 26 | Distribution of the number of total users at different times, grouped by site type (note that the three plots have different scales) | 29 |
| Figure 27 | Top twenty most frequently visited recreation sites, from responses to public recreation questionnaires in 1984, 2007 and 2019 | 32 |
| Figure 28 | Reasons given for visiting a certain recreational site, 1984-2019. | 34 |
| Figure 29 | Reasons given for not visiting a site, 1984-2019. Note that' time commitments' and 'age and health' were removed as a specific option in the 2019 survey | 35 |

# 1 Introduction

New Zealand is known as a water-loving nation, with many outdoor recreational activities being based on and around water bodies such as rivers, beaches, estuaries or lakes. Taranaki local coastal areas, rivers and lakes are viewed as an integral part of the region's natural landscape, and are used by the community for a variety of recreational activities. In Taranaki, as with the rest of the nation, recreational access and use of waterways occurs alongside, and sometimes in competition with, other uses of this resource to meet agriculture, industry, water-supply and power generation needs.

The Taranaki Regional Council (the Council) periodically undertakes a public survey of water recreational access and use in order to understand the public's perception and use of the region's water-based recreational resources. An initial survey was undertaken in 1980-82 (TCC, 1984), with a second survey completed in 2007 (TRC, 2008). The initial 1980-82 survey helped inform and establish the majority of the long-term monitoring sites in the Council's recreational water quality monitoring programme.

This report presents the findings of the Council's third such survey, conducted between April 2019 and March 2020. The maintenance and enhancement of public access to and along the region's water-based recreational areas is a matter of importance that must be recognised and provided for under the Resource Management Act 1991 (RMA). The purpose of the survey is to provide an up to date overview of use and access of Taranaki's coastal areas, lakes and rivers for state of environment (SoE) reporting.

The 2019-2020 recreational use survey consisted of two parts;

1. A public survey, carried out via online questionnaire in April 2019, and;
2. An observational counts of users, undertaken at recreational sites around the region over the summer of 2019-2020.

The results presented in this report give a current indication of the state of, and pressures on, the region's recreational water resources, while documenting factors which influence where and how people use the region's coast, rivers and lakes.

# 2 Background

## 2.1 Resource Management Act 1991

The Council is required to promote the sustainable management of natural and physical resources, including water, as stipulated in the *Resource Management Act 1991* (RMA). In promoting sustainable management, the Council is required to recognise and provide for the maintenance and enhancement of public spaces with regards to coastal marine areas, lakes and rivers. This is seen as a matter of national importance under Section 6(d) of the RMA 1991. In particular, regard is to be given to the maintenance and enhancement of the quality of the environment, and of amenity values. The recreational attributes of an area are one such amenity value.

In addition, Section 35 of the RMA requires local authorities to monitor, among other things, the state of the environment of their region or district, to the extent that is appropriate to enable them to effectively carry out their functions under the Act.

To this effect, the Council has established a state of the environment (SoE) monitoring programme for the region. This programme is outlined in the Council's 'State of the Environment Monitoring Procedures Document', which was prepared in 1997. The monitoring programme is based on the significant resource management issues that were identified in the *Council's Regional Policy Statement for Taranaki (1994),* and as such, enables the Council to determine if its policies and programmes are achieving success.

The SOE programme is made up of a number of individual monitoring activities, many of which are undertaken, managed and reported on an annual basis (from 1 July to 30 June). A 5-yearly overall state of environment report combines and summarises the state and progress of all the individual SOE programmes.

The water recreational access and use survey helps inform whether the Council is meeting the above requirements as set out under the RMA. The survey forms a part of the Council's SOE programme, with the results of the current report to be included in the next five-yearly state of environment report, due to be published in late 2022.

## 2.2 Regional Policy Statement for Taranaki 2010

The Regional Policy Statement for Taranaki, 2010 (RPS) highlights two significant issues relating to public access along rivers, lakes and along the coastal environments:

1. Providing for the maintenance and enhancement of public access to and along rivers, lakes and the coastal environment, and;
2. Avoiding, remedying or mitigating adverse effects that may arise from public access to and along rivers, lakes and the coastal environment.

The RPS specifically outlines the need to maintain and enhance public access along our river, lakes and coastal environment, as well as policy pertaining to maintaining and enhancing regional amenity values. The relevant policies include:

| | |
|---|---|
| Policy 6.7 | Maintaining and enhancing public access to and along rivers and lakes |
| Policy 8.3 | Maintaining and enhancing public access to and along the coastal environment |
| Policy 10.3 | Maintaining and enhancing amenity values |

The RPS provides a list of implementation and action plans, as well as the expected outcome when these action plans are achieved.

The water recreational access and use survey has been designed to help inform the Council and its communities on the effectiveness of these policies. It is worth noting that maintaining and enhancing amenity values are collectively the responsibility of the three local territorial authorities (New Plymouth, Stratford and South Taranaki District Councils), through their land use responsibilities. However, the Council works together with the territorial authorities to promote and enhance access to water recreation resources.

## 2.3 Recreational water quality monitoring

The Council has been monitoring and reporting on recreational bathing water quality since 1995. As a part of SOE, the recreational water quality monitoring programme has been designed both as a tool for informing the general public about the state of the water quality at recreational sites in the region, and in order to detect and analyse trends in recreational water quality.

Historically, the programme has involved testing of water quality at 16 freshwater and 11 beach recreational sites carried out on at least 13 occasions between November and March every summer. These data are assessed and reported in accordance with the 2003 Ministry of the Environment and Ministry of Health Microbiological Water Quality guidelines. The programme also includes monitoring of benthic cyanobacteria at nine of the river sites, and monitoring of planktonic cyanobacteria at all four lake sites. The results of the sampling are posted both on the Taranaki Regional Council and Land, Air, Water Aotearoa (LAWA) websites, and through signage at the recreational sites.

The perceived water quality of a waterbody is a contributing factor to people's recreational habits in and around that waterbody. In order to inform the Council of its effectiveness under Policy 10.3 of the 2010 RPS (pertaining to maintaining and enhancing amenity values), questions regarding the public's perception of recreational water quality in the region have been included in the questionnaire section of the recreational access and use survey. The current survey also provides an overview of the most frequented water recreation sites in the region, allowing a review of the representativeness of the sites monitored in the Council's recreational bathing water quality programme.

# 3 Survey methodology and design

The design of the recreational access and use survey broadly follows the methods used in the previous recreational surveys of 1980-82 and 2007. This ensures a level of consistency between the three surveys, which is needed for comparing results between the three. There are two separate components to the recreational survey; first, a questionnaire on recreational access and use is sent to a region wide study group. Following this, field counts of recreational users are undertaken at the region's popular beach, river and lake sites throughout the summer period. The two components of the survey complement each other, allowing validation of results, and further insights into recreational use habits in the region.

Further details on the methods used for the questionnaire and observation counts are outlined below.

## 3.1 Public questionnaire

Both the 1980-1982 and 2007 recreational surveys employed postal questionnaires to gather information on people's recreational use habits. In the first survey, addresses were selected at random from the Electoral Roll, whilst in 2007, a total of 500 names, split proportionally between the three districts, were selected at random from the white pages. An under-representation of under 20 year-olds was accounted for by collecting an additional 98 questionnaire responses through the region's high schools (TRC, 2008).

Following the 2007 survey, it was recommended that a web-based questionnaire and revised method for selecting the sample population should be considered for future surveys. The method of questionnaire distribution was thus reviewed prior to the 2019 survey, with a web-based questionnaire ultimately being decided on, as it was deemed more efficient than either postal or in-person surveys.

After looking at various options, Qualtrics was decided on as the most suitable online survey. While the format of the questionnaire was changed from previous surveys, effort was made to retain many of the same survey questions to enable comparisons. The transition to an online survey, while keeping the context of the original questionnaire, formed an interesting challenge, with trial surveys showing that any question requiring too much typing resulted in people abandoning the question. As a result, most questions were formatted with possible results in drop-down menus, with the option to type in a custom answer still available. Respondents could also leave comments or feedback, similar to the previous two surveys. The questionnaire was formatted to be mobile-friendly, as it was anticipated that most of the responses would be conducted this way. The final version of the questionnaire used can be found in Appendix I.

The recreational use questionnaire was promoted in local newspapers, social media, regional and district council websites and in radio interviews to try and maximise the number of questionnaire responses. As an incentive to participate in the questionnaire, respondents were entered in a prize draw to win a weekend's accommodation in TRC's Pukeiti Lodge.

## 3.2 Observational count

As in the previous two recreational use surveys, observation counts of users were undertaken at sites across the region with the aim of validating the results of the online questionnaire. The methods by which count sites were selected, and by which the counts were undertaken, however, were adapted for the current survey, in an effort to establish a reproducible and unbiased count methodology. Ultimately, a list of 41 'permanent' observational count locations was established, consisting of the 33 'well known' sites used for the 2007 recreational use survey, and an additional 8 sites which increased the geographic spread and recreational diversity of the count locations. These sites can be used in future recreational use surveys to ensure consistency and comparability in results. In addition to the permanent count locations, any sites which were identified from the online questionnaire as being in the top 20 most popular recreational waterbodies in the region were also surveyed. This brought the total number of sites in the 2019 observational count survey to 46. Further details on the full list of sites included in the survey can be found in Section 5.

In previous surveys, the number of observational counts conducted at each site has varied depending on the pre-perceived popularity of the site. As a result, in 2007, the number of counts undertaken at a site varied anywhere between one and 20. To remove any bias introduced by uneven sampling, for the current survey ten rounds of observational counts were planned at each of the 46 sites; five on weekdays and five on weekends, and all conducted during the period December 2019 to April 2020. Due to Covid19 lockdown in the end of March 2020, however, the final rounds did not go ahead, with a total of eight rounds undertaken at most sites. In order to gather more information on recreational use throughout the day, each round consisted of three counts taken at different times throughout the same day: in the morning (0800-1200), afternoon (1200-1600), and evening (1600-2000). For efficiency, the full list of 46 sites was split geographically into seven “runs”, with surveyors able to conduct three counts at all sites in a single run in the space of one day. The exception to this was the Tongaporutu site, where counts were undertaken by a local volunteer.

Information gathered during each observational count was collected on a standardised survey sheet, and included the total number of people present at the site; both on the beach/bank, and in the water, and the types of activities that were being undertaken. Metadata such as date, time and weather conditions were also collected, as were additional site specific comments, such as if a large organised event was taking place. This allowed anomalous counts to be accounted for in the overall analysis. For consistency, each count at a site was conducted from the same stationary spot, with surveyors instructed on procedures prior to going in the field.

## 3.3 Limitations of methods used

While the move to using an online questionnaire for the first stage of the survey is an appropriate move, there are none-the-less some limitations and bias associated with the method.

In particular, using a web-based questionnaire biases the respondent profiles towards those who can easily access the internet, as well as those that are most exposed to the promotion channels used. The prize incentive offered was also more attractive to some demographics than others. It is likely, therefore, that some demographics who either do not have access to, or use social and digital media less, such as lower socio-economic groups and the very young or elderly, are under-represented in the survey results. In the 2007 recreational use survey, such biases were somewhat accounted for through, for example, the distribution of the survey to a number of high schools. Such a step was not taken in the current study.

While using a digital platform for the survey enabled the efficient collection of a large number of responses, there were also some new risks introduced, such as the chance of people completing the survey multiple times, or a bot sending in automated responses. The chances of such results being included in analysis were been minimised through the use of Qualtrics’ Response Quality functionality. This checked the quality of the data collected, and was used to assess and flag survey responses where:

- The respondent finished the survey abnormally fast
- The respondent took the survey more than once (duplicates data)
- The response contained sensitive data
- The response was deemed a possible bot response (robot/computer generated responses)

It should be noted, that a feature of the Qualtrics™ online survey is that multiple survey responses cannot be submitted using the same internet provider (IP) address. This means that residents of the same address could not reply to the survey using the same device.

Similarly, while measures were taken in the 2019 observational count survey to mitigate and minimise method bias, there were still some notable limitations to the methods employed. One such limitation is that the counts were undertaken from a selected stationary point at each site. While this minimised intra-site variability and bias, it also had the drawback that at some sites a full view of the site was not possible. As a result, the recorded number of users at some sites may well be less than the true total number of users.

There will also be a measure of sampler bias in the results of the observational counts. Prior to the survey, all surveyors underwent training on how counts should be undertaken, however there is a measure of subjectivity to some results, such as where the boundaries of activities are vague, for example what constitutes relaxing versus sunbathing or spectating. To counter this uncertainty, no in-depth analysis has been undertaken on such results. Similarly, uncertainty has been introduced in the results on occasions when sites have been particularly popular and estimates on user numbers have had to be made. To mitigate this, reporting of the observational count results generally focus on the median and variability in the number of users, rather than fine-scale comparisons.

# 4 Survey results

The recreational use questionnaire was available online for five weeks, during which 685 responses were received. Of these, 42 responses were filtered out during quality control after being identified as duplicate responses, while a further 119 responses were omitted for not being complete. This left 80% of all responses as being valid, with only the results of the 524 fully complete and independent responses included in this report.

## 4.1 Respondent profile

An aim of any survey is to have a pool of respondents that accurately represent the demographic profile of the full population. In reality, however, this is hard to achieve without having a large and truly randomly selected sample pool. For this study, the demographic profile of questionnaire respondents is compared against Taranaki population data from the 2018 census (Figure 1). With 96.4% of respondents to the online questionnaire being Taranaki residents the comparison of demographic profiles highlights some short-comings of the online survey method.

While it can be argued that the respondents to the 2019 questionnaire present a more representative sample of ethnicities than in the 2007 survey (Figure 1 and Figure 2), the 2019 survey was less representative of the distribution of gender and age of Taranaki's population. In particular, females and 25-65 year olds were over-represented in the 2019 survey (Figure 3), while both the under 25 and over 65 age groups are severely under-represented. There are two likely contributing factors to this; firstly, the promotion channels and online format used for the questionnaire likely had less impact with younger and older demographics. Secondly, young children make up a significant proportion of the "under 20" category. While this youngest demographic is counted in census results, they are unlikely to contribute to questionnaire results, where their parents would be the primary respondent.

The distribution of respondents from each district shows that New Plymouth residents are over-represented in the 2019 questionnaire results, with South Taranaki, and to a lesser extent Stratford, under-represented. This represents a less balanced response than that received in the 2007 survey. This is an unsurprising result, however, as the method for questionnaire distribution in 2007 involved using white pages directories for the three districts, allowing a distribution of questionnaires that was proportional to district populations.

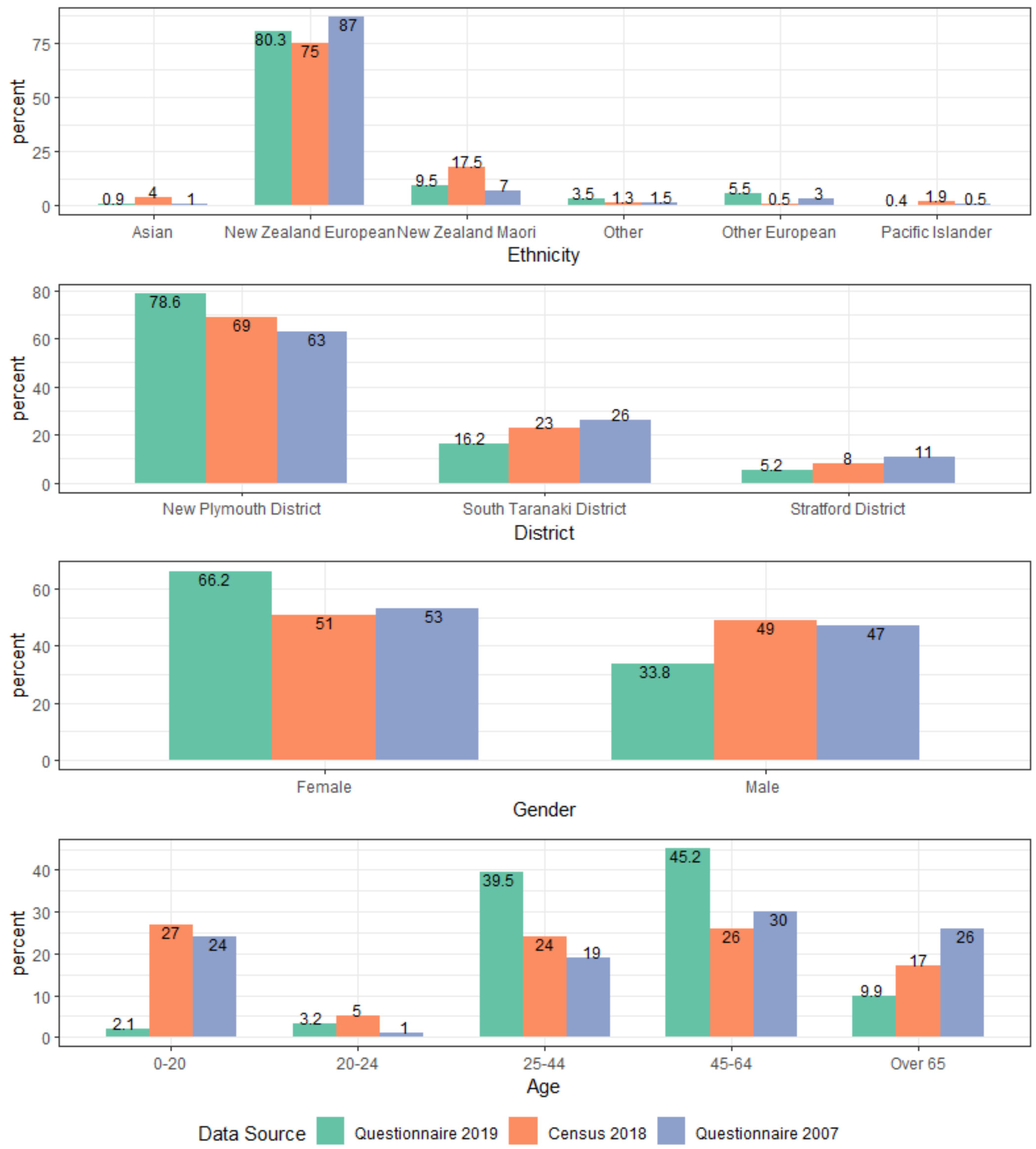


Figure 1 Comparison of respondent demographics between the recreational use questionnaires of 2019 and 2007, and Taranaki census data from 2018

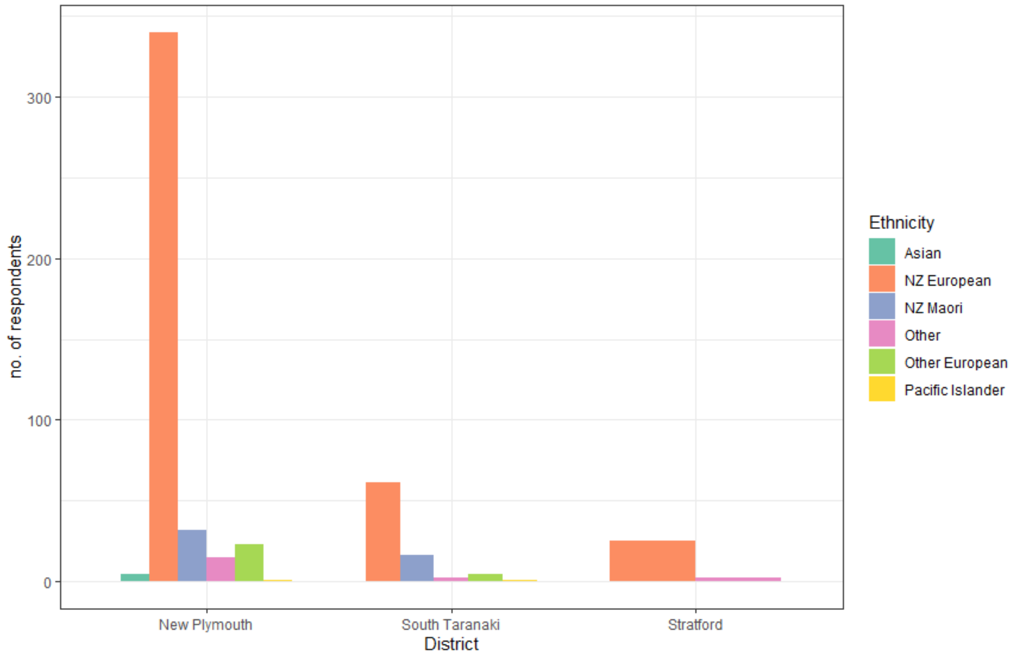


Figure 2 Distribution of respondent ethnicities, by district, for the 2019 questionnaire

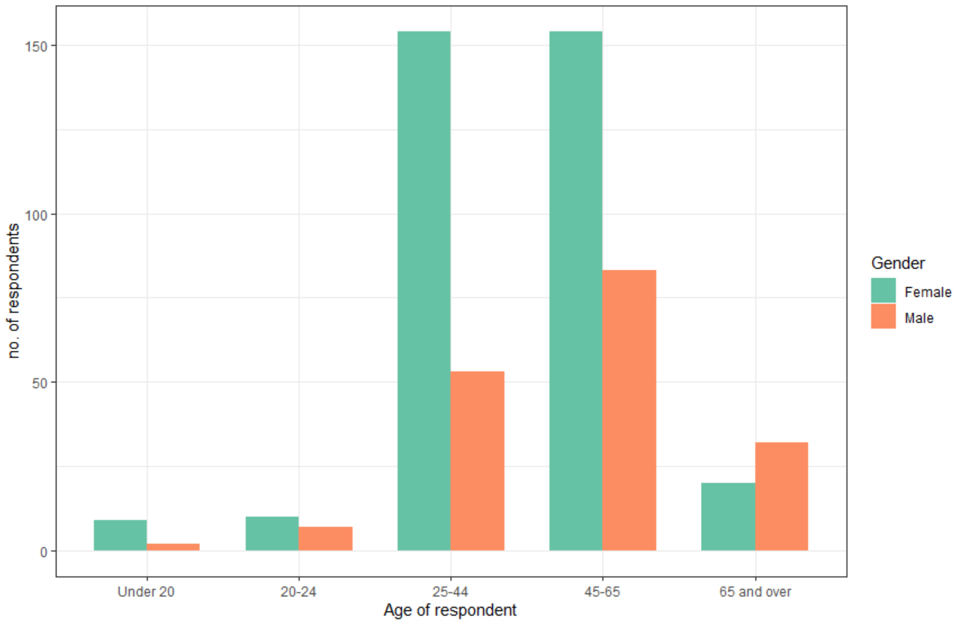


Figure 3 Age distribution of 2019 questionnaire respondents, by gender

## 4.2 Site Popularity

In the 12 months preceding the survey, 99.6% of those surveyed had visited a beach, river or lake in the Taranaki region. This result is not likely representative of the full population, however, as people using recreational areas would be more likely to undertake the voluntary online questionnaire. Perhaps more indicative are the results of Sport New Zealand's Active NZ 2018 Participation Report (Sport NZ, 2019), which uses the electoral role to representatively sample the population. The Active NZ report emphasises the importance and value of access to water recreational areas, with 54% of young people surveyed in Taranaki found to have used outdoor locations such as beaches, lakes, the bush or footpaths for recreation in the week prior to being surveyed. For adults, recreation locations were more varied; with 19% having used sea or coastal areas for recreation, and 11% utilising lakes, rivers or streams in the last week.

Participants of the online survey were asked roughly how many days per year they visited lake, river and beach sites. Of those who responded to the question, beaches were visited more frequently than either rivers, or lakes, with a median of 30, 20 and 10 days per year spent at each type of site respectively (Figure 4). This ranking of beach, river and lakes sites was consistent across both New Plymouth and South Taranaki residents, while Stratford residents frequented beach, lake and river sites roughly equally. Residents of New Plymouth generally visited sites more frequently than residents of the Stratford and South Taranaki, spending a median of 40, 20 and 10 days at beach, river and lake sites, respectively.

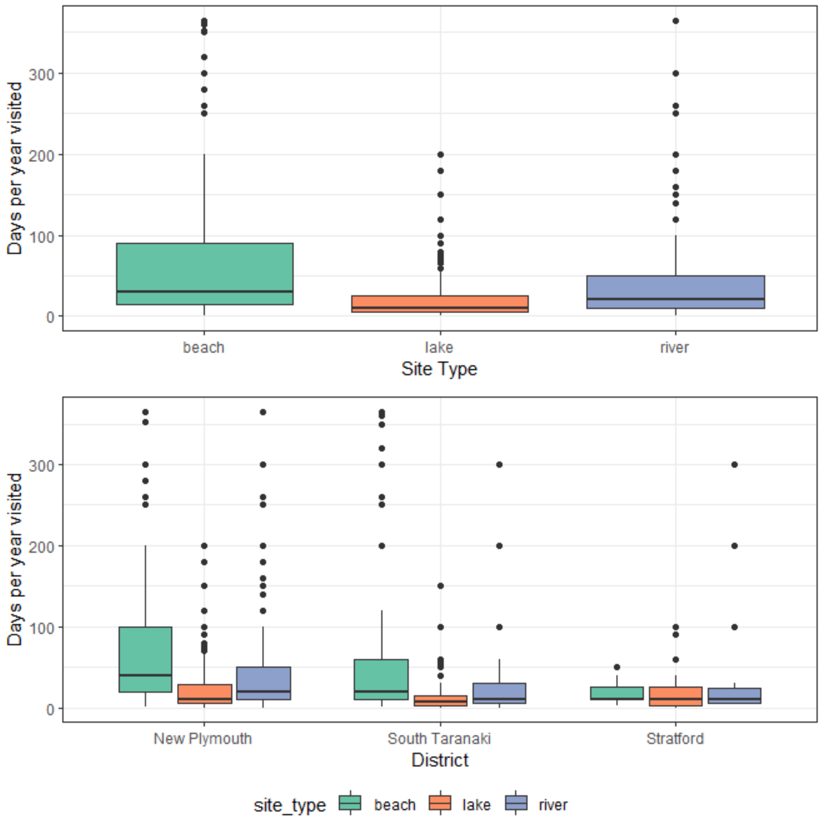


Figure 4 Boxplots of the number of days per year respondents visit beach, lake and river sites. (See Appendix II for an introduction to interpreting boxplots)

Participants were asked to name which particular sites in the region they had visited, as well as which one site they had visited most frequently, over the last 12 months. A comparison of the results from these questions is given in Table 1, along with the 20 most popular sites as observed during the recreational count survey. Note that only one result has been reported in the summary table when two sites are in very close proximity on the same beach/river. (i.e. Back Beach at Paritutu Rock and at Herekawe Stream, and Waiwhakaio River at Te Rewa Rewa bridge and river mouth). Full results can be found in Appendix III.

To rank the popularity of sites from the observational count survey, the mean number of users at each of the 46 observed sites has been calculated for both weekend and weekday use, with the maximum of these two means used to rank the popularity of the site. Public holidays and days with specific events at sites are not included in the calculation of mean use. Further details of the results of the observational count survey can be found in Section 55.

Table 1 Top 20 most popular sites as per recreational use questionnaire and observational count

| Location visited in last 12 months | No. of responses | Most frequently visited site in last 12 months | No. of responses | Observation count | Mean no. users |
|---|---|---|---|---|---|
| Coastal Walkway | 353 | Fitzroy Beach | 44 | Ōakura Beach | 114 |
| Fitzroy Beach | 352 | Coastal Walkway | 31 | Ngāmotu Beach | 104 |
| Pukekura Park | 338 | Back Beach | 30 | Tongaporutu | 102 |
| East End Beach | 336 | East End Beach | 29 | Fitzroy Beach | 92 |
| Ngāmotu Beach | 313 | Ōakura Beach | 29 | Coastal Walkway | 59 |
| Te Henui River mouth | 265 | Lake Mangamahoe | 25 | Back Beach | 56 |
| Waiwhakaiho River near mouth | 257 | Ngāmotu Beach | 23 | Corbett Park | 44 |
| Back Beach | 234 | Ohawe Beach | 20 | Timaru Stream | 40 |
| Lake Rotomanu | 219 | Ōpunake Beach | 20 | East End Beach | 38 |
| Ōakura Beach | 195 | Corbett Park | 15 | Merrilands Domain | 34 |
| Lake Mangamahoe | 188 | Urenui Beach | 12 | Ōpunake Beach | 34 |
| Lee Breakwater | 184 | Waiwhakaiho River | 11 | Lee Breakwater | 31 |
| Merrilands Domain | 178 | Waitara River | 10 | Lake Ratapiko | 28 |
| Urenui Beach | 167 | Lake Rotokare | 9 | Lake Rotomanu | 26 |
| Ōpunake Beach | 163 | Lake Rotorangi | 9 | Waiinu Beach | 24 |
| Huatoki River | 155 | Te Henui (mouth and walkway) | 9 | Pukekura Park | 23 |
| Kawaroa | 154 | Waitara Beaches | 9 | Waitara West Beach | 23 |
| Dawson Falls | 143 | Bell Block Beach | 8 | Wai-iti Beach | 22 |
| Corbett Park/Ōakura River mouth | 141 | Lake Rotomanu | 8 | Urenui River | 20 |
| Ahu Ahu Rd | 139 | Onaero Beach | 8 | Lake Rotokare | 19 |

Respondents of the online questionnaire identified 142 unique sites which they had visited in the twelve months from April 2018 - April 2019. A more comprehensive list of site popularities can be found in Appendix III.

As would be expected, the results of the two questionnaire questions aimed at determining site popularity gave fairly consistent results. Fitzroy Beach and the Coastal Walkway were the most popular recreation sites given by questionnaire respondents, with East End, Ngāmotu and Ōakura Beaches also highly popular. These results are corroborated by the results of the observational count survey, in which four of the five sites named above featured in the top five most popular sites by mean number of users (out of the 46 sites observed). Tongaporutu Beach and Estuary was the third most popular beach in the observational count, but did not feature in the top 20 sites from either questionnaire question. This is likely due to the high number of out-of-region tourists who frequent the site. Overall, beaches proved to be the most popular type of recreational site, with five to seven beaches among the top most popular sites in all three survey methods.

Sites along the Waiwhakaiho River, including near its mouth, at Merrilands Domain, and Meeting of the Waters, proved among the most popular river recreational sites regionally. Corbett Park, located at the Ōakura River mouth is the most popular river site outside of the New Plymouth urban area, and was the most popular river site regionally in the observational count. The Te Henui River, near its mouth, also ranked highly popular with questionnaire respondents. This site did not rank so highly in the observational count, but this is likely due to people spending only short spans of time at the site, with walking and cycling being the most popular activities observed at this site.

Pukekura Park, Lake Mangamahoe and Lake Rotomanu were the most popular lake sites among questionnaire respondents, although of these only Lake Rotomanu allows a full range of water recreation activities. Observational counts at Pukekura Park and Lake Mangamahoe likely did not accurately capture the number of people using these sites, with a wide network of tracks at both sites. The regional lakes Ratapiko, Rotorangi and Rotokare also featured in the top 20 sites in the questionnaire and observational counts, proving popular for water sports, camping and picnicking.

Figure 5 Examples of the range of recreational activities catered for by the Coastal Walkway

There are some notable differences between the most popular sites listed by residents of the region's three districts. Figure 6 gives a spatial representation of the top 10 most popular recreation sites by respondents' district of residency. While many New Plymouth beaches, Pukekura Park and the Coastal Walkway feature in the top 10 most popular sites for residents of all three districts, it is apparent that there is also a strong preference for local recreation sites. Sites such as Lake Rotokare, Dawson Falls and the Patea River are in the top 10 most popular sites recorded for Stratford residents, while the southern beaches of Ohawe, Waihi and Patea are popular amongst South Taranaki Residents. Ōpunake Beach was the most popular site outside of the New Plymouth District, making the top 10 most popular sites for both Stratford and South Taranaki residents. At a glance, Stratford and South Taranaki residents generally travel further to reach the recreational site of their choice, while the top ten popular sites used by New Plymouth district residents are all within-district, with the furthest top-ten site from New Plymouth being Ōakura Beach.

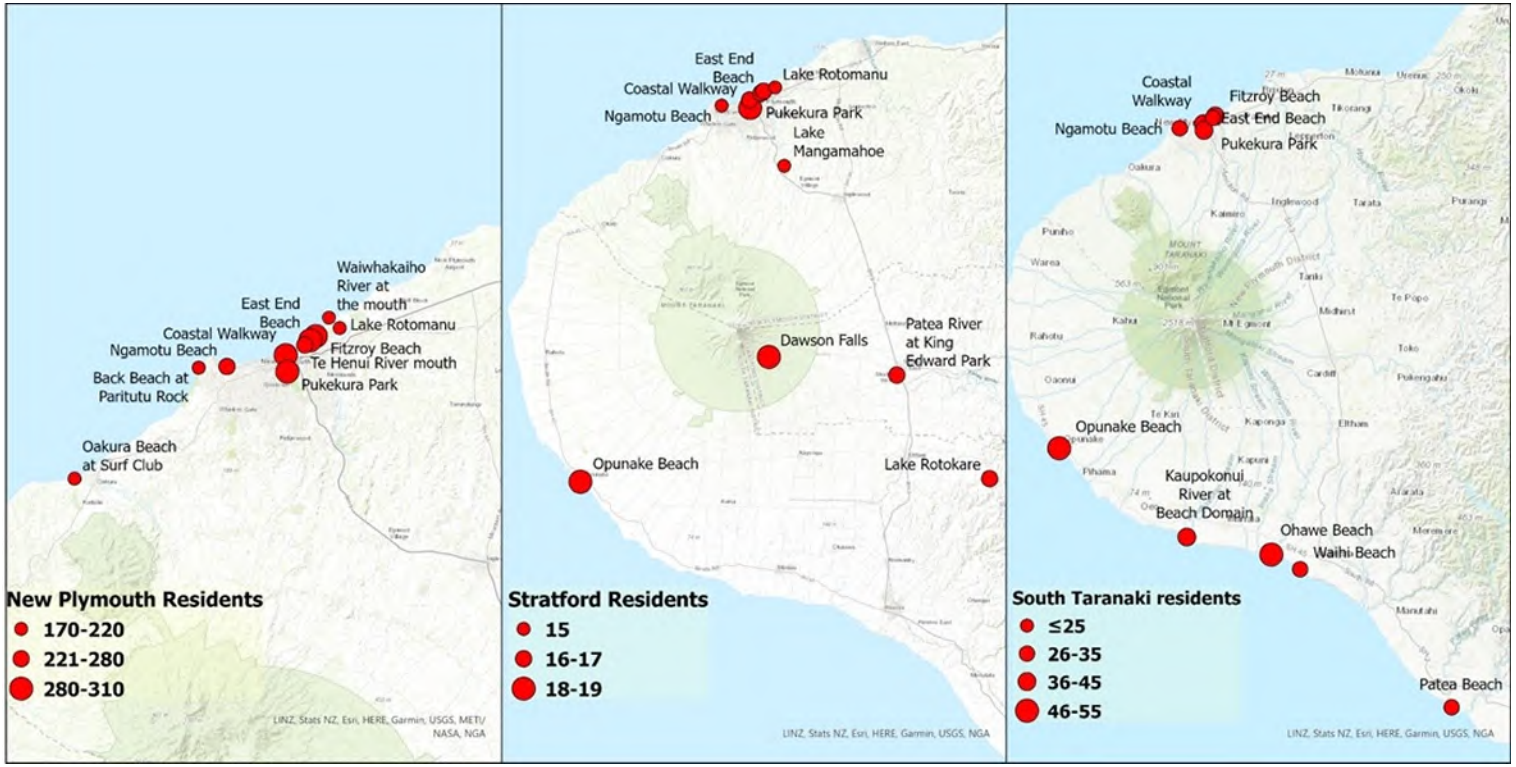


Figure 6 Top 10 most popular recreation sites for residents of each district, based off the number of respondents who had visited each site within the last 12-months

14

## 4.3 Activities at Sites

Respondents were asked to list what activities they undertook while visiting each of beach, lake and river sites, with the results shown in Figure 7. Walking was the most popular activity undertaken across all site types, with swimming being a close second at both beach and river sites. Scenic appreciation was also a popular activity at all site types, while surfing was the third most popular activity at beaches.

These results match well with those from the Sport New Zealand Active NZ 2018 Participation Report (Sport NZ, 2019), which indicated that running (58%), playing (41%) and swimming (35%) were the most popular types of weekly recreational activities for young people in Taranaki, while walking (54%) was the most popular form of exercise for adults. Swimming (33%), marine fishing (12%), canoeing/kayaking (8%), and surfing/body boarding (8%) also featured as top recreational activities for adults.

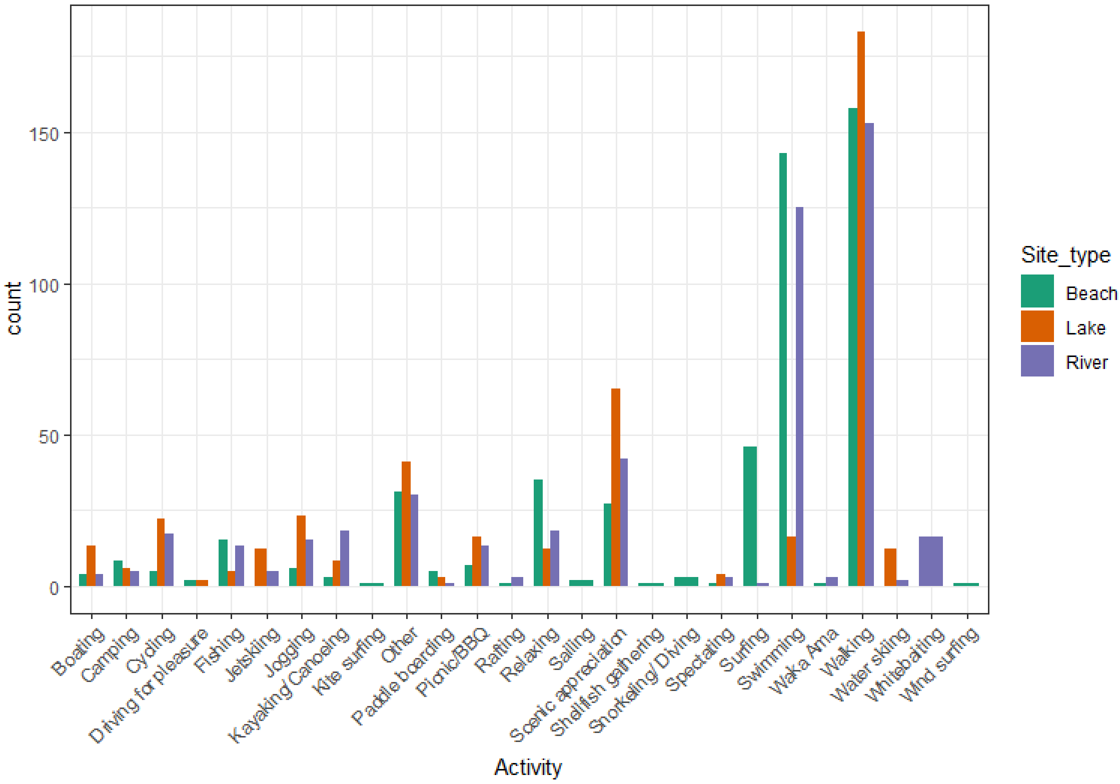


Figure 7 Activities undertaken by survey respondents at Beach, Lake and River sites

## 4.4 Reasons for visiting sites

A summary of the top three ranked reasons respondents had for visiting their favourite recreational site is given in Figure 8. "Close to home" was given by 205 of the 524 (39%) respondents as their top reason for visiting a site, with 317 (60%) having it as a top-three ranked reason. Closeness to home was the top reason for visiting a site for residents of both New Plymouth and South Taranaki districts, and the 2nd most stated reason for Stratford residents. This result agrees with the spatial distribution of the top-ten most popular sites given by residents of each district, which were found to strongly favour sites local to urban areas (Figure 6).

Other main reasons for visiting a site include ease of access (a top-three reason for 40% of respondents), natural character (34%), and the site's suitability for a particular activity (31%). These four top reasons were shared between New Plymouth and South Taranaki residents, with the site not being crowded being an additional important value for South Taranaki residents. The top reasons for visiting a site were slightly different for Stratford residents, with natural character, closeness to home and peace and quiet filling the top three spots. It should be noted, however, that the low sample of Stratford residents answering the survey mean these results may not be fully representative.

Of the 63 respondents who put down "other" as one of their top three reasons for visiting a site, 29 commented on the site's suitability for dog walking, nine visited the site for horse riding, and nine for surf conditions.

## 4.5 Factors discouraging visits

Of the survey respondents, 56% indicated that they do not visit beaches, rivers and lakes as often as they would like (Figure 9). While 44% of all respondents visited sites as often as they'd like, there were notable differences between districts, with only 36% and 27% of South Taranaki and Stratford residents, respectively, visiting as often as liked, compared to 48% of New Plymouth residents.

The main reasons people gave for not visiting as often as desired, however, were consistent across the three districts, with work and family commitments dominating (Figure 10). For Stratford district residents, the travel time to recreational sites was a larger factor discouraging visits than for New Plymouth and South Taranaki residents. This is perhaps unsurprising given the greater distance between Stratford district and popular beach locations.

Comparatively, lack of transport or the cost of transport, were infrequently the cause of people not visiting recreation sites as much as they'd have liked. Of those who listed other reasons for not visiting, the weather was the leading cause (21 answers), along with time restraints (29 answers). Water quality and pollution was a factor for seven respondents, while horse restrictions were a factor for five.

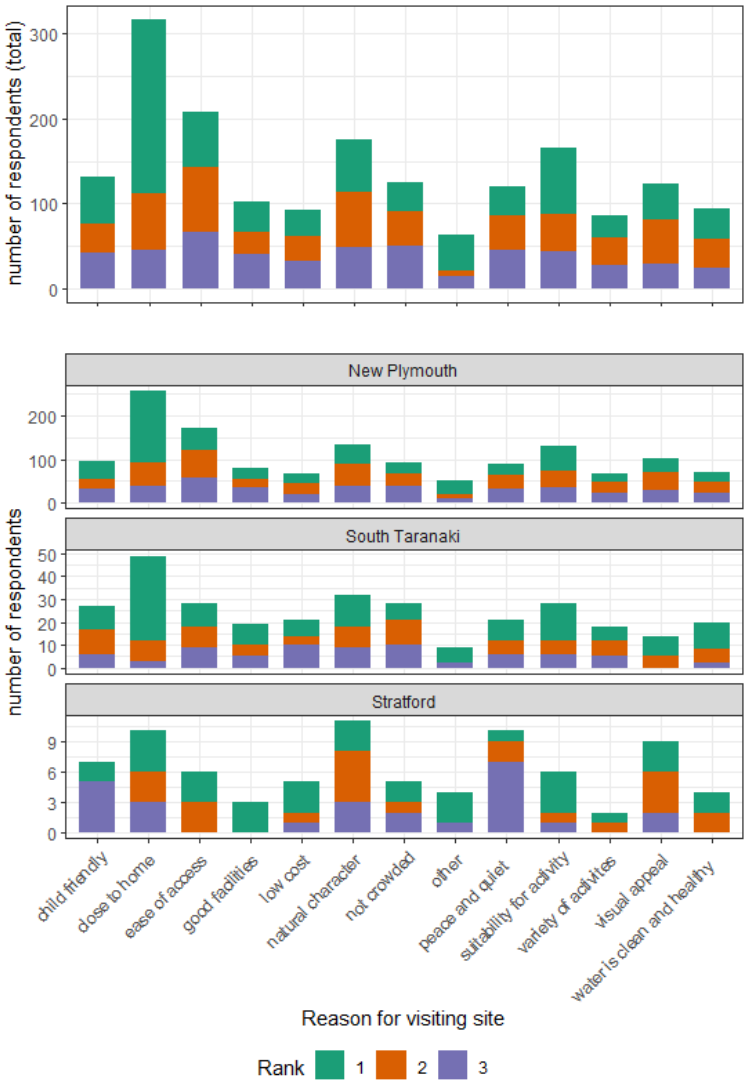


Figure 8 Survey respondents' top three reasons for visiting their favorite recreational sites, split by district residency

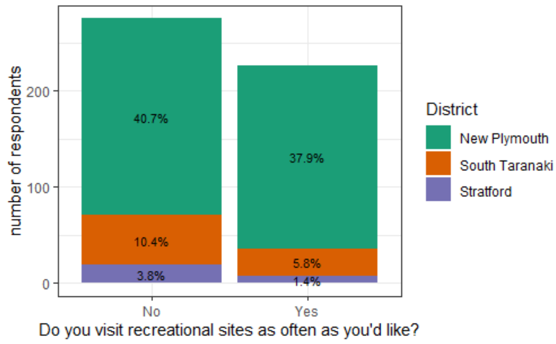


Figure 9 If residents of Taranaki's three districts visit recreational sites as often as desired (Respondents who didn't name their district of residence are not included)

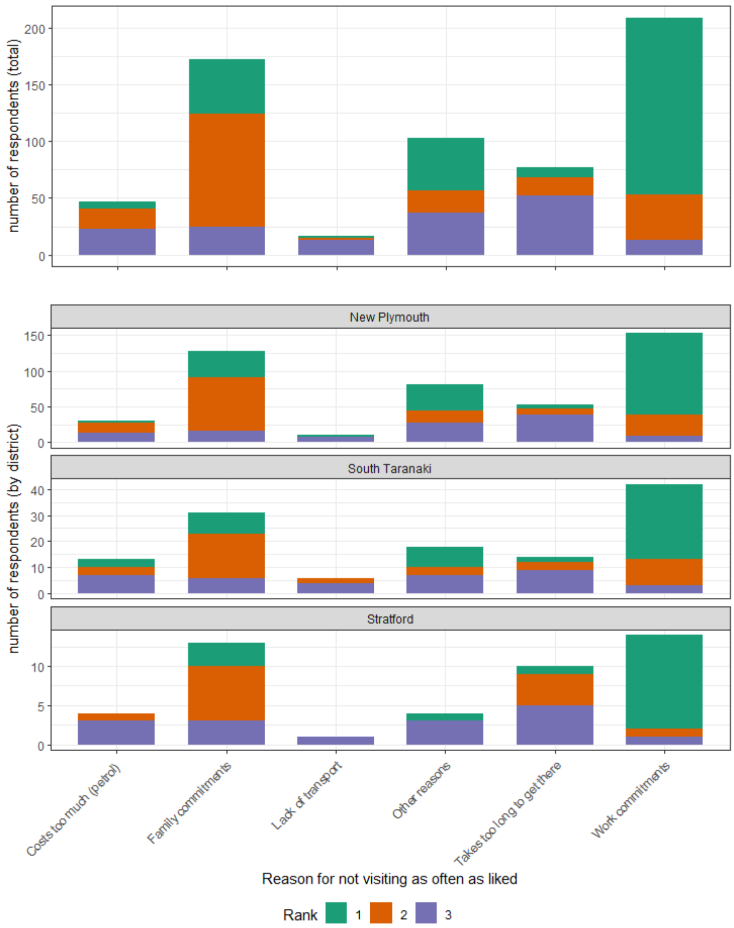


Figure 10 Survey respondents' top three reasons for not visiting recreational sites as often as they would like

## 4.6 Public access

Respondents were asked if, in the last year, they had been able to gain access to the water-recreational sites that they wanted to visit around the region. 87% of respondents indicated that they had been able to access sites, while 13% had not (Figure 11). Of those that had not been able to gain access, the reason most often given was that the access or entrance was closed (20%), or that access was too difficult (12.3%). Landowner issues were rarely a reason for lack of access (6.2%). The issue of water quality was raised by 22% of those who could not gain access to a site they wished to (specified under "Other reason"), a matter which is discussed further in Section 4.7 Other reasons for not being able to access sites included lack of awareness of access, restrictions on horse riding and dog walking, and erosion/storm damage.

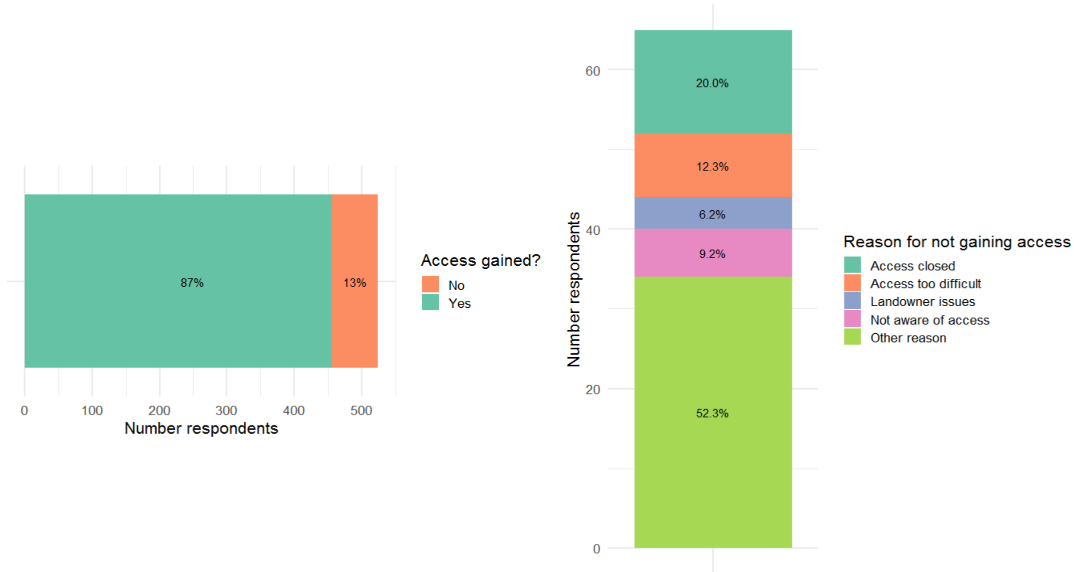


Figure 11 Left: Proportion of survey respondents who could gain access to their desired recreational sites in the past year. Right: Reasons given when access was not able to be gained

Overall, 85% of respondents rated the perceived level of access to recreational sites within Taranaki as being either good or excellent, with only 2.3% rating access as being poor (Figure 12). A selection of quotes representing comments made on the level of accessibility are:

*"Access across private land very good, as well as excellent public access."*

*"A lot of beach access is restricted by private farmland"*

*"I don't want access to be easy to my favourite river swimming. It will ruin the reason I go if too many people because of crowds and disrespect of environment."*

*"Taranaki has wonderful access and opportunities to visit beaches that are not crowded or polluted. Farmers allow reasonable access which is very good. Some tracks could be better maintained."*

*"The diversity of options is superb. The Coastal Walkway a huge asset to the region."*

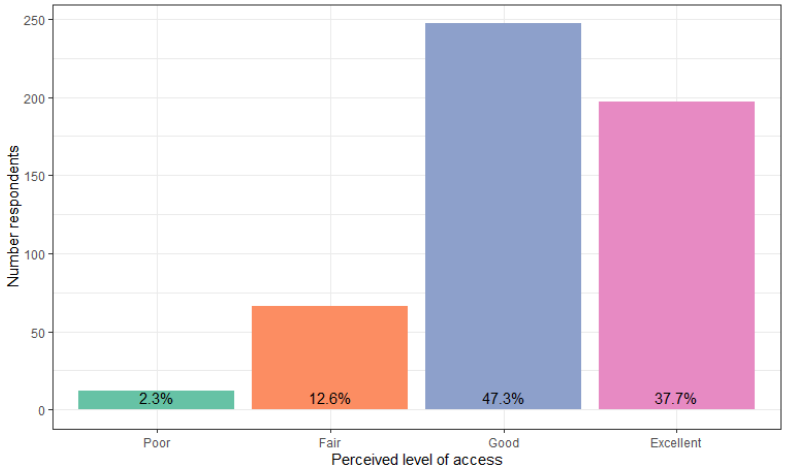


Figure 12 Perceived level of access to recreational sites in Taranaki by survey participants

## 4.7 Water quality

Survey respondents were asked to rate their overall perception of the water quality of Taranaki's rivers, lakes and beaches (Figure 13). While 84.6% of respondents perceived beach water quality to be good or excellent, the perceived water quality of rivers and lakes was less resounding. Only 59.1% and 48.7% of respondents consider water quality at river and lake sites, respectively, to be good or excellent. Around 17% of respondents considered water quality at both Taranaki's rivers and lakes to be poor.

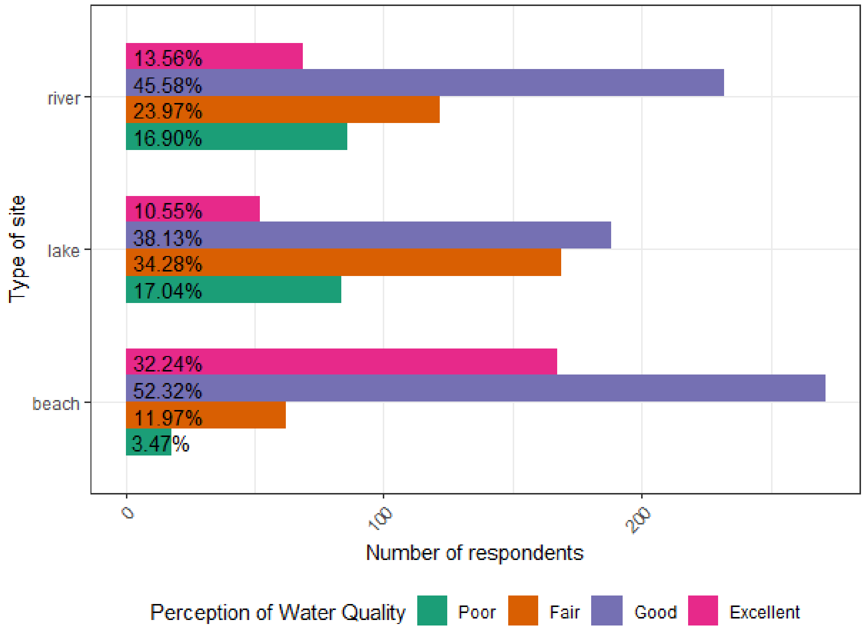


Figure 13 Perceived level of water quality at recreational sites in Taranaki

The perception of water quality given by survey respondents reasonably reflects the results of the recreational water quality sampling programme undertaken by the council over the 2018-2019 bathing season (*TRC, 2019. TRC 2019a*).

In this programme, 14 beach sites, 3 lakes and 13 river sites were sampled regularly between November 2018 and March 2019. *Escherichia coli* (*E.coli)* (for freshwater sites), and Enterococci (for marine sites) levels are compared against Ministry for the Environment guidelines (*MfE, 2003*), with levels deems to be at one of Surveillance, Alert or Action level. At Surveillance and Alert level, a site is deemed suitable for swimming and other recreational uses, although additional sampling and contamination identification is undertaken at Alert level. At Action level, a site is deemed unsuitable for recreation, with warning signs erected at the site, and full investigations as to contamination sources undertaken.

For the 2018-2019 bathing season, 243 samples were taken across the 14 beach sites regionally, with 91.8% of these samples returning Surveillance mode Enterococci levels. At the 13 river sites monitored, 59.1% of the 193 samples taken returned Surveillance mode *E.coli* levels, while at the three lake sites monitored, recreational water quality was deemed at Surveillance mode on 78.7% of the 47 sampling occasions. It is noted, however, that most of the samples were taken during fine weather, and that *E.coli*/Enterococci levels can be expected to be higher, and water quality generally worse, during and closely following rainfall.

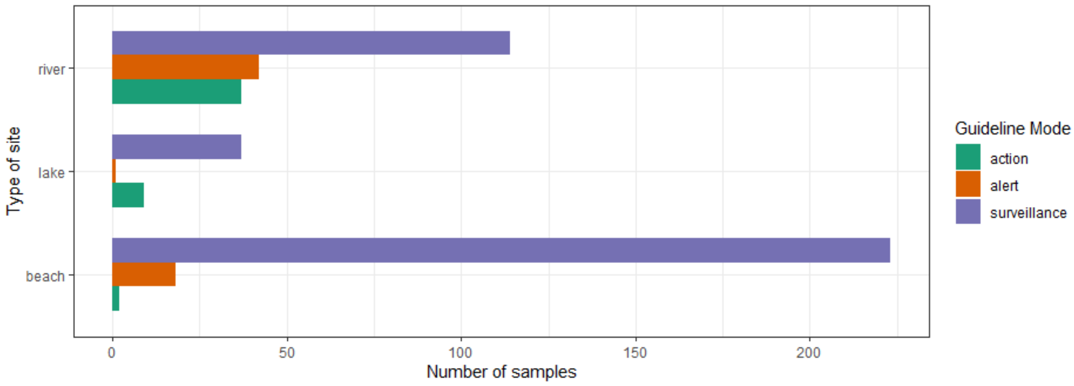


Figure 14 Number of *E.coli*/Enterococci samples falling in each band of the MfE contact recreation guidelines over the 2018-2019 bathing season

While water quality at the most popular beach bathing sites was generally good during the 2018-2019 season, there are known recreational water quality issues at some of the most popular fresh water recreational sites. These include the Waiwhakaiho River, near the mouth, which was found to be the most popular fresh water recreational site in the region. Here, *E.coli* levels were found to be either at alert or action level during all 13 regular samplings during the 2018-2019 season.

A number of other river recreational sites in the region experience *E.coli* issues, especially after heavy rainfall, due to the influence of upstream agricultural areas.

## 4.8 Site Conditions

Respondents to the public recreational use survey were asked if they checked on conditions prior to visiting a site (Figure 15). Just over 44% of participants responded that they do not check conditions, while 33% sometimes check and 23% always check. While 50% of those over 45 years old did not check on conditions, younger age groups tended to check conditions more, with only 36% of these age groups not checking prior to visiting. Of the people that did check conditions, the weather and tide times were the conditions most regularly checked (Figure 16), with only around 28% of respondents checking on water quality conditions prior to a visit. In line with these answers, when respondents were asked which websites they used to check conditions, Metservice was the most used website, giving weather and tide conditions. In contrast, less than 20% of respondents checked either regional or district council websites, with even fewer checking the Land, Air, Water Aotearoa (LAWA) website (Figure 17).

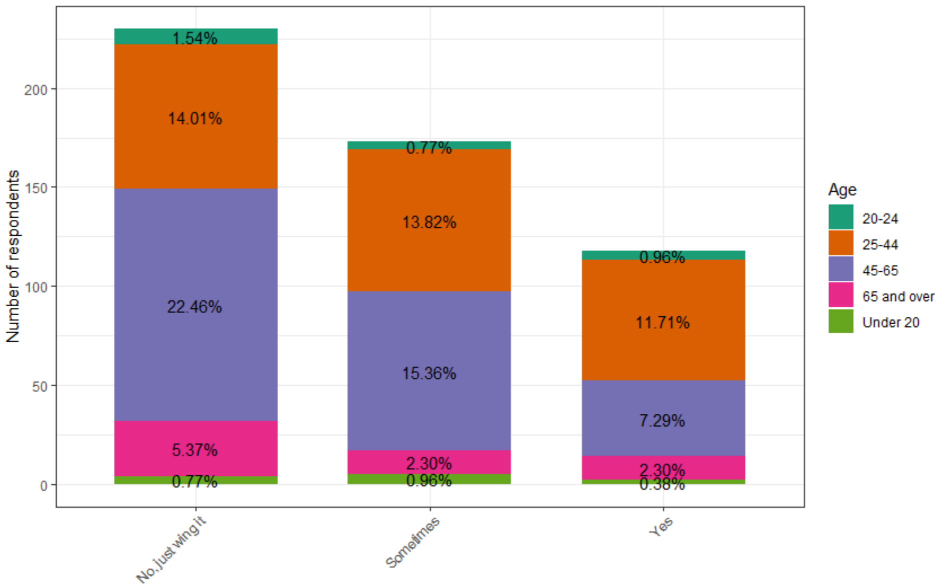


Figure 15 Do questionnaire respondents check conditions prior to visiting a recreational site?

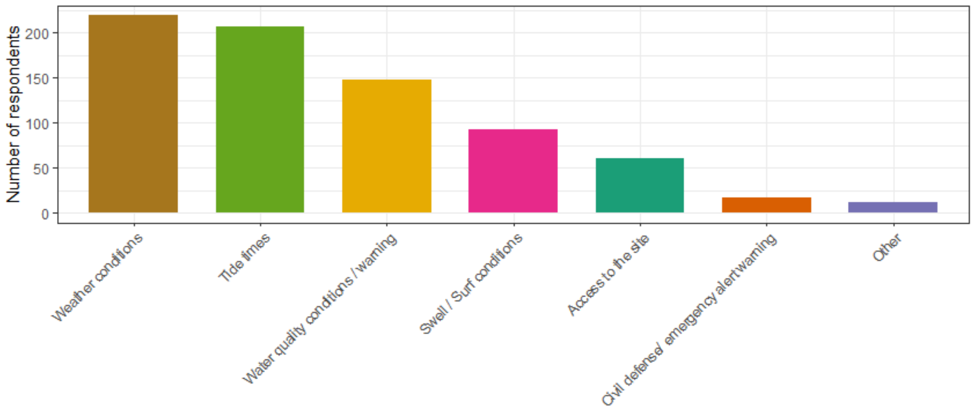


Figure 16 Conditions checked by survey respondents prior to visiting a site

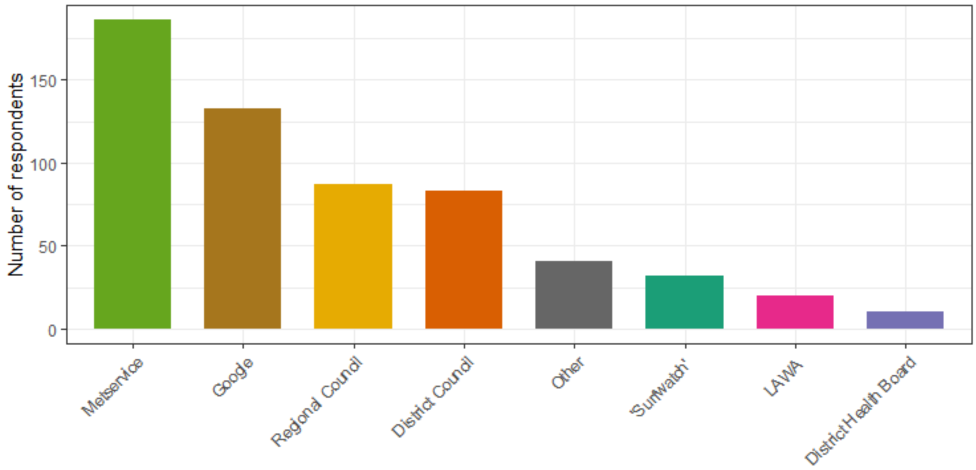


Figure 17 Websites used when checking site conditions prior to a visit

Questionnaire participants were asked a range of questions regarding the impact of water quality warnings at recreational sites. During the summer bathing season, the latest results from the Council's recreational water quality monitoring programme are published online as soon as they are available. Sampling results and the current health warning status can be found on the regional and district councils' websites and the national LAWA website. Given the lack of respondents checking these websites, it is worth reviewing the effectiveness of water quality result communication, and avenues through which public awareness of our region's sites' recreational water quality status can be raised.

In addition to communicating results via websites, the Council informs district councils and Taranaki District Health Board (TDHB) of water quality results as they come in. In the case of Alert and Action level results, the district councils erect warning signs at the relevant recreational sites, with these signs remaining up until a surveillance level follow-up sample is obtained. In the case of New Plymouth District sites, permanent signs are present at most sites, displaying the latest recreational health warning status.

When asked if they would still visit a recreational site even if a water quality warning was in place, 50% of respondents answered that they would not, while 30% would sometimes still visit, and 20% would always still visit (Figure 18). However, when asked if they would still use the water when a water quality warning was in place, 77% of respondents replied that they would not, 19% replied maybe, and 4% said that they would still get in the water (Figure 19). The main reason given for still visiting a site despite a water quality warning being in place was local knowledge and familiarity with the given site (Figure 20). A common reason given was also that whether people still visited a site or not depended on who was undertaking the activity. An assumption might be made that while people may still use the site personally, they would not make the same decision for others, e.g. children.

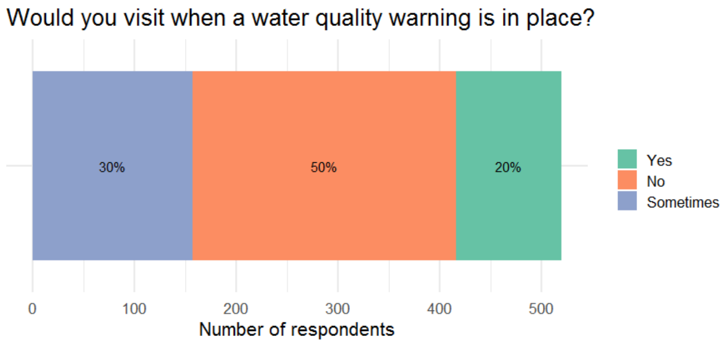


Figure 18 If questionnaire respondents would still visit a recreational site when a water quality warning is in place

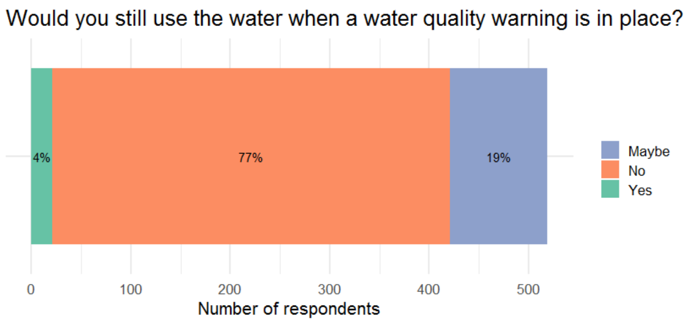


Figure 19 If respondents would still use the water when a water quality warning sign is in place

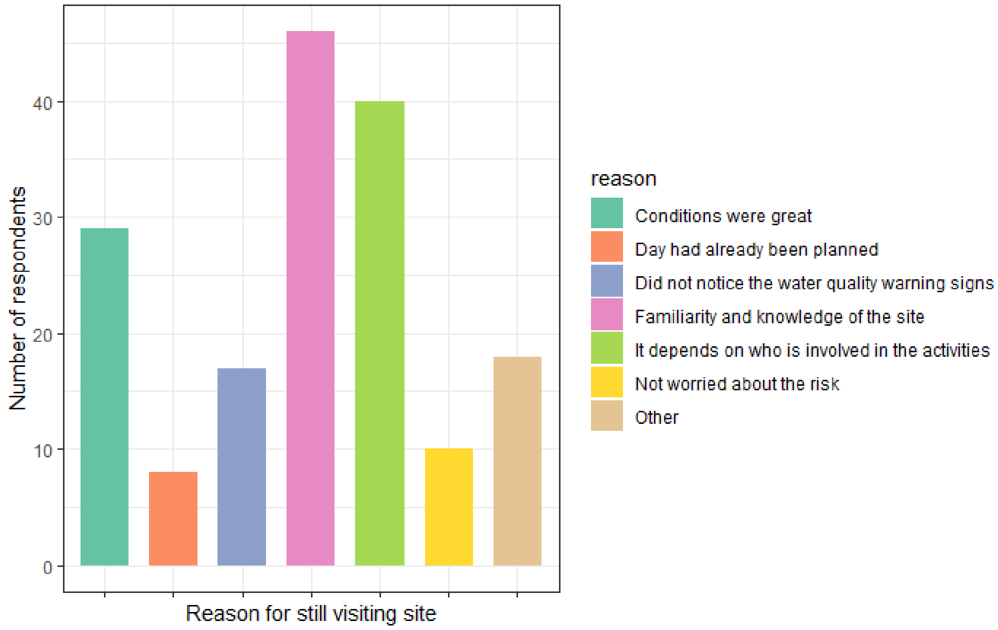


Figure 20 Reasons for still visiting a site despite a water quality warning being in place

# 5 Observational count results

As well as providing validation of the results of the online questionnaire, the observational count survey provides some more in-depth information on recreational use habits at individual sites. The following section provides an overview of the main results of the observational count survey.

## 5.1 Site Popularity

As mentioned in Section 4.2, the relative popularity of sites recorded in the observational count reflected the results of the online survey well. Comparisons of the number of people counted at the various beach, river and lake sites throughout the observational count survey are shown using boxplots in Figure 21 through to Figure 23. Days where large events or holidays biased the number of people at sites are not included in this analysis, but are discussed in Section 5.4.

The Coastal Walkway was consistently popular and had the highest median number of users of all sites in the count survey. Of the coastal sites, Fitzroy, Ngāmotu and Ōakura beaches, along with Tongaporutu, also had high usage, but with more variation in numbers depending on the weather conditions and time of day. Outside of public holidays and special events, the highest number of people at a site at one time was observed at Ōakura Beach, with 473 users.

Of the river recreation sites, Merrilands Domain had the highest median number of users, followed by Timaru Stream and Corbett Park. The highest number of users at a river site at one time was recorded at Corbett Park, with 219 people using the site. As the results of the online questionnaire suggested, the number of people recreating at lakes was generally fewer than at either river or beach sites. Of the lakes surveyed, Lake Rotomanu was the most popular, followed by Lakes Ratapiko, Rotokare and Rotorangi (at the Patea Dam), and Pukekura Park. It is noted that the number of people counted at lake sites is likely to be an under-representation, with boat users on the larger lakes, and exercisers at sites such as Pukekura Park, Lake Mangamahoe and Barret’s Domain being under-counted.

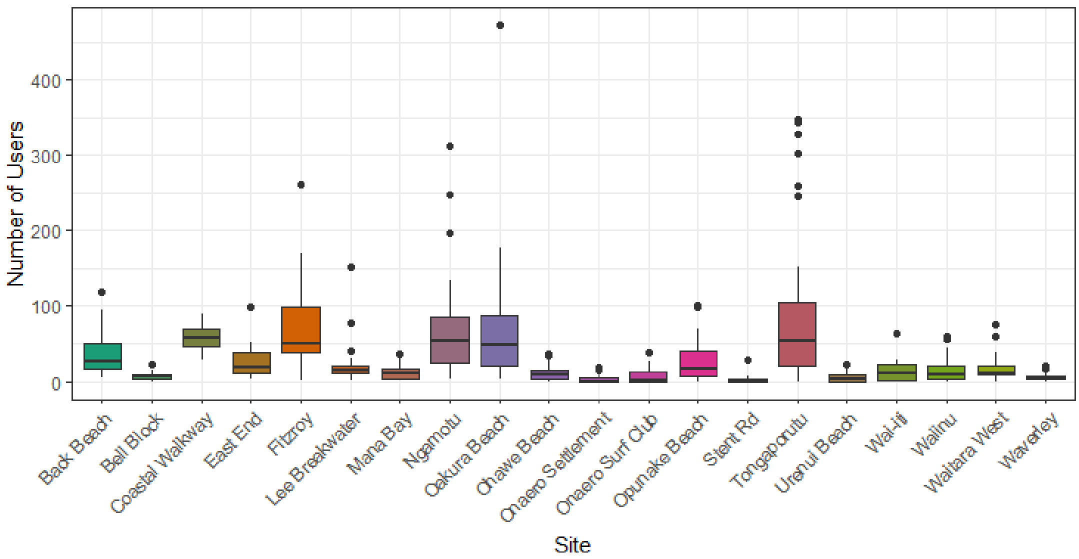


Figure 21 Boxplots of total number of users counted at beach sites throughout the observational count survey

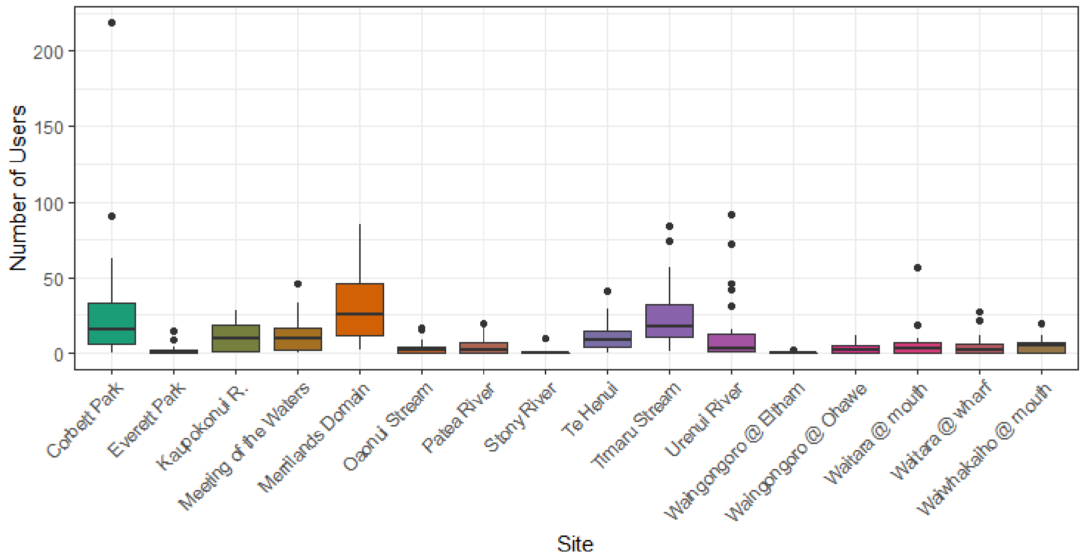


Figure 22 Boxplots of total number of users counted at river sites throughout the observational count survey

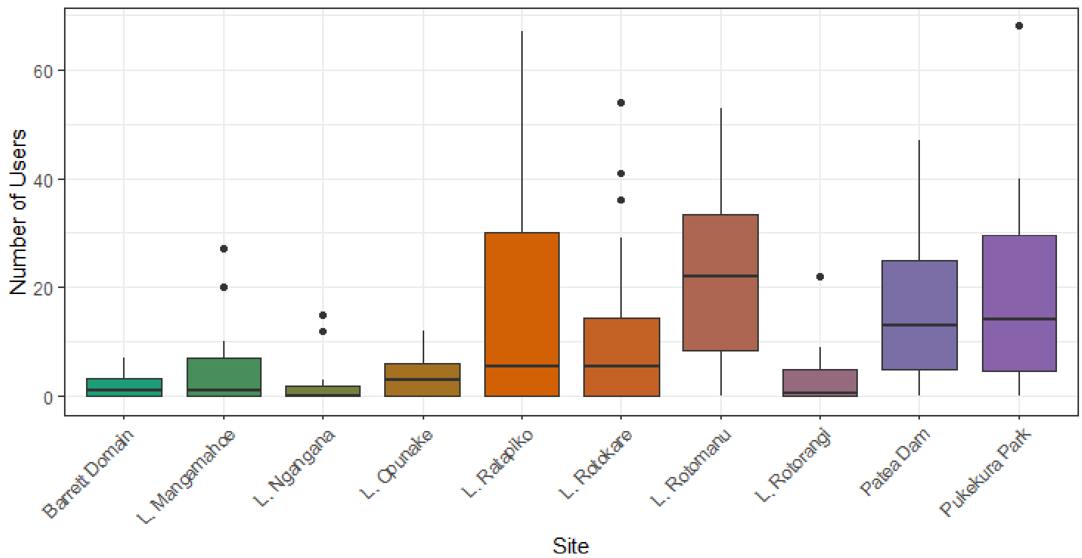


Figure 23 Boxplots of total number of users counted at lake sites throughout the observational count survey

## 5.2 Activities at Sites

During the observational counts, notes were taken on what activities people were undertaking at each site. With eight rounds of counts performed at each site (excepting Tongaporutu), some insights can be gained into what sites people tend to prefer for different activities. The mean number of people counted swimming and walking, which were the two most popular activities listed by questionnaire respondents (Section 4.3), are shown in Figure 24 and Figure 25, respectively. As suggested by questionnaire responses, beaches proved the most popular spots for swimming, with the highest mean number of swimmers observed at

Fitzroy, Ngāmotu and Ōakura beaches. Some river sites also proved very popular swimming spots, with Corbett Park and Merrilands Domain, respectively, having the 4th and 5th highest mean number of swimmers. The Coastal Walkway (at the Wind Wand), and Pukekura Park were the two most popular walking sites across the observational count locations, with other spots along the Coastal Walkway, such as Te Henui River mouth and Lee Breakwater, also proving popular (Figure 25). Sites along the Coastal Walkway also proved popular with cyclists, with the highest mean number of cyclists observed at the Wind-Wand, Te Henui River mouth, and the mouth of the Waiwhakaiho River (observational counts were not undertaken at the mountain bike park at Lake Mangamahoe).

The three most popular surfing spots in the observational count were found to be Back Beach, Fitzroy and Ōakura Beaches, respectively, while the coastal sites of Lee Breakwater, Waitara West, Wai-iti and Tongaporutu were found to be most popular for fishing. It must be noted, however, that angling numbers in rivers are under-represented in the count results due to the nature of the count locations. Tongaporutu Beach was a top site for camping, along with Waiinu and the lake sites of Rotomanu, Rotokare and Lake Ōpunake, all of which have designated freedom camping sites. When it came to picnicking, the New Plymouth sites of Ngāmotu Beach and Merrilands Domain proved most popular, followed by Pukekura Park and Lake Ratapiko.

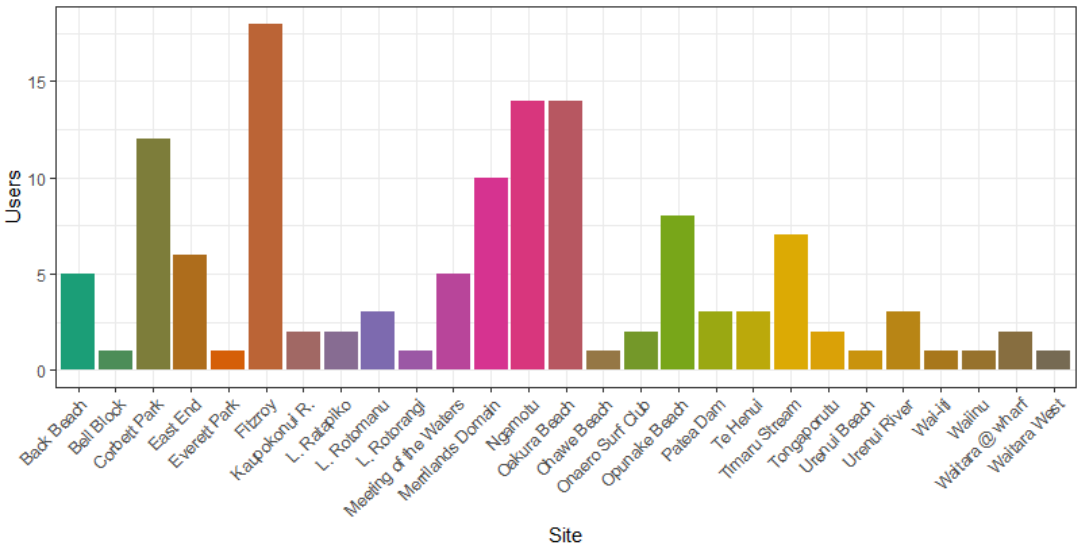


Figure 24 Mean number of swimmers recorded at sites during the observational count survey

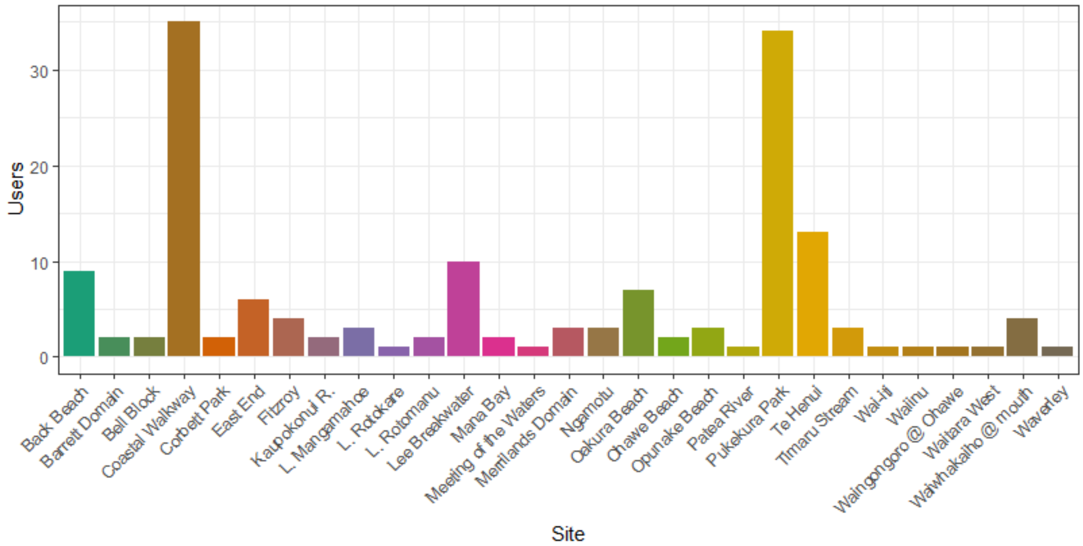


Figure 25 Mean number of walkers recorded at sites during the observational count survey

## 5.3 Temporal Patterns

The method used for the observational count allows for some insights to be made into what time of day people prefer to use various sites, and what usage is like during the weekdays compared to weekends. A summary of this information, grouped by site type, is presented in Figure 26, while individual site summaries are presented in Appendices IV and V.

While there was some variation at an individual site scale, in general there was no significant difference between the numbers of people recreating at sites across the three different recorded periods during the day. There was, however, a greater number of people recorded using sites during the weekend compared to weekdays. This pattern is notable across all three site types, and is irrespective of time of day. The result is not surprising given the main reasons questionnaire respondents gave for not visiting sites as often as they'd like were work and family commitments. The difference in weekday and weekend use patterns is most apparent at lake sites. As well as work commitments, the difference in use numbers at lakes is likely due to the generally greater distance required for travel to lake recreation sites from the main population centres, as well as the time required for the particular activities most popular at lake sites, including boating and fishing.

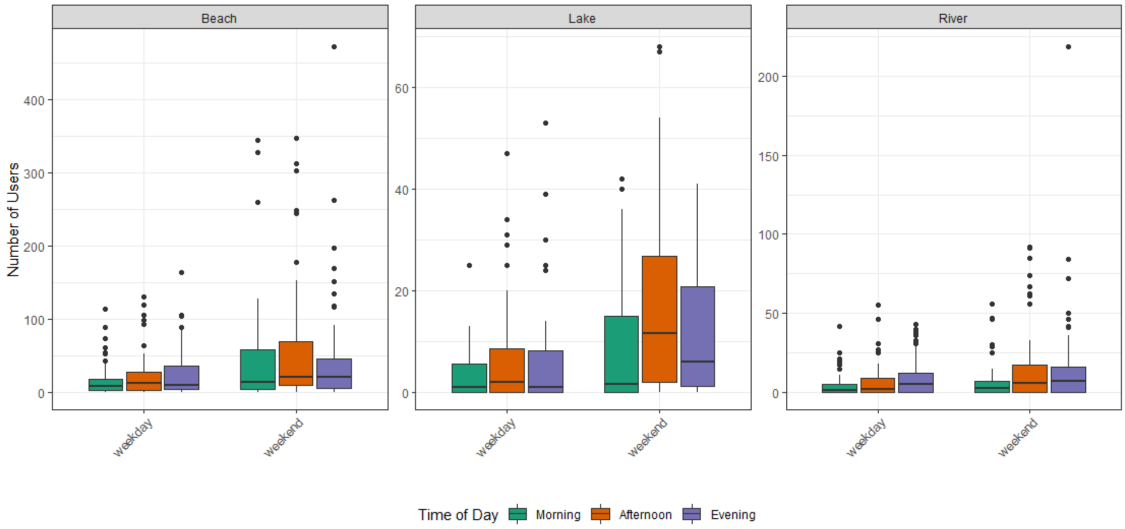


Figure 26 Distribution of the number of total users at different times, grouped by site type (note that the three plots have different scales)

## 5.4 Events

A number of the region's favourite recreational locations are used as venues for organised community and public events throughout the year. These events are not included within everyday use of the region's beaches and waterways, and as such have not been included in the reported results of the observational count survey. They do, however, draw large influxes of people to the region's water recreation sites, and are both drivers of, and results of the investment that goes into access and facilities at the region's recreational sites.

Examples of large events that took place over the 2019-2020 summer include, but are not limited to:

- Beach festivals and markets at Ōakura , Fitzroy, Ōpunake, and Ngāmotu Beaches, amongst others, which attract crowds in the thousands.
- Surf life-saving, surfing, ultimate-frisbee and sailing competitions at the likes of Back, Ōakura and Ngāmotu Beaches.
- WOMAD, held over 13$^{th}$-15$^{th}$ March at Pukekura Park, which attracted an average of 17000 people per day.
- The TSB Festival of Lights (Pukekura Park), and Te Kupenga International Stone Sculpture Symposium (Coastal Walkway), which occurred over longer time frames (December/January), and are thus incorporated into the observational count results.

In the case of WOMAD, observational counts undertaken during the 13$^{th}$/14$^{th}$ of March suggested the Coastal Walkway was twice as popular as usual, while more than five times the usual number of users were observed at the Tea House on the Lake spot in Pukekura Park.

## 5.5 Activities not captured by Observational Count

There are a number of water-based activities that are not fully captured in the observational count due to either their seasonal nature, or more mobile/remote nature. These include trout fishing, kayaking and whitebaiting, as well as land-based activities in reserves around waterways, such as walking and biking.

In 2019, the whitebaiting season ran from August 15$^{th}$ through November 30$^{th}$, and was thus missed by the observational count survey. A formal survey of whitebaiter numbers has never been undertaken in Taranaki, however whitebaiting is highly popular in the region, with 27 regional waterbodies identified by Fish and Game New Zealand as being of regional importance for trout fishing and/or whitebaiting.

Similarly, while trout fishing is popular in Taranaki, it is hard to get an accurate gauge on numbers given the remote nature of the activity, and the large number of fishable rivers running out from the national park. Fish and Game New Zealand records show, however, that around 1% of Taranaki's population hold trout fishing licenses with just over 1000 licenses sold in the year to July 2020 (Fish and Game Taranaki, 2020).

Lastly, while surfing was captured as a popular activity at the sites visited within the observational survey, there are numerous other breaks along the Surf Highway that were not covered. With approximately 50 different breaks spanning along the coastline, the regional popularity of surfing is likely underestimated in the results of the observational count survey.

# 6 Comparison with previous access surveys

Previous questionnaires on recreational use and access in Taranaki were carried out in 1980-1982 (published 1984), and 2007. In 1984, 213 responses to the postal questionnaire were received, while in 2007 418 completed surveys were processed. In 2019, 524 full and valid questionnaires were processed. Where appropriate, questions in the 2019 public questionnaire were posed in a way to allow comparison with the previous surveys, giving a picture of how recreational habits have changed over the last three decades. Given the difference in the number of responses processed in each survey, in the following results are compared as percentages where possible.

## 6.1 Site Popularity

Ranking and locations of the top 20 most frequently visited sites in the region, as given by respondents of the 1984, 2007 and 2019 public questionnaires are shown in Figure 27. Many locations have remained among the most frequently visited across all three surveys, with Fitzroy Beach the most frequently visited site regionally in both 2007 and 2019. Ngāmotu Beach, which ranked 2$^{nd}$ most frequently visited in both 1984 and 2007, also remains popular. While this site only ranked as 6$^{th}$ most frequently visited in 2019, it had the 2$^{nd}$ highest average number of users in the observational count. Other sites that have featured in the top 10 most frequently visited in all three surveys are Ōakura, Ohawe, Ōpunake and Back beaches. In addition to these beaches, the Coastal Walkway has proved popular since its opening, ranking as the 4$^{th}$ most frequently visited site in both 2007 and 2019.

While Lake Mangamahoe and Lake Rotomanu have remained among the three most frequently-visited lake sites, Lake Rotokare has increased in popularity and ranked as the second most frequently visited lake in 2019. This increase in popularity goes hand in hand with the formation and success of the Rotokare Scenic Reserve Trust, which was formed in 2004 and has restored the lake and its surrounds into a 230ha conservation sanctuary. While the reserve is enclosed by a predator and pest-free fence, which was completed in 2008, the area and lake remains open to public for recreation both on and off the water.

There has been little change in the most popular river recreation sites over the years, with sites such as Corbett Park, spots along the Waiwhakaiho, and Te Henui Stream, remaining popular. It should be noted that while Corbett Park didn’t appear in the top 20 ‘most frequented’ sites in the 2007 questionnaire, it was the third most popular site in the observational count that year.

There are a number of sites that have seen a decline in popularity over the three iterations of the recreational use survey. One such site is the Kaupokonui River at the Beach domain, which did not feature in the top 20 ‘most frequently visited’ sites in the 2019 survey, and has had a steady decline in the number of people counted using the site. A possible reason for this is water quality issues that have affected the river, with health warnings regarding both swimming and food gathering having frequently been in place at the site in recent times. Other sites which have seen a decline in popularity in the 2019 survey include the Waingongoro River at Eltham, and the Stony River. In the case of the former, the site is located at the Presbyterian Camp in Eltham, with popularity of the site dependent on what access is available to the site on a particular day.

The total number of sites visited by respondents to the public questionnaire in 2019 was 142, compared to 65 in 1984, and 85 in 2007. It is hard to know if, or to what extent, there has been a genuine increase in sites visited, however, as the online survey method used in 2019 allowed for the specification of a far greater number of sites than the postal surveys of either 1984 or 2007. For the same reason, the number of respondents who said that they had visited any one site was generally much higher in 2019 than either of the previous surveys.

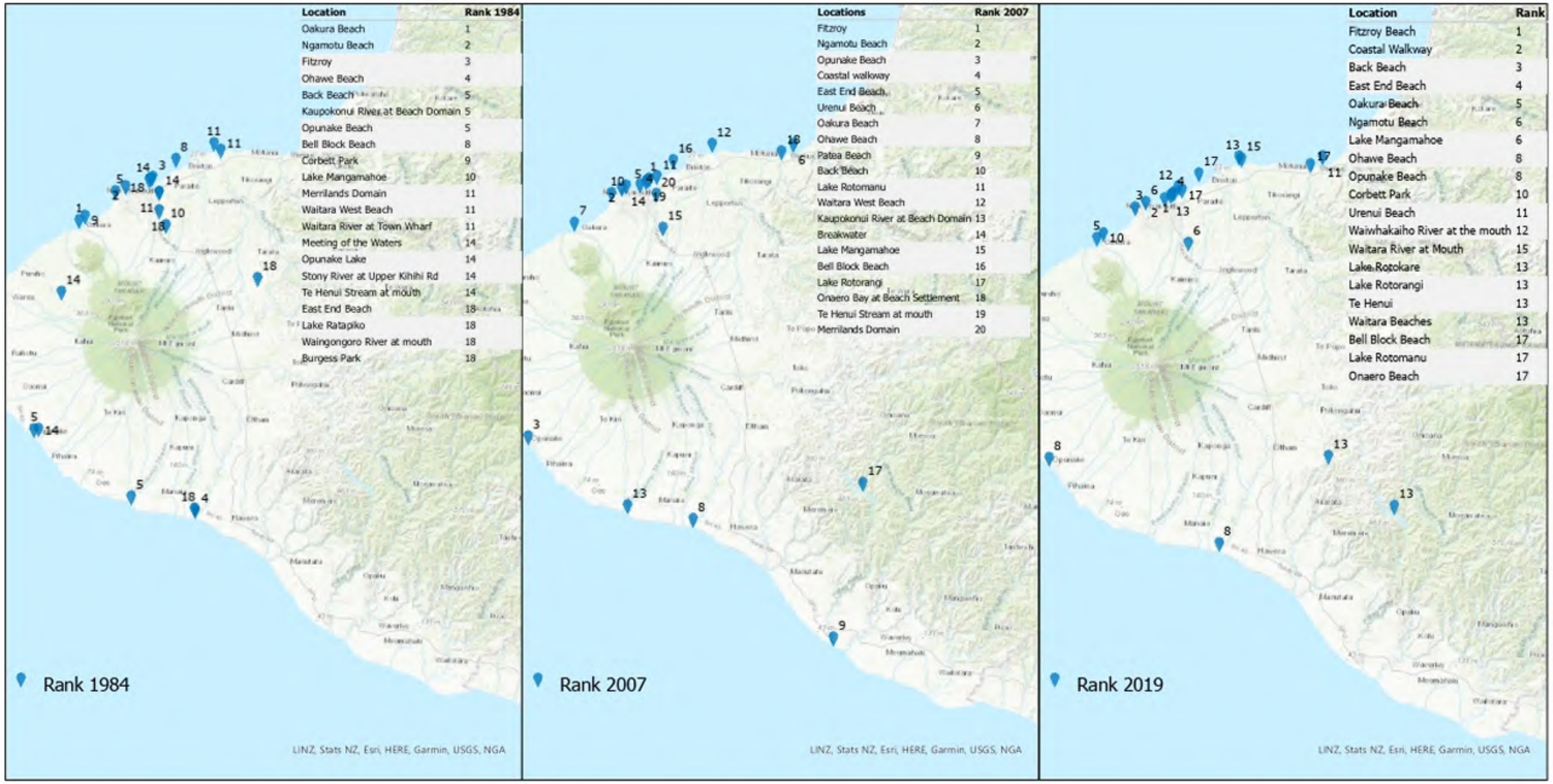


Figure 27 Top twenty most frequently visited recreation sites, from responses to public recreation questionnaires in 1984, 2007 and 2019

32

## 6.2 Activities at Sites

In both 2007 and 2019, walking was the most popular activity undertaken at recreational sites, irrespective of whether it was a beach, river or lake site. This is a change from the 1984 survey, where walking was a distant 6th most popular activity. Swimming, which was the most popular activity undertaken in 1984, was the second most popular activity at both beach and river sites in 2007 and 2019, but only the 4th (2007) and 7th (2019) most popular activity at lake sites. Lake sites continue to prove more popular for scenic appreciation than both beaches and rivers, however, with scenic appreciation ranking 3rd most popular activity at lakes in 2007 and 2nd in 2019.

At beach sites, surfing appears to be becoming more popular. Ranked as the 9th most popular activity in 1984 and 2007, surfing was the third most popular activity undertaken at beaches by questionnaire respondents in 2019, with 9% of respondents rating it their main beach activity.

At river sites, there has been an increase in the popularity of kayaking and canoeing amongst survey respondents, with 18% listing it as their main river activity in 2019, ranking it 4th most popular activity. In 2007, kayaking rated as only the 16th most popular river activity, and it didn't feature at all in the 1984 survey.

A full comparison of the popularity of activities at the different site-types between 2007 and 2019 is given in Appendix VI. 1984 results are not included in this appendix due to the lack of consistency in result format.

## 6.3 Reasons for visiting sites

Across all three iterations of the recreational use survey, the proximity of a recreational site to home has consistently been the top reason why people visit a particular site (Figure 28). This result is mirrored in the spatial distribution of the twenty top ranked "most frequently visited" sites from each survey, in Figure 27. Here, the top ranked sites are predominantly clustered around the major population centres of the region, including sites near Ōpunake, Hawera, Ōakura and Urenui, as well as many around the New Plymouth urban area.

The suitability of a site for activities has remained the second most important reason for visiting a site, along with the natural character of the site. The suitability of a site for children is less important as a deciding factor for visiting a site now compared to in 1984. In addition, compared to both the 1984 and 2007 surveys, and having an un-crowded site, or a site with low-cost, were less frequently the main reason for visiting a site.

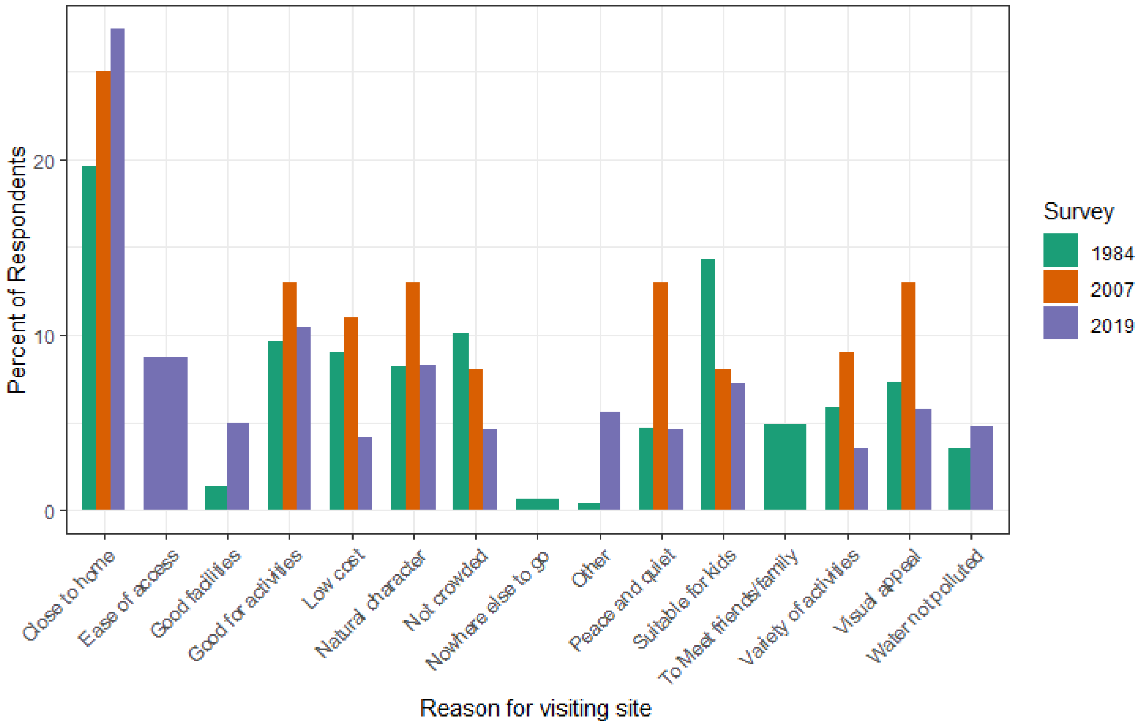


Figure 28 Reasons given for visiting a certain recreational site, 1984-2019.

The top reasons for people not visiting recreational sites as often as they like remain to be time-limitations (Figure 29) such as work and family commitments, or the travel time to a site being too long. These results match with the top reason people visit a site being its proximity to home. Compared to previous surveys, the cost of a site, or a lack of transport to reach the site, were less frequently the top reason for not visiting sites.

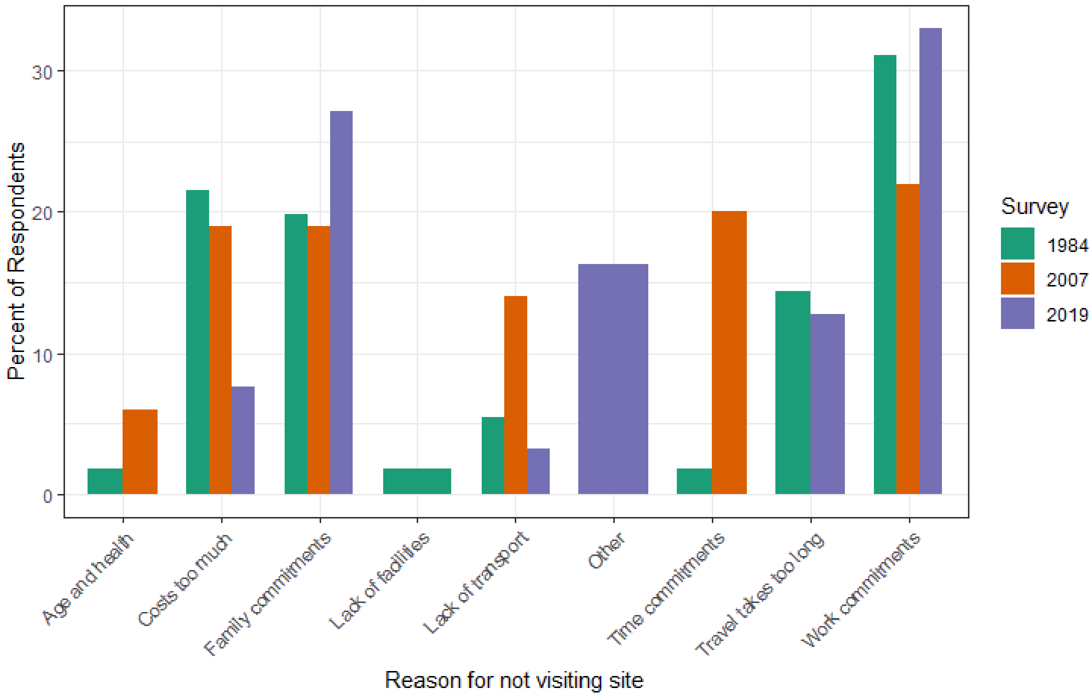


Figure 29 Reasons given for not visiting a site, 1984-2019. Note that' time commitments' and 'age and health' were removed as a specific option in the 2019 survey

## 6.4 Public Access

The perception of public access levels to recreational sites has remained relatively constant between the 2007 and 2019 surveys, with 10% and 12% of respondents, respectively, saying that they had not been able to access sites. The main reasons for not accessing a site remain to be closed gates/access. Or the access being too difficult. Only around 1% of all respondents to both the 2007 and 2019 surveys were denied access by land owners. Of note is that water quality was frequently raised as an access issue in the 2019 survey.

## 6.5 Water Quality

Overall, there has been a notable decrease in the perceived standard of water quality at recreational sites between 2007 and 2019. While the perceived level of water quality at beach sites remains relatively high, with over 80% of respondents deeming it 'good' or 'excellent', at lake and river sites the picture is not so good. 17% of questionnaire respondents view water quality in Taranaki rivers and lakes as being 'poor', compared to 7 and 4%, respectively, in 2007.

This change in the public perception of water quality in Taranaki reflects the increased publicity and focus on water quality at a national level over the last decade. The results also reflect the actual state of water quality in the region, and show that the Council has significant work to do to improve water quality in the region's lakes and rivers.

Table 2 Perceived water quality at Taranaki beaches, lakes and rivers, 2007 vs 2019 (percentage of respondents)

| | Beaches | | Lakes | | Rivers | |
|---|---|---|---|---|---|---|
| | 2007 | 2019 | 2007 | 2019 | 2007 | 2019 |
| Excellent | 30 | 32 | 12 | 11 | 17 | 14 |
| Good | 59 | 52 | 54 | 38 | 57 | 46 |
| Fair | 10 | 12 | 26 | 34 | 21 | 24 |
| Poor | 1 | 3 | 7 | 17 | 4 | 17 |

# 7 Discussion

Results from the online questionnaire and observational count give a generally consistent picture of the most popular recreational spots in the region. According to the online questionnaire, the Coastal Walkway, Fitzroy Beach and Pukekura Park are the three regional sites that are visited by the widest range of people. Fitzroy Beach and the Coastal Walkway were also recorded in the online questionnaire as being the most frequented sites, and had the highest median number of users recorded at them across the observational count survey. Other beaches central to New Plymouth, including Back, Ngāmotu and East End beaches also remain highly popular.

Regionally, access to recreation sites is deemed to be relatively good, and is rarely the primary reason for people not visiting a site. Rather, the main factors restricting questionnaire respondents from visiting sites as often as they'd like are time restraints such as work and family commitments, along with the time taken to travel to sites. In line with this, respondents stated that proximity to home was the main factor influencing what sites they choose to visit. This importance of having easy to access recreational sites close to home is further reinforced by the spatial distribution of the sites most often frequented by residents of the region's three districts (Figure 6). For New Plymouth and South Taranaki residents in particular, these sites are clustered around the main population centres of the respective districts.

Together, these findings emphasise the importance of local authorities focusing on the maintenance and enhancement of facilities and the ease-of-access at recreation areas close to population centres under Policies 6.7 and 8.3 of the RPS.

An example of one such successful initiative is the Coastal Walkway, which now spans 13km of the New Plymouth coastline, from Ngāmotu Beach in the south to Bell Block in the north. First opened in 2003, sites along the Coastal Walkway made up five of the top 10 most popular locations in the 2007 recreational questionnaire, and seven of the top 10 in the 2019 questionnaire. The walkway has been touted as one of the region's top assets, and allows easy access from both the centre and suburbs of New Plymouth to the multiple beaches, streams, estuaries and parks located along the promenade. Access from New Plymouth suburbs to the coast has also been enhanced in the last decade through the development of walkways along many of the city's urban streams. This has included the upgrade of the Mangati Walkway (2011), Waiwhakaiho Walkway (2012), Huatoki Walkway (2012-2014) and Te Henui Walkway (2013).

Going forward, further development of the Coastal Walkway is likely, with NZTA and NPDC having committed $4 million each towards a proposed 10km extension of the walkway north to Waitara. Initiatives are also underway in other parts of the region, with, for example, the Ōpunake Lions Club developing the Ōpunake Loop Trail, an 8km long loop connecting the town's beaches, lake and historical sites.

In general, the most popular recreational sites in the region, and the reasons why people visit particular sites, have remained relatively unchanged since the 2007 recreational use survey. One thing that has changed, however, is people's overall perception of water quality at recreational sites around the region, which is seen to be in decline. This is especially the case for the region's lakes and rivers, where 51% and 41% of questionnaire respondents only deemed water quality to be fair or poor. These perceptions are backed up by the results of the 2019-2020 bathing water quality monitoring programme, where 21.3% of lake site samples and 40.9% of river site samples had *E.Coli* levels at Alert or Action level. Managing the pressure on water resources from agricultural and industrial uses in order to maintain and enhance the recreational attributes of a waterbody can be a tricky equation. However, the findings of this survey emphasise that the Council must increase its efforts in this area in order to meet its requirements and goals under the RMA and Policy 10.3 of the RPS.

While improving recreational water quality around the region must be seen as a priority, there is also significant room for improvement in how the Council communicates the results of recreational water quality testing to the public. It is apparent from the results of the recreational use questionnaire that only a third of respondents check on water quality conditions prior to visiting a site, with the use of both local authorities' websites or LAWA to check conditions being very low. There is a significant gap between the 56% of people checking water quality conditions and the 77% of people surveyed who said they would not enter the water if a water quality warning was in place. Simple improvements such as more prominent signage at water recreation sites, more prominent placement of recreational water quality status' on the Council's website, and a more extensive use of different media channels for communicating results, would help raise public awareness in this regard.

The results of the recreational use survey show that there are a select number of sites in the region that are highly popular, yet either do not have recreational bathing water quality monitoring undertaken at them, or are only monitored every third summer. In particular, the Waiwhakaiho River at Meeting of the Waters, Lake Rotorangi, and Tongaporutu are three heavily frequented sites with no current water quality monitoring, while Waiinu and Wai-iti Beaches are listed among the 20 most popular sites in the observational count survey, yet are only monitored on a three year rotation. It is recommended that recreational water quality monitoring is undertaken at these sites in the next monitoring summer, with a review undertaken as to whether they should become permanent sites under the SOE programme.

Finally, while the general view of access to recreational areas in the region given by questionnaire respondents was positive, the current format of the survey does not provide sufficient information on specific site access. In order to inform on where and how access to the region's water recreational resources needs to be maintained or enhanced, as under Policies 6.7 and 8.3 of the RPS, further questions could be added to the use and access questionnaire. Such questions could include questions regarding both facilities and access at sites that people visit frequently, as well as what sites they would visit more frequently if not for the current state of facilities and access. Further improvements to the questionnaire and survey format are also recommended, both in order to capture a more representative cross-section of the region's population, and to enable the smooth and robust analysis of results. As examples, the additional distribution of questionnaires through schools, as well as finding participation incentives that appeal to a wider range of demographics, could aide in gaining a more balanced respondent demographic profile, while careful consideration of how questions are formatted will help in data analysis.

# 8 Recommendations

Following the results of the 2019-2020 recreational access and use survey, the following recommendations are made:

1. THAT a review is undertaken of how the results of bathing water quality monitoring results are communicated to the public, in order to increase the distribution and understanding of the results.
2. THAT five additional sites are monitored for bathing water quality over the next summer season, given their high usage as recorded in the observational count survey. These include Waiwhakaiho River at Meeting of the Waters, Lake Rotorangi, Tongaporutu, Waiinu and Wai-iti beaches.
3. THAT the Council increase its efforts to maintain and enhance the recreational water quality of the region's coast, rivers and lakes.
4. THAT the water recreational access and use survey be repeated in approximately three years.
5. THAT Matauranga Maori concepts and values are incorporated into the next recreational access and use survey.
6. THAT a review of the distribution methods of the questionnaire is undertaken in order to gain a more balanced representation of the region's demographics in the responses.
7. THAT a review of the questionnaire format is undertaken to enable smooth and robust analysis of the results.
8. THAT the observational count methods are reviewed with a view to increasing consistency between inter-site counts.

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# Appendix I

# Recreational use online questionnaire

# Recreational Use of Coast, Rivers and Lakes in Taranaki 2019 - Production

Start of Block: Introduction

Q00 **Where do you go for a swim? Let us know.**

Are you a swimmer, a sailor, a surfer or an angler who uses any of Taranaki's beautiful beaches, lakes or rivers? Or do you love to cycle, walk or picnic near them?
We want to hear all about it! By completing this quick survey (seven to 10 minutes), you can help us gauge where and how our beaches, rivers and lakes get the most recreational use, and how users are influenced by the amenities at their favourite haunts and the ease (or otherwise) of access.

This is our third major recreational use survey. Besides giving us an up-to-date picture of the recreational role of our beaches, lakes and rivers, the survey data will give a useful indication of the pressures on water resources at popular recreational spots.
So it's important! The survey runs until 15 May 2019. If you have any questions about the survey, contact the Taranaki Regional Council on 0800 736 222.

Be in to win!
You'll go into the draw for a free two-night stay for two at The Lodge, Pukeiti, with complimentary breakfasts. Be sure to leave your email address if you want to go in the draw for the special break at Pukeiti.

End of Block: Introduction

Start of Block: Background data

Q1 Please state your gender

- Male (1)
- Female (2)

Q2 What is your age?

- Under 20 (1)
- 20-24 (2)
- 25-44 (3)
- 45-65 (4)
- 65 and over (5)

Q3 What is your email address? (*only provide if you'd like to be included in the prize draw)

________________________________________________________________

Q4 Which ethnic group best describes you?

- New Zealand European (1)
- New Zealand Maori (2)
- Other European (3)
- Pacific Islander (4)
- Asian (5)
- Other - Please State (6) ________________________________________

Q5 Are you a Taranaki resident?

- Yes (1)
- No (2)

*Display This Question:*

*If Are you a Taranaki resident? = Yes*

Q6 Please state the area where you are living

- New Plymouth (1)
- Stratford (2)
- Eltham (3)
- Hawera (4)
- Inglewood (5)
- Waitara (6)
- Oakura (7)
- Okato (8)
- Opunake (9)
- Manaia (10)
- Patea (11)
- Waverley (12)
- Other - Please state (13) ________________________________________________

*Display This Question:*

*If Are you a Taranaki resident? = No*

Q7 Please state the region you came from

- Auckland (1)
- Bay of Plenty (2)
- Canterbury (3)
- Gisborne (4)
- Hawke's Bay (5)
- Manawatu-Wanganui (6)
- Marlborough (7)
- Nelson (8)
- Northland (9)
- Otago (10)
- Southland (11)
- Tasman (12)
- Waikato (13)
- Wellington (14)
- West Coast (15)
- Overseas - Please state (16) ________________________________________________

End of Block: Background data

Start of Block: Recreational use map and survey section

Q8 Have you visited any beaches, rivers or lakes in Taranaki in the past 12 months for reason other than to do with your work?

- ◯ Yes (1)
- ◯ No (2)

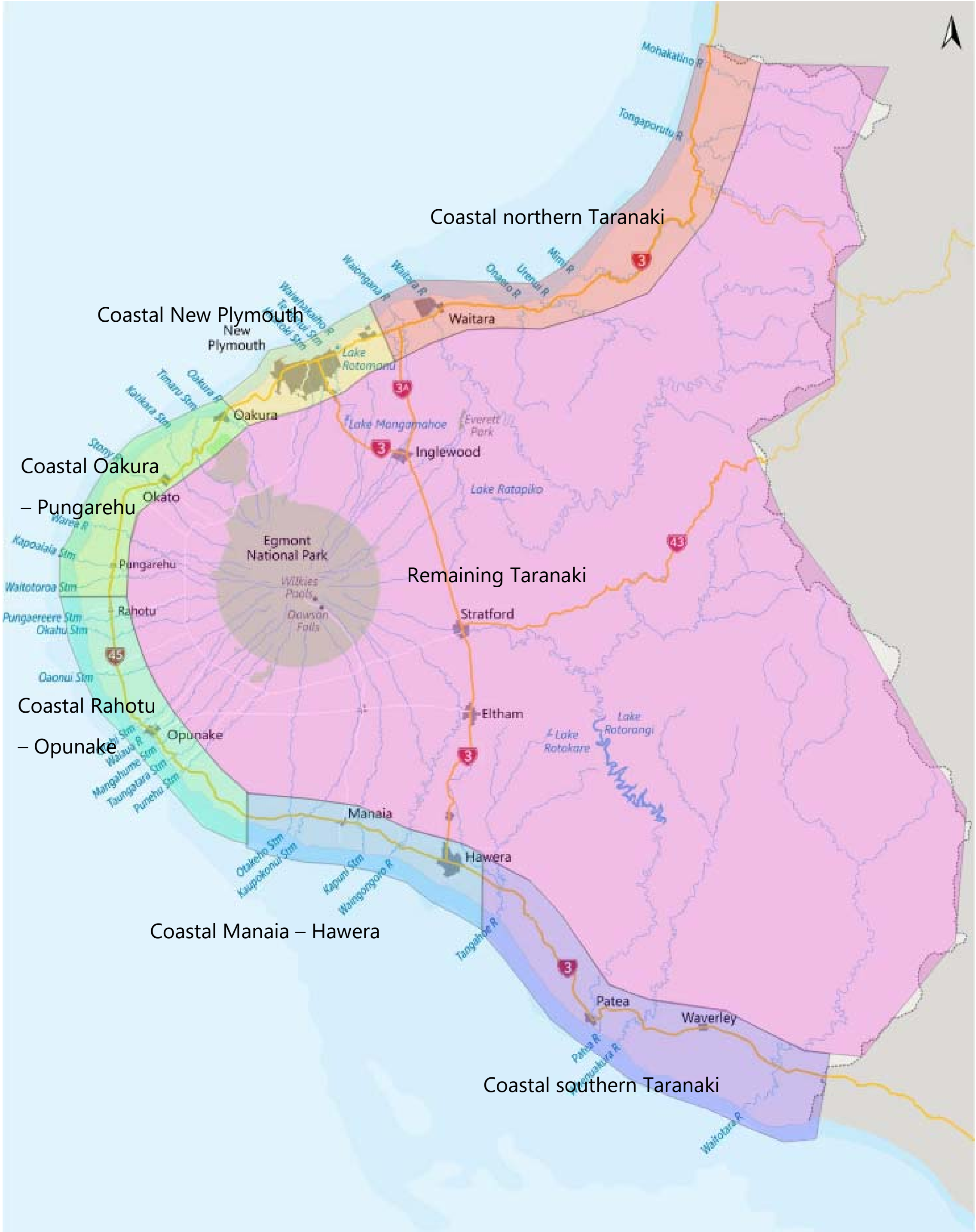
*Skip To: Q24 If Have you visited any beaches, rivers or lakes in Taranaki in the past 12 months for reason other... = No*

*Display This Question:*

*If Have you visited any beaches, rivers or lakes in Taranaki in the past 12 months for reason other... = Yes*

Q9 Please click on the map for areas you have visited in the past 12 months.

| | Off (1) | On (2) |
|---|---|---|
| coastal northern Taranaki (265) | | |
| coastal New Plymouth (266) | | |
| coastal Oakura - Pungarehu (267) | | |
| coastal Rahotu - Opunake (268) | | |
| coastal Manaia - Hawera (269) | | |
| coastal southern Taranaki (270) | | |
| remaining Taranaki (271) | | |



Coastal northern Taranaki
Coastal New Plymouth
Coastal Oakura – Pungarehu
Remaining Taranaki
Coastal Rahotu – Opunake
Coastal Manaia – Hawera
Coastal southern Taranaki
New Plymouth
Waitara
Oakura
Inglewood
Okato
Pungarehu
Rahotu
Opunake
Egmont National Park
Stratford
Eltham
Manaia
Hawera
Patea
Waverley

*Display This Question:*

*If Please click on the map for areas you have visited in the past 12 months.  = coastal northern Taranaki [ On ]*

Q10 You selected coastal northern Taranaki area. Please select the locations that you have visited (Sites not listed below can be added in the following question)

▢ Epiha Road Beach  (21)

▢ Lake Cowley  (19)

▢ Lake Nganana  (18)

▢ Manutahi  (20)

▢ Mimi River  (3)

▢ Mohakatino River  (1)

▢ Onaero Bay at Beach Settlement  (9)

▢ Onaero Bay at Surf Club  (22)

▢ Onaero River  (6)

▢ Pukearuhe (White Cliffs)  (15)

▢ Tongaporutu River  (2)

▢ Urenui Beach  (10)

▢ Urenui River  (4)

▢ Wai-iti Beach  (12)

▢ Waiongana River  (17)

▢ Waitoetoe campsite  (13)

▢ Waitara East Beach  (8)

▢ Waitara West Beach  (11)

▢ Waitara River at Town Wharf  (7)

*Display This Question:*

*If Please click on the map for areas you have visited in the past 12 months. = coastal New Plymouth [ On ]*

Q11 You selected coastal New Plymouth area. Please select the locations that you have visited (Sites not listed below can be added in the following question)

- ▢ Back Beach at Herekawe Stream (19)
- ▢ Back Beach at Paritutu Rock (14)
- ▢ Barrett Domain (17)
- ▢ Bell Block Beach (1)
- ▢ Lee Breakwater (13)
- ▢ Centennial Drive (20)
- ▢ Coastal Walkway (2)
- ▢ East End Beach (3)
- ▢ Fitzroy Beach (4)
- ▢ Huatoki River (12)
- ▢ Kawaroa (18)
- ▢ Lake Rotomanu (10)
- ▢ Ngamotu Beach (11)
- ▢ Pukekura Park (15)
- ▢ Te Henui River mouth (9)
- ▢ Waiwhakaiho River at Audrey Gale Park (Merrilands Domain) (6)
- ▢ Waiwhakaiho River at Burgess Park (8)
- ▢ Waiwhakaiho River at meeting of the waters (7)
- ▢ Waiwhakaiho River at Rimu Street (Telecom) (22)

- [ ] Waiwhakaiho River at Te Rewa Rewa Bridge (5)
- [ ] Waiwhakaiho River at the mouth (16)

Page Break

*Display This Question:*

*If Please click on the map for areas you have visited in the past 12 months. = coastal Oakura - Pungarehu [ On ]*

Q12 You selected coastal Oakura - Pungarehu area. Please select the locations that you have visited (Sites not listed below can be added in the following question)

- ▢ Ahu Ahu Road (7)
- ▢ Cape Egmont (17)
- ▢ Corbett Park/Oakura River mouth (10)
- ▢ Greenwood Road (12)
- ▢ Komene Road (14)
- ▢ Kumara Patch (13)
- ▢ Oakura Beach at Surf Club (1)
- ▢ Oakura Beach at Camp Ground (11)
- ▢ Paora Road (6)
- ▢ Puniho Road (8)
- ▢ Stent Road (16)
- ▢ Stony River (4)
- ▢ Tapuae Beach (9)
- ▢ Timaru Stream (3)
- ▢ Weld Road (5)

Page Break

*Display This Question:*

*If Please click on the map for areas you have visited in the past 12 months. = coastal Rahotu - Opunake [ On ]*

Q13 You selected coastal Rahotu - Opunake area. Please select the locations that you have visited (Sites not listed below can be added in the following question)

- ▢ Arawhata Road Beach (9)
- ▢ Greenmeadows Beach (7)
- ▢ Kahui Stream (14)
- ▢ Kina Road (15)
- ▢ Lake Opunake (2)
- ▢ Mangahume Stream (10)
- ▢ Middleton Bay (4)
- ▢ Oaonui Stream (16)
- ▢ Opunake Beach (3)
- ▢ Puketapu Road (11)
- ▢ Rahotu (13)
- ▢ Waiaua River (1)

Page Break

*Display This Question:*

*If Please click on the map for areas you have visited in the past 12 months. = coastal Manaia - Hawera [ On ]*

Q14 You selected coastal Manaia - Hawera area. Please select the locations that you have visited (Sites not listed below can be added in the following question)

- ▢ Kapuni Stream (4)
- ▢ Kaupokonui River at Beach Domain (3)
- ▢ Manaia (5)
- ▢ Nowells Lake (8)
- ▢ Ohawe Beach (2)
- ▢ Otakeho Stream (6)
- ▢ Waihi Beach (7)
- ▢ Waingongoro River mouth (1)

Page Break

*Display This Question:*

*If Please click on the map for areas you have visited in the past 12 months.  = coastal southern Taranaki [ On ]*

Q15 You selected coastal southern Taranaki area. Please select the locations that you have visited (Sites not listed below can be added in the following question)

- ▢ Mana Bay  (10)
- ▢ Mokoia Road  (7)
- ▢ Patea Beach  (9)
- ▢ Patea River at boat ramp  (1)
- ▢ Tangahoe River  (8)
- ▢ Wai-inu Beach  (2)
- ▢ Waipipi Beach  (6)
- ▢ Waverley Beach  (3)
- ▢ Whenuakura River  (5)

Page Break

*Display This Question:*

*If Please click on the map for areas you have visited in the past 12 months. = remaining Taranaki [ On ]*

Q16 You selected the remaining Taranaki area. Please select the locations that you have visited (Sites not listed below can be added in the following question)

- ☐ Dawson Falls (1)
- ☐ Everett Park (5)
- ☐ Lake Mangamahoe (10)
- ☐ Lake Rotokare (6)
- ☐ Lake Ratapiko (7)
- ☐ Lake Rotorangi (12)
- ☐ Maketawa River (4)
- ☐ Manganui River (11)
- ☐ Ngatoro Stream (2)
- ☐ Normanby weir (15)
- ☐ Patea Dam (8)
- ☐ Patea River at Carrington Walkway (14)
- ☐ Patea River at King Edward Park (9)
- ☐ Waingongoro River at Eltham Presbyterian Camp (13)
- ☐ Wilkies Pools (3)

Page Break

Q17 Are there any locations that was not identified in the previous areas where you do recreational activities?

○ Yes (1)

○ No (3)

*Display This Question:*

*If Are there any locations that was not identified in the previous areas where you do recreational a... = Yes*

Q18 Please mark on the map below for locations that were not listed in the previous questions. (Note: if you accidentally marked the wrong spot on the map, click on the same spot to remove the dot)

Q19 Please name the locations that you marked on the map.

____________________________________________________________

____________________________________________________________

Q20 Please choose the one spot that you visited most frequently during the last 12 months.

____________________________________________________________

Q21 For your answer above, what made you chose that location to visit?
Rank your 3 most important reasons where 1=main reason, 2=second reason, 3=third reason.

| | Rank |
|---|---|
| Close to home | |
| Ease of access | |
| Good facilities | |
| Doesn’t cost much to get there | |
| Visual appeal | |
| Natural character | |
| Variety of things to do | |
| Suitable for children | |
| Good for recreational activities | |
| Not crowded | |
| Peace and quiet | |
| Water is clean and healthy | |
| Other – Please state | |

Q22 For the sites you have visited in the last 12 months please tick the activities you undertook while visiting the area.

| | Beach (1) | River (2) | Lake (6) |
|---|---|---|---|
| Walking (Q22_1) | ☐ | ☐ | ☐ |
| Jogging (Q22_2) | ☐ | ☐ | ☐ |
| Cycling (Q22_3) | ☐ | ☐ | ☐ |
| Swimming (Q22_4) | ☐ | ☐ | ☐ |
| Surfing (Q22_5) | ☐ | ☐ | ☐ |
| Wind surfing (Q22_6) | ☐ | ☐ | ☐ |
| Kite surfing (Q22_7) | ☐ | ☐ | ☐ |
| Paddle boarding (Q22_8) | ☐ | ☐ | ☐ |
| Kayaking/Canoeing (Q22_9) | ☐ | ☐ | ☐ |
| Snorkeling/Diving (Q22_10) | ☐ | ☐ | ☐ |
| Sailing (Q22_11) | ☐ | ☐ | ☐ |
| Water skiing (Q22_12) | ☐ | ☐ | ☐ |
| Rafting (Q22_13) | ☐ | ☐ | ☐ |
| Boating (Q22_14) | ☐ | ☐ | ☐ |

| | | | |
|---|---|---|---|
| Jet skiing (Q22_15) | ▢ | ▢ | ▢ |
| Waka Ama (Q22_16) | ▢ | ▢ | ▢ |
| Fishing (Q22_17) | ▢ | ▢ | ▢ |
| Whitebaiting (Q22_18) | ▢ | ▢ | ▢ |
| Shellfish gathering (Q22_19) | ▢ | ▢ | ▢ |
| Picnic/BBQ (Q22_20) | ▢ | ▢ | ▢ |
| Camping (Q22_21) | ▢ | ▢ | ▢ |
| Horse riding (Q22_22) | ▢ | ▢ | ▢ |
| Hunting (Q22_23) | ▢ | ▢ | ▢ |
| Relaxing (Q22_24) | ▢ | ▢ | ▢ |
| Scenic appreciation (Q22_25) | ▢ | ▢ | ▢ |
| Watching other people's recreation (Q22_26) | ▢ | ▢ | ▢ |
| Driving for pleasure (Q22_27) | ▢ | ▢ | ▢ |
| Other - Please state (Q22_28) | ▢ | ▢ | ▢ |

Q23 From the answers selected above, please choose the **main** activity for visiting the area

| | Activity |
|---|---|
| Beach | Select from dropdown options |
| River | Select from dropdown options |
| Lake | Select from dropdown options |

Q24 On approximately how many days of the year would you visit these areas in Taranaki:

| | Days |
|---|---|
| Beach | |
| River | |
| Lake | |

Q25 What time of the year do you usually visit these areas?

- ◯ Summer (1)
- ◯ Autumn (2)
- ◯ Winter (3)
- ◯ Spring (4)
- ◯ All year round (5)

Q26 Do you visit beaches, rivers and lakes as often as you would like?

- Yes (1)
- No (2)

*Display This Question:*

*If Do you visit beaches, rivers and lakes as often as you would like? = No*

Q27 Which of the following reasons best explains why not? Please rank in order of importance 1=main reason, 2=second reason, 3=third reason

______ Takes too long to get there (1)
______ Costs too much (petrol) (2)
______ Work commitments (3)
______ Family commitments (4)
______ Lack of transport (5)
______ Other reasons - Please state (6)

**End of Block: Recreational use map and survey section**

**Start of Block: Public access section**

Q28 Within the last 12 months have you been able to gain access to rivers, lakes or parts of the coast in Taranaki that you wanted to have access to:

- Yes (1)
- No (2)

*Display This Question:*

*If Within the last 12 months have you been able to gain access to rivers, lakes or parts of the coas... = No*

Q29 What was the main reason or reasons why you have not been able to gain access?

○ Landowner or occupier denied access across their land (1)

○ Entrance or access closed (2)

○ Access was too difficult e.g. no road, track or bridge, steep topography etc. (3)

○ Not aware of any access to the site (4)

○ Other reason (5) ________________________________________________

---

Q30 Do you think the level of public access to Taranaki's rivers, lakes and the coast is

○ Excellent (1)

○ Good (4)

○ Fair (5)

○ Poor (2)

---

Q30a Comment (optional)

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

---

**End of Block: Public access section**

---

**Start of Block: Water quality section**

Q31 How would you rate the overall water quality of Taranaki's beaches, rivers and lakes:

| | Excellent (1) | Good (2) | Fair (3) | Poor (4) |
|---|---|---|---|---|
| Beaches (1) | ○ | ○ | ○ | ○ |
| Rivers (2) | ○ | ○ | ○ | ○ |
| Lakes (3) | ○ | ○ | ○ | ○ |

Q32 Do you/have you checked the conditions of the site before visiting?

○ Yes (1)

○ Sometimes (4)

○ No, just wing it (2)

*Skip To: Q35 If Do you/have you checked the conditions of the site before visiting? = No, just wing it*

Q33 What information do you look up before visiting the site?

- ▢ Access to the site (1)
- ▢ Weather conditions (2)
- ▢ Tide times (7)
- ▢ Swell / Surf conditions (3)
- ▢ Water quality conditions / warning (4)
- ▢ Civil defense/ emergency alert warning (5)
- ▢ Other - Please state (6) ________________________________________________

---

Q34 How do you go about finding information of the site before visiting?

- ▢ Check the district council website (1)
- ▢ Check the district health board website (3)
- ▢ Check the regional council website (5)
- ▢ Check the LAWA (Land Air Water Aotearoa) website (7)
- ▢ Check the Metservice website (8)
- ▢ Go directly to the 'Surfwatch' web page (11)
- ▢ Just Google it (9)
- ▢ Other - Please state (10) ________________________________________________

---

Q35 Would you still **visit** a site if a warning sign is up? E.g. sign stating the access is closed or a health warning or no swimming sign.

- Yes (4)
- Sometimes (5)
- No (6)

---

Q36 Would you still do ***recreational water-based activities***, e.g. swimming, surfing, kayaking, fishing, shellfish gathering if the warning signs indicated water quality conditions were over the guideline limit?

- Yes (1)
- Maybe (4)
- No (3)

*Skip To: End of Survey If Would you still do recreational water-based activities, e.g. swimming, surfing, kayaking, fishing... = No*

---

*Display This Question:*

*If Would you still do recreational water-based activities, e.g. swimming, surfing, kayaking, fishing... = Yes*

Q37 Why would you still visit the site if the water quality warning sign is up?

- ▢ Did not notice the water quality warning signs (5)
- ▢ Familiarity and knowledge of the site (7)
- ▢ It depends on who is involved in the activitities (e.g. I might not go ahead if it involved my children) (10)
- ▢ Not worried about the risk of being sick / getting infected (6)
- ▢ The activities for the day had already been planned (3)
- ▢ The conditions were great for recreational activity e.g. kite surfing, surfing, kayaking (4)
- ▢ To cool off on a hot day (1)
- ▢ Other - Please state (2) ________________________________________________

---

*Display This Question:*

*If Would you still do recreational water-based activities, e.g. swimming, surfing, kayaking, fishing... = Maybe*

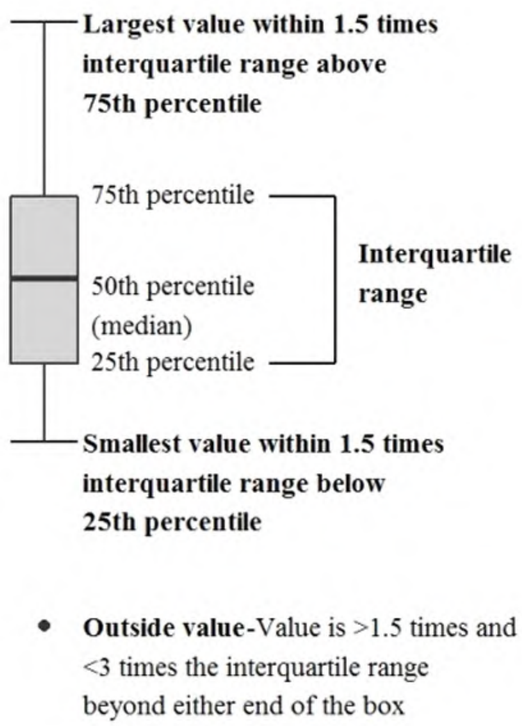
Q38 Why would you still visit the site if the water quality warning sign is up?

- ▢ Did not notice the water quality warning signs (5)
- ▢ Familiarity and knowledge of the site (8)
- ▢ It depends on who is involved in the activities (e.g. I might not go ahead if it involved my children) (7)
- ▢ Not worried about the risk of being sick / getting infected (6)
- ▢ The conditions were great for recreational activity e.g. kite surfing, surfing, kayaking (4)
- ▢ The activities for the day had already been planned (3)
- ▢ To cool off on a hot day (1)
- ▢ Other - Please state (2) ________________________________________________

**End of Block: Water quality section**

# Appendix II

# How to interpret a boxplot


Largest value within 1.5 times interquartile range above 75th percentile
75th percentile
Interquartile range
50th percentile (median)
25th percentile
Smallest value within 1.5 times interquartile range below 25th percentile
Outside value-Value is >1.5 times and <3 times the interquartile range beyond either end of the box

# Appendix III

# Ranking of all sites visited within the last year by questionnaire respondents

| Site | Number of Respondents who had visited |
|---|---|
| Coastal Walkway | 353 |
| Fitzroy Beach | 352 |
| Pukekura Park | 338 |
| East End Beach | 336 |
| Ngamotu Beach | 313 |
| Te Henui River mouth | 265 |
| Waiwhakaiho River at Te Rewa Rewa Bridge | 257 |
| Back Beach at Paritutu Rock | 234 |
| Waiwhakaiho River at the mouth | 225 |
| Lake Rotomanu | 219 |
| Back Beach at Herekawe Stream | 202 |
| Oakura Beach at Surf Club | 195 |
| Lake Mangamahoe | 188 |
| Lee Breakwater | 184 |
| Waiwhakaiho River, Merrilands Domain | 178 |
| Urenui Beach | 167 |
| Opunake Beach | 163 |
| Huatoki River | 155 |
| Kawaroa | 154 |
| Dawson Falls | 143 |
| Corbett Park/Oakura River mouth | 141 |
| Ahu Ahu Road | 139 |
| Waiwhakaiho River at meeting of the waters | 136 |
| Wai-iti Beach | 133 |
| Bell Block Beach | 130 |
| Oakura Beach at Camp Ground | 128 |
| Urenui River | 126 |
| Weld Road | 125 |
| Lake Rotokare | 115 |
| Wilkies Pools | 115 |
| Barrett Domain | 112 |
| Waitara River at Town Wharf | 108 |
| Waitara West Beach | 106 |
| Stony River | 101 |
| Cape Egmont | 99 |
| Tongaporutu River | 98 |
| Pukearuhe (White Cliffs) | 96 |
| Waiwhakaiho River at Burgess Park | 96 |
| Onaero Bay at Beach Settlement | 94 |

| | |
|---|---|
| Waiwhakaiho River at Rimu Street (Telecom) | 90 |
| Centennial Drive | 89 |
| Onaero River | 87 |
| Waitara East Beach | 86 |
| Everett Park | 82 |
| Ohawe Beach | 80 |
| Lake Rotorangi | 78 |
| Onaero Bay at Surf Club | 78 |
| Stent Road | 74 |
| Tapuae Beach | 68 |
| Kaupokonui River at Beach Domain | 64 |
| Puniho Road | 61 |
| Lake Opunake | 58 |
| Lake Ratapiko | 57 |
| Waihi Beach | 54 |
| Patea Beach | 52 |
| Waiongana River | 51 |
| Patea River at King Edward Park | 50 |
| Rahotu | 48 |
| Kina Road | 46 |
| Middleton Bay | 46 |
| Patea Dam | 45 |
| Patea River at boat ramp | 45 |
| Timaru Stream | 43 |
| Komene Road | 39 |
| Arawhata Road Beach | 37 |
| Epiha Road Beach | 37 |
| Mimi River | 37 |
| Paora Road | 37 |
| Waverley Beach | 36 |
| Manaia | 35 |
| Kumara Patch | 34 |
| Greenwood Road | 33 |
| Waingongoro River mouth | 33 |
| Mohakatino River | 31 |
| Patea River at Carrington Walkway | 28 |
| Manganui River | 26 |
| Waitoetoe campsite | 25 |
| Waipipi Beach | 22 |
| Oaonui Stream | 19 |
| Wai-inu Beach | 19 |
| Mana Bay | 17 |
| Manutahi | 17 |
| Waiaua River | 17 |

| | |
|---|---|
| Whenuakura River | 17 |
| Normanby weir | 16 |
| Mangahume Stream | 15 |
| Tangahoe River | 15 |
| Greenmeadows Beach | 14 |
| Ngatoro Stream | 14 |
| Kapuni Stream | 13 |
| Waingongoro River at Eltham Camp | 13 |
| Maketawa River | 12 |
| Mokoia Road | 12 |
| Nowells Lake | 12 |
| Puketapu Road | 12 |
| Waiwhakaio River (other sites) | 11 |
| Mt Taranaki | 10 |
| Kahui Stream | 9 |
| Waitara River | 8 |
| Te Henui | 7 |
| Tupare | 5 |
| Lake Cowley | 4 |
| Lake Nganana | 3 |
| Pukeiti | 3 |
| Ratapihipihi | 3 |
| York Rd | 3 |
| Otakeho Stream | 2 |
| Blue Rata Reserve | 2 |
| Cardiff Walkway | 2 |
| Lucy's Gully | 2 |
| Manawapou River | 2 |
| Ahukawakawa | 1 |
| Bertrand Rd | 1 |
| Fort St George | 1 |
| Hickford Park | 1 |
| Hollard Gardens | 1 |
| Kaihihi River | 1 |
| Kaitake Range | 1 |
| Kapoaiaia Stream | 1 |
| Kohi Rd | 1 |
| Makuri | 1 |
| Manado Rd | 1 |
| Mangakotukutuku Falls | 1 |
| Mangaoraka Stream | 1 |
| Mangati Stream | 1 |
| Manihi Beach | 1 |
| Matemateonga | 1 |

| | |
|---|---|
| Moeawatea | 1 |
| Oakura Hall | 1 |
| Okato Domain | 1 |
| Omoana | 1 |
| Pitone Rd | 1 |
| Porikapa | 1 |
| Purangi | 1 |
| Tarata Domain | 1 |
| Toko | 1 |
| Tuna | 1 |
| Turuturumokai | 1 |
| Upper Egmont Rd | 1 |
| Uriti Rd | 1 |
| Waverley River | 1 |
| White Cliffs | 1 |

# Appendix IV

# Site usage on weekdays vs weekends from observational count

Table 1 Summary of user numbers counted at monitored sites, categorized by site type. Land, Swim and Water refer to the mean number of people observed on the bank/beach, swimming in the water, or taking part in water based activities, respectively. Peak gives the maximum number of people counted at the site at one time, while N denotes the number of observational counts undertaken at the site.

| | Weekdays | | | | | | Weekends | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site | Total | Land | Swim | Water | Peak | n | Total | Land | Swim | Water | Peak | n |
| BEACHES | | | | | | | | | | | | |
| Coastal Walkway | 59 | 58 | 0 | 0 | 89 | 3 | 59 | 59 | 0 | 0 | 88 | 3 |
| Tongaporutu | 55 | 50 | 1 | 3 | 131 | 6 | 102 | 91 | 3 | 7 | 347 | 11 |
| Fitzroy | 53 | 31 | 10 | 12 | 164 | 4 | 92 | 53 | 26 | 13 | 262 | 4 |
| Ngamotu | 47 | 35 | 4 | 8 | 99 | 4 | 104 | 68 | 24 | 13 | 312 | 4 |
| Oakura Beach | 36 | 24 | 5 | 8 | 105 | 4 | 114 | 74 | 23 | 16 | 473 | 4 |
| Opunake Beach | 28 | 18 | 7 | 4 | 99 | 3 | 34 | 22 | 10 | 3 | 100 | 4 |
| Back Beach | 18 | 12 | 2 | 3 | 33 | 4 | 56 | 24 | 8 | 24 | 118 | 4 |
| East End | 16 | 13 | 3 | 1 | 41 | 4 | 38 | 24 | 9 | 6 | 99 | 4 |
| Lee Breakwater | 15 | 4 | 0 | 11 | 30 | 4 | 31 | 9 | 0 | 22 | 152 | 4 |
| Waitara West | 12 | 4 | 0 | 7 | 28 | 4 | 23 | 12 | 1 | 10 | 75 | 4 |
| Mana Bay | 11 | 7 | 0 | 3 | 26 | 4 | 15 | 13 | 1 | 2 | 37 | 4 |
| Waiinu | 9 | 8 | 0 | 0 | 40 | 4 | 24 | 22 | 1 | 1 | 60 | 4 |
| Ohawe Beach | 9 | 7 | 1 | 1 | 26 | 3 | 14 | 9 | 2 | 3 | 37 | 4 |
| Onaero Surf Club | 6 | 4 | 1 | 1 | 39 | 4 | 9 | 5 | 2 | 1 | 26 | 4 |
| Wai-iti | 5 | 4 | 0 | 1 | 25 | 4 | 22 | 15 | 1 | 6 | 63 | 4 |
| Bell Block | 5 | 5 | 0 | 0 | 12 | 4 | 8 | 6 | 1 | 1 | 23 | 4 |
| Waverley | 5 | 4 | 0 | 0 | 16 | 4 | 6 | 6 | 0 | 1 | 20 | 4 |
| Stent Rd | 5 | 4 | 0 | 2 | 29 | 3 | 2 | 1 | 0 | 1 | 7 | 4 |
| Urenui Beach | 4 | 2 | 1 | 0 | 18 | 4 | 8 | 6 | 1 | 1 | 23 | 4 |
| Onaero Settlement | 1 | 1 | 0 | 0 | 8 | 4 | 5 | 2 | 1 | 2 | 18 | 4 |
| LAKES | | | | | | | | | | | | |
| L. Rotomanu | 18 | 13 | 2 | 2 | 53 | 4 | 26 | 18 | 3 | 5 | 46 | 4 |
| Patea Dam | 16 | 12 | 2 | 2 | 47 | 4 | 15 | 9 | 4 | 3 | 30 | 3 |
| Pukekura Park | 14 | 14 | 0 | 0 | 31 | 2 | 23 | 22 | 0 | 1 | 68 | 3 |
| L. Opunake | 4 | 4 | 0 | 0 | 12 | 3 | 3 | 3 | 0 | 0 | 8 | 4 |
| L. Ratapiko | 3 | 3 | 0 | 0 | 20 | 4 | 28 | 22 | 3 | 3 | 67 | 4 |
| L. Rotokare | 3 | 3 | 0 | 0 | 9 | 4 | 19 | 17 | 0 | 2 | 54 | 4 |
| L. Mangamahoe | 2 | 2 | 0 | 0 | 9 | 3 | 6 | 6 | 0 | 0 | 27 | 4 |
| L. Rotorangi | 2 | 0 | 2 | 0 | 8 | 4 | 5 | 3 | 0 | 2 | 22 | 4 |
| Barrett Domain | 2 | 2 | 0 | 0 | 6 | 4 | 2 | 2 | 0 | 0 | 7 | 4 |
| L. Ngangana | 1 | 1 | 0 | 0 | 3 | 4 | 3 | 2 | 0 | 1 | 15 | 4 |
| RIVERS | | | | | | | | | | | | |
| Merrilands Domain | 25 | 15 | 10 | 0 | 55 | 3 | 34 | 24 | 10 | 0 | 85 | 4 |
| Meeting of the Waters | 15 | 8 | 7 | 1 | 46 | 3 | 9 | 4 | 4 | 0 | 28 | 4 |
| Corbett Park | 14 | 10 | 4 | 0 | 40 | 4 | 44 | 22 | 20 | 2 | 219 | 4 |
| Timaru Stream | 10 | 6 | 1 | 3 | 31 | 4 | 40 | 16 | 13 | 11 | 84 | 4 |
| Kaupokonui R. | 9 | 7 | 1 | 2 | 22 | 3 | 10 | 7 | 2 | 1 | 28 | 4 |

| | Weekdays | | | | | | Weekends | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Te Henui | 8 | 8 | 0 | 0 | 29 | 4 | 14 | 9 | 5 | 1 | 41 | 4 |
| Urenui River | 8 | 5 | 2 | 1 | 42 | 4 | 20 | 13 | 4 | 4 | 92 | 4 |
| Waiwhakaiho @ mouth | 5 | 2 | 0 | 2 | 19 | 4 | 4 | 2 | 0 | 2 | 11 | 4 |
| Waitara @ wharf | 4 | 2 | 2 | 0 | 27 | 4 | 4 | 2 | 2 | 0 | 21 | 4 |
| Patea River | 3 | 2 | 1 | 1 | 12 | 4 | 5 | 4 | 0 | 1 | 19 | 4 |
| Waingongoro @ Ohawe | 3 | 2 | 0 | 0 | 8 | 3 | 4 | 3 | 1 | 0 | 11 | 4 |
| Waitara @ mouth | 2 | 1 | 0 | 1 | 9 | 4 | 13 | 6 | 0 | 8 | 56 | 4 |
| Everett Park | 1 | 1 | 0 | 0 | 3 | 3 | 3 | 1 | 2 | 0 | 14 | 4 |
| Oaonui Stream | 1 | 1 | 0 | 0 | 6 | 3 | 5 | 2 | 0 | 2 | 16 | 4 |
| Stony River | 1 | 1 | 0 | 0 | 9 | 3 | 0 | 0 | 0 | 0 | 0 | 4 |
| Waingongoro @ Eltham | 0 | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 4 |

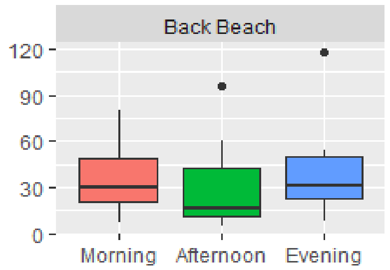
# Appendix V

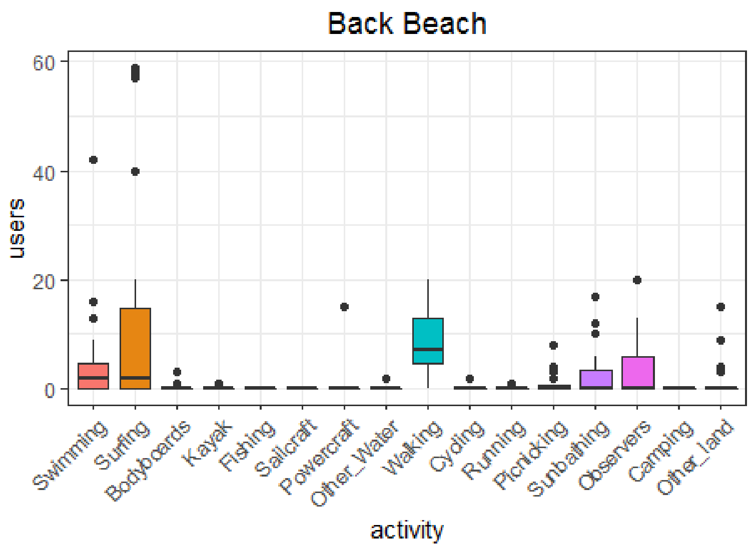
# Individual site summaries from observational count results

For each site, a boxplots comparing usage of the site at different times of day, and the activities undertaken by people at the site, are given.

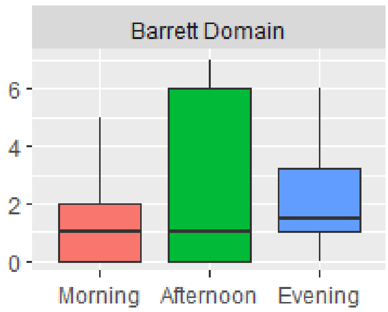
## New Plymouth District

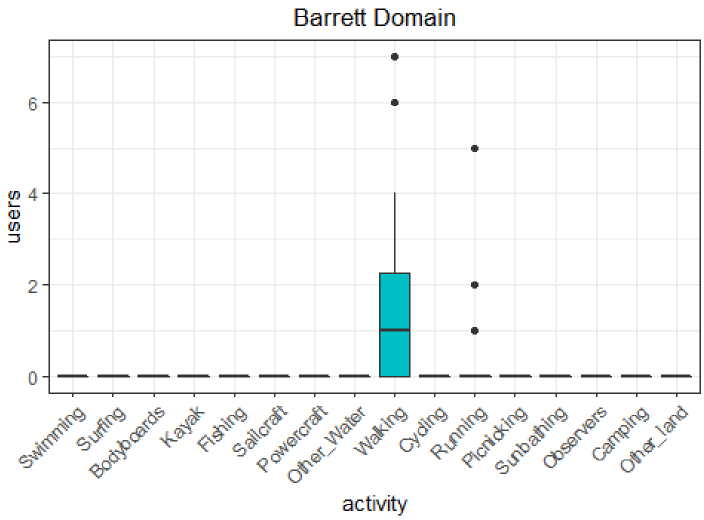
### Back Beach (at Herekawe Stream)



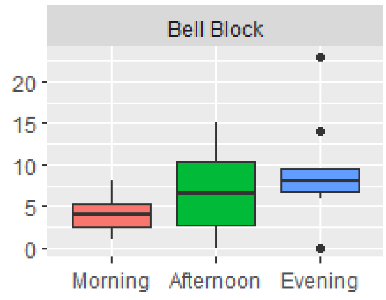



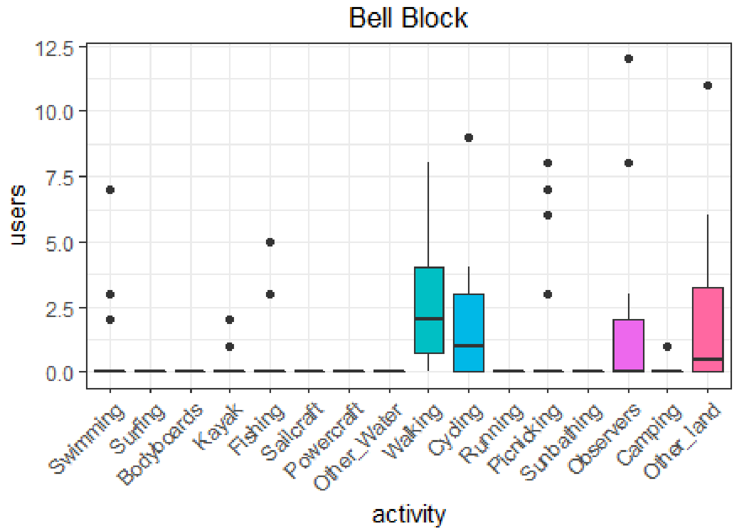

### Barrett (Rotokare) Domain (at Roto St)



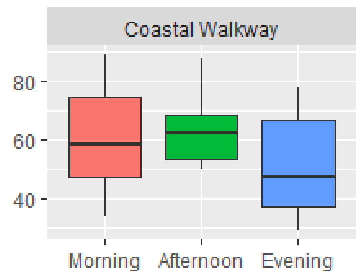



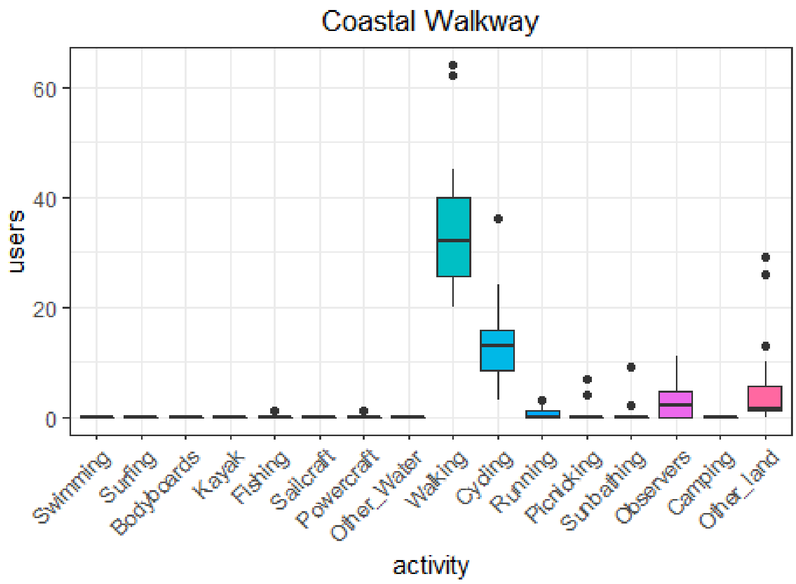
## Bell Block Beach (at Mangati Rd)



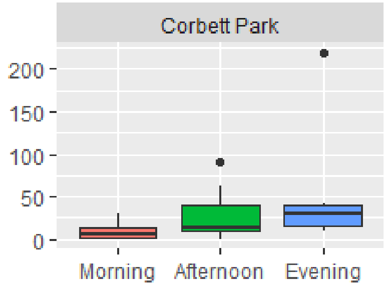



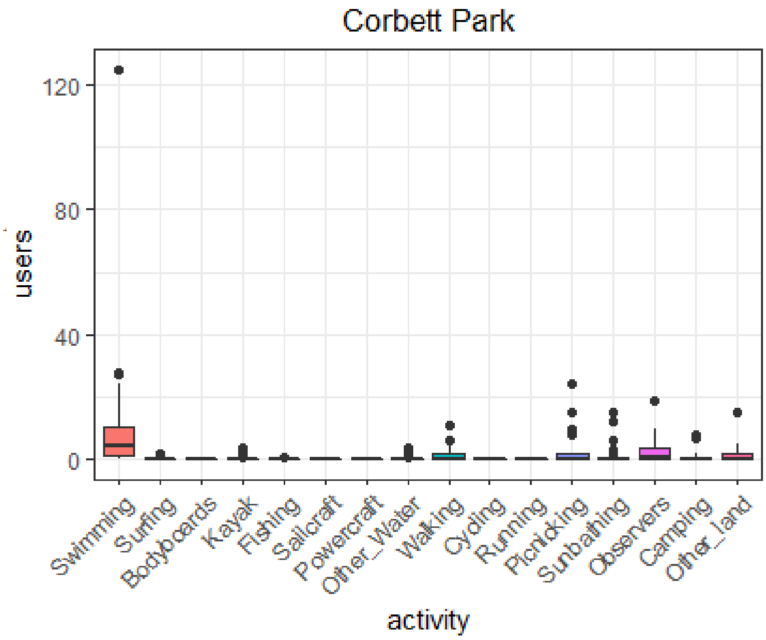

## Coastal Walkway (at Wind-wand)



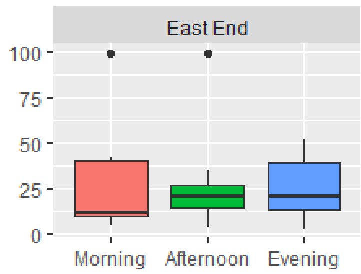



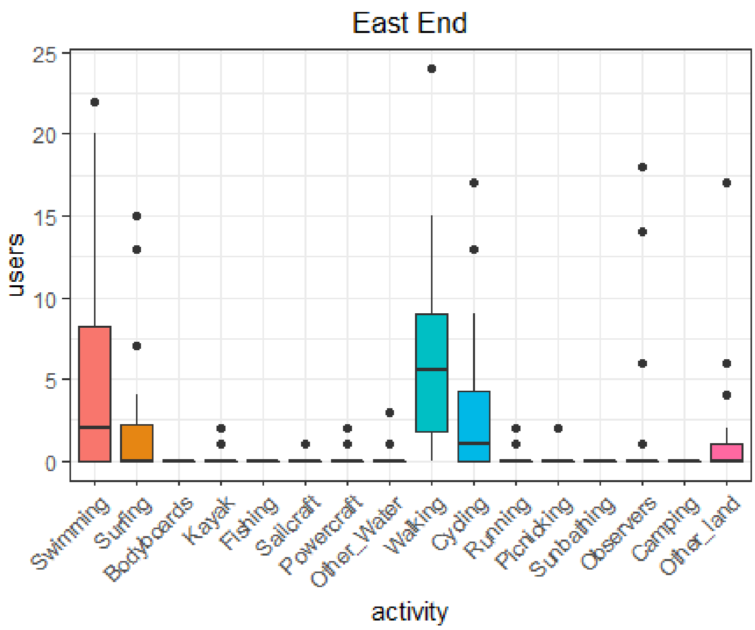
## Corbett Park, Oakura River



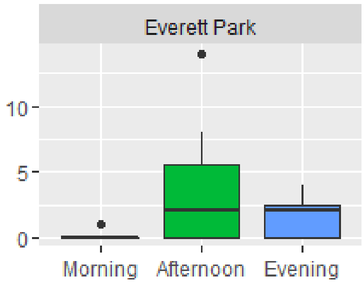



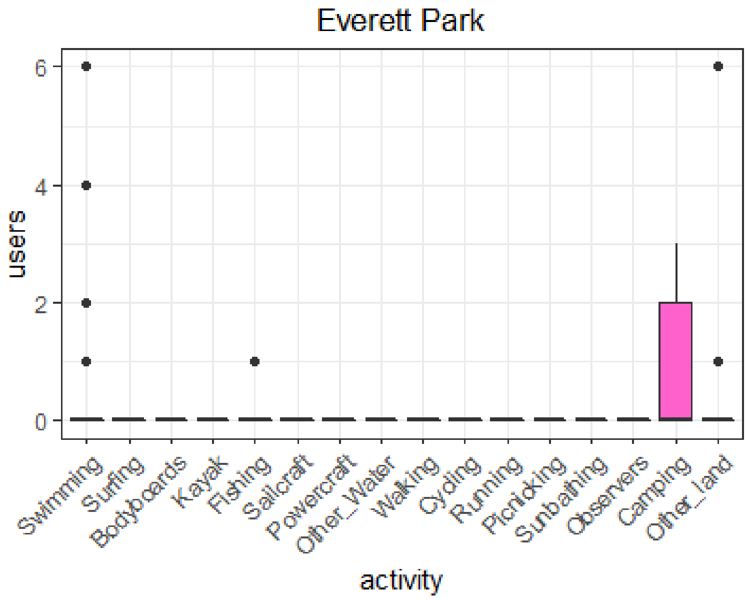

## East End Beach (at Surfclub)



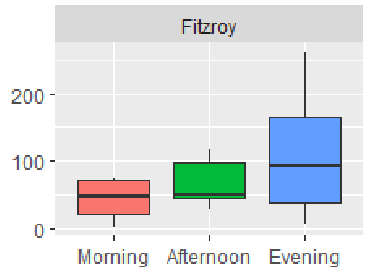



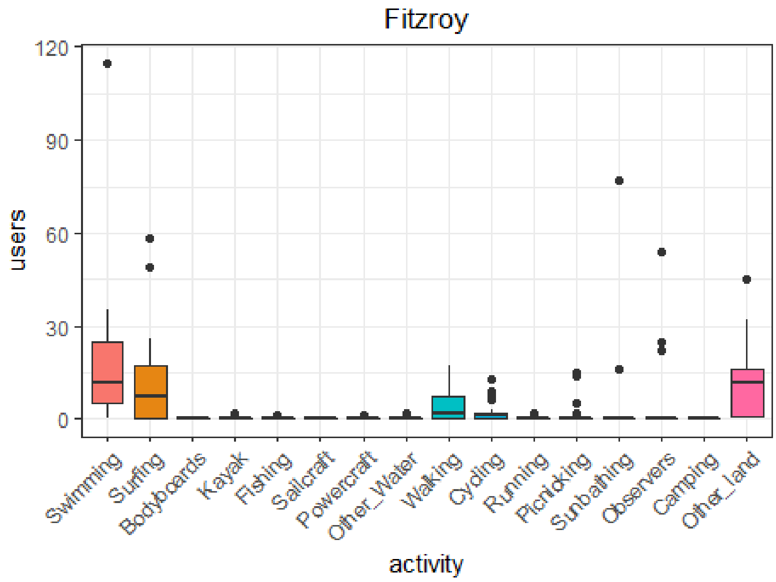
## Everett Park (Manhanui River)



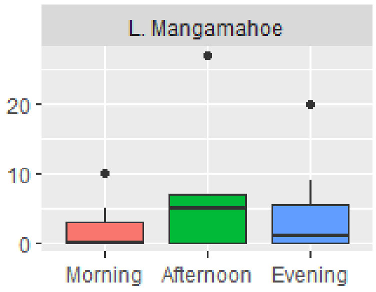



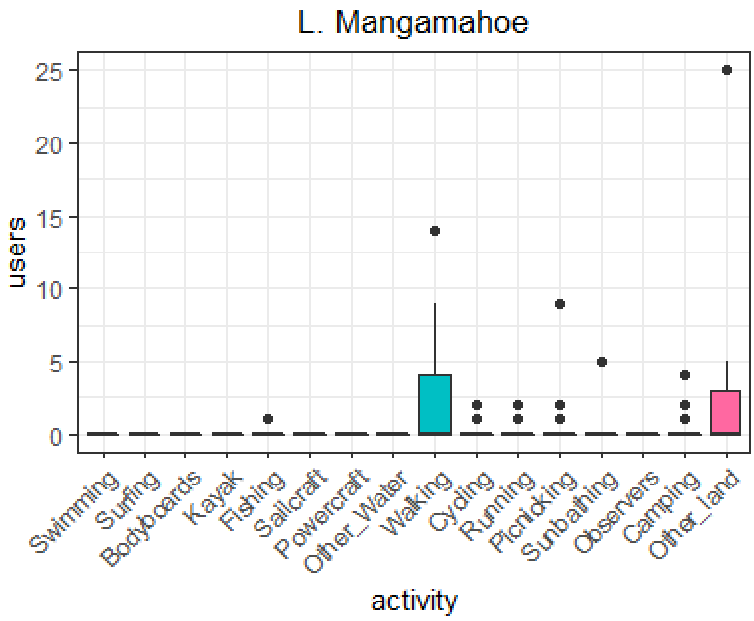

## Fitzroy Beach (at Surfclub)



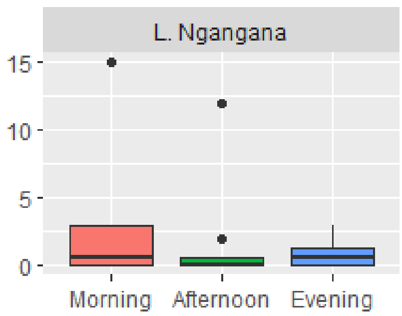



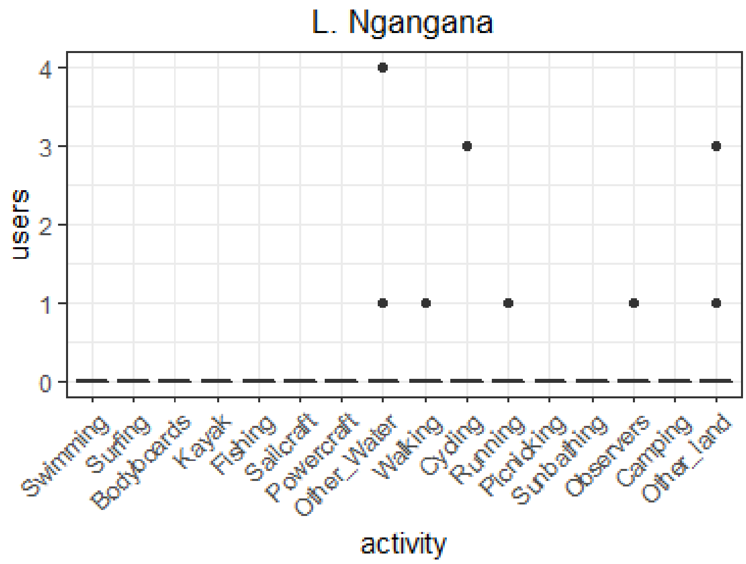
## Lake Mangamahoe



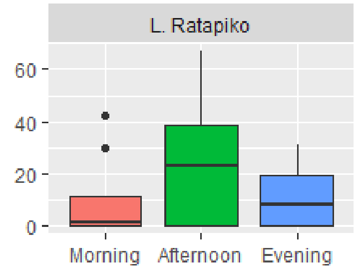



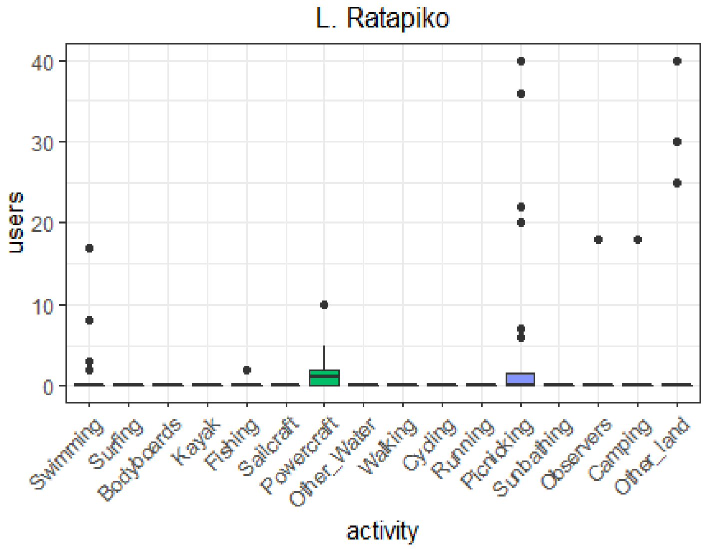

## Lake Ngangana



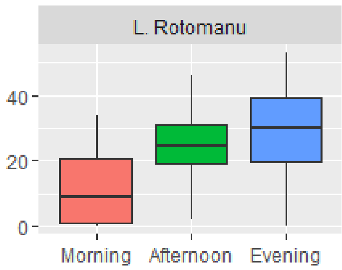



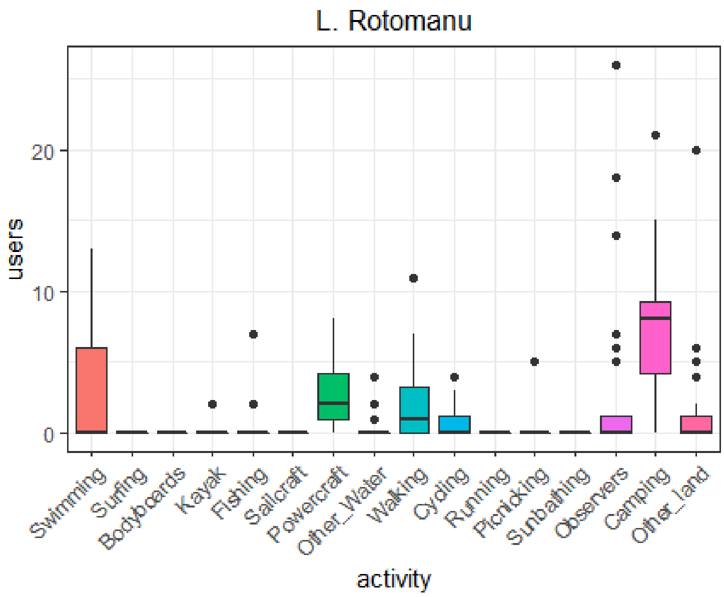
## Lake Ratapiko



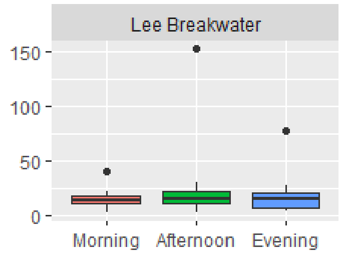



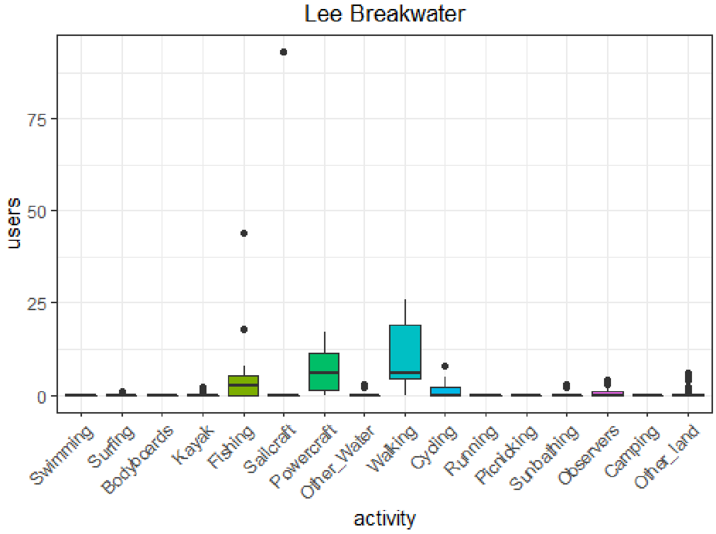

## Lake Rotomanu



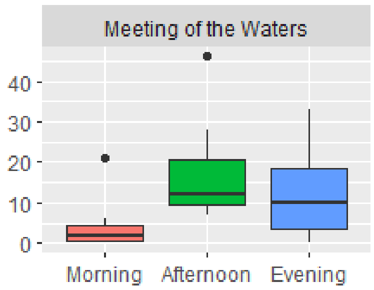



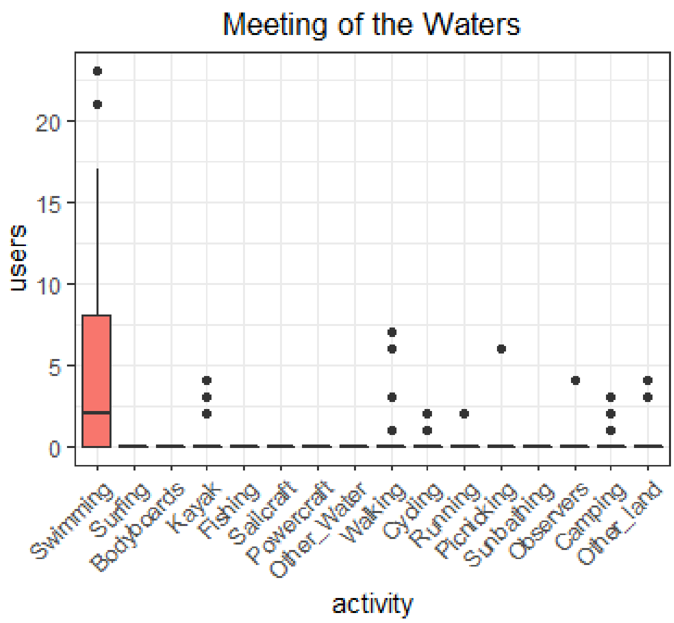
## Lee Breakwater



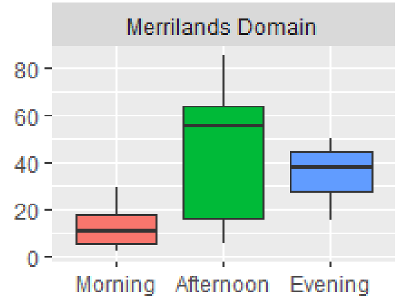



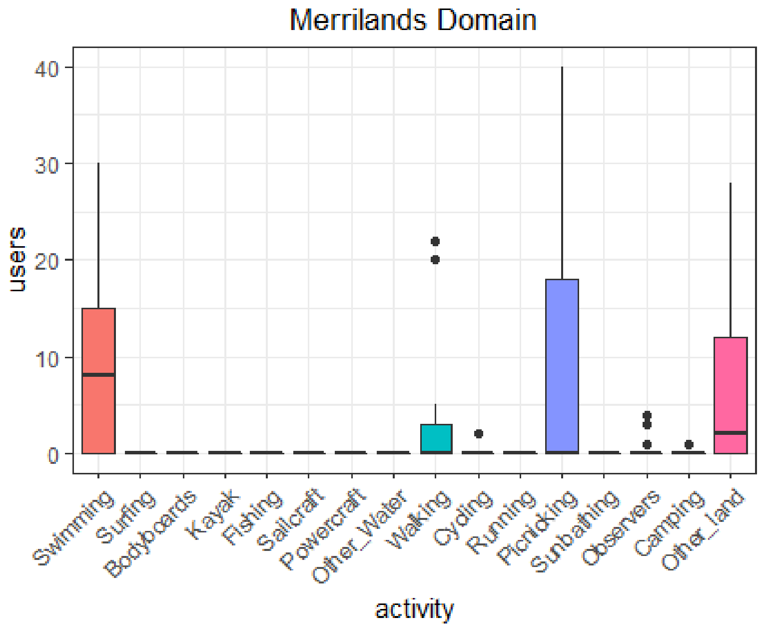

## Meeting of the Waters (Waiwhakaiho River)



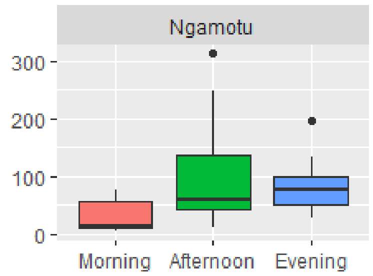
## Merrilands Domain (Waiwhakaiho River)

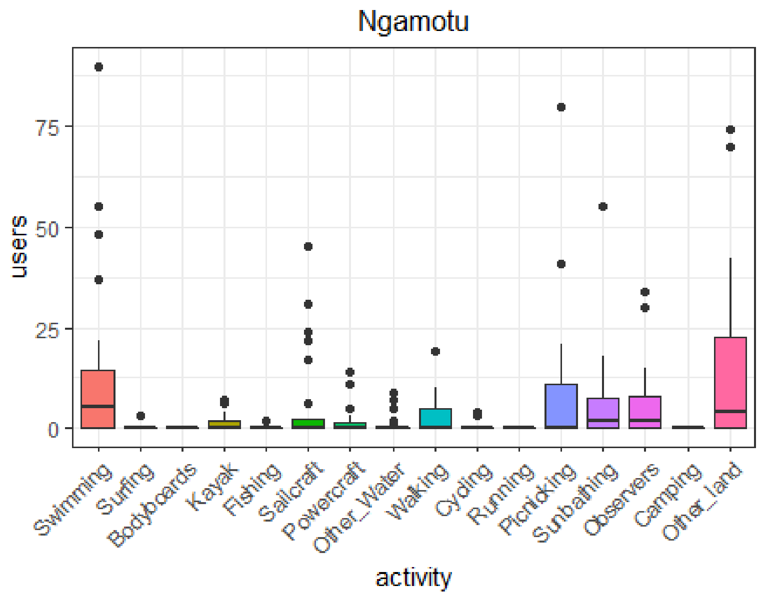



Note: “Other land” activities include playing frisbee golf, and people hanging out by cars.

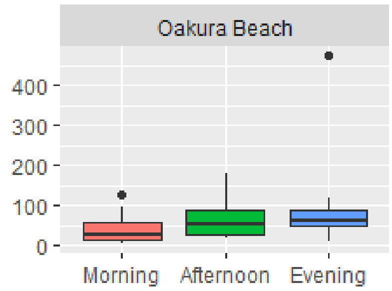
## Ngamotu Beach

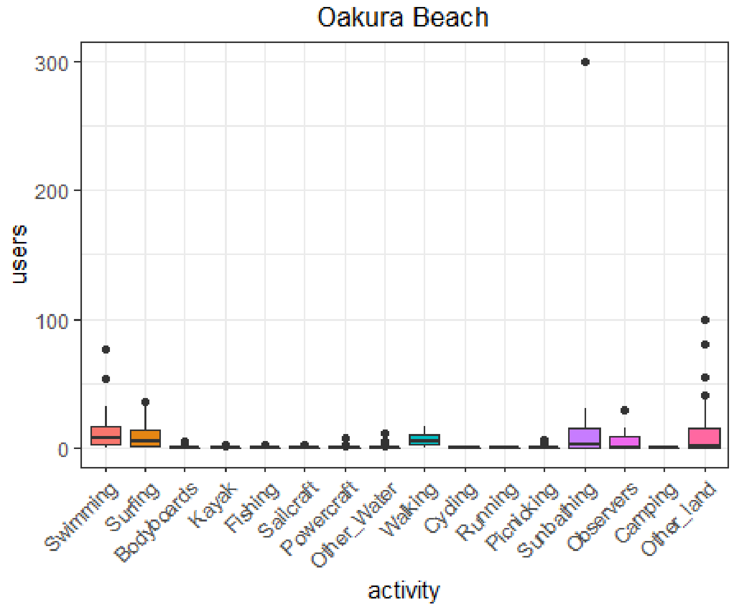



Note: Other land activities include people on the playground, sailing club members and others preparing boats, people playing on the beach and people sitting in cars.

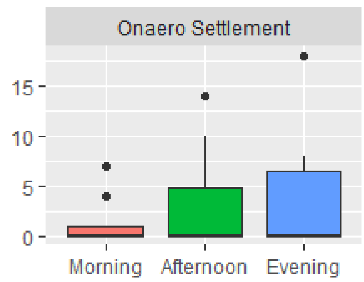
## Oakura Beach (at Surfclub)

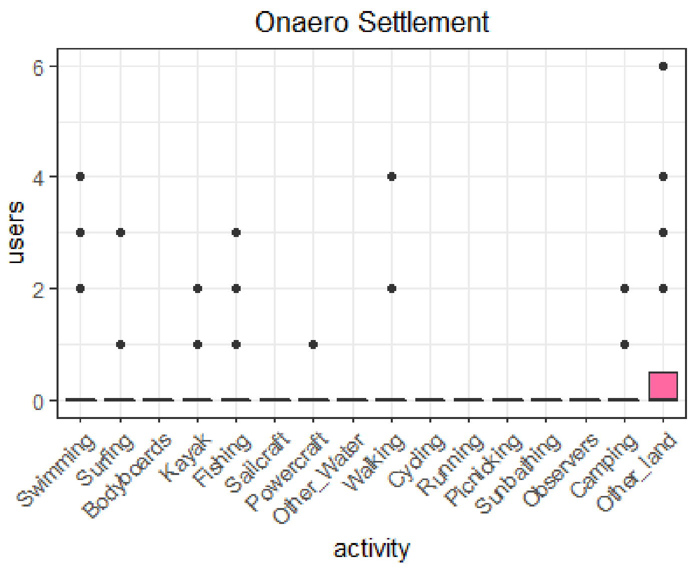



Other land activities include playing games on the beach, surf lifesaving, and people sitting in cars.

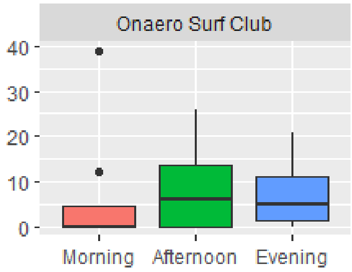
## Onaero Bay (from settlement)

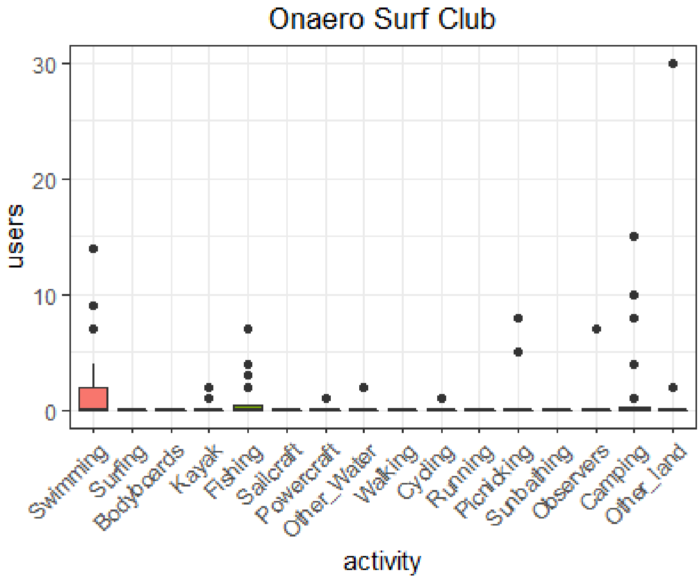


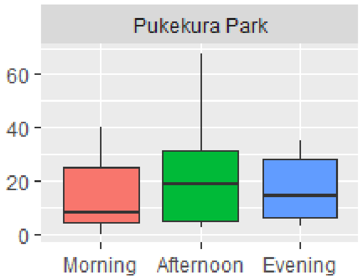

Other land activities were predominantly people sitting in cars.

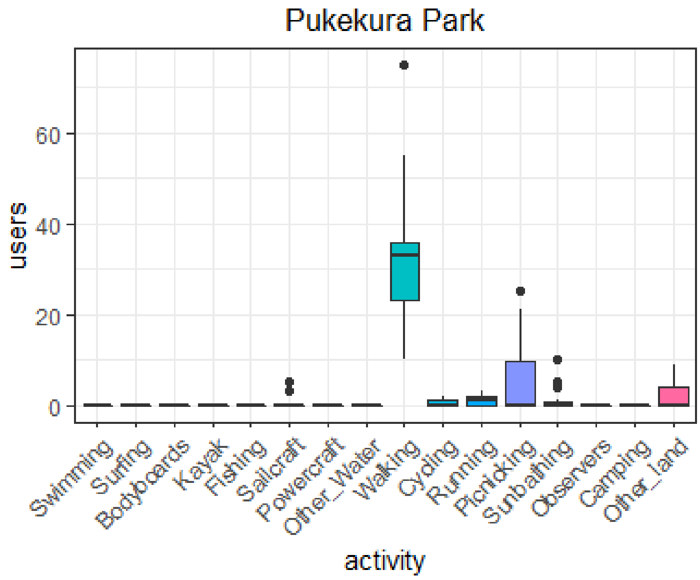
## Onaero Beach (at Surfclub)



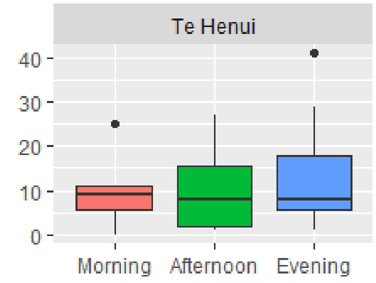



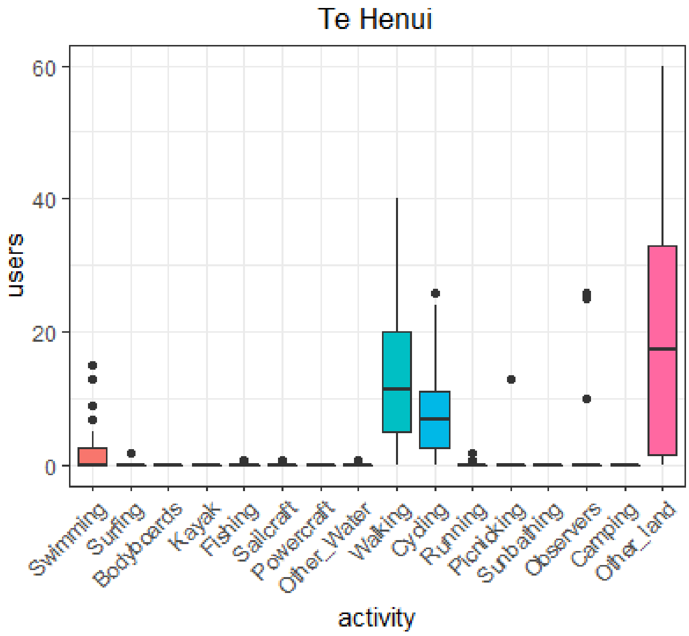

## Pukekura Park Lake (at Teahouse)



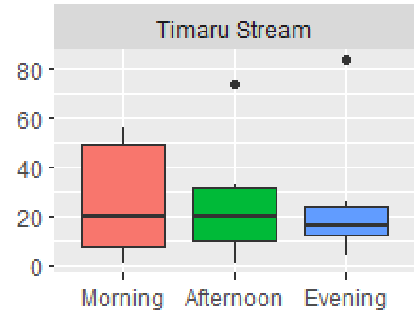
## Te Henui Stream (at mouth)

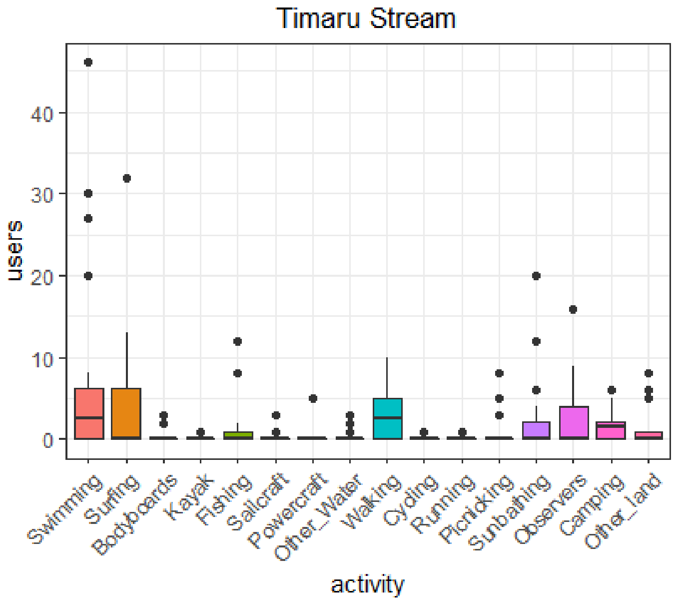


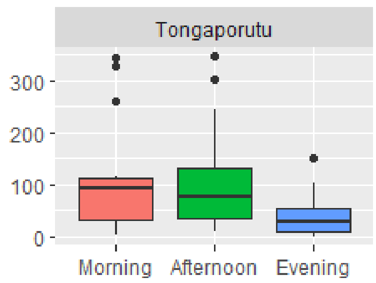

Other activities mainly include café users, with a small number of scooters and skateboarders.

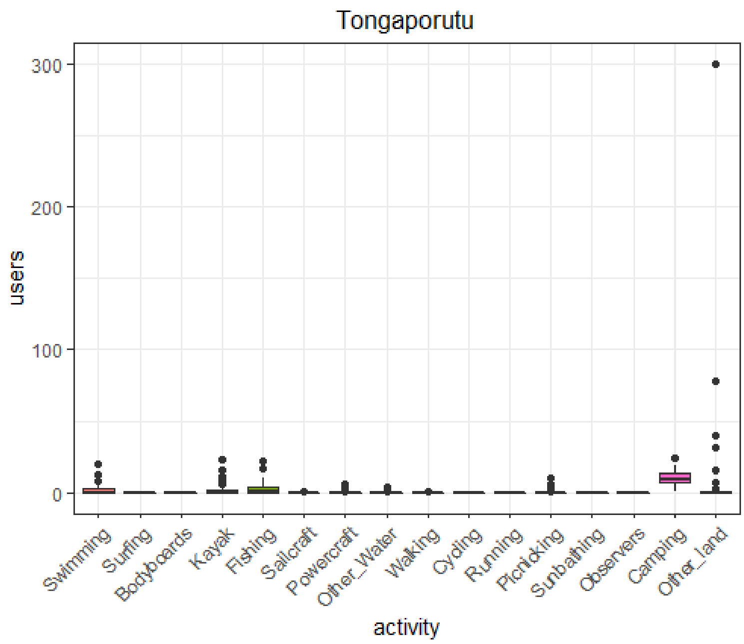
## Timaru Stream (Weld Rd Carpark)



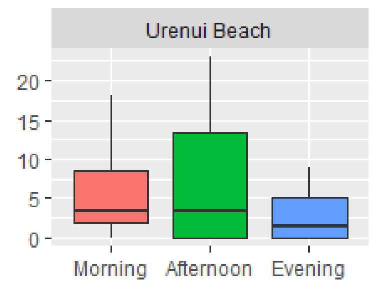
## Tongaporutu Beach

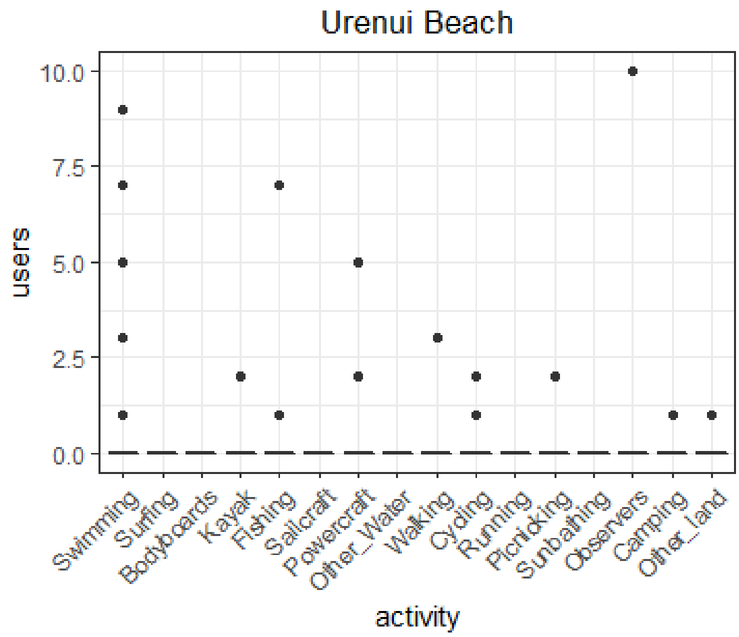


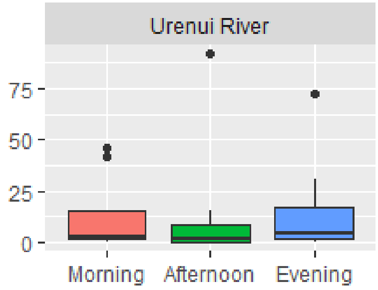

Other land users include photography and tourist groups, and bach users. Note that activity numbers are likely undercounted and distorted at this site due to a lack of consistency in recording. On occasion there were large numbers of users counted on the riverbank and seafront, but little note of what activities they were undertaking.

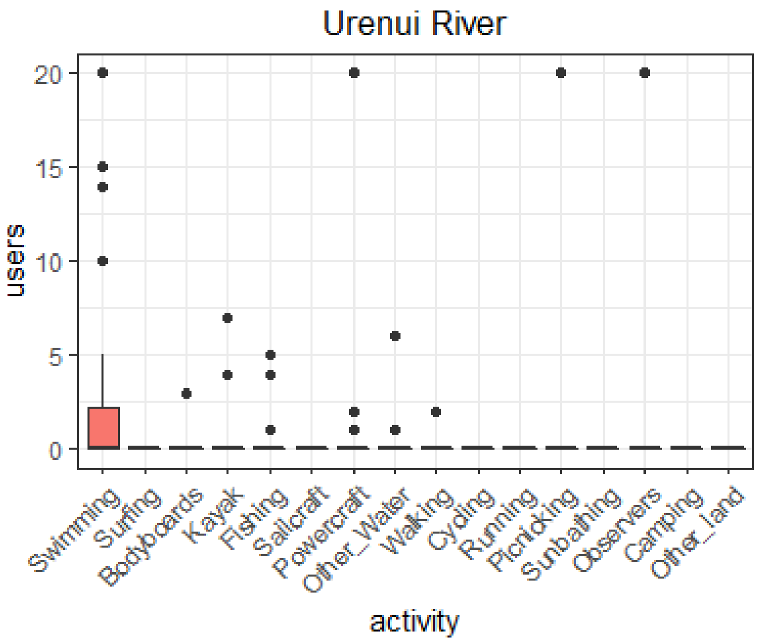
## Urenui Beach



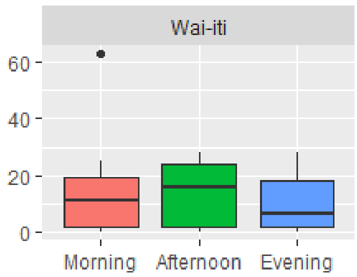



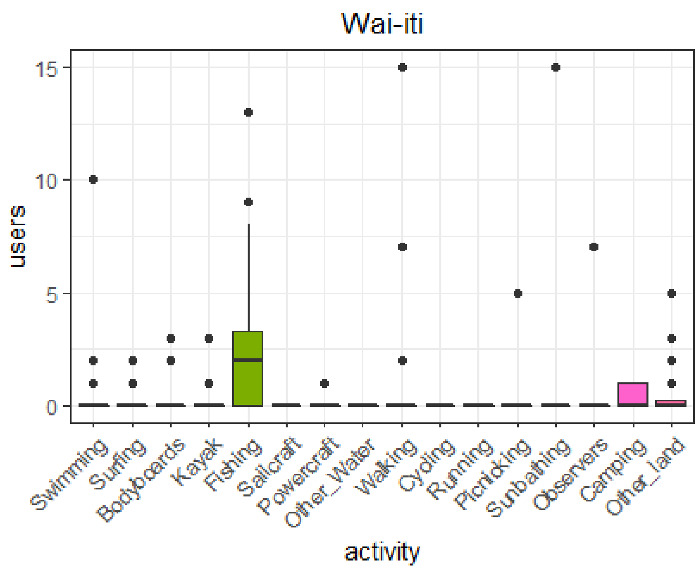
## Urenui River



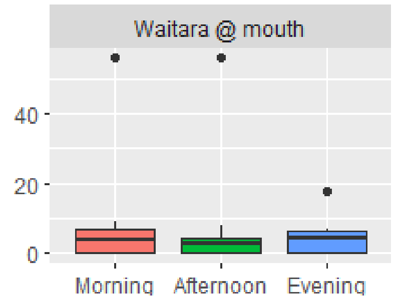



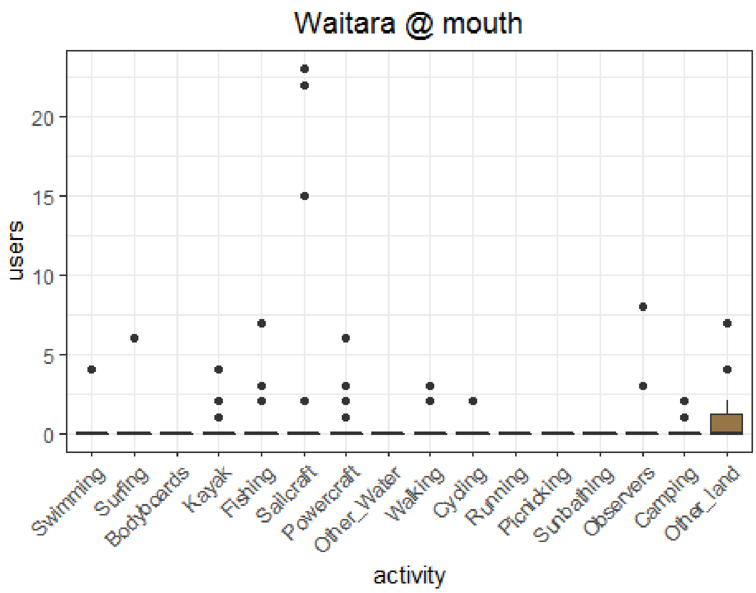

## Wai-iti Beach



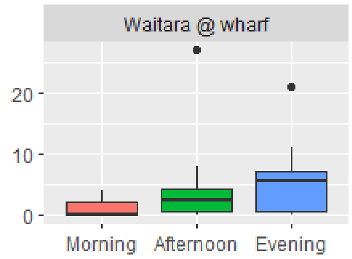



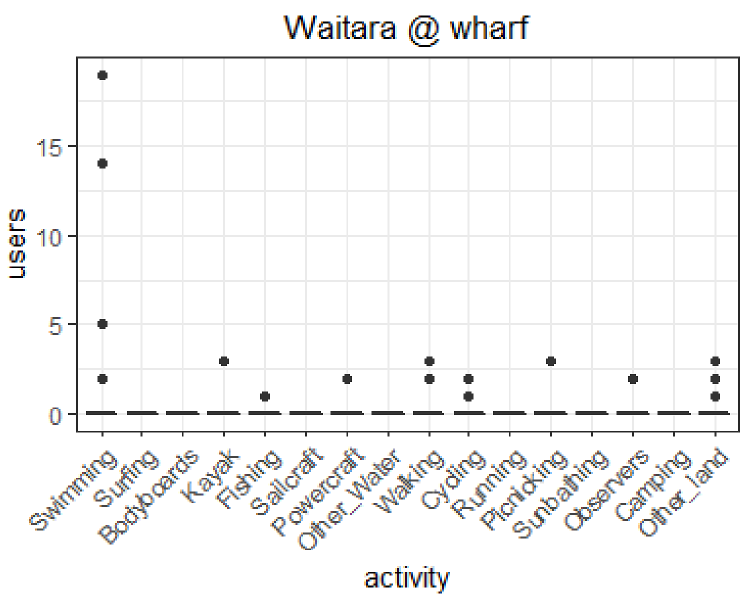
## Waitara River (at mouth)



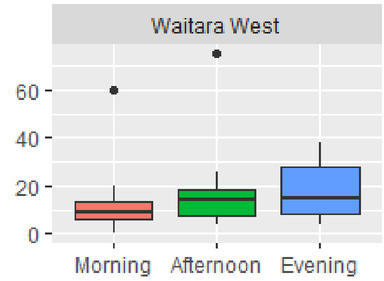



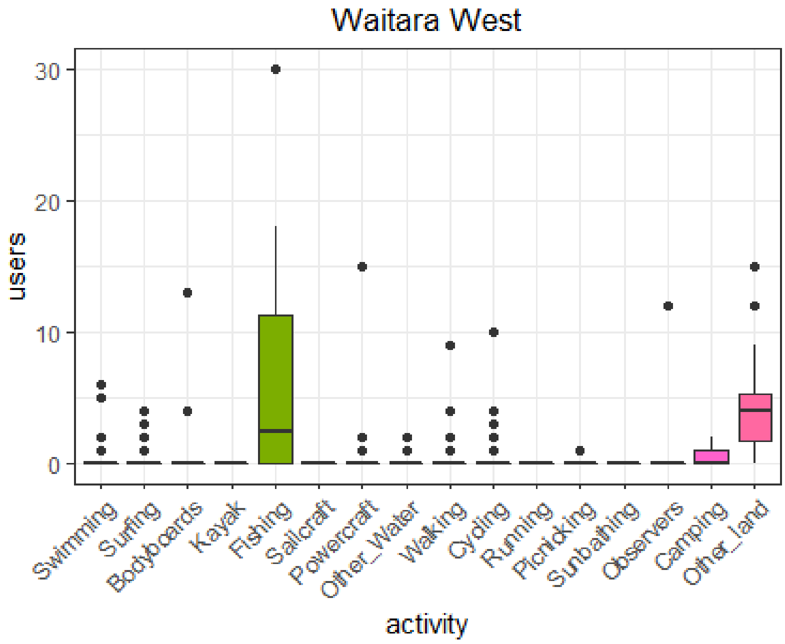

## Waitara River (at wharf)



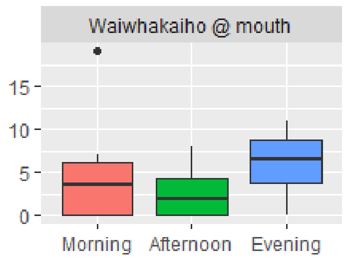



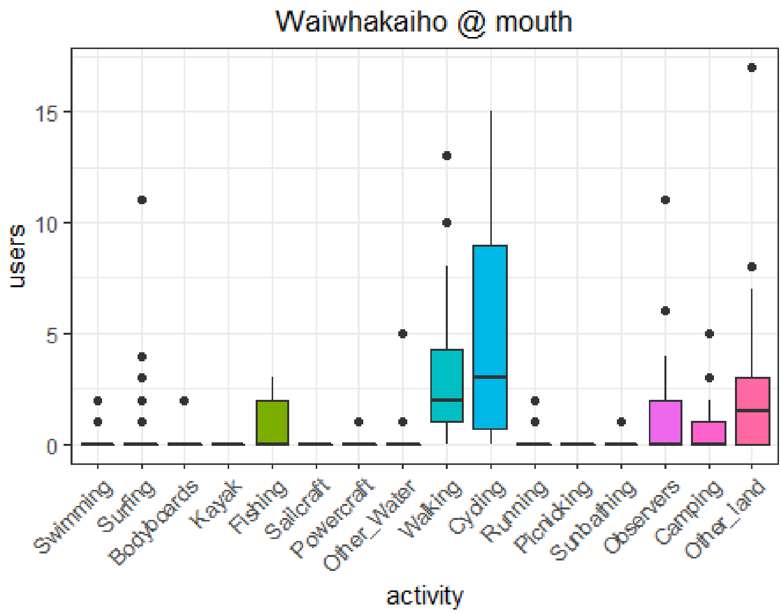
## Waitara West Beach



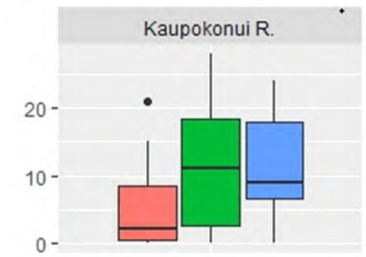

## Waiwhakaiho River (at mouth)

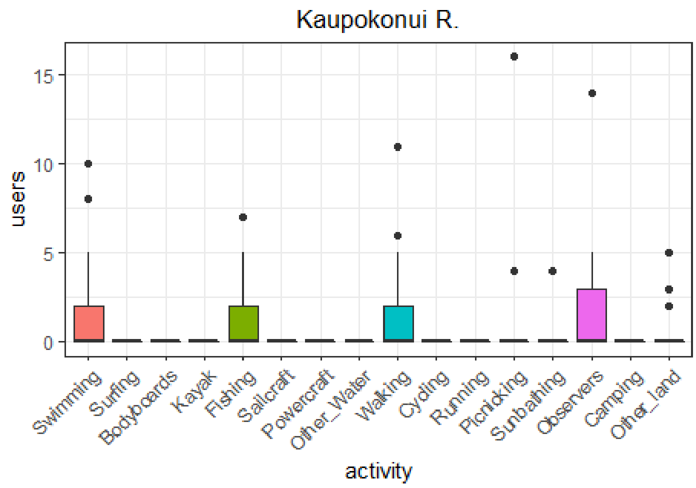


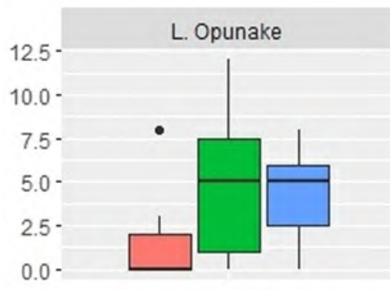
## South Taranaki District

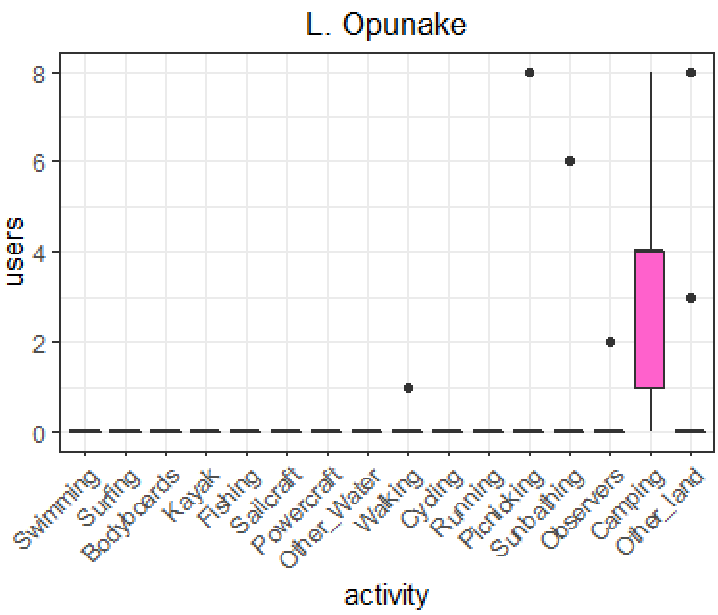
### Kaupokonui River (at Lower Glenn Rd)



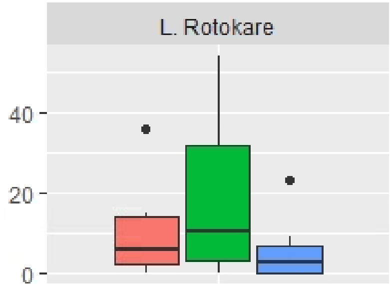



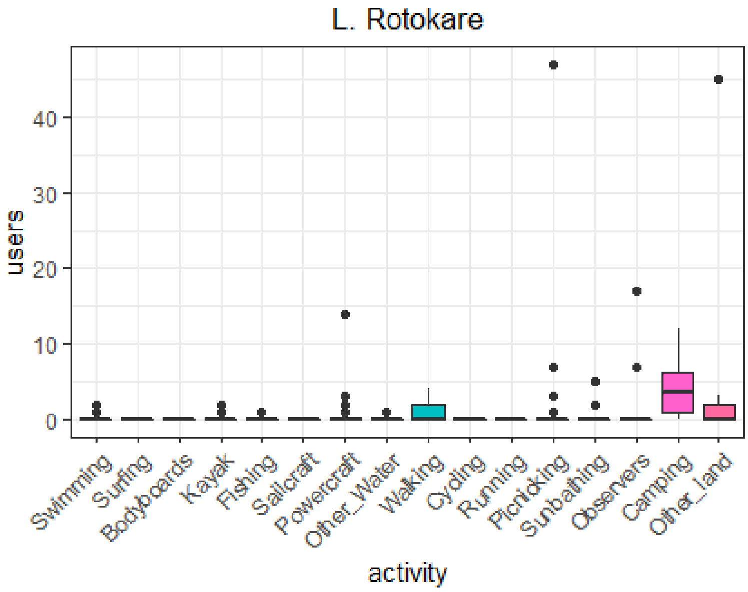

### Lake Opunake



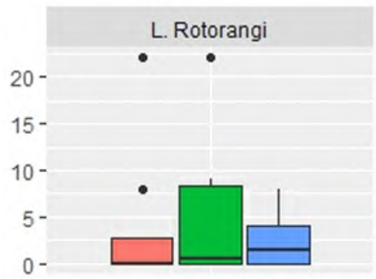



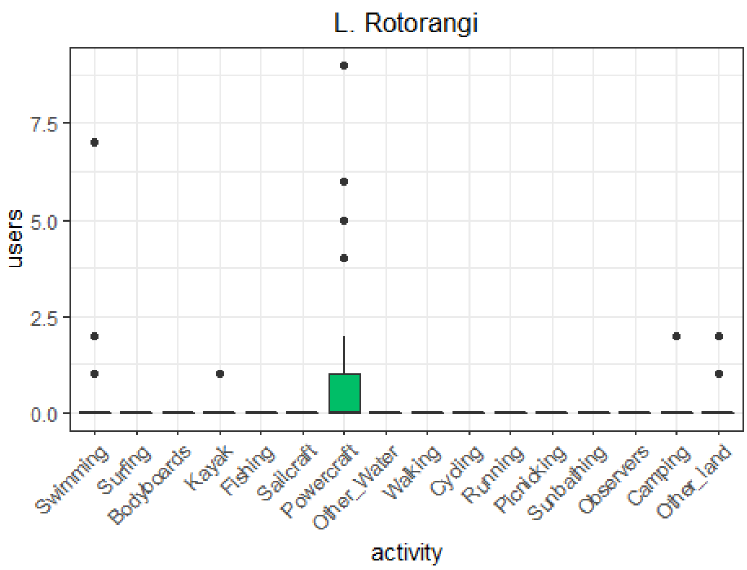
## Lake Rotokare



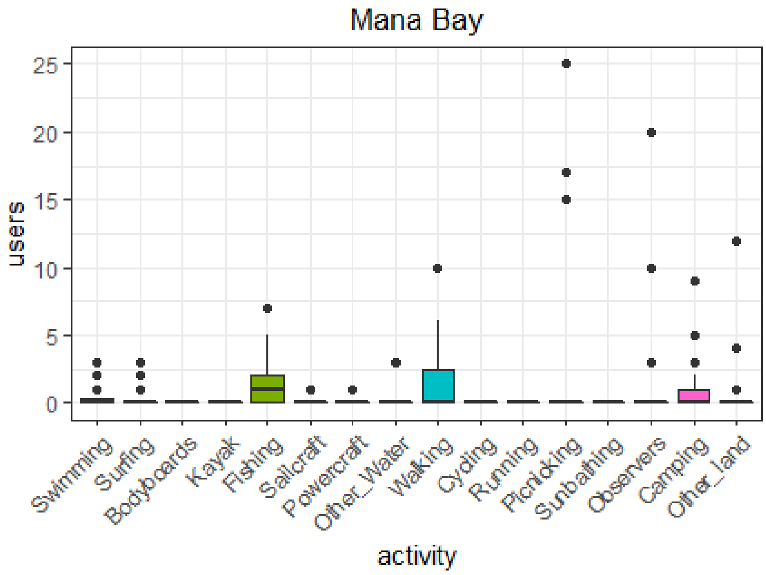




## Lake Rotorangi

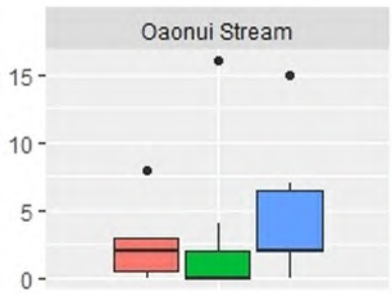


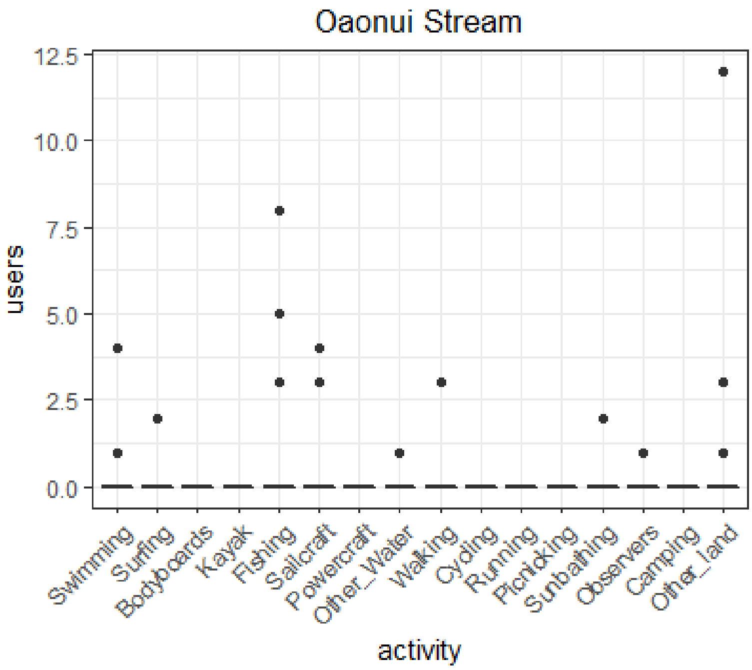



## Mana Bay and Patea Beach

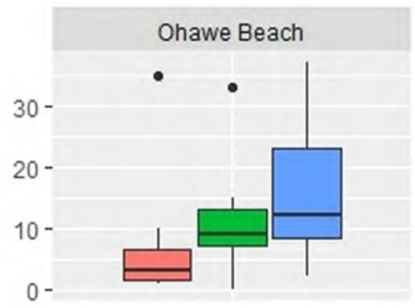



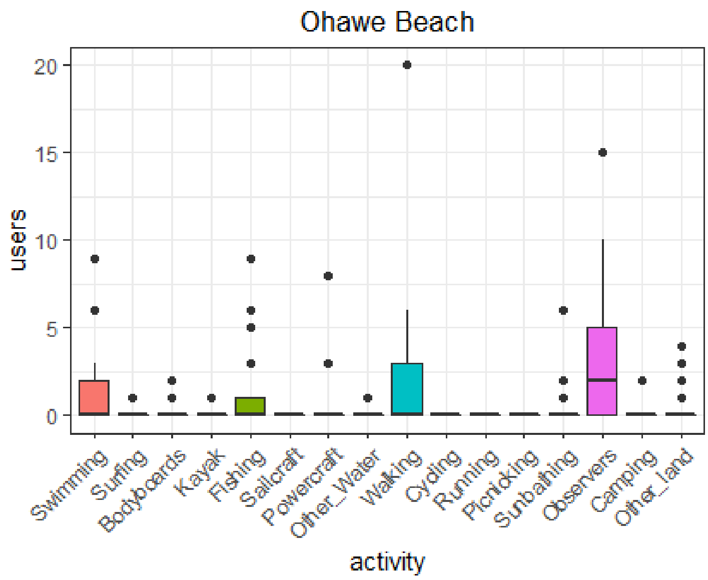

## Oaonui Stream (at Lower Kina Rd)



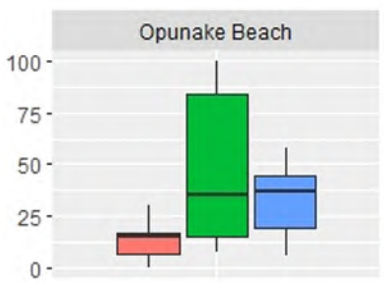



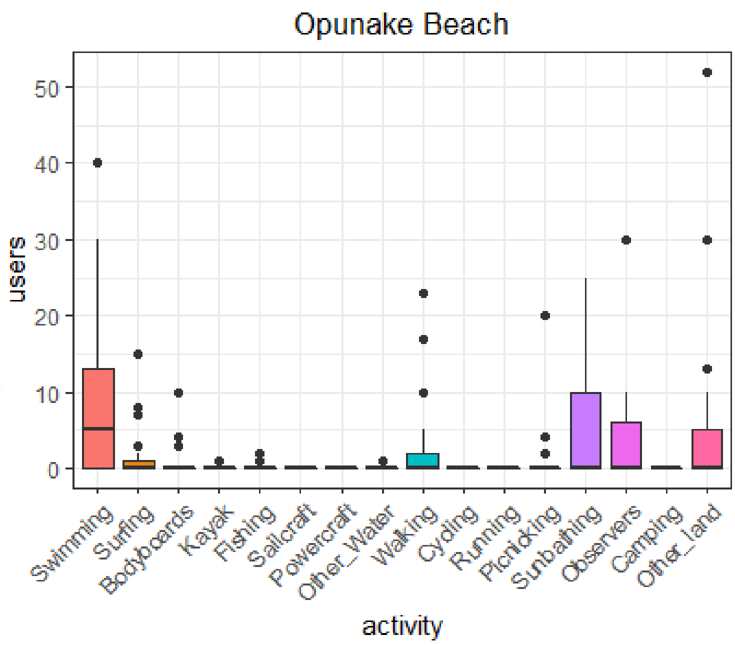
## Ohawe Beach (at boat ramp)



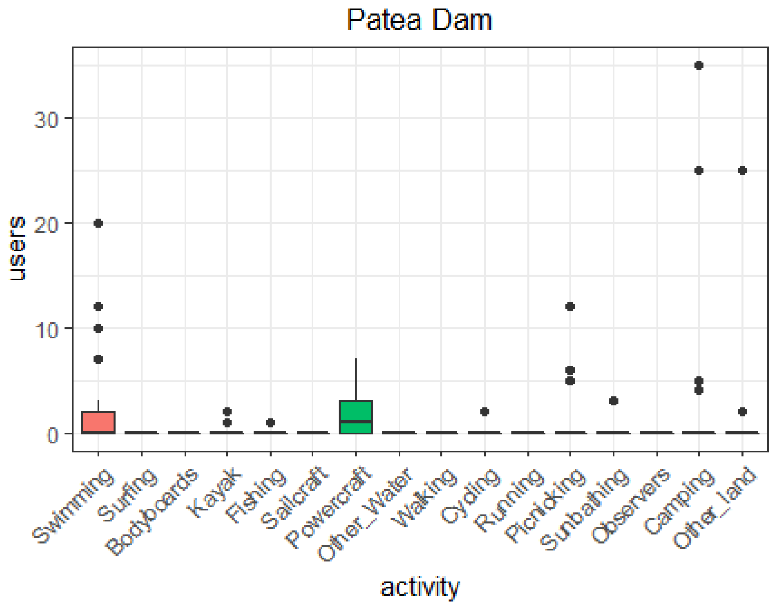




## Opunake Beach

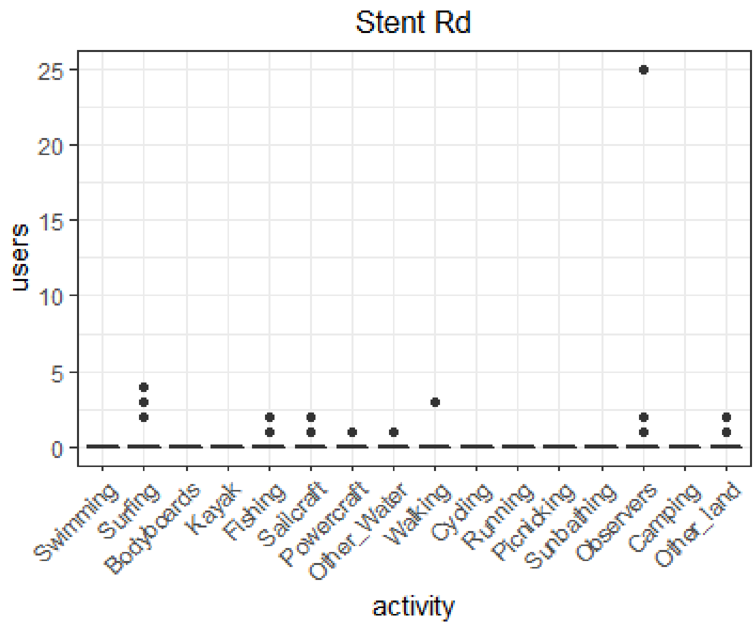


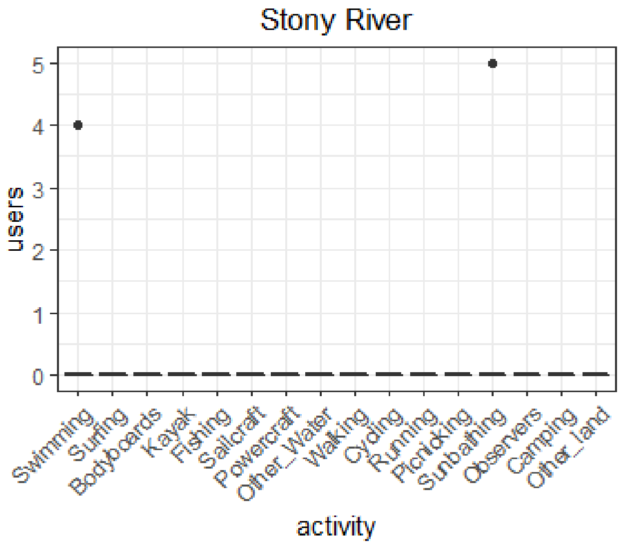
## Patea Dam



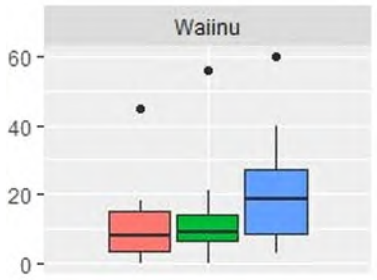

## Stent Rd Beach

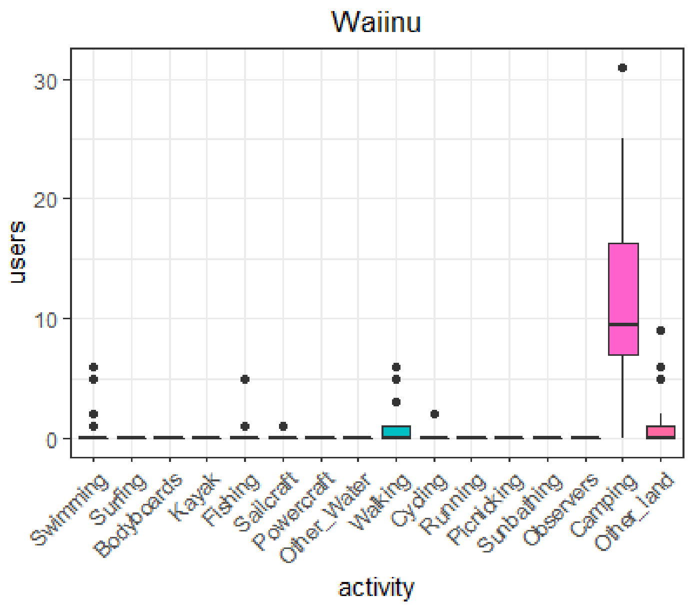



## Stoney River (at Upper Kaihihi Rd)

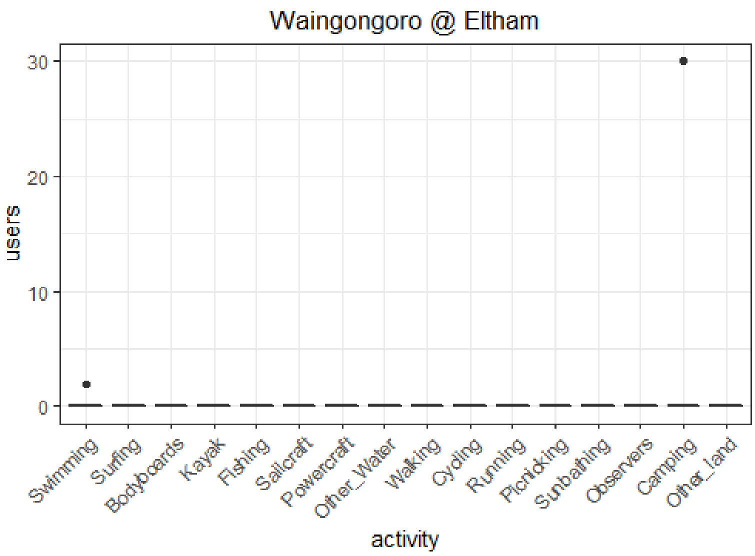



## Waiinu



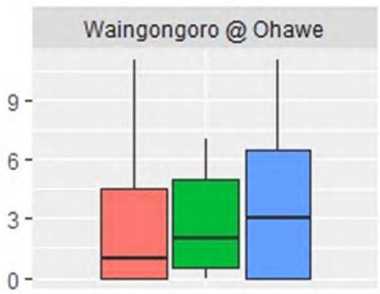



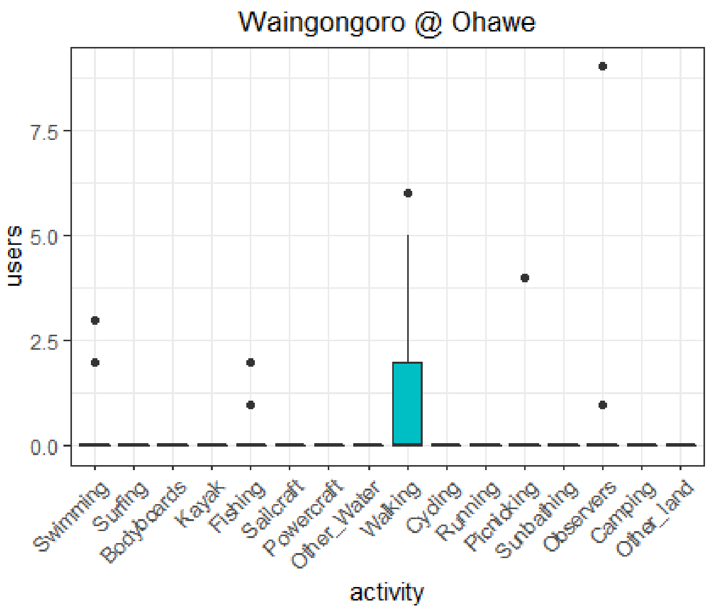
## Waingongoro River (at Eltham, EPC)



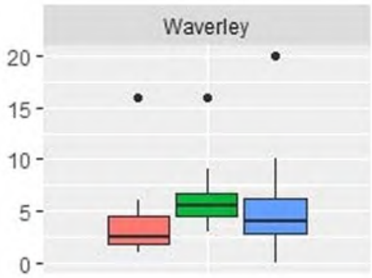

Note that access to this site was severely restricted, with the camp gate being closed on most count surveys. There were only two instances when users were found to be using this site.

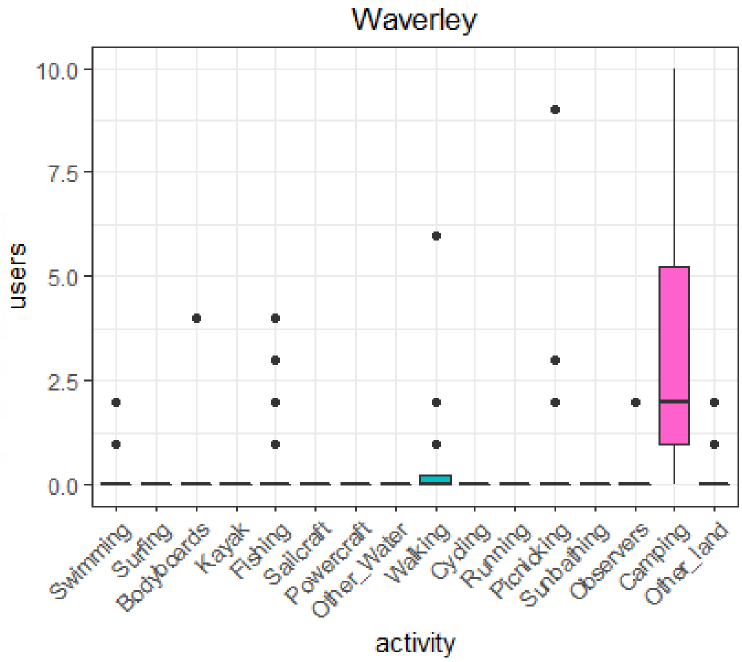
## Waingongoro River (at mouth, Ohawe)



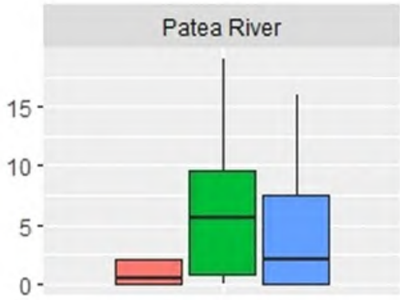
## Waverley (Long and Cave Beaches)

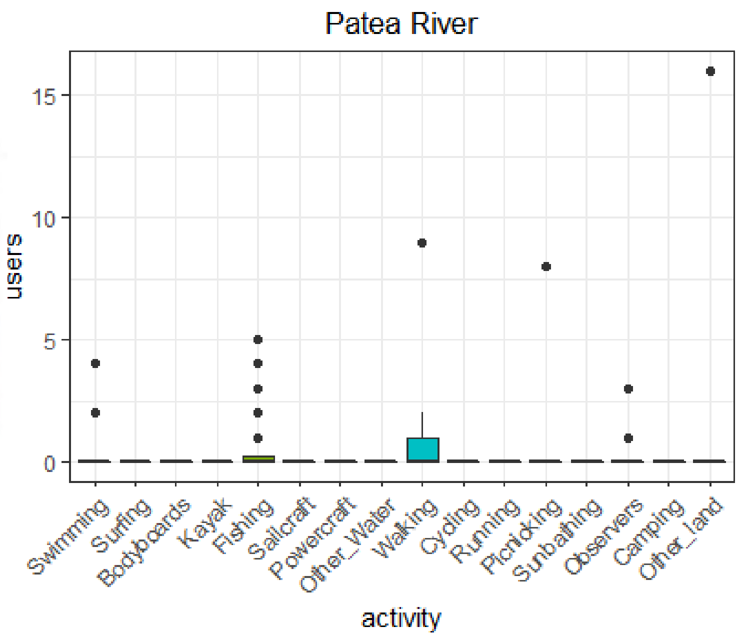


## Stratford District

### Patea River (at the Scout Hall, Stratford)



# Appendix VI

# Comparison of popularity of activities between 2007 and 2019 recreational questionnaires

Table 1 Most popular activities undertaken at beaches, from questionnaire respondents, 2007 and 2019

| Beach Activities | % respondents 2019 | rank 2019 | rank 2007 |
|---|---|---|---|
| Walking | 31.2 | 1 | 1 |
| Swimming | 28.3 | 2 | 2 |
| Surfing | 9.1 | 3 | 9 |
| Relaxing | 6.9 | 4 | 3 |
| Other | 6.1 | 5 | |
| Scenic appreciation | 5.3 | 6 | 6 |
| Fishing | 3.0 | 7 | 4 |
| Camping | 1.6 | 8 | 10 |
| Picnic/BBQ | 1.4 | 9 | 5 |
| Jogging | 1.2 | 10 | 11 |
| Cycling | 1.0 | 11 | 18 |
| Paddle boarding | 1.0 | 11 | |
| Boating | 0.8 | 13 | 16 |
| Kayaking/Canoeing | 0.6 | 14 | 13 |
| Snorkeling/ Diving | 0.6 | 14 | |
| Driving for pleasure | 0.4 | 16 | 7 |
| Sailing | 0.4 | 16 | 15 |
| Kite surfing | 0.2 | 18 | |
| Rafting | 0.2 | 18 | |
| Shellfish gathering | 0.2 | 18 | 14 |
| Spectating | 0.2 | 18 | 8 |
| Waka Ama | 0.2 | 18 | |
| Wind surfing | 0.2 | 18 | 16 |

Table 2 Most popular activities undertaken at rivers, from questionnaire respondents, 2007 and 2019

| Rivers | % respondents 2019 | rank 2019 | rank 2007 |
|---|---|---|---|
| Walking | 31.4 | 1 | 1 |
| Swimming | 25.7 | 2 | 2 |
| Scenic appreciation | 8.6 | 3 | 4 |
| Other | 6.2 | 4 | |
| Kayaking/Canoeing | 3.7 | 5 | 16 |
| Relaxing | 3.7 | 6 | 3 |
| Cycling | 3.5 | 7 | |
| Whitebaiting | 3.3 | 8 | 7 |
| Jogging | 3.1 | 9 | 12 |
| Fishing | 2.7 | 10 | 6 |

| | | | |
|---|---|---|---|
| Picnic/BBQ | 2.7 | 10 | 5 |
| Camping | 1.0 | 12 | 10 |
| Jetskiing | 1.0 | 12 | |
| Boating | 0.8 | 13 | 9 |
| Rafting | 0.6 | 14 | 15 |
| Spectating | 0.6 | 14 | 8 |
| Waka Ama | 0.6 | 14 | |
| Water skiing | 0.4 | 17 | 14 |
| Paddle boarding | 0.2 | 18 | |
| Surfing | 0.2 | 18 | |

Table 3 Most popular activities undertaken at lakes, from questionnaire respondents, 2007 and 2019

| Lake | % respondents 2019 | rank 2019 | rank 2007 |
|---|---|---|---|
| Walking | 41.3 | 1 | 1 |
| Scenic appreciation | 14.7 | 2 | 3 |
| Other | 9.3 | 3 | |
| Jogging | 5.2 | 4 | 10 |
| Cycling | 5.0 | 5 | |
| Picnic/BBQ | 3.6 | 6 | 5 |
| Swimming | 3.6 | 6 | 4 |
| Boating | 2.9 | 8 | 8 |
| Jetskiing | 2.7 | 9 | 10 |
| Relaxing | 2.7 | 9 | 2 |
| Water skiing | 2.7 | 9 | 9 |
| Kayaking/Canoeing | 1.8 | 12 | 10 |
| Camping | 1.4 | 13 | 14 |
| Fishing | 1.1 | 14 | 10 |
| Spectating | 0.9 | 15 | 6 |
| Paddle boarding | 0.7 | 16 | |
| Driving for pleasure | 0.5 | 17 | 7 |

MEMORANDUM
Policy & Planning

**Date** 23 November 2021

## Subject: Lake Rotorangi SEM Annual Monitoring Reports

**Approved by:** AJ Matthews, Director - Environment Quality

S J Ruru, Chief Executive

**Document:** 2912151

### Purpose

1. The purpose of this memorandum is to provide Council with a report on state and trends in water quality and ecosystem health for Lake Rotorangi.
2. A summary of report findings is provided, along with copies of two state of environment reports covering the 2019-2020 and 2020-2021 reporting periods. Copies of these reports are available on request, and will be made available via the Taranaki Regional Council (TRC) website.

### Executive summary

3. State of environment (SoE) monitoring provides robust information for a range of ecosystem health (biological) and water quality (physicochemical) indicators. One of the Council's SoE monitoring programmes measures the ecological health and water quality of Lake Rotorangi, as the region's largest lake. Data and information to assess the effects of consented activities is collected through a combination of TrustPower's consent monitoring requirements and Council's SoE monitoring programme.
4. The state of Lake Rotorangi is determined each year through water quality monitoring surveys carried out seasonally, and through phytoplankton, benthic invertebrate, and macrophyte (aquatic plants) surveys conducted at various intervals.
5. Analytical methods have changed from previous years. While this brings the analyses into line with current practices, it has resulted in changes to the terminology used and changes in reported trends for some parameters.
6. Based on these surveys and studies, the lake's condition continues to be classified as mildly eutrophic, with some deterioration showing in trophic level over the period 1996-2021, albeit at a low level of confidence. The deterioration is at a rate which is barely detectable however, if this trend continues, then in the very long term the lake's condition may continue to deteriorate. Phytoplankton densities remain low, restricted by lack of nutrients and by inflows (otherwise known as freshes), which shorten lake residence times and flush existing algal communities). Given the lake displays only

moderate levels of chlorophyll-*a*, significant deterioration in lake health is not anticipated.

7. Levels of service and targets pertaining to the maintenance and enhancement of overall water quality in the region's rivers and lakes are set out in Council's Long-term Plan (LTP). Targets include maintaining lake trophic state as it was in 1988 (mesotrophic/mildly eutrophic), and ensuring the current life-supporting capacity remains stable and healthy. Measures include both biological and water quality (physicochemical) parameters.
8. The Council continues to meet its LTP levels of service and targets in respect of Lake Rotorangi. Ongoing monitoring is necessary to keep a watching brief on changes in lake health and water quality, as well as continue to ensure compliance with resource consent conditions associated with the Pātea hydroelectric power scheme.
9. We recommend that the monitoring programme for this lake continues within minor modifications including:
   - the removal of the triennial benthic macroinvertebrate survey due to the negligible information obtained from this survey; and
   - a reduction in the frequency of technical reporting from annually to three-yearly given the insignificant changes in lake health detected between years.

   We note that monitoring data for Lake Rotorangi is readily available to the public via the Land, Air, Water Aotearoa (LAWA) website.
10. In recent years there has been an increasing interest in the state of freshwater. In addition to community interest in the health and wellbeing of New Zealand's rivers and streams, there has been an emerging focus on wetlands and lakes.
11. New requirements for lake monitoring and reporting were recently introduced through Government's *National Policy Statement for Freshwater Management 2020* (NPS-FM). The NPS-FM imposes a range of obligations upon councils in respect to water quality monitoring and in the assessment of monitoring data at regionally representative lakes. Lake Rotorangi is currently the only lake within the region with sufficient data to provide an assessment of current state against criteria set out in the NPS-FM. The overview of the results of this assessment are set out in this agenda memorandum.
12. Work is currently underway to establish a broader lakes monitoring programme to ensure Council is well placed to meet the new NPS-FM requirements. Council officers are currently working with local iwi/hapū and land owners to identify and access suitable lakes for inclusion within the programme. This includes giving consideration to a range of criteria such as lake type, size, and environmental pressures to provide a representative picture of lake health within the region, as well as practical considerations such as ongoing access and staff health and safety. Scoping of this programme is underway, with monitoring expected to commence in 2022-2023. A report on the new lakes programme will be presented to Council in due course.

## Recommendations

That the Taranaki Regional Council:

a) receives this memorandum noting the preparation of reports into the state of the water quality and biological programme of Lake Rotorangi as determined in monitoring during 2019-2020 and 2020-2021 and notes the specific recommendations therein.

b) notes that scoping of a state of environment lakes monitoring programme is underway, to align with NPS-FM requirements.

## Background

13. State of environment monitoring provides robust information on a range of ecosystem health (biological) and water quality (physicochemical) indicators. One of the Council's SoE monitoring programmes measures the ecological health and water quality of Lake Rotorangi, as the region's largest lake. Monitoring of the lake has been undertaken since its construction in 1984, with reporting to the Council since 1988.
14. Management of activities that affect lake health and quality is provided in part through conditions imposed within consents held by TrustPower. Data and information to assess the effects of consented activities is collected through a combination of TrustPower's consent monitoring requirements and Council's SoE monitoring programme.
15. Reporting was initially by way of consent compliance reporting, up until 2010-2011, with subsequent lake monitoring being reported as an SoE annual report, partially financed by TrustPower.
16. In addition to informing regional and national environmental reporting, these programmes can also provide an indication of the effectiveness of the Council's and wider community's interventions and resource management initiatives to address freshwater management issues in the region.
17. Council's '*Regional Freshwater Plan for Taranaki'* addresses lake and river water quality jointly as 'surface water' quality. Objectives include:
    - promoting the sustainable management of the surface waters of Taranaki while avoiding, remedying or mitigating any actual or potential adverse effects from the taking, use, damming or diversion of surface water; and
    - maintaining and enhancing the quality of the surface water resources of Taranaki by avoiding, remedying or mitigating the adverse effects of contaminants discharged to land and water from both point sources and diffuse sources.
18. Council's Long Term Plan 2018-2028 (LTP) at the time of reporting, included the measurement of physicochemical and biological parameters for quality of Lake Rotorangi. A specific target requires that the trophic state (an indication of the ecological condition as affected by nutrient enrichment) of Lake Rotorangi remains as it was in 1988 (mesotrophic/mildly eutrophic, or the middle category of trophic states). This is measured against a baseline whereby the current life-supporting capacity of the lake is stable and relatively healthy (better than almost 2/3 of lakes monitored nationally), and the state of lake remains at least mesotrophic/mildly eutrophic. This has since been superseded by the 2021-2031 LTP, with the target unchanged.

## Discussion

**State of Lake Rotorangi**

19. Staff have now reported the data for the 2019-2020 and 2020-2021 years, including an analysis of trends in the trophic state of the lake over the period 1996-2021. Two sites are monitored, L2 and L3. Site L2 is in the mid-reaches of the lake, near the Hawera Water Ski Club. Water quality at this site can at times show a strong riverine influence, especially when river flows have been recently elevated. Site L3 is situated near the

Patea dam and the water quality is much more typically lacustrine (lake-like) than at site L2.

20. Deep lakes (those deeper than 10 metres) are often stratified in summer, meaning environmental conditions such as temperature and dissolved oxygen level change over the depth of the water column. During the summer, warm water, which is less dense will sit on top (epilimnion) of colder, denser, deeper water (hypolimnion) separated by the thermocline (or metalimnion).

21. As summer proceeds, dissolved oxygen in the hypolimnion can decrease. Water below the thermocline fails to circulate to the surface and re-aerate, while organisms and the decay of organic matter in the bottom waters deplete the available oxygen. Lakes can therefore become anoxic in their bottom waters as a result of these processes. As winter approaches, the temperature of the surface water will drop. A point is reached where the density of the cooling surface water becomes greater than the density of the deep water, then the different layers will start to mix (overturn) as the dense surface water moves down under the influence of gravity.

22. Changes in thermal stratification in Lake Rotorangi during the year were largely similar to that typically recorded in previous surveys of this reservoir-type lake. Thermal stratification was beginning to form at both sites during the spring surveys, and was typically well developed during late summer - autumn at both the mid and lower lake sites, with dissolved oxygen depletion evident in the lower waters of the hypolimnion at both sites. Partial overturn was apparent at both sites by mid-winter (a degree of re-oxygenation was evident).

23. The process of overturn re-oxygenates the deeper parts of the lake (eg down to 25 metres), and also brings minor amounts of phosphorus solubilised from sediment under anaerobic conditions to the surface in late winter, potentially promoting algal growth in spring-summer. Despite nutrient enrichment in the lake, phytoplankton abundances were low to moderate, coincident with low chlorophyll-*a* levels. On the other hand, phytoplankton diversity was higher than usual. The main limiting factors for proliferation of communities within the lake is likely to be plant nutrient availability and frequency of river freshes. Previous studies have concluded that low levels of dissolved reactive phosphorus and ammonia indicated a relative lack of nutrient release under anoxic conditions, consistent with lakebed sediment not yet contaminated with high nutrient levels.

24. As has also been the case in previous years, there were no phytoplankton blooms in the lake during the period under review. Phytoplankton community composition tends to reflect environmental conditions prevailing at the time of each survey, rather than showing any long-term trends. Algal blooms tend to be opportunistic and short-lived. With the exception of the spring 2020 sample, species diversity (taxa richness) at both sites was substantially higher than average. Despite this higher than usual diversity, chlorophyll-*a* concentrations were within a relatively low and small range. This indicates that although there was increased diversity, there were not particularly high abundances of taxa present.

25. An aquatic macrophyte survey was conducted in April 2021. The invasive weed hornwort (*Ceratophyllum demersum*) continues to spread, but does not yet dominate the upper reaches.

26. The lake biologically continues to exhibit conditions around the boundary of mesotrophic and eutrophic. To date, the lake has not become eutrophic as was originally

predicted during the process associated with granting the original water rights (consents). This is in spite of high turbidity (due to river silt) and associated elevated nutrients. Nutrient data surveyed during the period under review were within ranges recorded since 1996 for all sites. Total phosphorus has shown increasing concentrations, while total nitrogen has shown decreasing concentrations; both trends are detected with high confidence.

27. Therefore the target set out in the Council's LTP is presently being maintained: *the trophic state (an indication of the ecological condition as affected by nutrient enrichment) of Lake Rotorangi to remain as it was in 1988 (mesotrophic/mildly eutrophic, or the middle category of trophic states*).

28. The baseline condition of Lake Rotorangi referenced in the LTP notes that from a national study in 2010 it was found that the lake was in better condition than almost 2/3 of lakes monitored nationally. More recently, an updated survey of the conditions of selected lakes nationwide has been undertaken (NIWA, 2018). The report does not provide a collective overview across all lakes, but does look at classes of lakes based on depth and altitude. Lake Rotorangi fits most closely into two low altitude classes, of lakes either 15-50 metres deep or greater than 50 metres deep. Within these two classes, Lake Rotorangi has typical to better than typical concentrations of phytoplankton (and much better than other lowland lakes); somewhat higher concentrations of ammonia and total nitrate; and typical concentrations of total phosphorus. Levels of turbidity are typical to above typical when compared to equivalent lakes. For total phosphorus, total nitrogen, and turbidity, Lake Rotorangi has much better results than shallower lowland lakes.

29. While these results would indicate that Lake Rotorangi is under slightly greater pressure when compared to lakes elsewhere, the fact that phytoplankton levels are lower than in other equivalent lakes indicates that such pressures are not driving the lake towards an excessively productive state. That said, it is important to maintain a watching brief on water quality and lake ecosystem to ensure there are no significant changes in the health of Lake Rotorangi over time.

30. Recommendations set out in the latest (2020-2021) report include:

    a) THAT the Lake Rotorangi physicochemical and biological water quality monitoring programme continue on an annual basis as a component of Council’s SoE monitoring programme, with every third year of the programme also undertaken in conjunction with the Patea Hydro Electric Power Scheme – aquatic monitoring plan (next in 2023-2024).

    b) THAT the triennial benthic macroinvertebrate survey be discontinued due to negligible value provided by the resulting data.

    c) THAT in future the Lake Rotorangi physicochemical and biological water quality monitoring programme is reported on a triennial basis, in the year in which the triennial biological components are undertaken (next in 2023-2024).

**Lake monitoring under the NPS-FM**

31. In August 2020, the Government released an "Essential Freshwater" reform package which included new regulations, national standards and the revised *National Policy Statement for Freshwater Management 2020* (NPS-FM). In addition to a range of policy requirements, regional councils are required to monitor water bodies and freshwater ecosystems that are representative of each Freshwater Management Unit (FMU), and take action if degradation is detected.

32. The NPS-FM sets out a framework for freshwater monitoring and reporting through the National Objectives Framework (NOF). This framework includes attribute tables for a range of indicators, which stipulate criteria against which lake water quality or ecosystem health must be measured and reported. Attributes specific to lakes include: phytoplankton (assessed by chlorophyll-*a* concentration); total nitrogen; total phosphorus; ammonia; *Escherichia coli (E. coli)*; cyanobacteria; submerged native plants; submerged invasive plants; lake-bottom dissolved oxygen; and mid-hypolimnetic dissolved oxygen.
33. Presently, Lake Rotorangi is the only lake in the Taranaki region monitored for state of environment purposes, though other lakes are monitored for specific water quality indicators, such as suitability for bathing. To ensure Council meets its requirements under the NPS-FM, work is now underway to establish a new lakes monitoring programme. This will include an expansion in the number of lakes monitored, and the type of monitoring undertaken. A programme is currently being scoped, and will be presented to Council in early-mid 2022, with the intention of commencing the new programme in the 2022-2023 reporting year.
34. Council will need to reassess its current approach to monitoring and reporting in relation to Lake Rotorangi, if this lake is to be included as part of the broader lakes monitoring programme. While the Lake Rotorangi monitoring programme for 2021-2022 is already underway, it is intended that this programme be assessed in line with the development of the new lakes monitoring programme. Any recommendations for changes to this programme will be made in consultation with TrustPower and Council's Consents team.
35. Lake Rotorangi water quality and ecosystem health data, where available, were assessed against NOF attribute criteria. While some attributes are unable to be assessed, a limited assessment showed that those attributes that are able to be assessed range from Band A to C, with the exception of low dissolved oxygen levels which fall within Band D.
36. A number of attributes have a prescribed minimum standard, referred to as the national bottom line. Councils and communities can choose to maintain or enhance freshwater bodies where they are better than (above) the national bottom line, but are required to improve water quality where they fall below the bottom line. An exception is where the state of an attribute is found to be due to naturally occurring processes (for example, elevated phosphorus due to naturally occurring volcanic soils and geology).
37. Different actions are required depending on the NOF attribute state of a particular waterbody. To maintain or improve water quality, certain attributes require limits to be set, while others require the development of action plans.
38. For lakes, attributes requiring limits include: phytoplankton; nutrients including total nitrogen and total phosphorus, and ammoniacal nitrogen as a measure of toxicity for aquatic species); bacteria as *E. coli* as a measure of the risk of *Campylobactor* infection and cyanobacteria (both assessing the suitability of a particular waterbody for human contact year-round.
39. Attributes requiring action plans for lakes include: submerged plants (both native and invasive species); lake-bottom and hypolimnetic dissolved oxygen (as indicators of the ability of a lake to sustain fish species); and bacteria as *E. coli* which applies only during the bathing season.
40. The following table presents monitoring data for Lake Rotorangi collected in 2019-2020 and 2020-2021, assessed against attribute criteria set out in the NOF. Where different

attribute states were determined across sites, or in different years, the poorer result is presented. A number of attributes, particularly those indicating lake ecosystem health and the suitability of the lake for human contact, will require additional data or alternative analyses to provide a full NOF assessment.

Table 1 NOF assessment for water quality and ecosystem health attributes monitored in Lake Rotorangi.

| Attribute | Unit | Attribute Band | Description |
|---|---|---|---|
| Ecosystem health (aquatic life) | | | |
| Phytoplankton (trophic state) | Annual median (mg chl-a/m³) | B | Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions |
| | Annual maximum (mg chl-a/m³) | B | |
| Submerged plants (natives) | Lake submerged plant (Native Condition Index % of maximum potential score) | NA | Insufficient data to assess this attribute |
| Submerged plants (invasive species) | Lake submerged plant (Invasive Impact Index% of maximum potential score) | NA | Insufficient data to assess this attribute however, available information suggests this may not achieve the national bottom line due to the presence of invasive species |
| Ecosystem health (water quality) | | | |
| Total nitrogen (trophic state) | Annual median (mg/m³) | C | Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions |
| Total phosphorus (trophic state) | Annual median (mg/m³) | C | Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions |
| Ammonia (toxicity) | Annual median (mg $NH_4$-N/L) | A | 99% species protection level: No observed effect on any species tested |
| | Annual maximum (mg $NH_4$-N/L) | B | 95% species protection level: Starts impacting occasionally on the 5% most sensitive species |
| Lake-bottom dissolved oxygen | Measured or estimated annual minimum (mm/L) | D | Likelihood from lake-bottom dissolved oxygen of biogeochemical conditions resulting in nutrient release from sediments |
| Mid-hypolimnetic dissolved oxygen in seasonally stratified lakes | Measured or estimated annual minimum (mm/L) | D | Significant stress on a range of fish species seeking thermal refuge in the hypolimnion. Likelihood of local extinctions offish species and loss of ecological integrity |
| Human contact | | | |
| Escherichia coli (E. coli) | % exceedances over 540/100mL (E. coli/100mL) | NA | There is presently insufficient data to assess E. coli. Sampling at the Pātea Dam commenced in 2020-2021 |
| | % exceedances over 260/100mL (E. coli/100mL) | NA | |
| | Median concentration/100mL (E. coli/100mL) | NA | |
| | 95th percentile of E. coli/100mL (E. coli/100mL) | NA | |
| Escherichia coli (E. coli) at primary contact sites (during the bathing season) | Number of E. coli per hundred millilitres (95th percentile of E. coli/100 mL) | NA | |
| Cyanobacteria (planktonic) | Biovolume – 80th percentile (mm³/L) | NA | Not currently assessed however data suggests that cyanobacteria are rarely present at Lake Rotorangi |

41. Lake processes are complex, and lake systems unique. As such, actions to improve lake health often need to be established for each lake individually. For Lake Rotorangi, in

addition to aligning the monitoring programme with the new NPS-FM requirements, there will also be a need to assess potential drivers of lake water quality. This will include whether naturally occurring processes and/or the actions of people are contributing to the health of Lake Rotorangi.

42. Where waterbodies are not achieving national minimum standards, action must be taken to address the issues identified. This may involve setting limits for certain activities or alternatively, lead to the development of an action plan. The Council's riparian and sustainable hill country programmes, together with recently tightened controls upon the discharge from the Stratford wastewater treatment plant and the Council's policy of diversion of dairy effluent discharges away from waterways, are examples of elements of an action plan that the NPS-FM might require to reduce current levels of inputs of nutrients and sediment to waterbodies in the region.

## Financial considerations—LTP/Annual Plan

43. This memorandum and the associated recommendations are consistent with the Council’s adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

## Policy considerations

44. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

## Iwi considerations

45. This memorandum and the associated recommendations are consistent with the Council’s policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

## Community considerations

46. This memorandum and the associated recommendations have considered the views of the community, interested and affected parties and those views have been recognised in the preparation of this memorandum.

## Legal considerations

47. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

## References

Larned S, Snelder T, Whitehead A, Fraser C. 2018. Water quality state and trends in New Zealand lakes Analyses of national data ending in 2017. NIWA report prepared for Ministry for the Environment, December 2018.

## Attachments

Document 2795799: *Lake Rotorangi State of the Environment Monitoring Annual Report 2019-2020.* Technical Report 2021-09.

Document 2886677: *Lake Rotorangi State of the Environment Monitoring Annual Report 2020-2021*. Technical Report 2021-63.

## National Objectives Framework (NOF) attribute assessment for Lake Rotorangi (2019/2020 and 2020/2021)

The following summary presents monitoring data for Lake Rotorangi collected in 2019-2020 and 2020-2021, assessed against attribute criteria set out in the NOF.

**Phytoplankton**: an ecosystem health (aquatic life) indicator used to express the degree to which lake ecological communities are expected to be impacted by algal and plant growth.

- There are two numeric attribute states for phytoplankton: an annual median (average) and annual maximum. The national bottom line is set at Band D, which is no greater than 12 mg chl-a/m$^3$ for the annual median and no greater than 60 mg chl-a/m$^3$ for the annual maximum.
- Two sites are monitored in Lake Rotorangi (sites L2 and L3). The median at site L2 during 2019-2020 was 3.6 mg chl-a/m$^3$, with a maximum of 10.7 mg chl-a/m$^3$, while at site L3 (near the dam) the median was 2.9 mg chl-a/m$^3$ and the maximum was 13.0 mg chl-a/m$^3$. In 2020-2021, the median at site L2 was 2.6 mg chl-a/m$^3$, with a maximum of 7.5 mg chl-a/m$^3$, while at site L3 the median was 2.3 mg chl-a/m$^3$, with a maximum of 4.4 mg chl-a/m$^3$.
- These results classify the lake as Band B. In 2019-2020, the annual maximum classifies both sites Band B, while the 2020-2021 results classifies both sites Band A.

**Total nitrogen**: an ecosystem health (water quality) indicator used to express the degree to which lake ecological communities are expected to be impacted by algal and plant growth as a result of nutrient levels.

- For seasonally stratified and brackish lakes, the national bottom line is set at Band D, which is no greater than 750 mg/m$^3$ for the annual median.
- In 2019-2020, the total nitrogen at site L2 had a median value of 605 mg/m$^3$. At site L3 the median value was 670 mg/m$^3$. In 2020-2021, the median values were 600 mg/m$^3$ and 730 mg/m$^3$ at sites L2 and L3 respectively.
- These results fall in the middle of Band C.

**Total phosphorus:** an ecosystem health (water quality) indicator used to express the degree to which lake ecological communities are expected to be impacted by algal and plant growth as a result of nutrient levels.

- For all lake types, the national bottom line is set at Band D, which is no greater than 50 mg/m$^3$ for the annual median.
- In 2019-2020, the total phosphorus at site L2 had a median value of 16 mg/m$^3$. At site L3 the median value was 10 mg/m$^3$. In 2020-2021 the median values were 23 mg/m$^3$ and 14 mg/m$^3$ at sites L2 and L3, respectively.
- In 2019-2020, these results would see the lake assigned Band B at site L2 and Band A at site L3. In 2020-2021, the lake would be assigned Band C at site L2, and Band B at site L3.

**Ammoniacal nitrogen:** an ecosystem health (water quality) indicator used to express the survival risk for aquatic species.

- The national bottom line is set at Band C, which is no greater than 0.24 g/m$^3$ for the annual median, and no greater than 0.40 g/m$^3$ for the annual maximum.

- In 2019-2020, site L2 had a median value of 0.016 g/m³ and a maximum value of 0.062 g/m³. Site L3 had a median value 0.005 g/m³ and a maximum value of 0.010 g/m³.In 2020-2021, the ammonia at site L2 had a median value of 0.011 g/m³ and a maximum of 0.062 g/m³. At site L3 the median value was 0.004 g/m³ and the maximum was 0.009 g/m³.
- Overall results would see the lake assigned to Band B at site L2 and Band A at site L3. All annual medians would class the lake Band A.

**Escherichia coli (E. coli)**: describes the risk of *Campylobactor* (bacterial) infection as a result of human contact with the lake.

- The suitability of lakes and rivers for human contact is determined through a range of criteria, with a waterbody's final grade based on the worst of the four results.
- Presently, there is insufficient data to assess this attribute for Lake Rotorangi. The action level for contact recreation was not reached in 2019-2020 or 2020-2021. Sampling at the Patea Dam commenced in 2020-2021 as a part of the Council's State of the Environment Contact Recreational Monitoring, and will be assessed and reported under that programme as the data becomes available.

**Cyanobacteria:** describes the human health risk of exposure to cyanobacteria (potentially toxic algae).

- Measured as the 80th percentile using at least 12 samples collected over 3 years. The national bottom line is set at Band D, which is no greater than 1.8 mm³/L of potentially toxic cyanobacteria, or no greater than 10 mm³/L total volume of all cyanobacteria.
- Council does not currently monitor specifically for cyanobacteria at Lake Rotorangi. Phytoplankton monitoring suggests that cyanobacteria are rarely present in Lake Rotorangi, and the phytoplankton densities are generally low. Cyanobacteria biovolumes will be calculated as necessary during phytoplankton sample processing.

**Submerged native plants**: native aquatic plant species are surveyed to assess the ecological condition of a lake, providing an indicator of ecosystem health (aquatic life).

- Surveys are required to be undertaken every three years. The national bottom line is set at Band D, which requires lakes achieve at least 20% of the maximum potential score for the Native Condition Index using the LakeSPI method.
- The last survey of the aquatic macrophytes in Lake Rotorangi was undertaken on 16 April 2021 and is described in the 2020-2021 annual report. The next macrophyte survey is due to be undertaken in autumn 2024.
- The current monitoring method does not enable the NOF submerged native plants attribute to be assessed, and will need to be reviewed prior to the next macrophyte survey (scheduled for autumn 2024). This review will need to give regard to both TrustPower consent requirements and NPS-FM monitoring requirements.

**Submerged invasive plants:** invasive aquatic plant species are surveyed to assess the ecological condition, providing an indicator of ecosystem health (aquatic life).

- The national bottom line is set at Band D, which requires lakes have no greater than 90% of the maximum potential score for the Invasive Impact Index using the LakeSPI method.

- The last survey of the aquatic macrophytes in Lake Rotorangi was performed on 16 April 2021, and is described in the 2020-2021 annual report. Surveys are now undertaken every three years.
- Available information suggests that lake may not meet the national bottom line, however the current methodology is inadequate to fully assess this attribute.
- Monitoring methodology will need to be reviewed prior to the next macrophyte survey (scheduled for autumn 2024). This review will need to give regard to both TrustPower consent requirements and NPS-FM monitoring requirements.

**Lake-bottom dissolved oxygen:** this attribute assesses the likelihood of lake-bottom dissolved oxygen causing biogeochemical conditions that result in nutrient release from lake sediments. It is measured near the base of the lake using either continuous monitoring sensors or discrete dissolved oxygen profiles.

- The national bottom line is set at Band D, which is no less than 0.5 $g/m^3$ (measured or estimated annual minimum) within 1 metre of the lake bottom.
- At both lake monitoring sites, dissolved oxygen concentrations fell below the national bottom line during periods of stratification, when oxygen consumed by either biological or chemical processes cannot be replaced due to thermal separation from the more oxygenated surface waters. This causes oxygen depletion in the hypolimnion unless re-mixing occurs, either as a result of natural overturn processes in winter or as a result of flood events in the river inflow. These results are typical of those recorded in Lake Rotorangi in the past 25 years.
- It is important to note that any lake supporting a healthy ecosystem will inevitably experience oxygen depletion during a period of thermal stratification. There is no quick or simple 'fix' to raising the lake-bottom oxygen levels under such conditions, as nutrient levels in the lake are by no means excessive to begin with.

**Mid-hypolimnetic dissolved oxygen:** this attribute assesses the level of stress on a range of fish species seeking thermal refuge in the hypolimnion.

- The national bottom line is set at Band D, which is no less than 4.0 $g/m^3$ (measured or estimated annual minimum).
- At both lake monitoring sites, mid-hypolimnetic concentrations of dissolved oxygen fell below the national bottom line seasonally during stratified periods. As with the lake-bottom dissolved oxygen limits, the NPS-FM requires that Council prepare an action plan to enhance dissolved oxygen levels in the lake.

## Technical Report 21-09 *Lake Rotorangi State of the Environment Monitoring Annual Report 2019-2020*

### Executive summary

Lake Rotorangi was formed in May 1984 by the construction of an earth fill dam on the Patea River for hydroelectric power generation. In recognition of both the regionally significant recreational resource created, and the considerable environmental impacts which might occur, a comprehensive monitoring programme was developed and implemented for the lake. This report presents the results of monitoring for the period July 2019-June 2020.

Four water quality surveys were undertaken at two sites during the period under review. One site is located in the mid reaches of the lake, while the second site is located nearer the dam.

Thermal stratification is when the upper and lower water columns separate into different layers within the lake. Processes occurring within these layers can cause substantial differences in water quality between the layers. Stratification was beginning to form in the spring survey, was fully developed in the late summer and early autumn surveys, and had overturned by the winter survey. Oxygen depletion was evident in the late summer and early autumn surveys, and persisted at the lower lake site during the winter survey despite uniform water temperatures throughout the water column. This pattern has been typical of Lake Rotorangi since monitoring began.

Physicochemical monitoring showed that lake water chemistry largely remained within the range which has been typical of the lake over the past 25 years. *E. coli* levels were within the 'surveillance' level (amber traffic light) under contact recreational guidelines for the entire period in the lower lake (site L3), and in the mid lake (site L2) in late summer and early autumn. In spring and winter the 'action' level (red traffic light) was reached at this site.

The trend analysis methodology implemented for this report has been updated from that used in previous years. This has resulted in changes to the results when compared to those previously reported. Increasing trends in chlorophyll-*a*, conductivity and total phosphorus were detected, while total nitrogen showed a decreasing trend for the period 1996-2020. When analysed over the most recent ten year period, decreasing trends in total phosphorus and chlorophyll-*a*, and an increasing trend in conductivity were detected.

National Objectives Framework (NOF) attributes for total nitrogen and phytoplankton classify the lake in the 'B' band, or as being slightly impacted compared to reference conditions, while total phosphorus concentrations classify the lake as being in the 'C' band, or moderately impacted compared to reference conditions.

The trophic state of the lake remains eutrophic, while on the basis of individual sites varies between eutrophic and mesotrophic and the L2 and L3 sites, respectively.

The monitoring of Lake Rotorangi will continue in its present format for the 2020-2021 monitoring year, with the inclusion of the triennial biological surveys for consent compliance purposes. This report also includes recommendations for the 2020-2021 monitoring year

### Recommendations

The following recommendations are based on the results of the 2019-2020 water quality and biological monitoring programmes and the contractual requirements of the resource consents held by Trustpower for the Patea Hydro Electric Power Scheme on Lake Rotorangi:

1. THAT Lake Rotorangi physicochemical and biological water quality monitoring continue on an annual basis as a component of the Council's State of the Environment monitoring programme, with every third year of the programme also undertaken in conjunction with the Patea Hydro Electric Power Scheme – aquatic monitoring plan (next in 2020-2021). Further, that the requisite macrophyte and benthic macroinvertebrate surveys be components of the 2020-2021 programme.
2. THAT the format and frequency of reporting of Lake Rotorangi physicochemical and biological monitoring be reviewed in the 2020-2021 year.

## Technical Report 21-63 *Lake Rotorangi State of the Environment Monitoring Annual Report 2020-2021*

### Executive summary

Lake Rotorangi was formed in May 1984 by the construction of an earth fill dam on the Patea River for hydroelectric power generation. In recognition of both the regionally significant recreational resource created, and the considerable environmental impacts which might occur, a comprehensive monitoring programme was developed and implemented for the lake. This report presents the results of monitoring for the period July 2020-June 2021.

Four water quality surveys were undertaken at two sites during the period under review. One site is located in the mid reaches of the lake, while the second site is located nearer the dam.

Thermal stratification is when the upper and lower water columns separate into different layers within the lake. Processes occurring within these layers can cause substantial differences in water quality between the layers. Stratification was beginning to form in the spring survey, was fully developed in the later summer and early autumn surveys, and had overturned by the winter survey. Oxygen depletion was evident in the late summer and early autumn surveys, and persisted at the lower lake site in the winter survey despite the uniform water temperatures throughout the water column. This pattern has been typical of Lake Rotorangi since monitoring began.

Physicochemical monitoring showed that lake water chemistry largely remained within the range which has been typical of the lake over the past 25 years. *E. coli* levels were within the 'surveillance' level (green traffic light) under contact recreational guidelines for the entire period in the lower lake (site L3), and in the mid lake (site L2) in late summer and early autumn, while in spring and winter the 'action' level (red traffic light) was reached at this site.

The trend analysis methodology implemented for this report was updated in the 2019-2020 period. This has resulted in changes to the results when compared to those previously reported. The methodology is briefly described in Section 2.4, with more detail provided in Appendix I.

Increasing trends in chlorophyll-*a*, conductivity and total phosphorus were detected, while total nitrogen showed a decreasing trend for the period 1996-2021. When analysed over the most recent ten year period, decreasing trends in dissolved reactive phosphorus, total phosphorus and chlorophyll-*a*, and an increasing trend in conductivity were detected.

National Objectives Framework (NOF) attributes for ammonia and phytoplankton classify the lake in the 'B' band, or as being slightly impacted compared to reference conditions, while total nitrogen concentrations classify the lake as being in the 'C' band, or moderately impacted compared to reference conditions. Total phosphorus classifies the upper lake as moderately impacted and the lower lake as mildly impacted.

The trophic state of the lake remains eutrophic, while on the basis of individual sites L2 is eutrophic and site L3 is mesotrophic.

The monitoring of Lake Rotorangi will continue in its present format for the 2021-2022 monitoring year, with the triennial biological monitoring next due for inclusion in the 2023-2024 year. This report also includes recommendations for the 2021-2022 monitoring year.

## Recommendations

The following recommendations are based on the results of the 2020-2021 water quality and biological monitoring programmes and the contractual requirements of the resource consents held by Trustpower for the Patea Hydro Electric Power Scheme on Lake Rotorangi:

3. THAT the Lake Rotorangi physicochemical and biological water quality monitoring programme continue on an annual basis as a component of Council's State of the Environment monitoring programme, with every third year of the programme also undertaken in conjunction with the Patea Hydro Electric Power Scheme – aquatic monitoring plan (next in 2023-2024).
4. THAT the triennial benthic macroinvertebrate survey be discontinued due to negligible value provided by the resulting data.
5. THAT in future the Lake Rotorangi physicochemical and biological water quality monitoring programme is reported on a triennial basis, in the year in which the triennial biological components are undertaken (next in 2023-2024).

# Lake Rotorangi

## State of the Environment Monitoring

## Annual Report

## 2019-2020

## Technical Report 2021-09

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2019-2020

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Physicochemical monitoring showed that lake water chemistry largely remained within the range which has been typical of the lake over the past 25 years. *Escherichia coli* (*E. coli)* levels were within the 'surveillance' level (amber traffic light) under contact recreational guidelines for the entire period in the lower lake (site L3), and in the mid lake (site L2) in late summer and early autumn. In spring and winter the 'action' level (red traffic light) was reached at this site.

The trend analysis methodology implemented for this report has been updated from that used in previous years. This has resulted in changes to the results when compared to those previously reported. Increasing trends in chlorophyll-a, conductivity and total phosphorus were detected, while total nitrogen showed a decreasing trend for the period 1996-2020. When analysed over the most recent ten year period, decreasing trends in total phosphorus and chlorophyll-a, and an increasing trend in conductivity were detected.

National Objectives Framework (NOF) attributes for total nitrogen and phytoplankton classify the lake in the 'B' band, or as being slightly impacted compared to reference conditions, while total phosphorus concentrations classify the lake as being in the 'C' band, or moderately impacted compared to reference conditions.

The trophic state of the lake remains eutrophic, while on the basis of individual sites varies between eutrophic and mesotrophic and the L2 and L3 sites, respectively.

The monitoring of Lake Rotorangi will continue in its present format for the 2020-2021 monitoring year, with the inclusion of the triennial biological surveys for consent compliance purposes. This report also includes recommendations for the 2020-2021 monitoring year.

# Table of contents

| | | | Page |
|---|---|---|---|
| 1 | | Introduction | 1 |
| | 1.1 | Background | 1 |
| | 1.2 | Lake Rotorangi | 1 |
| | | 1.2.1 Lake stratification processes | 2 |
| 2 | | Monitoring methodology | 3 |
| | 2.1 | Physicochemical monitoring | 5 |
| | 2.2 | Biological monitoring | 5 |
| | 2.3 | Trophic state | 5 |
| | 2.4 | Analysis | 6 |
| 3 | | Results | 8 |
| | 3.1 | General observations/hydrological conditions | 8 |
| | 3.2 | Physicochemical | 10 |
| | | 3.2.1 Stratification | 10 |
| | | 3.2.2 Water chemistry | 12 |
| | 3.3 | Biological | 20 |
| | | 3.3.1 Phytoplankton | 20 |
| | | 3.3.2 Benthic macroinvertebrates | 21 |
| | | 3.3.3 Macrophytes | 21 |
| | 3.4 | Trophic state | 22 |
| | 3.5 | Temporal trends | 23 |
| 4 | | Discussion | 29 |
| | 4.1 | Changes to data analysis from previous reporting | 30 |
| 5 | | Recommendations | 31 |
| Glossary of common terms and abbreviations | | | 32 |
| Bibliography and references | | | 34 |
| Appendix I | | Trend analysis methodology | |
| Appendix II | | Physicochemical Monitoring Results 2019-2020 | |
| Appendix III | | Trophic Level Index | |
| Appendix IV | | Trend plots for the period 1996-2020 | |
| Appendix V | | Trend plots for the period 2011-2020 | |

Appendix VI Comparison of trends reported using a significance based and a confidence based interpretation

Appendix VII Comparison of currently and previously reported trends

# List of tables

| | | |
|---|---|---|
| Table 1 | Monitoring site locations in Lake Rotorangi | 3 |
| Table 2 | Seasonal sampling and targeted stratification conditions | 3 |
| Table 3 | Physicochemical parameters monitored at each sampling depth in Lake Rotorangi | 5 |
| Table 4 | Confidence categorisation for trend direction results | 7 |
| Table 5 | Observations at Lake Rotorangi monitoring sites on sampling occasions during 2019-2020 | 8 |
| Table 6 | Trophic State of Lake Rotorangi based on total nitrogen and total phosphorus National Objective Framework attributes. (Note that units used in the NOF differ from the units primarily used throughout this report) | 17 |
| Table 7 | Phytoplankton attribute state of Lake Rotorangi under the National Objectives Framework. (Note that units used in the NOF differ from the units primarily used throughout this report) | 20 |
| Table 8 | Trophic level and values of key variables defining the trophic status* of Lake Rotorangi in 2019-2020. (Note that units used in the trophic level calculations differ from the units primarily used throughout this report) | 22 |
| Table 9 | Trend analysis of selected variables in Lake Rotorangi for the period 1996-2020. Trends of high confidence are identified in red (degrading trend) or blue (improving trend) | 24 |
| Table 10 | Trend analysis of selected variables for Lake Rotorangi over the most recent ten year period (2011-2020). Trends of high confidence are identified in red (degrading trend) or blue (improving trend) | 26 |

# List of figures

| | | |
|---|---|---|
| Figure 1 | Location of monitoring sites in Lake Rotorangi with inset showing the location and catchment of the lake. Sites L2 and L3 are currently monitored, while monitoring at Site L1 was discontinued in 2010 due to the predominantly riverine nature of the lake at this northern location | 4 |
| Figure 2 | Synthetic inflow at Lake Rotorangi for the period 1 July 2019 to 30 June 2020 | 9 |
| Figure 3 | Temperature (°C) and dissolved oxygen (g/m$^3$) profiles for sites L2 and L3 on sampling occasions in 2019 – 2020. Sampling depths are indicated by letters (E = epilimnion; H = hypolimnion; B = near benthos) | 11 |
| Figure 4 | Measures of visual clarity in Lake Rotorangi. Historical summary data for the period 1996-2019 is represented by boxplots, while the measurement recorded in the period under review is represented as a diamond | 12 |
| Figure 6 | Epilimnetic and hypolimnetic physicochemical parameters in Lake Rotorangi. Historical summary data for the period 1996-2019 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond | 13 |

| | | |
|---|---|---|
| Figure 5 | *E. coli* measured at the surface of Lake Rotorangi. Historical summary data for the period 1996-2019 is represented by boxplots, while the measurement recorded in the period under review is represented as a diamond. The red line indicates the threshold below which data is censored. Statistics below this threshold should be interpreted with caution. Black threshold lines represent guidelines for recreational use | 14 |
| Figure 7 | Epilimnetic and hypolimnetic nutrient concentrations at site L2 in Lake Rotorangi. Historical summary data for the period 1996-2019 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution | 15 |
| Figure 8 | Epilimnetic and hypolimnetic nutrient concentrations at site L3 in Lake Rotorangi. Historical summary data for the period 1996-2009 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution | 16 |
| Figure 9 | Selected parameters sampled in Lake Rotorangi in the hypolimnion and near the bottom of the water column at site L2. Historical summary data for the period 1996-2019 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution | 18 |
| Figure 10 | Selected parameters sampled in Lake Rotorangi in the hypolimnion and near the bottom of the water column at site L3. Historical summary data for the period 1996-2009 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution | 19 |
| Figure 11 | Seasonal chlorophyll-a concentrations in the photic zone of Lake Rotorangi. Historical summary data is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution | 20 |
| Figure 12 | Phytoplankton taxa richness at site L2 since 1989 | 21 |
| Figure 13 | Phytoplankton taxa richness at site L3 since 1989 | 21 |
| Figure 14 | Trophic level index in Lake Rotorangi over the period 1996-2020. The four components of the TLI (chlorophyll-a, secchi depth, total nitrogen and total phosphorus) are plotted individually, as well as the overall TLI. The trend shown relates to the overall TLI. The lowess curve for the overall TLI is in purple | 23 |

# 1 Introduction

## 1.1 Background

The *Resource Management Act 1991* (RMA) sets out requirements for local authorities to undertake environmental monitoring. Section 35 of the RMA requires local authorities to monitor, among other things, the state of the environment of their region or district, to the extent that is appropriate to enable them to effectively carry out their functions under the Act.

To this effect, the Taranaki Regional Council (Council) has established a state of the environment monitoring (SoE) programme for the region. This programme is outlined in the Council's 'State of the Environment Monitoring Procedures Document', which was prepared in 1997. The monitoring programme is based on the significant resource management issues that were identified in the *Council's Regional Policy Statement for Taranaki (1994)*.

Council's SoE programme encompasses a number of individual monitoring activities, many of which are undertaken and managed on an annual basis (from 1 July to 30 June). Where possible, individual consent monitoring programmes have been integrated within the SoE programme to save duplication of effort and minimise costs. The purpose of SoE reporting is to summarise and interpret regional environmental monitoring activity results and report on any changes (trends) in these data. These reports in turn provide key information for Council's five yearly regional state of environment report, which is due to be published in the first half of 2022. Copies of these reports are made available on Council's website.

## 1.2 Lake Rotorangi

Lake Rotorangi was formed in May 1984 by the construction of an earth fill dam on the Patea River for the purpose of a hydro-electric power scheme. An initial sampling programme was designed to assess the state and environmental consequences of the new lake. The results of this intensive monitoring programme were published in the 'Lake Rotorangi - Monitoring a New Hydro Lake' (Taranaki Catchment Board, 1988) report. Results of monitoring since this time are published in annual reports listed in the references of this report.

Early monitoring determined that the lake was mildly eutrophic or mesotrophic. Further, the annual thermal stratification cycle which the lake undergoes was identified as the single most important factor influencing water quality within the lake.

Since monitoring began, the trophic state of Lake Rotorangi has been increasing (degrading) at a very slow rate, in the order of 0.02±0.01 units per year. Initial monitoring showed the lake was in a mesotrophic state, and has over time moved to a mildly eutrophic state. Previous analysis has determined that the trophic level is heavily influenced by high turbidity values and therefore not a true indication of actual trophic status (as determined by primary production) of the lake (Burns 2006).

The appearance of Lake Rotorangi, its biological value, and its suitability for a range of recreational and commercial uses is directly related to lake water quality. Consequently, all lake management decisions and lake uses need to be undertaken in consideration of maintaining good lake water quality conditions.

The Patea catchment upstream of the dam covers an area of 86,944 ha. This includes both the Patea river sub-catchment and the Mangaehu River sub-catchment. Approximately 841 ha (1%) of this area is urban, while another 6,589 ha (8%) is conservation land. The remainder of the catchment (71,514 ha, 91%) is in pastoral land, with a mixture of dry stock and dairy farming in the catchment. Identifying and implementing actions to address hill country erosion is a significant focus for this catchment. Farm plans addressing land management and sediment issues currently cover around 48,210 ha (49%) of the catchment, primarily in the area where dry stock faming is the dominant land use.

### 1.2.1 Lake stratification processes

Thermal stratification is a seasonal process, which occurs when the upper water column near the surface warms much faster than the lower water column. Changes in the density of water at differing temperatures creates a physical barrier separating the upper water column (epilimnion) and lower water column (hypolimnion). Biological and chemical processes differ between the epilimnion and hypolimnion, causing substantial differences in water quality between the layers. In Lake Rotorangi, this process is one of the primary factors impacting observed water quality.

Typically, the epilimnion has the majority of primary production because light levels are highest in the upper water column. Organic detritus sinks from the epilimnion though the water column, resulting in the transfer of nutrients to the hypolimnion. Over time, the concentrations of bioavailable nutrients decreases in the epilimnion compared to the hypolimnion.

Oxygen depletion may occur in the hypolimnion, because oxygen consumed by biological and chemical processes cannot be replaced due to the physical separation from the more oxygenated surface waters. Replacement of oxygen in the hypolimnion results from mixing caused by either natural overturn processes or as a result of flood events in the river inflow.

Furthermore, as oxygen depletion occurs in the hypolimnion, this can in turn alter the pH of the hypolimnion. The increased pH in anoxic waters creates a risk of nutrient release from the lakebed sediment into the water column.

# 2 Monitoring methodology

The current Lake Rotorangi Monitoring programme consists of two primary components; physicochemical and biological monitoring. Sampling is undertaken at two sites along the lake, on four occasions each year. The sampling occasions are timed to target particular conditions with regard to stratification of the lake. Details of the sites are provided in Table 1 and Figure 1.

Table 1 Monitoring site locations in Lake Rotorangi

| Site code | Site | Location |
|---|---|---|
| LRT000300 | L2 (near Tangahoe Valley Road) | E1729856 N5626435 |
| LRT000450 | L3 (near Patea Dam) | E1734948 N5621974 |

The targeted conditions are described in Table 2. Sampling in the specified months is aimed to be undertaken on or near the 20th of the month. The dates sampled in the 2019-2020 year are also provided in Table 2.

Table 2 Seasonal sampling and targeted stratification conditions

| Season | Month | Target conditions | Sampling date |
|---|---|---|---|
| Spring | October | Pre-stratification | 17 October 2019 |
| Late Summer | February | Stable stratification | 19 February 2020 |
| Early Autumn | March | Pre-overturn | 19 March 2020 |
| Winter | June | Post-overturn | 23 June 2020 |

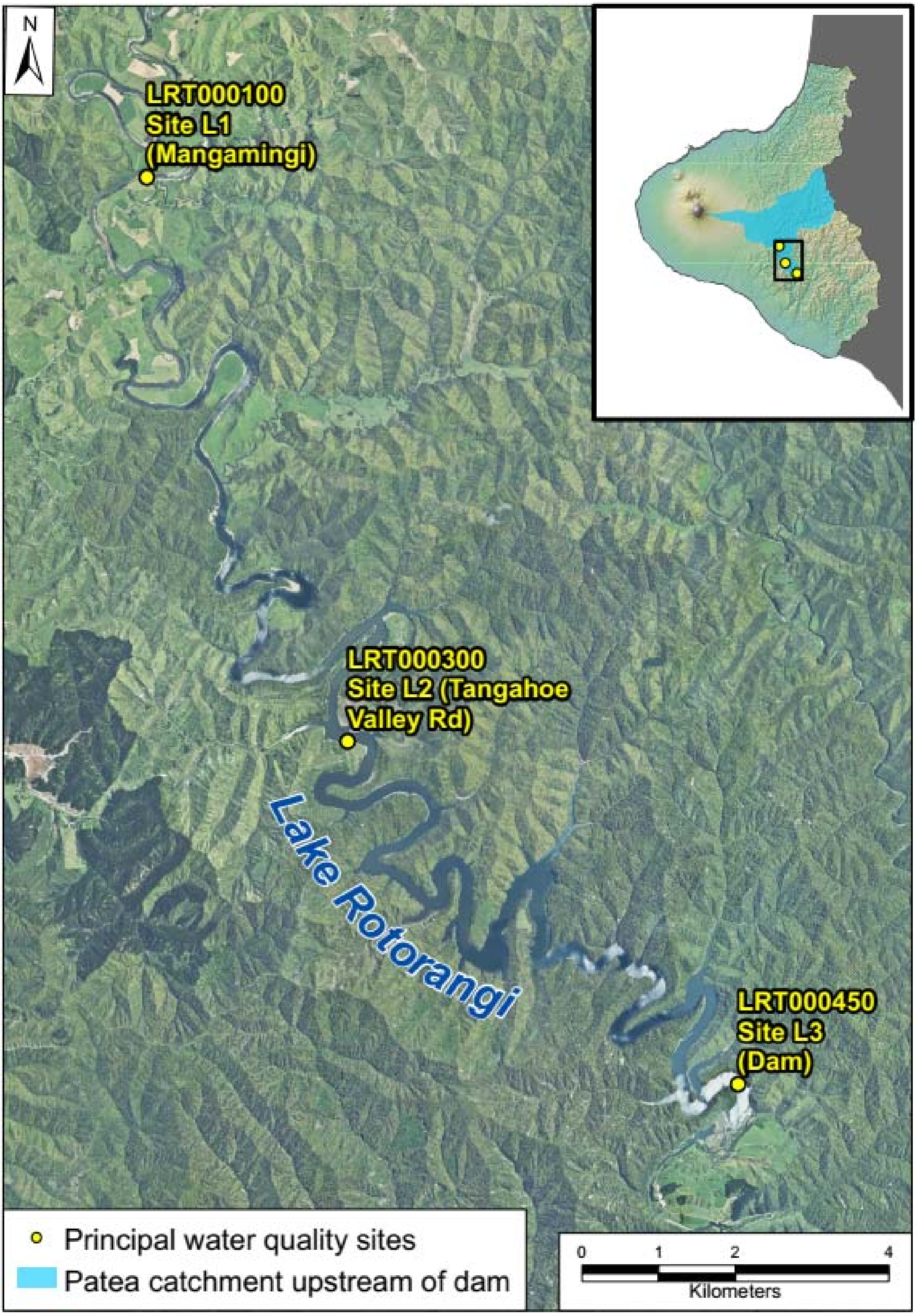


Figure 1 Location of monitoring sites in Lake Rotorangi with inset showing the location and catchment of the lake. Sites L2 and L3 are currently monitored, while monitoring at Site L1 was discontinued in 2010 due to the predominantly riverine nature of the lake at this northern location

## 2.1 Physicochemical monitoring

At each site a depth profile is collected measuring temperature and dissolved oxygen. On all sampling occasions, water samples are collected using a grab sample to reflect conditions at the surface, and using a van-Dorn sampler at points in the water column to represent conditions in the epilimnion and the hypolimnion. In February and March (under stratified conditions), additional water samples are collected near the base of the water column to assess the impact of anoxia at the sediment-water interface.

Table 3 Physicochemical parameters monitored at each sampling depth in Lake Rotorangi

| Parameter | Units | Surface | Epilimnion | Hypolimnion | Lower hypolimnion[1] |
|---|---|---|---|---|---|
| Black disc transparency | m | x | | | |
| Secchi disc transparency | m | x | | | |
| pH | pH units | x | x | x | x |
| Conductivity | µS/cm | x | x | x | |
| Turbidity | FNU | x | x | x | x |
| Suspended solids | $g\ m^{-3}$ | x | x | x | |
| *E. coli* | MPN/100mL | x | | | |
| Dissolved reactive phosphorus | $g\ m^{-3}$ P | | x | x | x |
| Total phosphorus | $g\ m^{-3}$ P | | x | x | x |
| Ammoniacal nitrogen | $g\ m^{-3}$ N | | x | x | x |
| Nitrite nitrogen | $g\ m^{-3}$ N | | x | x | |
| Nitrate nitrogen | $g\ m^{-3}$ N | | x | x | |
| Nitrate and nitrite nitrogen | $g\ m^{-3}$ N | | x | x | x |
| Total Kjeldahl nitrogen | $g\ m^{-3}$ N | | x | x | |
| Total nitrogen | $g\ m^{-3}$ N | | x | x | |

[1] Sampled in late summer and early autumn only

Samples are collected in accordance with the National Environmental Monitoring Standard (NEMS) for discrete lake water quality data (NEMS, 2019).

## 2.2 Biological monitoring

The upper part of the lake where light can penetrate is known as the photic zone. Sampling of the photic zone is undertaken in conjunction with physicochemical monitoring. A depth integrated sample is collected and analysed for chlorophyll-a, and a subsample used to identify the phytoplankton species present.

Every three years, a benthic macroinvertebrate sample is collected at each site in conjunction with the spring physicochemical monitoring. A macrophyte survey is also undertaken triennially in autumn. Both the benthic macroinvertebrate and the macrophyte survey are due to be completed in the 2020-2021 monitoring year.

## 2.3 Trophic state

The trophic level index (TLI) is calculated for the lake as a whole as well as for individual sites. The equations used vary from those used by Burns (1999), and are consistent with those used by Lakewatch (which was previously used to calculate the TLI). This change to the equation for secchi disc was made after removal of peat-stained lakes, and is appropriate for Lake Rotorangi which is not affected by peat.

Furthermore, following the Lakewatch methodology, the calculation of TLI is dependent on the stratification of the lake. Epilimnetic data is used during stratified periods, while both epilimnetic and hypolimnetic data is used when the lake is isothermal (defined as less than 3°C differences between the surface and lake bottom water temperature). In calculating the TLI, censored values have been treated as the detection limit. Annual average values of the four parameters used are calculated, and are then input into equations to calculate the four components of the TLI as follows:

$$TLc = 2.22 + 2.54 \log(Chla)$$
$$TLs = 5.56 + 2.60 \log((1/Secchi) - (1/40))$$
$$TLp = 0.218 + 2.92 \log(TP)$$
$$TLn = -3.61 + 3.01 \log(TN)$$

These four component values are then averaged to obtain the overall TLI.

It should be noted that in previous reports the TLI has been calculated per calendar year. In this report an adjustment has been made to this calculation, so that the analysis year is from July-June to align with the reporting period. Furthermore, this change aligns with the recommendation in Burns et al, (2000) and Schallenberg & van der Zon (2021) by ensuring that the calculation year includes an entire period of stratification. Although Burns et al, (2000) and Schallenberg & van der Zon (2021) recommend using a September to August calculation period to best align with the stratification cycle, in this instance the standardised sampling regime used in Lake Rotorangi does not include sampling between July-October. Because of this the calculation on the existing dataset will provide the same result whether the annual period starts in July or September.

## 2.4 Analysis

A number of changes to data analysis methodologies have been implemented in this report. A brief description of the current methods used is given below, with a more detailed discussion in Appendix I. A discussion of how these differ from methods used in previous TRC SoE lake reports is given in Section 4.1 and Appendix VII of this report.

In this report, trend analysis has been carried out using the LWP-Trends library R package (version 1901), developed by Land Water People (LWP) Ltd. (Snelder & Fraser, 2019). The methods employed have the primary purpose of establishing the direction and rate of any trend, along with a measure of the uncertainty in the result. The use of the LWP-Trends package represents a major change in trend analysis methodology compared to previous TRC Lake SoE reports, in part due to different methods used in the past, but also due to a recent conceptual shift in how to assess confidence in trend analysis results (Greenland et al. 2016, McBride 2019, Helsel et al. 2020).

The data is assessed using a Kruskal-Wallis test to determine whether the data is seasonal. Either a Mann-Kendall or seasonal Kendall test is used to determine the trend direction. A trend rate and confidence in the trend are also generated using a sen-slope regression. Censored data is handled using the methods of Helsel (2011). A note is included when this is affected by censored data, which generally indicates that the trend rate is smaller than can be detected. The confidence in the trend direction is assessed following the credible interval assessment method of McBride (2019). The confidence in the reported trend direction (ranging from 50% to 100%) is categorised based on the categories in Table 4.

Table 4 Confidence categorisation for trend direction results

| Confidence Category | Confidence in reported trend direction |
|---|---|
| Very Likely Improving | 90 – 100% |
| Likely Improving | 67 – 90% |
| Indeterminate | 50 – 67% |
| Likely Degrading | 67 – 90% |
| Very Likely Degrading | 90 – 100% |

The trend methods implemented are limited to identifying a single direction (monotonic) trend over time. In many cases, trend in environmental data may vary throughout the time series, due to changes in conditions or individual events resulting in changed trends. A Loess curve has been overlaid on the trend analysis to assist with assessment of non-monotonic trends and investigation into causes of any changes in trends. In addition, a comparison of long term (25 year) and short term (10 year) quantitative trends is undertaken.

In the case of parameters which are sampled at multiple depths within the lake, trend analysis has been carried out on the data from the epilimnion. Differences in the water chemistry between the epilimnion and hypolimnion during the stratified period mean that combining the data from both stratified layers may mask any trends present. For the analysis of the lake as a whole, results taken at different sites, within the same layer of the water column and on the same day, are averaged to provide a single result. These average values are analysed as described above. Both the use of epilimnion data and averaging across the whole lake are consistent with national reporting (Larned et al, 2015).

# 3 Results

## 3.1 General observations/hydrological conditions

Sampling was undertaken on the dates specified in Table 2. General observations made on each of the sampling occasions during the period under review are presented in Table 5.

Table 5 Observations at Lake Rotorangi monitoring sites on sampling occasions during 2019-2020

| Date | Lake level (m asl) | Weather | Wind | | Lake appearance | |
|---|---|---|---|---|---|---|
| | | | L2 | L3 | L2 | L3 |
| 17 October 2019 | 75.7 | Broken cloud, fine | Light NW | Moderate NW | Turbid, brown; surface rippled | Slightly turbid, dark green; surface rippled |
| 19 February 2020 | 77.3 | Overcast, drizzle; heavy rain preceding | Calm | Calm | Clear, dark green; surface flat | Clear, dark green; surface rippled |
| 19 March 2020 | 76.8 | Overcast, light rain | Light NW breeze | Calm | Clear, green-brown; surface rippled | Clear, brown-green; surface flat |
| 23 June 2020 | 77.0 | Foggy | Calm | Calm | Slightly turbid, brown; surface flat | Clear, brown-green; surface flat |

The synthetic inflow data for Lake Rotorangi is presented in Figure 2. This synthetic flow is the flow entering the head of the lake (at Mangamingi) and equates to flows from the Patea River and Mangaehu River catchments above Mangamingi.

The spring survey occurred under fresh recession inflow conditions following three moderate freshes in the preceding month. The late summer and early autumn surveys were carried out under steady baseflow conditions, with one minor fresh in the month preceding the late summer survey, and two moderate and two minor freshes in the month preceding the early autumn survey. The winter survey was performed under fresh recession inflow conditions, with three moderate and one minor fresh in the preceding month.

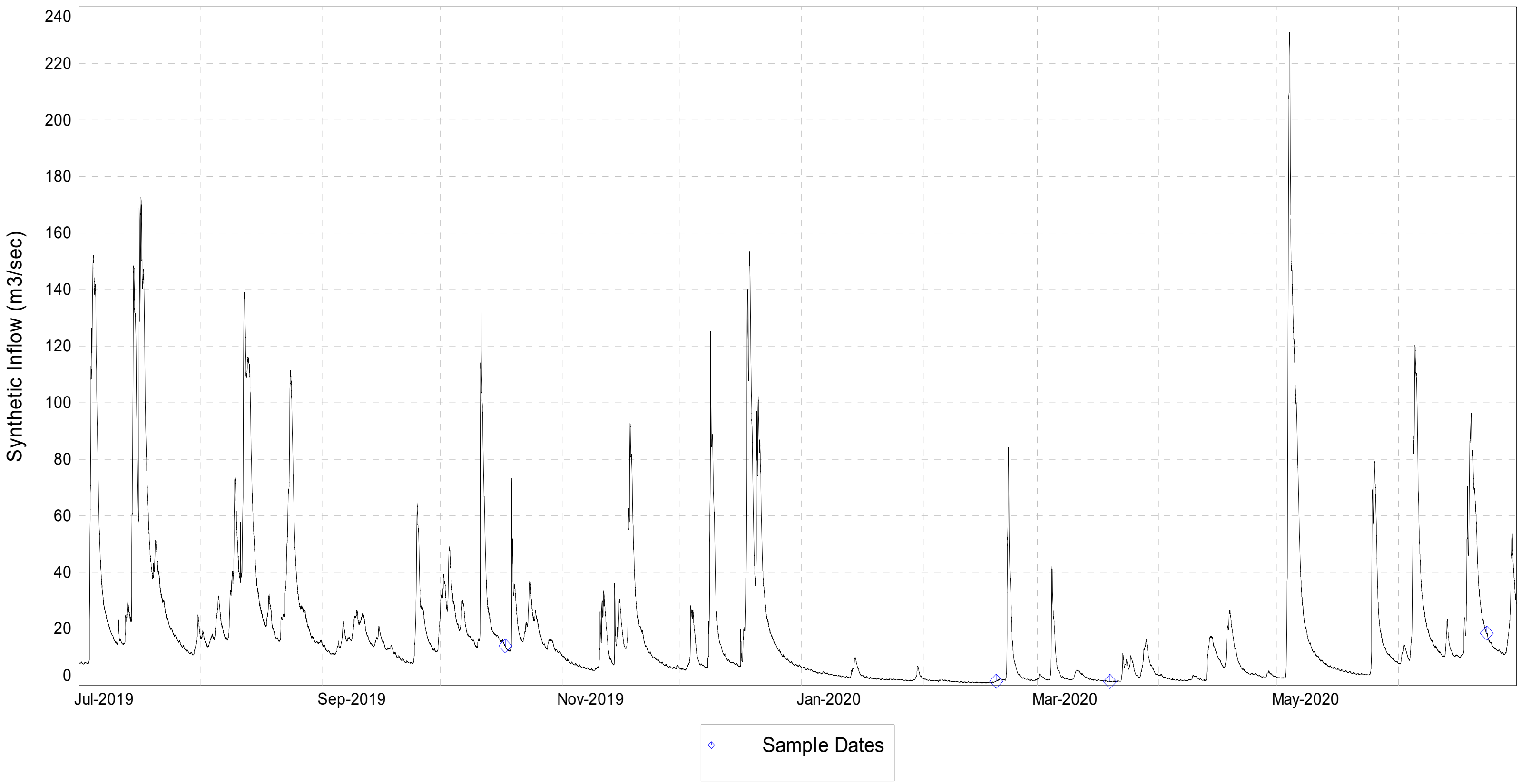


Figure 2 Synthetic inflow at Lake Rotorangi for the period 1 July 2019 to 30 June 2020

## 3.2 Physicochemical

Physicochemical monitoring data collected during the period under review are provided in full in Appendix II.

### 3.2.1 Stratification

Thermal stratification was weakly developed at both sites during October 2019 sampling, and was strongly developed during both the February and March 2020 sampling occasions. The lake was isothermal during June 2020. The thermocline was located at between 6 m and 12 m depth at site L2 on the sampling occasions, while at site L3 the thermocline location was between 5 m and 7 m below the surface (Figure 3).

Dissolved oxygen stratification was evident at site L3 on all sampling occasions, while at site L2 the dissolved oxygen stratification was strongly developed in February and March 2020 but less pronounced in October 2019 and June 2020 (Figure 3). This pattern of dissolved oxygen stratification persisting at site L3 has been typical of Lake Rotorangi in previous monitoring years and indicates that although temperatures are similar throughout the water column, vertical mixing of the water column was not complete.

Surface water temperatures were within the previously recorded ranges during 2019-2020, while water temperatures just above the lake bed were above median during this period.

Surface dissolved oxygen concentrations were within previously recorded ranges, with the exception of site L2 in the spring, where the recorded concentration of 8.1 g/m$^3$ was the lowest recorded since 1996. Dissolved oxygen concentrations in the water near the lake bed were generally low.

Anoxic conditions, when dissolved oxygen is less than 0.5 g/m$^3$, was observed in the hypolimnion at site L2, below 22 m in February and March 2020 and below 34 m in June 2020. At site L3 anoxia was recorded below 32 m during February and March 2020 and below 26 m in June 2020.

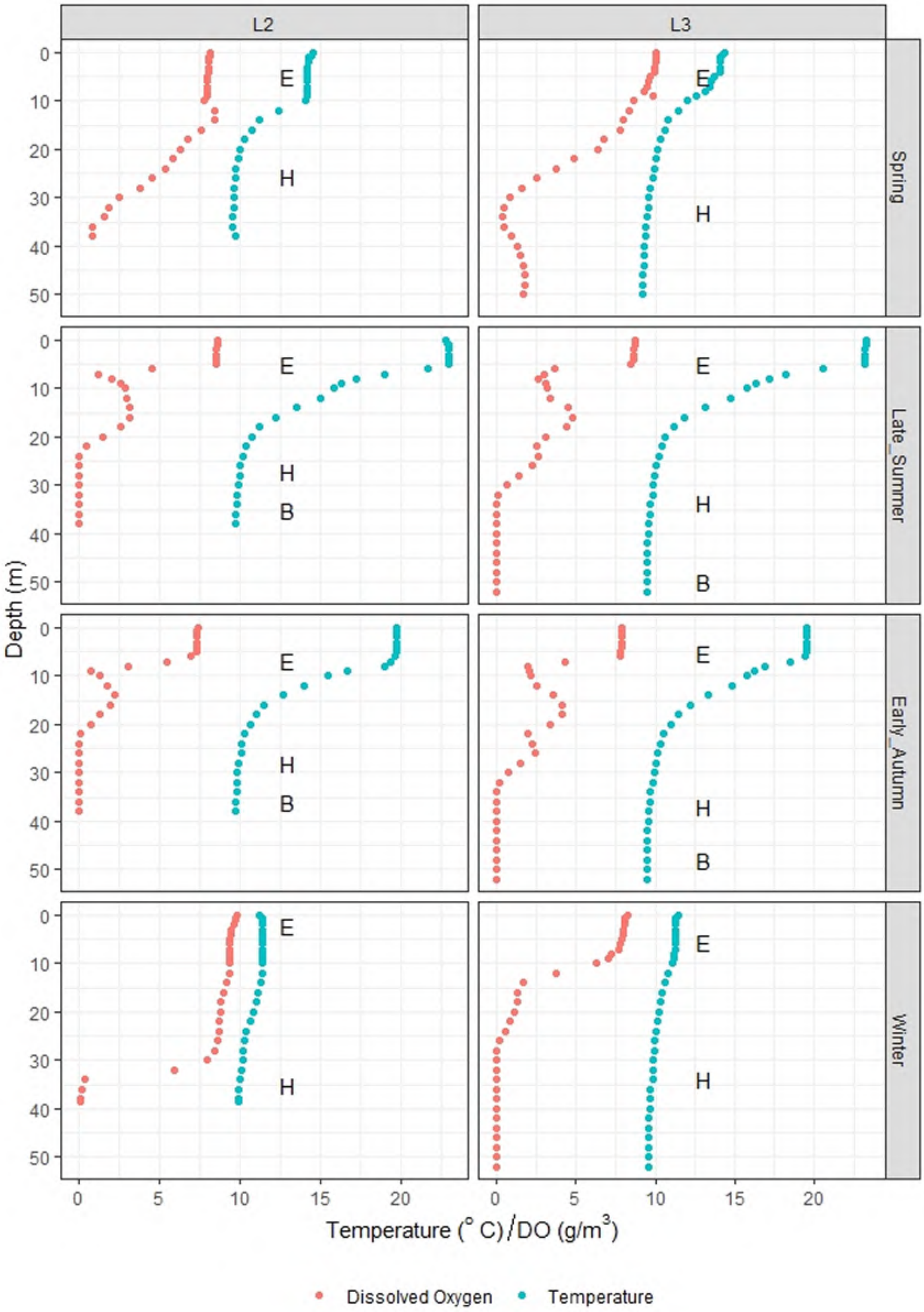


Figure 3 Temperature (°C) and dissolved oxygen (g/m³) profiles for sites L2 and L3 on sampling occasions in 2019 – 2020. Sampling depths are indicated by letters (E = epilimnion; H = hypolimnion; B = near benthos)

### 3.2.2 Water chemistry

Physicochemical monitoring results collected during the period under review are provided in full in Appendix II. Selected results and associated historical data for water clarity, conductivity, turbidity and suspended solids are discussed in more detail below.

Black disc measurements provide an estimate of horizontal water clarity, while secchi disc provides an estimate of vertical water clarity. Together, these measurements can be used to provide information on the penetration of diffuse light into the water column. As might be expected, there is a direct relationship between the two measurements, with the secchi disc greater than the black disc by a ratio of about 1.2:1 in Lake Rotorangi.

At site L2, black disc and secchi disc were greater than median values in late summer, and lower than median values for the remainder of the sampling occasions during the year. In contrast, site L3 recorded higher than median back disc and secchi disc in spring and early autumn, and lower than median concentrations in late summer in winter. Both black disc and secchi disc recorded a narrower range at site L3 compared to site L2 during the period under review.

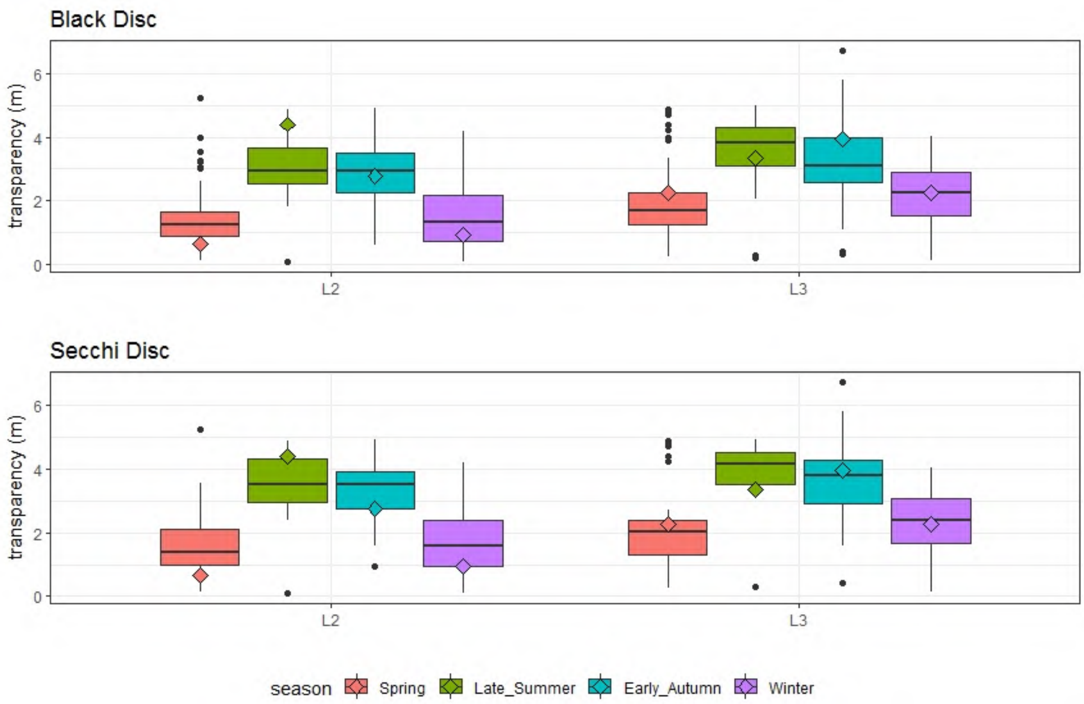


Figure 4 Measures of visual clarity in Lake Rotorangi. Historical summary data for the period 1996-2019 is represented by boxplots, while the measurement recorded in the period under review is represented as a diamond

Conductivity at site L2 was in the upper quartile of the previously recorded data at the surface and in the epilimnion during the late summer and early autumn (Figure 6). Site L3 recorded conductivity higher than median during the spring, late summer and early autumn sampling. The conductivity in the hypolimnion was in the upper quartile of the previously recorded range at both sites during all four sampling occasions.

Turbidity was slightly elevated at site L2 in spring, while the remainder of the sample results at both sites during the period under review were below or near to median results.

Suspended solids remained at low concentrations at both sites L2 and L3 throughout the period under review. It should be noted that the majority of suspended solids results during this period, including all results from L3, were below the detection limit of this test. Suspended solids data has not been presented in the body of this report due to the extremely high proportion of censored data for this parameter.

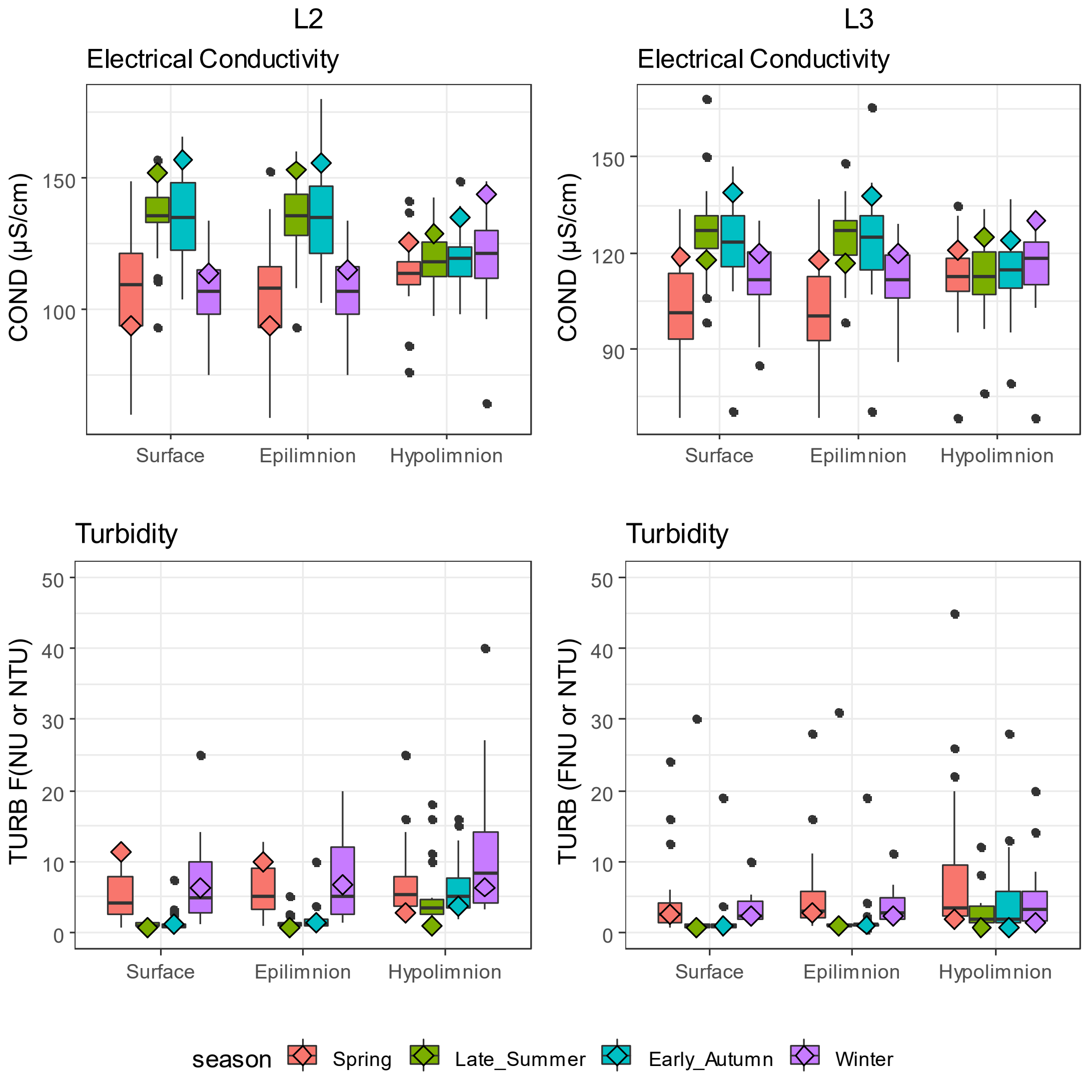


Figure 5 Epilimnetic and hypolimnetic physicochemical parameters in Lake Rotorangi. Historical summary data for the period 1996-2019 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond

### 3.2.2.1 Bacteria (*E. coli*)

In recognition of the recreational uses of Lake Rotorangi (mainly boating and waterskiing at site L2, but also at site L3; see Taranaki Regional Council, 2008a), samples taken at the surface are tested for *E. coli*. These results are presented in Figure 6. During the period under review, samples taken at site L2 reached the amber alert level for primary contact recreation in spring and winter (MfE, 2003), while site L3 had low levels of *E. coli* present, and was suitable for swimming and contact recreation on all occasions.

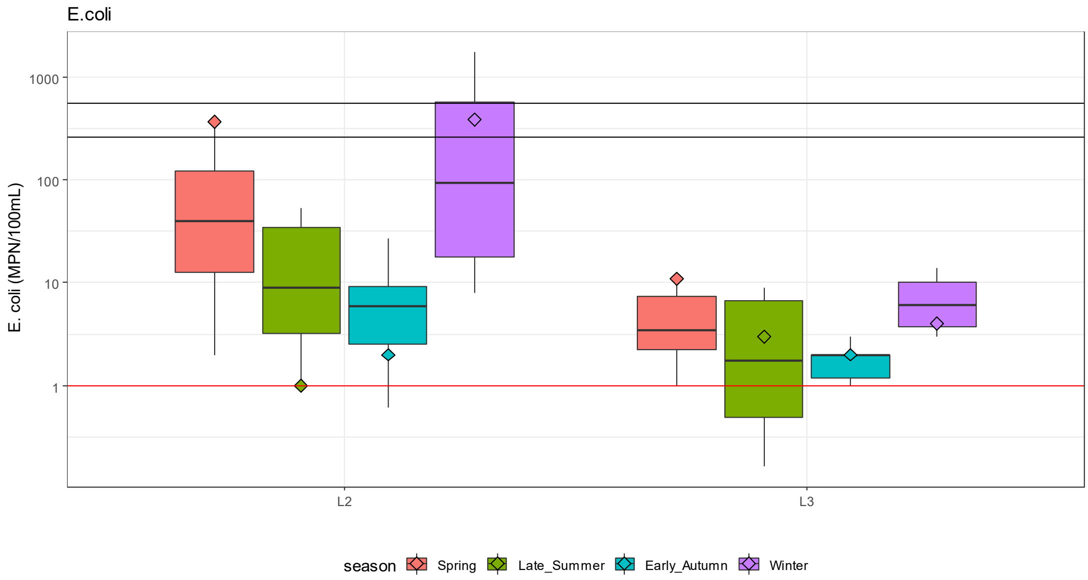


Figure 6 *E. coli* measured at the surface of Lake Rotorangi. Historical summary data for the period 1996-2019 is represented by boxplots, while the measurement recorded in the period under review is represented as a diamond. The red line indicates the threshold below which data is censored. Statistics below this threshold should be interpreted with caution. Black threshold lines represent guidelines for recreational use

### 3.2.2.2 Nutrients

Ammoniacal nitrogen was above detection limits at site L2 throughout the period under review, except in the hypolimnion in spring (Figure 7). Nitrate and total nitrogen in the hypolimnion were similar to or lower than typical, while in the epilimnion these parameters were generally within a typical range. Total phosphorus and total Kjeldahl nitrogen were also generally within a typical range, except in spring in the epilimnion when it was slightly elevated compared to typical results. Dissolved reactive phosphorus was also elevated slightly in this sample, while it was fairly typical in the epilimnion for the remainder of the period and showed more variability than typical in the hypolimnion.

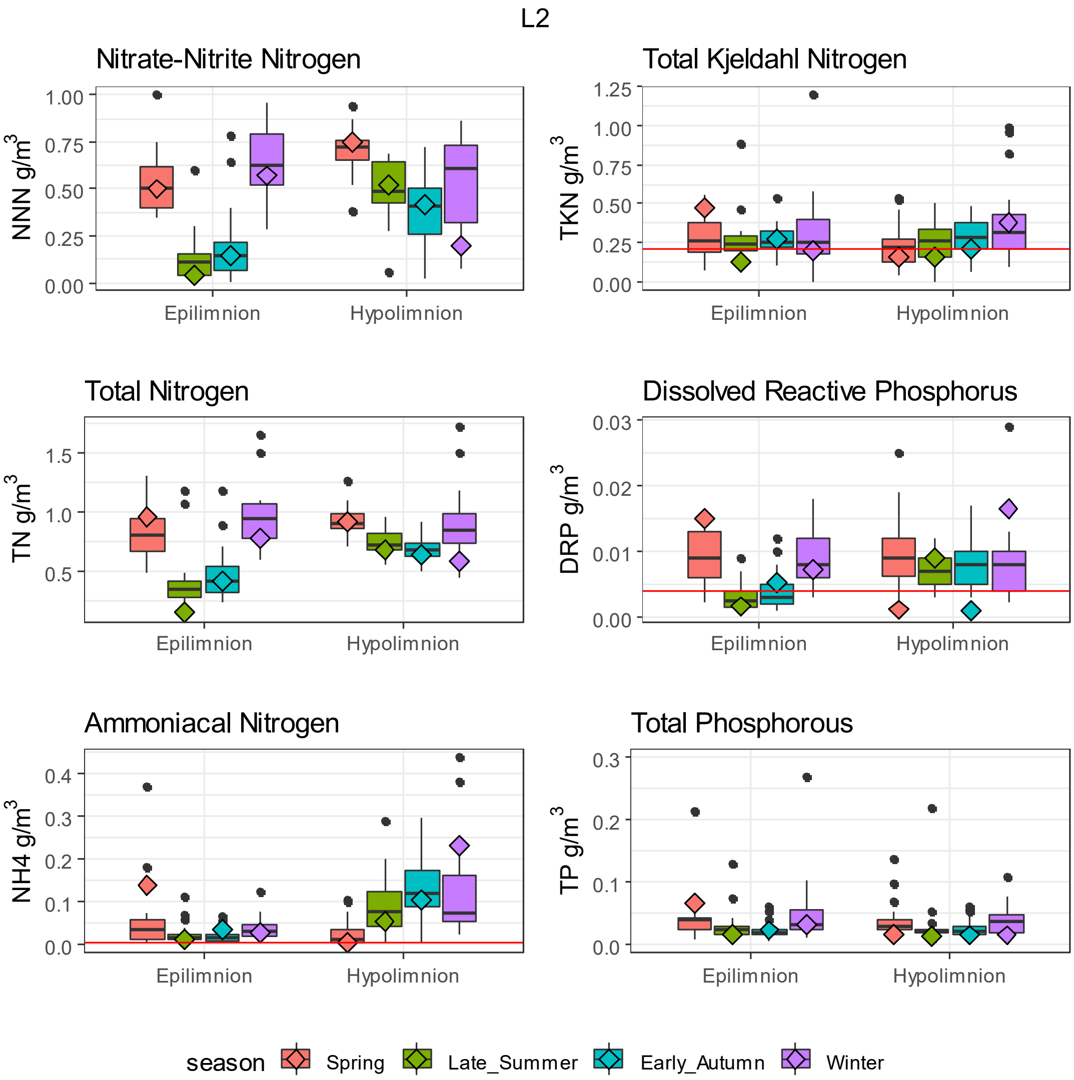


Figure 7 Epilimnetic and hypolimnetic nutrient concentrations at site L2 in Lake Rotorangi. Historical summary data for the period 1996-2019 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

Ammoniacal nitrogen at site L3 remained at low concentrations at or around the detection limit in both the epilimnion and hypolimnion (Figure 8). Nitrite nitrogen and dissolved reactive phosphorus concentrations also remained at the detection limit in the hypolimnion, while in the epilimnion nitrite concentrations were below medians throughout the period. Dissolved reactive phosphorus was below detection limits in the epilimnion at the time of the late summer and early autumn sampling (when the lake was stratified), while for the remainder of the year the concentrations remained at fairly typical levels. Total phosphorus and total Kjeldahl nitrogen remained at fairly typical concentration in both the epilimnion and hypoliminion during the period under review.

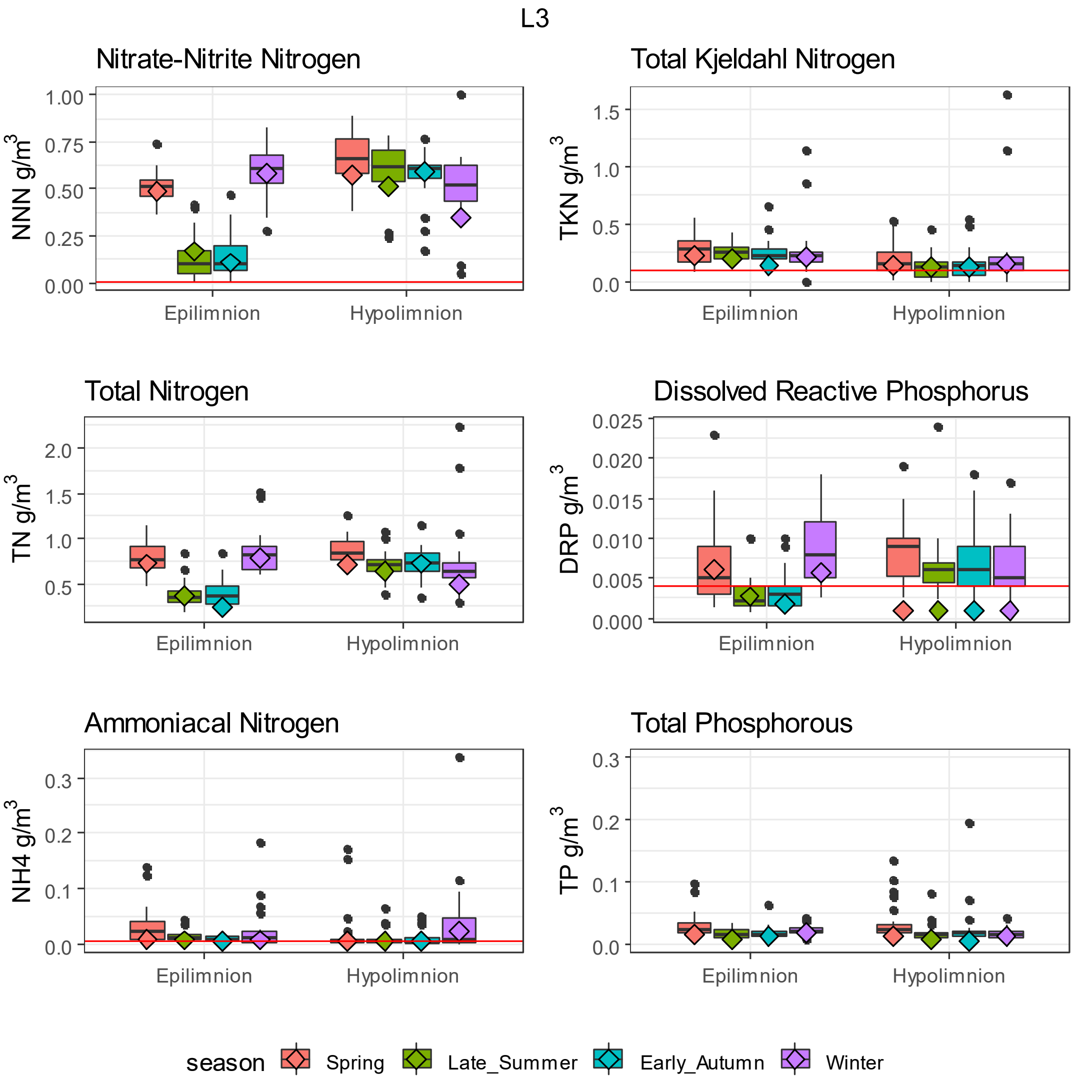


Figure 8 Epilimnetic and hypolimnetic nutrient concentrations at site L3 in Lake Rotorangi. Historical summary data for the period 1996-2009 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

The epilimnion recorded relatively low levels of bioavailable nutrients (nitrate and dissolved reactive phosphorus) at both sites L2 and L3 throughout the year. A marked decrease in nitrate and dissolved reactive phosphorus was evident during the stratified period at both sites (Figure 7 and Figure 8). This is typical for Lake Rotorangi and can most likely be attributed to uptake of nutrients by phytoplankton. The dead plant material then sinks into the hypolimnion, and nutrients in the epilimnion are not replenished until overturn occurs resulting in vertical mixing of the water column.

Assessment of total nitrogen and total phosphorus concentrations against the National Objectives Framework (NOF) numeric attribute state (New Zealand Government, 2017) places both sites in the C band for both nitrogen, while both sites sits within the B band for phosphorus (Table 6). It should be noted that Lake Rotorangi is a seasonally stratified lake. This assessment is based on data collected in the epilimnion.

Table 6 Trophic State of Lake Rotorangi based on total nitrogen and total phosphorus National Objective Framework attributes. (Note that units used in the NOF differ from the units primarily used throughout this report)

| Parameter | Site | Median (mg/m$^3$) | Band | Narrative Attribute State |
|---|---|---|---|---|
| Total Nitrogen | L2 | 605 | C | Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions |
| | L3 | 670 | C | Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions |
| Total Phosphorus | L2 | 15.5 | B | Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated above natural reference conditions |
| | L3 | 9.5 | B | Lake ecological communities are slightly impacted by additional algal and plant growth arising from nutrient levels that are elevated above natural reference conditions |

#### 3.2.2.2.1 Sediment/water interface

Anoxia in the lower hypolimnion means the biogeochemical conditions are likely to cause release of nutrients from lakebed sediment into water column during periods of stratification. In recognition of this, water samples taken for nutrients at bottom of water column during stratified periods since 1996. Over this time period, the data has shown a small increase in ammoniacal nitrogen and a very small decrease in nitrate nitrogen near the lakebed compared to in the hypolimnetic water column. This change may result from the reduction of nitrate to ammonia in the water column or the release of ammonia from anoxic sediments. At site L2 no change has been seen in phosphorus levels, while at site L3 an increase in total phosphorus has been observed near the lakebed, in conjunction with an increase in turbidity. This is likely related to disturbance of the lakebed during sampling rather than hypoxic nutrient release because no such increase in DRP is observed.

Anoxic conditions were present at both sites during the late summer and early autumn sampling in the hypolimnion as well as near the bottom of the water column. Ammonia concentrations at both sites L2 and L3 were elevated in the water column near the lakebed compared to higher in the hypolimnion (Figure 9 and Figure 10). At site L3 there was a noticeable decrease in nitrate lower in the water column. When considered in conjunction with the increase in ammonia, this indicates that reduction of nitrogen may be occurring in the anoxic conditions present. DRP concentrations remained largely similar, or were at lower concentrations, in the water column near the lakebed compared to higher in the hypolimnion. Both total phosphorus and turbidity were relatively low in the hypolimnion and near the lake bed at both sites.

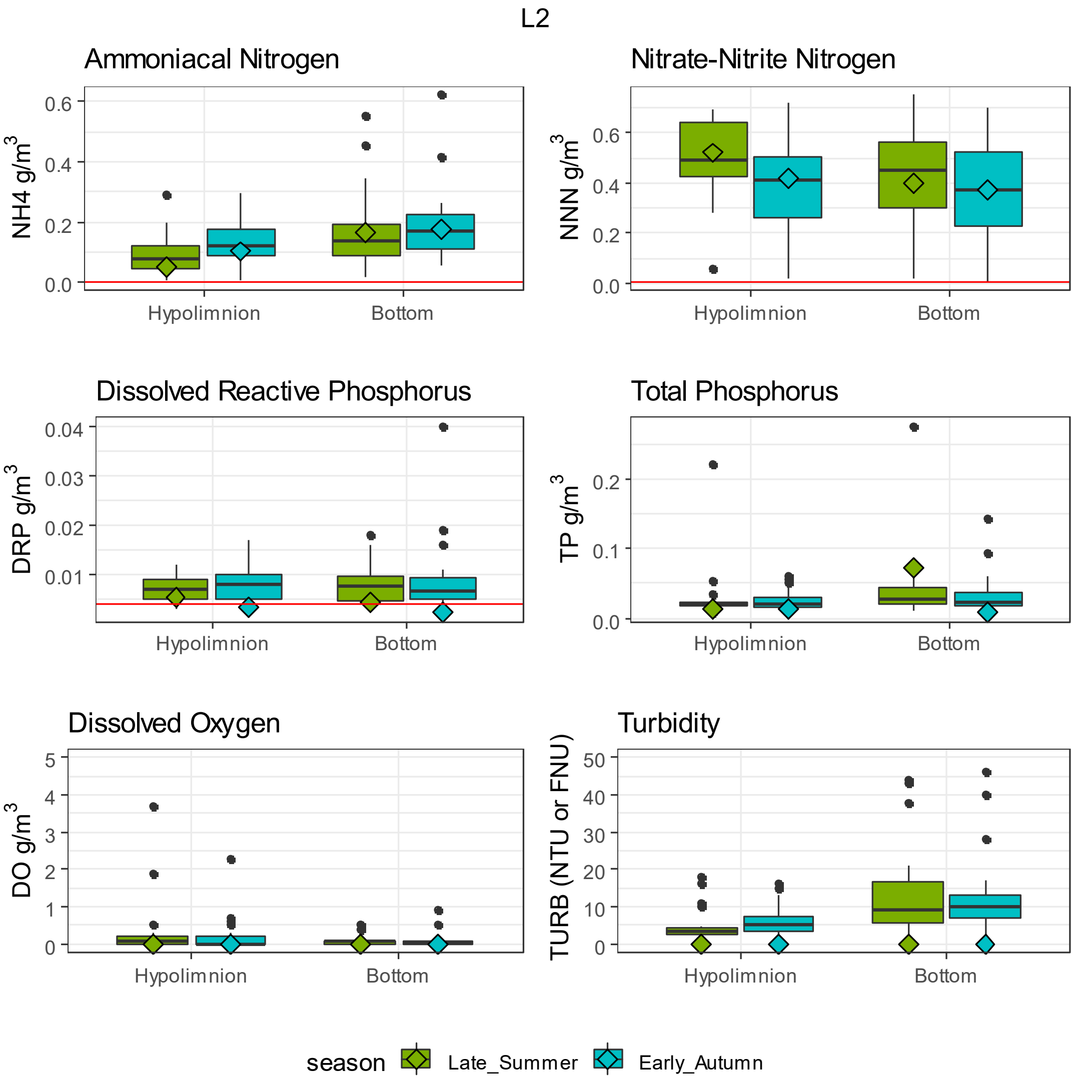


Figure 9 Selected parameters sampled in Lake Rotorangi in the hypolimnion and near the bottom of the water column at site L2. Historical summary data for the period 1996-2019 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

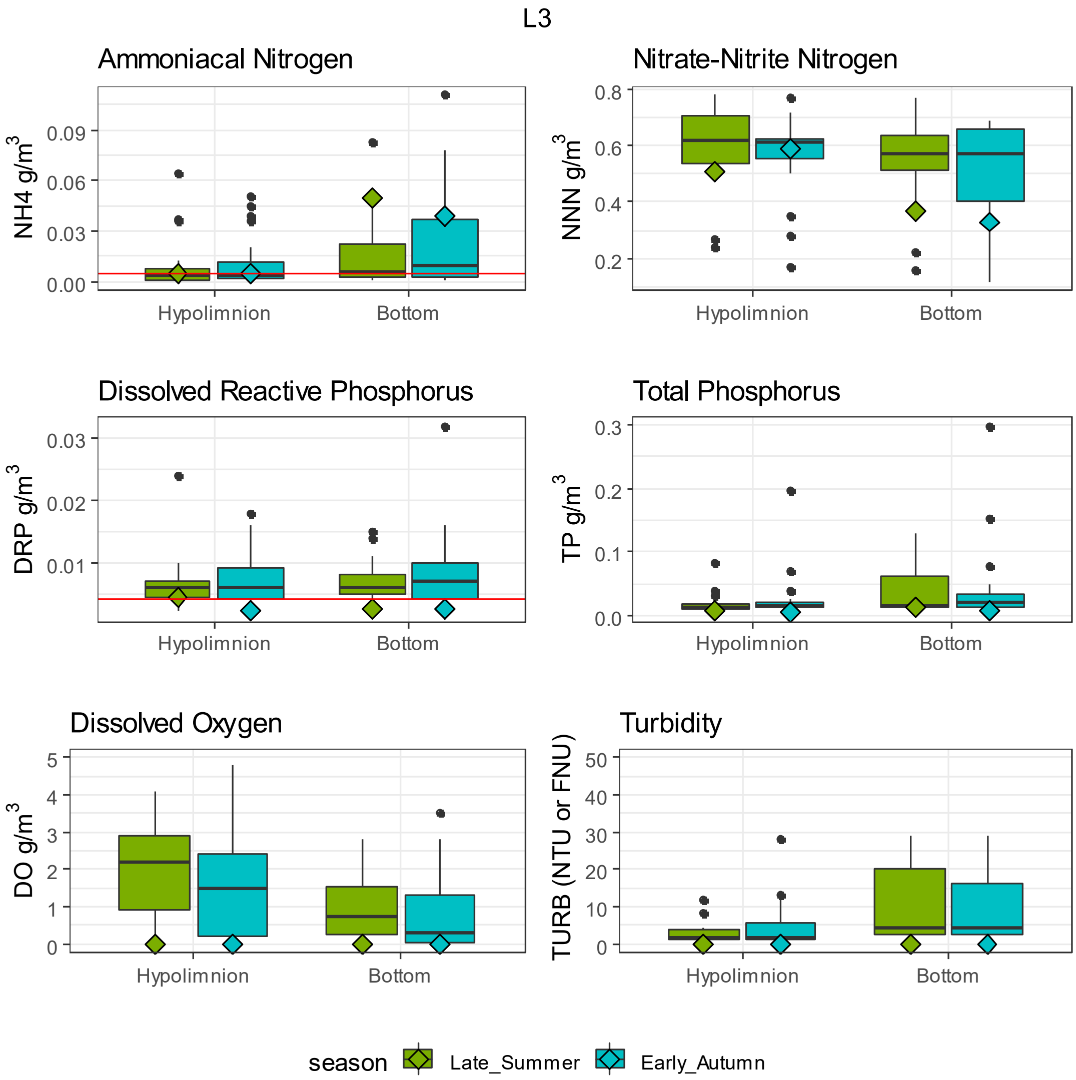


Figure 10 Selected parameters sampled in Lake Rotorangi in the hypolimnion and near the bottom of the water column at site L3. Historical summary data for the period 1996-2009 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

## 3.3 Biological

### 3.3.1 Phytoplankton

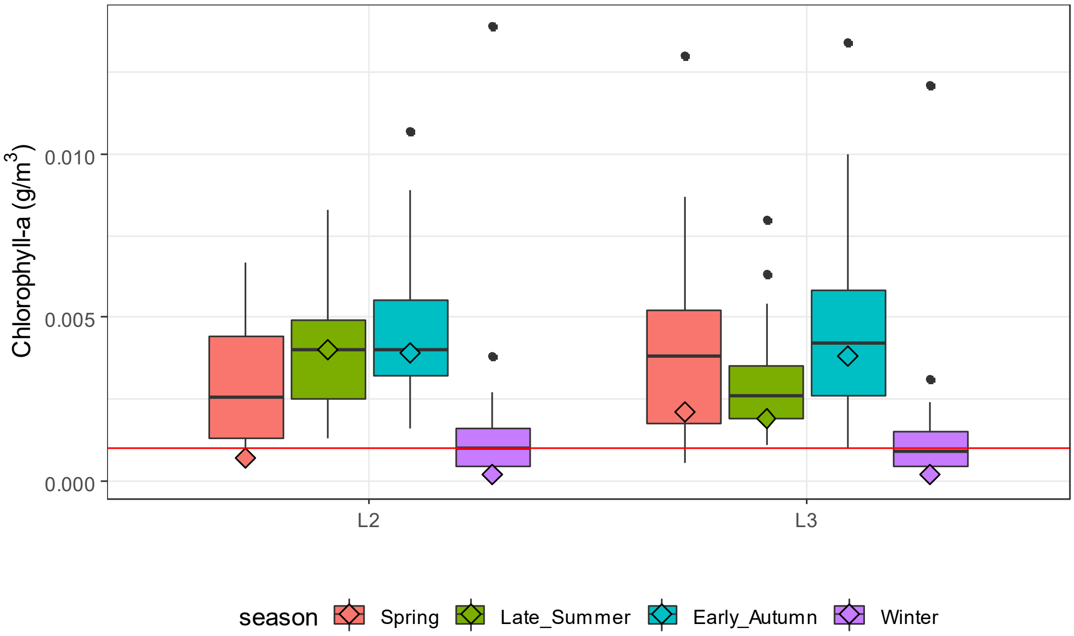


Figure 11 Seasonal chlorophyll-a concentrations in the photic zone of Lake Rotorangi. Historical summary data is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

Chlorophyll-a concentrations during the period under review were within the previously recorded ranges and were equal to or less than the median concentrations (Figure 11). In winter 2020, both site L2 and site L3 recorded concentrations below the detection limit.

Assessment of chlorophyll concentrations in Lake Rotorangi based on three years of data against the phytoplankton NOF attribute places both sites in the B band for phytoplankton (Table 1 and Table 7) (New Zealand Government, 2017).

Table 7 Phytoplankton attribute state of Lake Rotorangi under the National Objectives Framework. (Note that units used in the NOF differ from the units primarily used throughout this report)

| Site | Median ($mg/m^3$) | Maximum ($mg/m^3$) | Band | Narrative Attribute State |
|---|---|---|---|---|
| L2 | 3.6 | 10.7 | B | Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions |
| L3 | 2.9 | 13.0 | B | Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions |

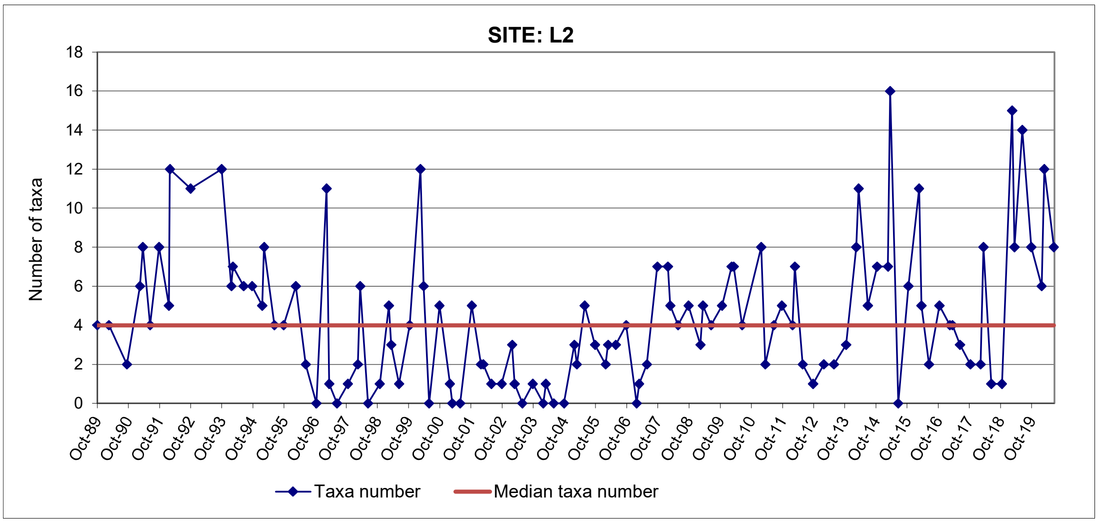


Figure 12 Phytoplankton taxa richness at site L2 since 1989

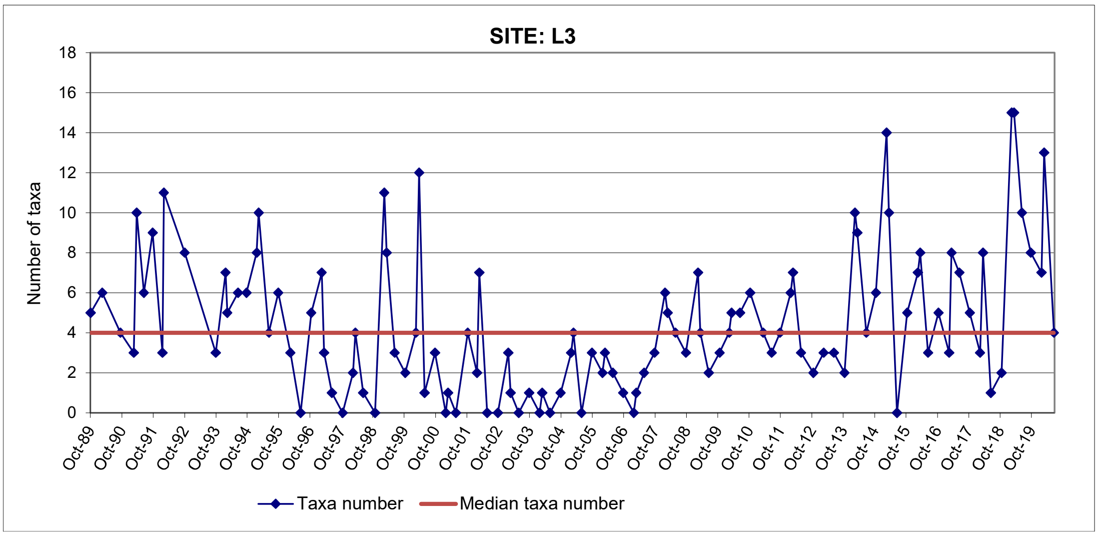


Figure 13 Phytoplankton taxa richness at site L3 since 1989

Phytoplankton taxa richness was higher than has been typical for both sites L2 and L3 during the 2019-2020 period (Figure 12 and Figure 13). Richness was between 6 and 12 taxa at site L2, and 4 and 13 taxa at site L3.

### 3.3.2 Benthic macroinvertebrates

Macroinvertebrate sampling was last undertaken in October 2017. This is next scheduled for the 2020-2021 monitoring year. The results of the October 2017 macroinvertebrate survey are discussed in full in the 2016-2018 Lake Rotorangi water quality and biological monitoring report (TRC 2018).

### 3.3.3 Macrophytes

The macrophyte survey was last undertaken in April 2018. This is next scheduled for the 2020-2021 monitoring year. The results of the April 2017 macrophyte survey are discussed in full in the 2016-2018 Lake Rotorangi water quality and biological monitoring report (TRC 2018).

## 3.4 Trophic state

The trophic state of Lake Rotorangi is shown in Table 8. Annual trophic level values are provided in Appendix III for the lake as a whole and for the individual sites. The trophic level for the year under review was 4.04 TLI units, classifying the lake as eutrophic. When the individual components of the TLI are considered, chlorophyll-a concentrations categorise the lake as mesotrophic, while secchi depth, total nitrogen and total phosphorus categorise the lake as eutrophic. This is consistent with previous observations, which note that the trophic status of the lake is influenced by turbidity.

When the trophic status is examined for the sites individually, site L2 is classed as mesotrophic while site L3 is eutrophic.

Table 8 Trophic level and values of key variables defining the trophic status* of Lake Rotorangi in 2019-2020. (Note that units used in the trophic level calculations differ from the units primarily used throughout this report)

| Trophic Level Component | Unit | L2 | L3 | Whole Lake |
|---|---|---|---|---|
| Overall Trophic Status | | Eutrophic | Mesotrophic | Eutrophic |
| Trophic Level | TLI units | 4.23 | 3.80 | 4.04 |
| Chlorophyll a | mg $m^{-3}$ | 2.17 (M) | 1.97 (O) | 2.08 |
| Secchi Depth | m | 2.19 (E) | 2.95 (M) | 2.57 |
| Total Nitrogen | mg N $m^{-3}$ | 549 (E) | 494 (E) | 521 |
| Total Phosphorus | mg P $m^{-3}$ | 31.5 (E) | 13.0 (M) | 22.3 |

* Letters in brackets relate to the trophic status of individual trophic level components. O=Oligotrophic, M=Mesotrophic, E=Eutrophic

The trophic level of Lake Rotorangi has shown an increase over time (Figure 14), albeit at a very slow rate of change (see Table 9). The loess curve shown in Figure 14 shows distinct peaks in 2004 and 2015, both years in which flood inflows affected the water chemistry of the lake, and illustrates the relatively riverine nature of Lake Rotorangi.

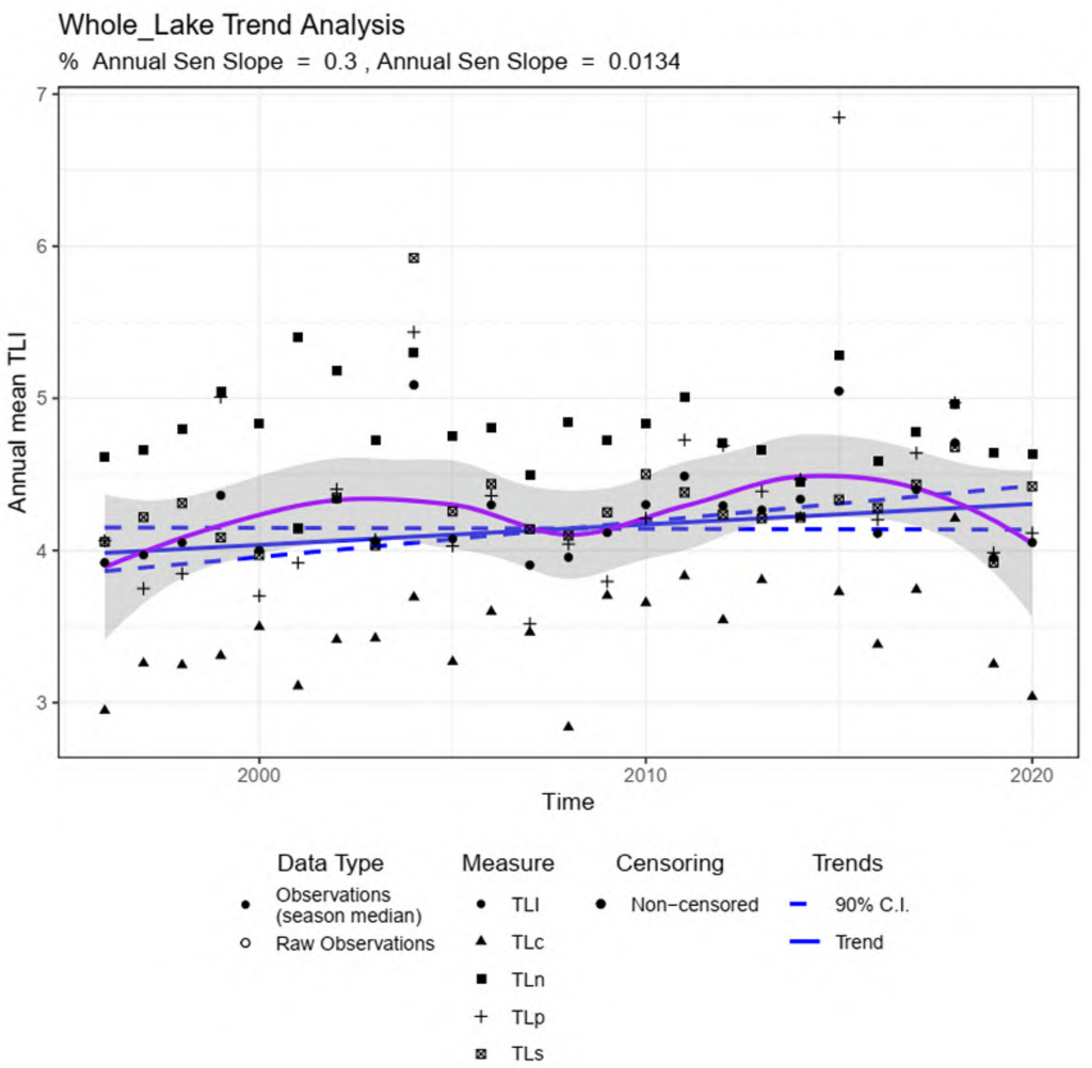


Figure 14 Trophic level index in Lake Rotorangi over the period 1996-2020. The four components of the TLI (chlorophyll-a, secchi depth, total nitrogen and total phosphorus) are plotted individually, as well as the overall TLI. The trend shown relates to the overall TLI. The lowess curve for the overall TLI is in purple

## 3.5 Temporal trends

Where possible, trend analysis is carried out based upon data from the epilimnion. In the case of chlorophyll-a and secchi distance, which are not measured in the epilimnion, data is from the photic zone and surface, respectively. Hypolimnetic data is not trended due to the magnitude of change occurring seasonally as a result of stratification processes, which has the potential to mask changes in the data over longer time frames. This is consistent with national analyses (Larned *et al.*, 2015).

Trend analysis results for the period 1996-2020 are provided in Table 9, and for the most recent ten years (2010-2020) in Table 10. Although it is typical to report statistical analysis for a lake holistically, the riverine nature of Lake Rotorangi means that there are substantial differences in water chemistry between the mid and lower lake sites. Therefore, the trend analysis for the whole lake should be interpreted with caution.

Trend plots for each variable are provided in Appendix IV for the period 1996-2020 and Appendix V for the period 2011-2020.

Table 9 Trend analysis of selected variables in Lake Rotorangi for the period 1996-2020. Trends of high confidence are identified in red (degrading trend) or blue (improving trend)

| Measure | Site | No. of Surveys | Seasonality | Proportion censored | Median Slope | Percent Annual Change | Trend | Confidence (%) |
|---|---|---|---|---|---|---|---|---|
| CHLA | L2 | 98 | Seasonal | 0.16 | 0.00005 | 1.79 | Very Likely Degrading | 99.60 |
| | L3 | 98 | Seasonal | 0.13 | 0.00004 | 1.70 | Very Likely Degrading | 99.50 |
| | Whole Lake | 98 | Seasonal | 0.10 | 0.00006 | 2.06 | Very Likely Degrading | 99.94 |
| COND | L2 | 100 | Seasonal | 0.00 | 2.75994 | 0.23 | Likely Degrading | 89.03 |
| | L3 | 100 | Seasonal | 0.00 | 3.79836 | 0.32 | Very Likely Degrading | 98.65 |
| | Whole Lake | 100 | Seasonal | 0.00 | 3.15944 | 0.27 | Very Likely Degrading | 98.68 |
| DRP | L2 | 100 | Seasonal | 0.34 | 0.00000 | 0.00 | Indeterminate | 55.05 |
| | L3 | 100 | Seasonal | 0.45 | 0.00000 | 0.00 | Very Likely Improving | 92.27 |
| | Whole Lake | 100 | Seasonal | 0.38 | 0.00000 | 0.00 | Indeterminate | 61.16 |
| NH4 | L2 | 100 | Seasonal | 0.10 | 0.00000 | 0.00 | Indeterminate | 50.00 |
| | L3 | 100 | Seasonal | 0.17 | -0.00027 | -2.48 | Very Likely Improving | 98.46 |
| | Whole Lake | 100 | Seasonal | 0.01 | -0.00015 | -0.85 | Likely Improving | 79.33 |
| NNN | L2 | 92 | Seasonal | 0.00 | -0.00138 | -0.37 | Likely Improving | 78.25 |
| | L3 | 92 | Seasonal | 0.02 | 0.00000 | 0.00 | Indeterminate | 51.06 |
| | Whole Lake | 92 | Seasonal | 0.00 | -0.00066 | -0.17 | Indeterminate | 62.44 |
| SECCHI | L2 | 100 | Seasonal | 0.00 | -0.00892 | -0.33 | Likely Degrading | 73.59 |

| Measure | Site | No. of Surveys | Seasonality | Proportion censored | Median Slope | Percent Annual Change | Trend | Confidence (%) |
|---|---|---|---|---|---|---|---|---|
| | L3 | 100 | Seasonal | 0.00 | -0.00767 | -0.25 | Likely Degrading | 76.58 |
| | Whole Lake | 100 | Seasonal | 0.00 | -0.00333 | -0.11 | Indeterminate | 61.04 |
| TLI | L2 | 25 | NonSeasonal (Annual Mean) | 0.00 | 0.01047 | 0.25 | Very Likely Degrading | 95.59 |
| | L3 | 25 | NonSeasonal (Annual Mean) | 0.00 | 0.01204 | 0.29 | Very Likely Degrading | 91.59 |
| | Whole Lake | 25 | NonSeasonal (Annual Mean) | 0.00 | 0.01342 | 0.32 | Very Likely Degrading | 93.55 |
| TN | L2 | 100 | Seasonal | 0.00 | -0.00500 | -0.80 | Very Likely Improving | 98.80 |
| | L3 | 100 | Seasonal | 0.00 | -0.00495 | -0.81 | Very Likely Improving | 98.94 |
| | Whole Lake | 100 | Seasonal | 0.00 | -0.00500 | -0.80 | Very Likely Improving | 99.53 |
| TP | L2 | 100 | Seasonal | 0.00 | 0.00057 | 2.31 | Very Likely Degrading | 99.99 |
| | L3 | 100 | Seasonal | 0.00 | 0.00016 | 0.84 | Very Likely Degrading | 93.30 |
| | Whole Lake | 100 | Seasonal | 0.00 | 0.00041 | 1.79 | Very Likely Degrading | 99.86 |
| TURB | L2 | 100 | Seasonal | 0.00 | 0.02227 | 0.97 | Very Likely Degrading | 94.79 |
| | L3 | 100 | Seasonal | 0.00 | 0.00909 | 0.61 | Likely Degrading | 86.41 |
| | Whole Lake | 100 | Seasonal | 0.00 | 0.01484 | 0.82 | Very Likely Degrading | 93.11 |

Improving trends in total nitrogen were detected with high confidence at both sites L2 and L3 and for the lake as a whole, albeit at a relatively slow rate of change of 0.8 % (or 0.04 and 0.05 g N $m^{-3}$ at L2 and L3 respectively) per year.

Both sites show a degrading trend in chlorophyll-a, with increases of approximately 1.7-1. 8% per year. For the lake as a whole, a similar trend is detected, with a change of more than 2 % per year. This long-term increasing trend in chlorophyll-a merits further attention, although given the low levels of chlorophyll-a in the lake currently this increase is roughly 0.00005 g $m^{-3}$ per year.

A degrading trend in conductivity was detected with high confidence at site L3 and for the lake as a whole, however the magnitude of this trend is relatively minor at around 0.3 % per year.

Site L2, and the lake as a whole show degrading trends of high confidence for total phosphorus, with an increase of approximately 1.8 % per year for the lake as a whole. Ammonia is decreasing at a rate of approximately 2.5 % per year at site L3, however, at site L2 results suggest the level is remaining relatively steady. While there is a degrading trend for the lake as a whole, this result is detected with low confidence and shouldn't be read into too deeply.

The trophic level index shows an increasing trend of high confidence at site L2. An increasing trend was also detected for site L3 and the lake as a whole, but with a relatively lower level of confidence in the result. It should be noted that because this is a calculation resulting in one annual data point, the ability to detect a trend is reduced compared to parameters which are sampled four times a year. Consequently a ten year trend has not been calculated for the TLI due to insufficient data.

Table 10 Trend analysis of selected variables for Lake Rotorangi over the most recent ten year period (2011-2020). Trends of high confidence are identified in red (degrading trend) or blue (improving trend)

| Measure | Site | No. of Surveys | Seasonality | Proportion censored | Median Slope | Percent Annual Change | Trend | Confidence (%) |
|---|---|---|---|---|---|---|---|---|
| CHLA | L2 | 38 | Seasonal | 0.13 | -0.00007 | -1.95 | Likely Improving | 83.56 |
| | L3 | 38 | Seasonal | 0.11 | -0.00020 | -5.92 | Very Likely Improving | 96.79 |
| | Whole Lake | 38 | Seasonal | 0.11 | -0.00014 | -3.86 | Very Likely Improving | 93.43 |
| COND | L2 | 40 | Seasonal | 0.00 | 9.52249 | 0.79 | Likely Degrading | 85.87 |
| | L3 | 40 | Seasonal | 0.00 | 21.00697 | 1.79 | Very Likely Degrading | 99.64 |
| | Whole Lake | 40 | Seasonal | 0.00 | 15.08232 | 1.29 | Very Likely Degrading | 99.22 |
| DRP | L2 | 40 | Seasonal | 0.38 | 0.00000 | 0.00 | Likely Improving | 83.01 |
| | Whole Lake | 40 | Seasonal | 0.32 | 0.00000 | 0.00 | Likely Improving | 87.00 |
| NH4 | L2 | 40 | Non-Seasonal | 0.15 | 0.00097 | 4.60 | Likely Degrading | 77.28 |
| | L3 | 40 | Non-Seasonal | 0.20 | -0.00011 | -1.34 | Likely Improving | 82.12 |

| Measure | Site | No. of Surveys | Seasonality | Proportion censored | Median Slope | Percent Annual Change | Trend | Confidence (%) |
|---|---|---|---|---|---|---|---|---|
| | Whole Lake | 40 | Non-Seasonal | 0.00 | 0.00014 | 0.93 | Indeterminate | 61.02 |
| NNN | L2 | 40 | Seasonal | 0.00 | -0.00500 | -1.30 | Likely Improving | 77.65 |
| | L3 | 40 | Seasonal | 0.05 | 0.00000 | 0.00 | Indeterminate | 51.79 |
| | Whole Lake | 40 | Seasonal | 0.00 | -0.00501 | -1.21 | Indeterminate | 62.31 |
| SECCHI | L2 | 40 | Seasonal | 0.00 | -0.00123 | -0.04 | Indeterminate | 50.00 |
| | L3 | 40 | Seasonal | 0.00 | 0.04425 | 1.36 | Likely Improving | 82.67 |
| | Whole Lake | 40 | Seasonal | 0.00 | 0.01507 | 0.49 | Indeterminate | 65.63 |
| TLI | L2 | 10 | NonSeasonal (Annual Mean) | 0.00 | -0.03340 | -0.75 | Likely Improving | 81.45 |
| | L3 | 10 | NonSeasonal (Annual Mean) | 0.00 | -0.04568 | -1.09 | Likely Improving | 81.45 |
| | Whole Lake | 10 | NonSeasonal (Annual Mean) | 0.00 | -0.04521 | -1.05 | Likely Improving | 81.45 |
| TN | L2 | 40 | Seasonal | 0.00 | -0.01164 | -1.89 | Likely Improving | 84.91 |
| | L3 | 40 | Seasonal | 0.00 | -0.00873 | -1.51 | Likely Improving | 84.91 |
| | Whole Lake | 40 | Seasonal | 0.00 | -0.01116 | -1.93 | Very Likely Improving | 90.31 |
| TP | L2 | 40 | Non-Seasonal | 0.00 | -0.00099 | -3.15 | Likely Improving | 83.92 |
| | L3 | 40 | Seasonal | 0.00 | -0.00171 | -7.95 | Very Likely Improving | 99.85 |
| | Whole Lake | 40 | Seasonal | 0.00 | -0.00137 | -5.23 | Very Likely Improving | 97.56 |

| Measure | Site | No. of Surveys | Seasonality | Proportion censored | Median Slope | Percent Annual Change | Trend | Confidence (%) |
|---|---|---|---|---|---|---|---|---|
| TURB | L2 | 40 | Seasonal | 0.00 | 0.01083 | 0.47 | Indeterminate | 53.57 |
| | L3 | 40 | Seasonal | 0.00 | -0.04257 | -3.04 | Very Likely Improving | 90.31 |
| | Whole Lake | 40 | Seasonal | 0.00 | -0.00700 | -0.39 | Indeterminate | 55.34 |

Over the most recent ten year period, decreasing trends of relatively low confidence were found in chlorophyll-a for the lake as a whole, and at site L3. The magnitude of this trend is relatively large, at approximately 6 % per year. This is in contrast to the long-term increasing trends found in chlorophyll-a.

Conductivity showed a similar pattern in the short term trend as over the longer record, although the magnitude of the trend over the shorter term was much greater, at around 1.3 % for the lake as a whole.

An improving trend with very high confidence was detected in total phosphorous at site L3, and for the lake as a whole. The magnitude of this trend is significant, with a decrease of approximately 8 % per year at site L3 and for the whole lake. This is in contrast with the 25 year trend where total phosphorus is increasing, and occurs in conjunction with an improving trend in turbidity at this site.

# 4 Discussion

During 2019-2020, stratification was recorded in Lake Rotorangi at both the mid and lower sites in late summer and early autumn. Anoxia was recorded in the hypolimnion in both late summer and early autumn. Overturn was complete at site L2 and only partially complete at site L3 at the time of the winter sampling.

The anoxic conditions in the lower hypolimnion have the potential to result in the release of nutrients from the lakebed sediments, particularly during periods when the lake is stratified. Monitoring of the water column near the lakebed during the stratified period shows very slight increases in ammonia concentrations and very slight decreases in nitrate concentrations compared to higher in the hypolimnion. Dissolved reactive phosphorus concentrations do not show any increase lower in the water column. It is unclear whether the increase in ammonia results from hypoxic nutrient release, or simply occurs due to anoxia causing the reduction of nitrate in the water column to ammonia. A lack of hypoxic nutrient release would indicate that nutrient concentrations in the lakebed sediments remain relatively low (Burns 2006). There is insufficient evidence to conclude whether hypoxic nutrient release is occurring in Lake Rotorangi, however given the small magnitude of the changes in water chemistry this is considered unlikely.

Total phosphorus showed an improving trend at site L3, and total nitrogen showed a decreasing trend at both sites L2 and L3. All other nutrients measured did not show any trend over time at individual sites. It is worth noting that because of the low nutrient concentrations in Lake Rotorangi, several parameters have a large amount of censored data, impacting upon the ability to determine the change over time. This is particularly relevant for suspended solids, which has been removed from the trend analysis because approximately two-thirds of the data is censored.

When only the most recent ten years of data is considered, total phosphorus shows an improving trend at site L3 and conductivity shows a degrading trend at this site, while the remainder of the nutrients did not show a trend with any confidence at an individual site over this period.

Chlorophyll concentrations in Lake Rotorangi remain relatively low, as does phytoplankton species diversity. However, trend analysis indicates that chlorophyll- a concentrations are increasing over time at both sites L2 and L3. However, the rate of change at both sites is less than 2 % per year, and based on the current annual medians, at site L3 chlorophyll-a concentrations would need to increase by more than double to reach eutrophic status based on this parameter (Burns, 1999; Appendix III). Site L2 currently has chlorophyll-a concentrations around the oligotrophic/mesotrophic boundary. The shorter term trend shows improving chlorophyll-a concentrations in Lake Rotorangi, with a high level of confidence at site L3 however, it is unclear what is driving this change.

The trends for Lake Rotorangi have been calculated for the lake as a whole as well as for the individual sites. It is typical to analyse lakes holistically, however Lake Rotorangi is quite riverine in nature and this is more pronounced at the mid lake site compared to the lower lake site. This leads to differences in the water chemistry and ecology between the sites which makes the individual site analysis potentially more insightful than the analyses of the whole lake.

The trends for the lake as a whole showed degrading chlorophyll-a, conductivity and total phosphorus; and improving total nitrogen over the 25 year record. In contrast, the most recent ten year period shows a degrading trend in conductivity and an improving trend in total phosphorus over this period. Drivers of lake water quality are complex. It is plausible that the total phosphorus levels are related to the suspended sediment within the water column however, the high amount of censored data for suspended solids prevents analysis of any correlation between these parameters.

Ecosystem health is assessed on the basis of NOF attributes and classifies the lake as being in a mildly impacted state. This is based upon total phosphorus and chlorophyll-a concentrations. Total nitrogen concentrations class the lake as being in a moderately impacted state. This is congruent with previous observations which class the lake as being mildly phosphorus limited. (Burns, 2006).

The most recent macrophyte survey, in 2018 recorded several invasive species, including hornwort (*Ceratophyllum demersum*). While the effects on the ecology of Lake Rotorangi and the hydroelectric scheme are not anticipated to be significant, there is the potential for spread to other lakes where the effects may be more severe. Appropriate warning signage regarding the potential problems caused by aquatic weeds and the responsibilities of recreational lake users are in place at the three principal boat ramps in Lake Rotorangi. These were updated in the 2015-2016 monitoring year to include specific reference to hornwort.

## 4.1 Changes to data analysis from previous reporting

Significant changes to the data analysis methodology have been made in the current report. Previously LakeWatch software has been used for analysis and it is no longer being supported. Moving away from using the LakeWatch analysis software has provided the opportunity to review and update the analytical methods used. A summary of the main changes can be found in Appendix VII.

In essence, the parameters for which a significant trend has been reported have changed. A comparison between the results of the confidence grading system and the previous p-value based significance method is also given in Appendix VI. This analysis shows that the confidence based system identifies the same trends as the significance based system, when the statistical output is interpreted correctly. A further analysis is provided in Appendix VII, identifying the changes in reported trends compared to previous reporting periods where the p-value of the f-statistic was incorrectly reported. This shows that between the two periods there are few similarities in reported trends, with only chlorophyll-a at all sites, TLI at site L2 and total phosphorus for the whole lake showing increasing trends in both analyses. Previous reporting did not detect any decreasing trends, which is due to the interpretation of trends in previous years. It should also be noted that the parameters used in the trend analysis have changed slightly, with turbidity now included in the analysis and suspended solids, dissolved oxygen and temperature no longer trended.

# 5 Recommendations

The following recommendations are based on the results of the 2019-2020 water quality and biological monitoring programmes and the contractual requirements of the resource consents held by Trustpower for the Patea Hydro Electric Power Scheme on Lake Rotorangi:

1. THAT Lake Rotorangi physicochemical and biological water quality monitoring continue on an annual basis as a component of the Council's State of the Environment monitoring programme, with every third year of the programme also undertaken in conjunction with the Patea Hydro Electric Power Scheme – aquatic monitoring plan (next in 2020-2021). Further, that the requisite macrophyte and benthic macroinvertebrate surveys be components of the 2020-2021 programme.
2. THAT the format and frequency of reporting of Lake Rotorangi physicochemical and biological monitoring be reviewed in the 2020-2021 year.

# Glossary of common terms and abbreviations

The following abbreviations and terms are used within this report:

| | |
|---|---|
| anoxia | absence of dissolved oxygen (defined as dissolved oxygen concentrations less than 0.5 $g/m^3$) |
| aquatic macrophyte | water plants |
| benthic | bottom living |
| black/secchi disc | measurement of visual clarity (metres) through the water (horizontally/vertically) |
| biomonitoring | assessing the health of the environment using aquatic organisms |
| chlorophyll-a | productivity using measurement of phytoplankton pigment ($mg/m^3$) |
| cumec | volumetric measure of flow (cubic metre per second) |
| conductivity | Conductivity, an indication of the level of dissolved salts in a sample, usually measured at 25°C and expressed in µS/cm |
| DO | dissolved oxygen measured as $g/m^3$ (or saturation (%)) |
| DRP | dissolved reactive phosphorus |
| *E.coli* | *Escherichia coli*, an indicator of the possible presence of faecal material and pathological micro-organisms. Expressed as the number of organisms per 100ml |
| epilimnion | lake zone above the thermocline (mixed surface layer) |
| Faecal coliforms | an indicator of the possible presence of faecal material and pathological micro-organisms. Expressed as the number of organisms per 100ml |
| FNU | formazin nephelometric unit, a measure of the turbidity of water |
| fresh | elevated flow in a stream, such as after heavy rainfall |
| $g/m^3$ | grammes per cubic metre, and equivalent to milligrammes per litre (mg/L). In water, this is also equivalent to parts per million (ppm), but the same does not apply to gaseous mixtures |
| hypolimnion | zone below the thermocline in a stratified lake |
| imputed value | a calculated estimate of value produced when an exact value cannot be obtained |
| isothermal | thermally mixed lake; defined in this report as less 3°C difference in water temperature between the lake surface and lake bottom |
| L/s | litres per second |
| mesotrophic | intermediate condition of nutrient enrichment between oligotrophic and eutrophic in lakes |
| mS/m | millisiemens per metre |
| µS/cm | microsiemens per centimetre. |
| $NH_4$ | ammonium, normally expressed in terms of the mass of nitrogen (N) |
| $NO_3$ | nitrate, normally expressed in terms of the mass of nitrogen (N) |
| NTU | Nephelometric Turbidity Unit, a measure of the turbidity of water |
| overturn | remixing of a lake after stratification |

| | |
|---|---|
| pH | a numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline. The scale is logarithmic i.e. a change of 1 represents a ten-fold change in strength. For example, a pH of 4 is ten times more acidic than a pH of 5 |
| photic zone | upper section of lake penetrated by light |
| physicochemical | measurement of both physical properties(e.g. temperature, clarity, density) and chemical determinants ( e.g. metals and nutrients) to characterise the state of an environment |
| plankton | Small and microscopic plants and animals living in the water column |
| resource consent | refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15) |
| RMA | Resource Management Act 1991 and subsequent amendments |
| SS | suspended solids |
| stratification | formation of thermal layers in lakes |
| temp | temperature, measured in ˚C (degrees Celsius) |
| thermocline | zone of most rapid temperature change in stratified lakes |
| TLI | trophic level index, a method of measuring the trophic level of a lake |
| trophic level | amount of nutrient enrichment of a lake |
| turb | turbidity, expressed in NTU or FNU |
| UI | Unauthorised Incident |
| UIR | Unauthorised Incident Register – contains a list of events recorded by the Council on the basis that they may have the potential or actual environmental consequences that may represent a breach of a consent or provision in a Regional Plan |
| VHOD | Volumetric hypolimnetic oxygen depletion. The note of dissolved oxygen decrease in the lower layer of the lake under stratified conditions. A measure of lake productivity |
| water column | water overlying the lake bed |

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# Appendix I

# Trend analysis methodology

A number of changes to data analysis methodologies have been implemented in this report. A brief description of the current methods used is given below, while a discussion of how these differ from methods used in previous TRC SEM lake reports is given in Section 4.1 and Appendix VI of this report.

When assessing point (state) statistics, such as those used to construct the boxplots in this report, censored data has been handled using the NADA R package (vers. 1.6-1.1; Lopaka Lee, 2020). Left censored data has been replaced with imputed values using regression on order statistics (ROS). This method fits a distribution to the non-censored values in the data record and uses the resulting model to impute replacement values for the censored data. The resulting calculated summary statistics and boxplots are more robust than those used in previous reports, where summary statistics were biased by censored data being replaced with a value equal to half the censor limit. Even with this improved method of handling censored data, however, summary statistics (e.g. 25$^{th}$ percentile, median) that are less than the highest common censor limit, should not be directly interpreted.

In this report, trend analysis has been carried out using the LWP-Trends library R package (version 1901), developed by Land Water People Ltd. (Snelder & Fraser, 2019). The methods employed have the primary purpose of establishing the direction and rate of any trend, along with a measure of the uncertainty in the result. The use of the LWP-Trends package represents a major change in trend analysis methodology compared to previous TRC Lake SEM reports, in part due to different methods used in the past, but also due to a recent conceptual shift in how to assess confidence in trend analysis results (Greenland et al. 2016, McBride 2019, Helsel et al. 2020).

As a first step in the trend analysis, a visual inspection of the raw time-series data is undertaken, giving a view of the proportion and temporal distribution of censored data. A Kruskal-Wallis test, using a threshold of $\alpha$=0.05, is employed to determine whether data is seasonal or not over the four separate annual samplings.

Depending on the result of the seasonality test, a non-parametric Mann-Kendall or seasonal Kendall test is used to determine the direction of a monotonic trend through the time-series data. Trend rate and the confidence in trend rate are evaluated using Sen-slope regression of observations against time. This is a non-parametric regression procedure, where the Sen-slope estimate (SSE) is taken as the median of all possible inter-observation slopes (Hirsch et al. 1982). In calculating the Kendall S statistic, censored data are dealt with as robustly as possible, following the methods of Helsel (2011), this allows inter-observation increases and decreases to be identified whenever possible (Snelder and Fraser, 2019). In calculating the SSE, censored data are replaced by a value 0.5 times the highest common censor limit. While this biases inter-observation slopes associated with censored data, in most cases with a small proportion of censored data, the median slope will be unaffected. A note is included in the reported results when the median Sen-slope is affected by censored data. In general, when the SSE is affected by censored data, this usually indicates that the trend rate is smaller than can be detected. Trends noted as being affected by censored data are critically analysed to assess if the resulting statistics are meaningful or not. In a small number of cases, trend assessment is not carried out due to insufficient unique data. This occurs when there are <5 non-censored data, or if there are 3 or less unique non-censored values.

While past trend analysis has reported on the 'significance' of any reported trend, in this report the assessment of confidence in a trend direction moves away from the traditional null hypothesis significance testing (NHST) approach and instead follows the recommended credible interval assessment method of McBride (2019). As a result of this change, the confidence in the reported trend direction (ranging from 50 to 100%) is now categorised as in Table 4. A comparison between the results of the confidence grading system and the previous p-value based significance method is given in Appendix V.

Table 1 Confidence categorisation for trend direction results

| Confidence Category | Confidence in reported trend direction |
|---|---|
| Very Likely Improving | 90 – 100% |
| Likely Improving | 67 – 90% |
| Indeterminate | 50 – 67% |
| Likely Degrading | 67 – 90% |
| Very Likely Degrading | 90 – 100% |

It is noted that the trend analysis methods implemented above are constrained to identifying a monotonic (single direction) trend through any time-series. In many cases, however, environmental time-series data is not monotonic, with a change of conditions or individual events resulting in changes of behaviour at monitoring sites. To account for this, a Loess curve has been overlaid on trend-analysis plots to allow for a qualitative assessment of any non-monotonic trends, and further investigation into the possible cause of any change of behaviour. In addition, a comparison of long term (25 year) and short term (10 year) quantitative trends is undertaken.

In the case of parameters which are sampled at multiple depths within the lake, trend analysis has been carried out on the data from the epilimnion. Differences in the water chemistry between the epilimnion and hypolimnion during the stratified period mean that combining the data from both stratified layers may mask any trends present. Furthermore, the magnitude of the seasonal change in the hypolimnion is greater for many parameters, and the magnitude of seasonal variation may hinder the ability to detect the trend over time. The use of epilimnion data in trend analysis is consistent with national reporting (Larned et al, 2015).

For the analysis of the lake as a whole, results taken at different sites, within the same layer of the water column and on the same day, are averaged to provide a single result. These average values are analysed as described above. This is consistent with the methodology used in Larned et al, 2015).

# Appendix II

# Physicochemical Monitoring Results 2019-2020

Physicochemical monitoring results collected at Lake Rotorangi on 17 October 2019

| Parameter | Unit | L2 | | | | | L3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Photic | Epilimnion | Hypolimnion | Near benthos | Surface | Photic | Epilimnion | Hypolimnion | Near benthos |
| Sample depth | m | 0 | 1.6 | 5 | 25.6 | N/S | 0 | 5.6 | 5 | 32.95 | N/S |
| Temperature | ° C | 14.2 | - | 14.2 | 9.7 | N/S | 14.1 | - | 13.7 | 9.55 | N/S |
| Black disc transparency | m | 0.475 | - | - | - | N/S | 1.505 | - | - | - | N/S |
| Secchi disc transparency | m | 0.655 | - | - | - | N/S | 2.255 | - | - | - | N/S |
| Dissolved oxygen | g/m³ | 8.1 | - | 7.9 | 4.9 | N/S | 10.0 | - | 9.7 | 0.35 | N/S |
| pH | pH units | 7.3 | - | 7.2 | 7.1 | N/S | 7.7 | - | 7.6 | 7.0 | N/S |
| Conductivity | µS/cm | 94 | - | 94 | 126 | N/S | 119 | - | 118 | 121 | N/S |
| Turbidity | FNU | 12.6 | - | 12.6 | 3.2 | N/S | 2.3 | - | 2.7 | 1.71 | N/S |
| Suspended solids | g/m³ | 8 | - | 9 | < 3 | N/S | < 3 | - | < 3 | < 3 | N/S |
| *E. coli* | MPN/100mL | 365 | - | - | - | N/S | 11 | - | - | - | N/S |
| Dissolved reactive phosphorus | g/m³ P | - | - | 0.0100 | 0.0042 | N/S | - | - | 0.0023 | 0.0031 | N/S |
| Total phosphorus | g/m³ P | - | - | 0.066 | 0.016 | N/S | - | - | 0.016 | 0.012 | N/S |
| Ammoniacal nitrogen | g/m³ N | - | - | 0.138 | < 0.005 | N/S | - | - | 0.008 | < 0.005 | N/S |
| Nitrite nitrogen | g/m³ N | - | - | 0.0150 | 0.0012 | N/S | - | - | 0.0060 | < 0.0010 | N/S |
| Nitrate nitrogen | g/m³ N | - | - | 0.48 | 0.75 | N/S | - | - | 0.48 | 0.57 | N/S |
| Nitrate and nitrite nitrogen | g/m³ N | - | - | 0.50 | 0.75 | N/S | - | - | 0.49 | 0.57 | N/S |
| Total Kjeldahl nitrogen | g/m³ N | - | - | 0.47 | 0.16 | N/S | - | - | 0.23 | 0.14 | N/S |
| Total nitrogen | g/m³ N | - | - | 0.96 | 0.91 | N/S | - | - | 0.72 | 0.71 | N/S |
| Chlorophyll-a | g/m³ | - | 0.0007 | - | - | N/S | - | 0.0021 | - | - | N/S |

N/S = not sampled

Physicochemical monitoring results collected at Lake Rotorangi on 19 February 2020

| Parameter | Unit | L2 | | | | | L3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Photic | Epilimnion | Hypolimnion | Near benthos | Surface | Photic | Epilimnion | Hypolimnion | Near benthos |
| Sample depth | m | 0 | 11 | 4.95 | 27.0 | 35.0 | 0 | 8.3 | 4.95 | 33.5 | 50 |
| Temperature | ° C | 22.8 | - | 23.0 | 10.0 | 9.7 | 23.3 | - | 23.2 | 9.7 | 9.5 |
| Black disc transparency | m | 2.84 | - | - | - | - | 2.075 | - | - | - | - |
| Secchi disc transparency | m | 4.40 | - | - | - | - | 3.335 | - | - | - | - |
| Dissolved oxygen | $g/m^3$ | 8.6 | - | 8.47 | 0 | 0 | 8.71 | - | 8.42 | 0 | 0 |
| pH | pH units | 7.9 | - | 7.7 | 6.9 | 7.0 | 7.8 | - | 7.7 | 6.9 | 6.9 |
| Conductivity | µS/cm | 15.2 | - | 15.3 | 12.9 | - | 11.8 | - | 11.7 | 12.5 | - |
| Turbidity | FNU | 0.60 | - | 0.60 | 0.93 | 43 | 0.63 | - | 0.81 | 0.69 | 4.9 |
| Suspended solids | $g/m^3$ | < 3 | - | < 3 | < 3 | - | < 3 | - | < 3 | < 3 | - |
| *E. coli* | MPN/100mL | 1 | - | - | - | - | 3 | - | - | - | - |
| Dissolved reactive phosphorus | $g/m^3$ P | - | - | 0.0029 | 0.0052 | 0.0042 | - | - | 0.0016 | 0.0044 | 0.0026 |
| Total phosphorus | $g/m^3$ P | - | - | 0.015 | 0.013 | 0.073 | - | - | 0.008 | 0.008 | 0.013 |
| Ammoniacal nitrogen | $g/m^3$ N | - | - | 0.012 | 0.052 | 0.163 | - | - | 0.007 | < 0.005 | 0.050 |
| Nitrite nitrogen | $g/m^3$ N | - | - | 0.0017 | 0.0091 | - | - | - | 0.0027 | < 0.0010 | - |
| Nitrate nitrogen | $g/m^3$ N | - | - | 0.037 | 0.51 | - | - | - | 0.165 | 0.51 | - |
| Nitrate and nitrite nitrogen | $g/m^3$ N | - | - | 0.038 | 0.52 | 0.40 | - | - | 0.168 | 0.51 | 0.37 |
| Total Kjeldahl nitrogen | $g/m^3$ N | - | - | 0.12 | 0.16 | - | - | - | 0.20 | 0.12 | - |
| Total nitrogen | $g/m^3$ N | - | - | 0.15 | 0.68 | - | - | - | 0.37 | 0.64 | - |
| Chlorophyll-a | $g/m^3$ | - | 0.0040 | - | - | - | - | 0.0019 | - | - | - |

Physicochemical monitoring results collected at Lake Rotorangi on 19 March 2020

| Parameter | Unit | L2 | | | | | L3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Photic | Epilimnion | Hypolimnion | Near benthos | Surface | Photic | Epilimnion | Hypolimnion | Near benthos |
| Sample depth | m | 0 | 7.8 | 5.4 | 37 | 48 | 0 | 6.9 | 6.9 | 28 | 36 |
| Temperature | ° C | 19.4 | - | 19.5 | 9.6 | 9.5 | 19.7 | - | 19.4 | 9.9 | 9.7 |
| Black disc transparency | m | 2.39 | - | - | - | - | 2.14 | - | - | - | - |
| Secchi disc transparency | m | 3.95 | - | - | - | - | 2.76 | - | - | - | - |
| Dissolved oxygen | $g/m^3$ | 7.86 | - | 7.82 | -0.12 | -0.17 | 7.35 | - | 5.40 | -1.0 | -0.15 |
| pH | pH units | 7.4 | - | 7.5 | 7.0 | 7.2 | 7.4 | - | 7.3 | 7.3 | 7.3 |
| Conductivity | µS/cm | 13.9 | - | 13.8 | 12.4 | - | 15.7 | - | 15.6 | 13.5 | - |
| Turbidity | FNU | 0.82 | - | 0.96 | 0.63 | 3.4 | 1.00 | - | 1.35 | 3.6 | 9.8 |
| Suspended solids | $g/m^3$ | < 3 | - | < 3 | < 3 | - | < 3 | - | < 3 | < 3 | - |
| *E. coli* | MPN/100mL | 2 | - | - | - | - | 2 | - | - | - | - |
| Dissolved reactive phosphorus | $g/m^3$ P | - | - | 0.0011 | 0.0023 | 0.0026 | - | - | 0.0022 | 0.0033 | 0.0024 |
| Total phosphorus | $g/m^3$ P | - | - | 0.013 | 0.005 | 0.009 | - | - | 0.022 | 0.014 | 0.008 |
| Ammoniacal nitrogen | $g/m^3$ N | - | - | < 0.005 | < 0.005 | 0.039 | - | - | 0.033 | 0.102 | 0.177 |
| Nitrite nitrogen | $g/m^3$ N | - | - | 0.0017 | < 0.0010 | - | - | - | 0.0053 | < 0.0010 | - |
| Nitrate nitrogen | $g/m^3$ N | - | - | 0.105 | 0.59 | - | - | - | 0.141 | 0.42 | - |
| Nitrate and nitrite nitrogen | $g/m^3$ N | - | - | 0.107 | 0.59 | 0.33 | - | - | 0.146 | 0.42 | 0.37 |
| Total Kjeldahl nitrogen | $g/m^3$ N | - | - | 0.14 | 0.13 | - | - | - | 0.27 | 0.21 | - |
| Total nitrogen | $g/m^3$ N | - | - | 0.24 | 0.72 | - | - | - | 0.41 | 0.64 | - |
| Chlorophyll-a | $g/m^3$ | - | 0.0038 | - | - | - | - | 0.0039 | - | - | - |

Physicochemical monitoring results collected at Lake Rotorangi on 23 June 2020

| Parameter | Unit | L2 | | | | | L3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Photic | Epilimnion | Hypolimnion | Near benthos | Surface | Photic | Epilimnion | Hypolimnion | Near benthos |
| Sample depth | m | 0 | 2.3 | 2.3 | 35 | N/S | 0 | 5.6 | 5.6 | 34 | N/S |
| Temperature | ° C | 11.2 | - | 11.4 | 9.9 | N/S | 11.4 | - | 11.3 | 9.8 | N/S |
| Black disc transparency | m | 0.78 | - | - | - | N/S | 1.64 | - | - | - | N/S |
| Secchi disc transparency | m | 0.93 | - | - | - | N/S | 2.25 | - | - | - | N/S |
| Dissolved oxygen | $g/m^3$ | 9.82 | - | 9.65 | 0.11 | N/S | 8.25 | - | 7.80 | 0 | N/S |
| pH | pH units | 7.4 | - | 7.5 | 7.0 | N/S | 7.0 | - | 7.4 | 6.9 | N/S |
| Conductivity | µS/cm | 11.4 | - | 11.5 | 14.4 | N/S | 12.0 | - | 12.0 | 13.0 | N/S |
| Turbidity | FNU | 6.2 | - | 6.6 | 6.3 | N/S | 2.2 | - | 2.2 | 1.34 | N/S |
| Suspended solids | $g/m^3$ | 5 | - | 5 | 3 | N/S | < 3 | - | < 3 | < 3 | N/S |
| *E. coli* | MPN/100mL | 384 | - | - | - | N/S | 4 | - | - | - | N/S |
| Dissolved reactive phosphorus | $g/m^3$ P | - | - | 0.0075 | 0.0034 | N/S | - | - | 0.0042 | 0.0031 | N/S |
| Total phosphorus | $g/m^3$ P | - | - | 0.032 | 0.014 | N/S | - | - | 0.018 | 0.012 | N/S |
| Ammoniacal nitrogen | $g/m^3$ N | - | - | 0.028 | 0.23 | N/S | - | - | 0.007 | 0.022 | N/S |
| Nitrite nitrogen | $g/m^3$ N | - | - | 0.0074 | 0.0166 | N/S | - | - | 0.0057 | < 0.0010 | N/S |
| Nitrate nitrogen | $g/m^3$ N | - | - | 0.57 | 0.183 | N/S | - | - | 0.58 | 0.35 | N/S |
| Nitrate and nitrite nitrogen | $g/m^3$ N | - | - | 0.57 | 0.20 | N/S | - | - | 0.58 | 0.35 | N/S |
| Total Kjeldahl nitrogen | $g/m^3$ N | - | - | 0.20 | 0.38 | N/S | - | - | 0.21 | 0.15 | N/S |
| Total nitrogen | $g/m^3$ N | - | - | 0.77 | 0.58 | N/S | - | - | 0.79 | 0.50 | N/S |
| Chlorophyll-a | $g/m^3$ | - | < 0.0002 | - | - | N/S | - | < 0.0002 | - | - | N/S |

N/S = not sampled

# Appendix III

# Trophic Level Index

Trophic level and state, with trophic level components and annual average values used in to calculate the trophic level of Lake Rotorangi as a whole

| Monitoring Year | Chlorophyll-a (mg m$^{-3}$) | Secchi Depth (m) | Total Nitrogen (mg m$^{-3}$) | Total Phosphorus (mg m$^{-3}$) | TLc | TLs | TLn | TLp | TLI | Trophic State |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 1.93 | 3.46 | 538.75 | 20.75 | 2.95 | 4.06 | 4.61 | 4.06 | 3.92 | Mesotrophic |
| 1997 | 2.56 | 3.03 | 559.00 | 16.20 | 3.26 | 4.22 | 4.66 | 3.75 | 3.97 | Mesotrophic |
| 1998 | 2.54 | 2.81 | 623.00 | 17.50 | 3.25 | 4.31 | 4.80 | 3.85 | 4.05 | Eutrophic |
| 1999 | 2.68 | 3.38 | 751.00 | 43.70 | 3.31 | 4.09 | 5.05 | 5.01 | 4.36 | Eutrophic |
| 2000 | 3.19 | 3.71 | 641.00 | 15.60 | 3.50 | 3.97 | 4.84 | 3.70 | 4.00 | Eutrophic |
| 2001 | 2.24 | 3.22 | 989.00 | 18.50 | 3.11 | 4.14 | 5.41 | 3.92 | 4.14 | Eutrophic |
| 2002 | 2.95 | 2.73 | 836.00 | 27.10 | 3.41 | 4.35 | 5.19 | 4.40 | 4.34 | Eutrophic |
| 2003 | 2.97 | 3.52 | 586.25 | 20.88 | 3.42 | 4.03 | 4.72 | 4.07 | 4.06 | Eutrophic |
| 2004 | 3.80 | 0.71 | 914.00 | 61.20 | 3.69 | 5.92 | 5.30 | 5.44 | 5.09 | Supertrophic |
| 2005 | 2.59 | 2.94 | 601.00 | 20.20 | 3.27 | 4.26 | 4.75 | 4.03 | 4.08 | Eutrophic |
| 2006 | 3.49 | 2.53 | 624.00 | 26.20 | 3.60 | 4.44 | 4.80 | 4.36 | 4.30 | Eutrophic |
| 2007 | 3.08 | 3.23 | 493.33 | 13.50 | 3.46 | 4.14 | 4.50 | 3.52 | 3.90 | Mesotrophic |
| 2008 | 1.75 | 3.34 | 643.00 | 20.40 | 2.84 | 4.10 | 4.84 | 4.04 | 3.96 | Mesotrophic |
| 2009 | 3.84 | 2.95 | 586.00 | 16.80 | 3.70 | 4.25 | 4.72 | 3.80 | 4.12 | Eutrophic |
| 2010 | 3.67 | 2.40 | 640.00 | 23.30 | 3.66 | 4.50 | 4.84 | 4.21 | 4.30 | Eutrophic |
| 2011 | 4.31 | 2.65 | 732.00 | 35.00 | 3.83 | 4.38 | 5.01 | 4.73 | 4.49 | Eutrophic |
| 2012 | 3.32 | 2.99 | 580.00 | 34.00 | 3.54 | 4.24 | 4.71 | 4.69 | 4.29 | Eutrophic |
| 2013 | 4.21 | 3.05 | 558.00 | 26.80 | 3.81 | 4.21 | 4.66 | 4.39 | 4.27 | Eutrophic |
| 2014 | 6.12 | 3.04 | 475.00 | 28.50 | 4.22 | 4.22 | 4.45 | 4.47 | 4.34 | Eutrophic |
| 2015 | 3.92 | 2.76 | 900.00 | 186.20 | 3.73 | 4.33 | 5.28 | 6.85 | 5.05 | Supertrophic |
| 2016 | 2.87 | 2.88 | 530.00 | 23.12 | 3.38 | 4.28 | 4.59 | 4.20 | 4.11 | Eutrophic |
| 2017 | 3.98 | 2.54 | 614.00 | 32.70 | 3.74 | 4.43 | 4.78 | 4.64 | 4.40 | Eutrophic |
| 2018 | 6.08 | 2.07 | 707.00 | 42.40 | 4.21 | 4.68 | 4.97 | 4.97 | 4.71 | Eutrophic |
| 2019 | 2.55 | 3.86 | 552.00 | 19.50 | 3.25 | 3.92 | 4.64 | 3.98 | 3.95 | Mesotrophic |
| 2020 | 2.10 | 2.57 | 549.00 | 21.60 | 3.04 | 4.42 | 4.64 | 4.11 | 4.04 | Eutrophic |

Trophic level and state, with trophic level components and annual average values used in to calculate the trophic level at site L2 in Lake Rotorangi

| Monitoring Year | Chlorophyll-a (mg m$^{-3}$) | Secchi Depth (m) | Total Nitrogen (mg m$^{-3}$) | Total Phosphorus (mg m$^{-3}$) | TLc | TLs | TLn | TLp | TLI | Trophic State |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 2.50 | 3.05 | 575.00 | 24.50 | 3.23 | 4.21 | 4.70 | 4.27 | 4.10 | Eutrophic |
| 1997 | 2.28 | 2.36 | 558.00 | 21.20 | 3.13 | 4.52 | 4.66 | 4.09 | 4.10 | Eutrophic |
| 1998 | 2.15 | 2.36 | 642.00 | 21.00 | 3.06 | 4.52 | 4.84 | 4.08 | 4.13 | Eutrophic |
| 1999 | 2.53 | 3.29 | 690.00 | 37.75 | 3.25 | 4.12 | 4.93 | 4.82 | 4.28 | Eutrophic |
| 2000 | 4.35 | 3.52 | 676.00 | 18.20 | 3.84 | 4.03 | 4.91 | 3.90 | 4.17 | Eutrophic |
| 2001 | 2.72 | 3.34 | 1010.00 | 16.00 | 3.33 | 4.10 | 5.43 | 3.73 | 4.15 | Eutrophic |
| 2002 | 2.15 | 2.50 | 894.00 | 32.80 | 3.06 | 4.45 | 5.27 | 4.64 | 4.36 | Eutrophic |
| 2003 | 2.92 | 3.20 | 674.00 | 24.20 | 3.40 | 4.15 | 4.90 | 4.26 | 4.18 | Eutrophic |
| 2004 | 3.18 | 0.83 | 981.43 | 102.29 | 3.49 | 5.74 | 5.40 | 6.09 | 5.18 | Supertrophic |
| 2005 | 2.42 | 2.59 | 628.00 | 24.80 | 3.20 | 4.41 | 4.81 | 4.29 | 4.18 | Eutrophic |
| 2006 | 3.90 | 2.04 | 784.00 | 32.60 | 3.72 | 4.70 | 5.10 | 4.64 | 4.54 | Eutrophic |
| 2007 | 3.90 | 2.88 | 500.00 | 13.33 | 3.72 | 4.28 | 4.51 | 3.50 | 4.00 | Eutrophic |
| 2008 | 1.95 | 2.94 | 718.33 | 23.67 | 2.96 | 4.26 | 4.99 | 4.23 | 4.11 | Eutrophic |
| 2009 | 3.85 | 3.24 | 578.00 | 19.80 | 3.71 | 4.14 | 4.70 | 4.00 | 4.14 | Eutrophic |
| 2010 | 3.75 | 2.00 | 678.00 | 27.40 | 3.68 | 4.72 | 4.91 | 4.42 | 4.43 | Eutrophic |
| 2011 | 4.65 | 2.56 | 808.00 | 43.40 | 3.92 | 4.42 | 5.14 | 5.00 | 4.62 | Eutrophic |
| 2012 | 3.20 | 2.23 | 628.00 | 46.40 | 3.50 | 4.59 | 4.81 | 5.08 | 4.50 | Eutrophic |
| 2013 | 4.00 | 2.88 | 580.00 | 34.00 | 3.75 | 4.28 | 4.71 | 4.69 | 4.36 | Eutrophic |
| 2014 | 3.33 | 3.00 | 453.33 | 26.67 | 3.55 | 4.23 | 4.39 | 4.38 | 4.14 | Eutrophic |
| 2015 | 3.98 | 2.56 | 854.00 | 159.60 | 3.74 | 4.43 | 5.21 | 6.65 | 5.01 | Supertrophic |
| 2016 | 2.80 | 2.76 | 644.00 | 27.60 | 3.36 | 4.33 | 4.84 | 4.43 | 4.24 | Eutrophic |
| 2017 | 4.32 | 2.27 | 638.00 | 42.60 | 3.84 | 4.57 | 4.83 | 4.98 | 4.55 | Eutrophic |
| 2018 | 5.82 | 1.60 | 780.00 | 63.40 | 4.16 | 4.98 | 5.10 | 5.48 | 4.93 | Eutrophic |
| 2019 | 2.78 | 3.28 | 532.00 | 25.40 | 3.35 | 4.12 | 4.59 | 4.32 | 4.10 | Eutrophic |
| 2020 | 2.20 | 2.19 | 574.00 | 29.80 | 3.09 | 4.61 | 4.69 | 4.52 | 4.23 | Eutrophic |

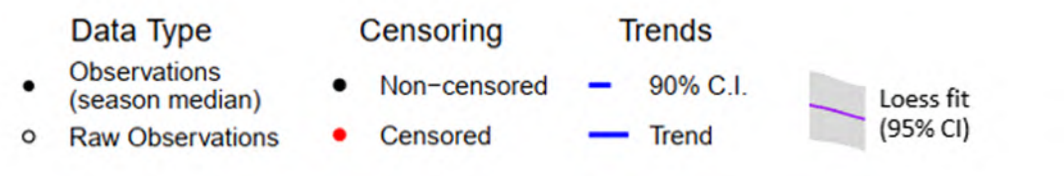
Trophic level and state, with trophic level components and annual average values used in to calculate the trophic level at site L3 in Lake Rotorangi

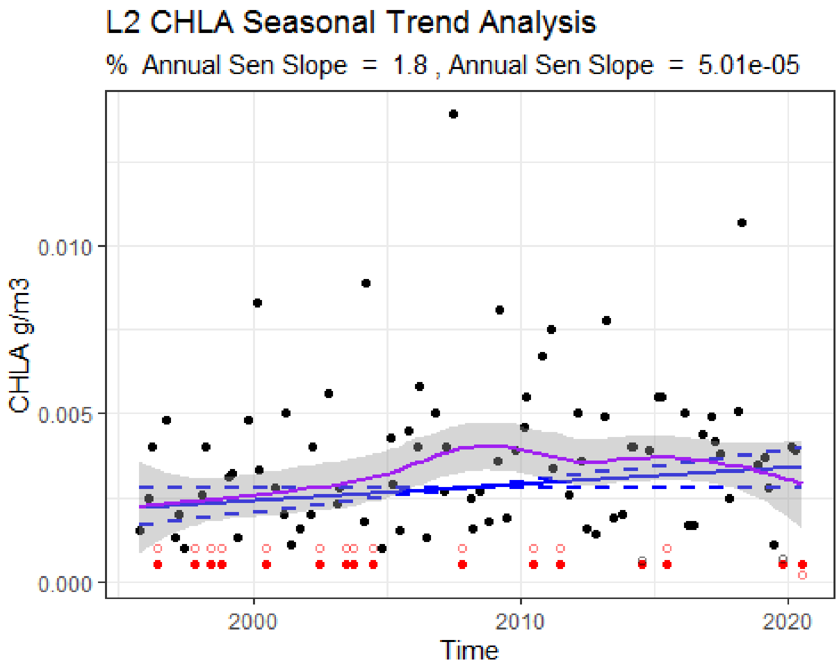
| Monitoring Year | Chlorophyll-a (mg m$^{-3}$) | Secchi Depth (m) | Total Nitrogen (mg m$^{-3}$) | Total Phosphorus (mg m$^{-3}$) | TLc | TLs | TLn | TLp | TLI | Trophic State |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 1.37 | 3.87 | 502.50 | 17.00 | 2.56 | 3.92 | 4.52 | 3.81 | 3.70 | Mesotrophic |
| 1997 | 2.85 | 3.70 | 560.00 | 11.20 | 3.38 | 3.97 | 4.66 | 3.28 | 3.82 | Mesotrophic |
| 1998 | 2.92 | 3.26 | 604.00 | 14.00 | 3.40 | 4.13 | 4.76 | 3.56 | 3.97 | Mesotrophic |
| 1999 | 2.38 | 2.66 | 791.67 | 47.67 | 3.17 | 4.38 | 5.11 | 5.12 | 4.45 | Eutrophic |
| 2000 | 2.02 | 3.90 | 606.00 | 13.00 | 3.00 | 3.91 | 4.77 | 3.47 | 3.79 | Mesotrophic |
| 2001 | 1.75 | 3.10 | 968.00 | 21.00 | 2.84 | 4.19 | 5.38 | 4.08 | 4.12 | Eutrophic |
| 2002 | 3.75 | 2.96 | 778.00 | 21.40 | 3.68 | 4.25 | 5.09 | 4.10 | 4.28 | Eutrophic |
| 2003 | 3.02 | 3.85 | 555.00 | 23.00 | 3.44 | 3.92 | 4.65 | 4.19 | 4.05 | Eutrophic |
| 2004 | 4.42 | 0.59 | 840.00 | 50.80 | 3.86 | 6.13 | 5.19 | 5.20 | 5.10 | Supertrophic |
| 2005 | 2.75 | 3.28 | 574.00 | 15.60 | 3.34 | 4.12 | 4.69 | 3.70 | 3.96 | Mesotrophic |
| 2006 | 3.08 | 3.03 | 464.00 | 19.80 | 3.46 | 4.22 | 4.42 | 4.00 | 4.02 | Eutrophic |
| 2007 | 2.27 | 3.58 | 486.67 | 13.67 | 3.12 | 4.01 | 4.48 | 3.53 | 3.79 | Mesotrophic |
| 2008 | 1.55 | 3.75 | 634.00 | 17.80 | 2.70 | 3.96 | 4.82 | 3.87 | 3.84 | Mesotrophic |
| 2009 | 3.83 | 2.66 | 594.00 | 13.80 | 3.70 | 4.38 | 4.74 | 3.55 | 4.09 | Eutrophic |
| 2010 | 3.60 | 2.80 | 602.00 | 19.20 | 3.63 | 4.32 | 4.76 | 3.97 | 4.17 | Eutrophic |
| 2011 | 3.98 | 2.73 | 656.00 | 26.60 | 3.74 | 4.34 | 4.87 | 4.38 | 4.33 | Eutrophic |
| 2012 | 3.23 | 3.33 | 540.00 | 22.75 | 3.51 | 4.10 | 4.61 | 4.18 | 4.10 | Eutrophic |
| 2013 | 4.42 | 3.22 | 536.00 | 19.60 | 3.86 | 4.14 | 4.60 | 3.99 | 4.15 | Eutrophic |
| 2014 | 8.90 | 3.07 | 496.67 | 30.33 | 4.63 | 4.20 | 4.51 | 4.55 | 4.47 | Eutrophic |
| 2015 | 3.88 | 2.96 | 946.00 | 212.80 | 3.71 | 4.25 | 5.35 | 7.02 | 5.08 | Supertrophic |
| 2016 | 2.93 | 3.01 | 502.50 | 21.00 | 3.41 | 4.23 | 4.52 | 4.08 | 4.06 | Eutrophic |
| 2017 | 3.62 | 2.81 | 590.00 | 22.80 | 3.64 | 4.31 | 4.73 | 4.18 | 4.22 | Eutrophic |
| 2018 | 6.32 | 2.54 | 634.00 | 21.40 | 4.25 | 4.44 | 4.82 | 4.10 | 4.40 | Eutrophic |
| 2019 | 2.33 | 4.45 | 572.00 | 13.60 | 3.15 | 3.74 | 4.69 | 3.53 | 3.78 | Mesotrophic |
| 2020 | 2.00 | 2.95 | 524.00 | 13.40 | 2.98 | 4.25 | 4.58 | 3.51 | 3.83 | Mesotrophic |

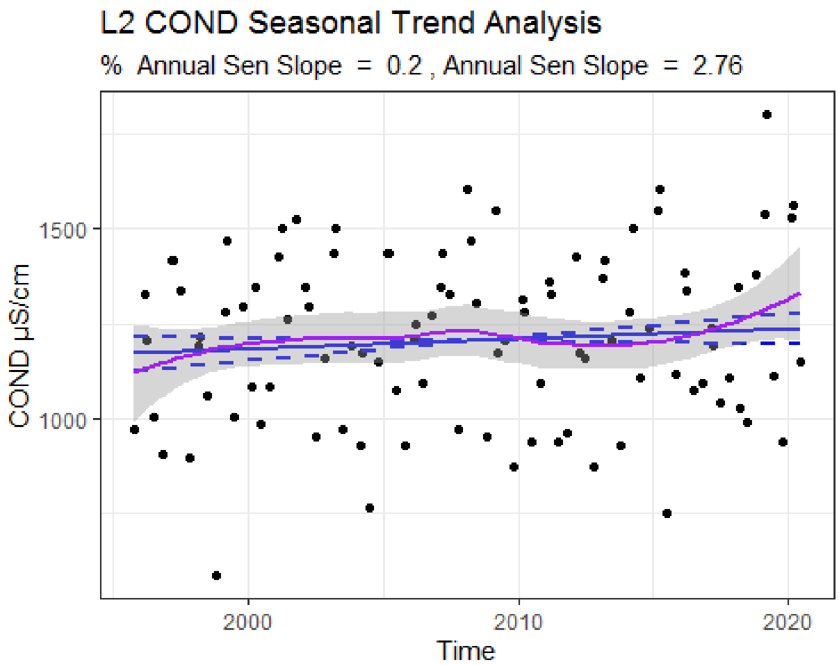
# Appendix IV

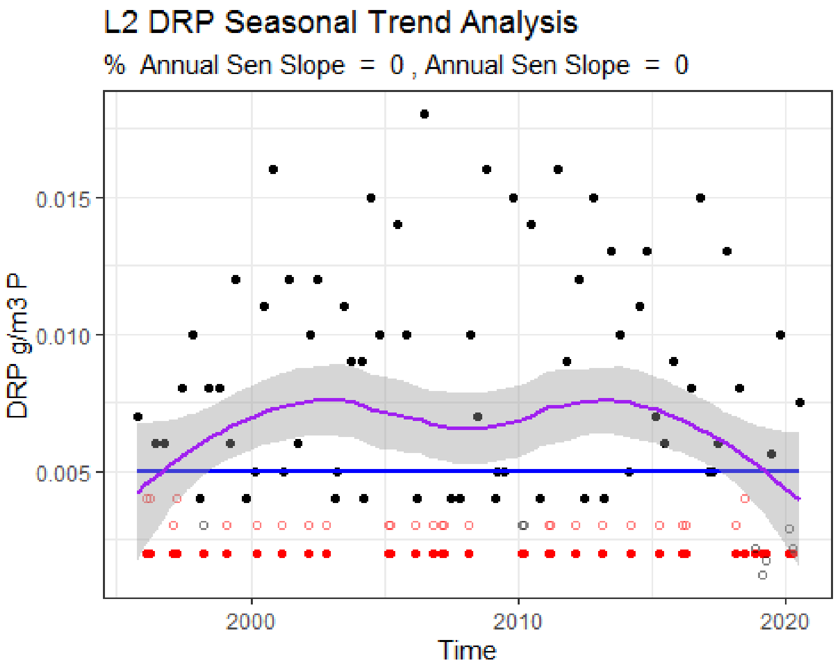
# Trend plots for the period 1996-2020

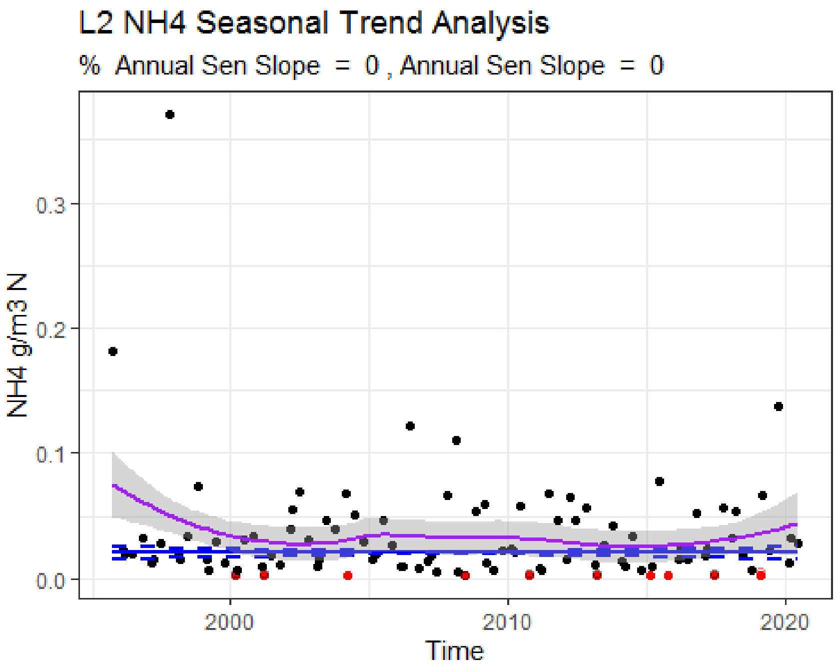
Legend for all trend plots:

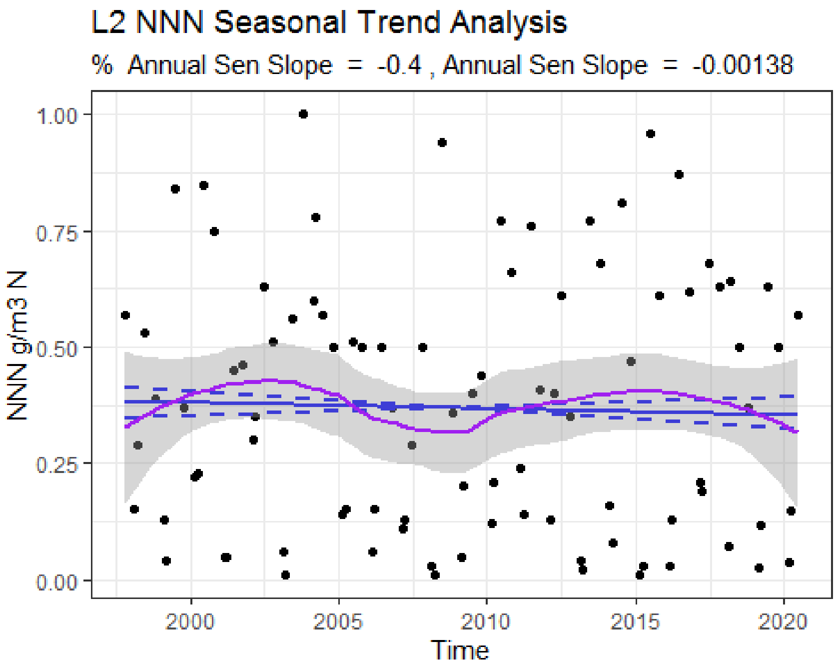


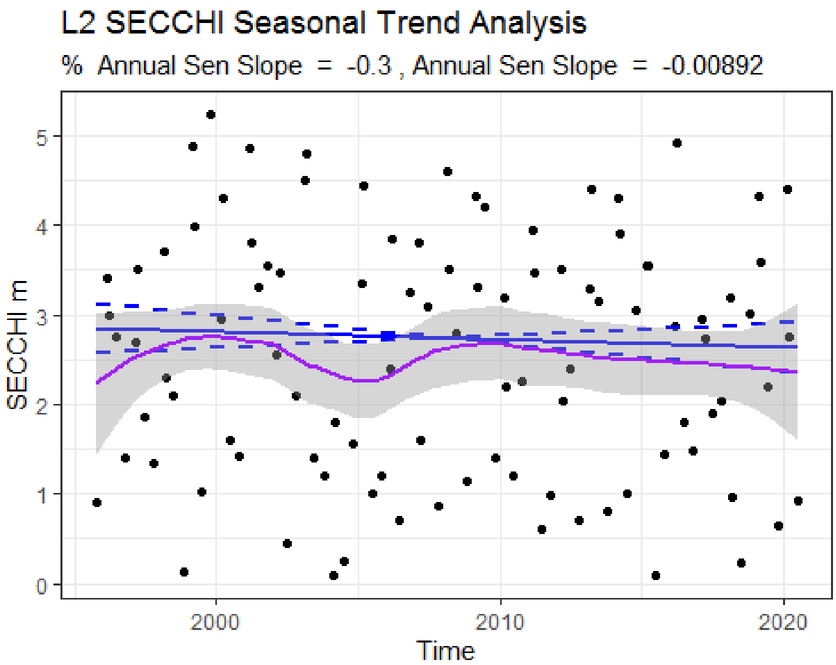

L2 CHLA Seasonal Trend Analysis
% Annual Sen Slope = 1.8 , Annual Sen Slope = 5.01e-05
CHLA g/m3
0.010
0.005
0.000
2000
2010
2020
Time

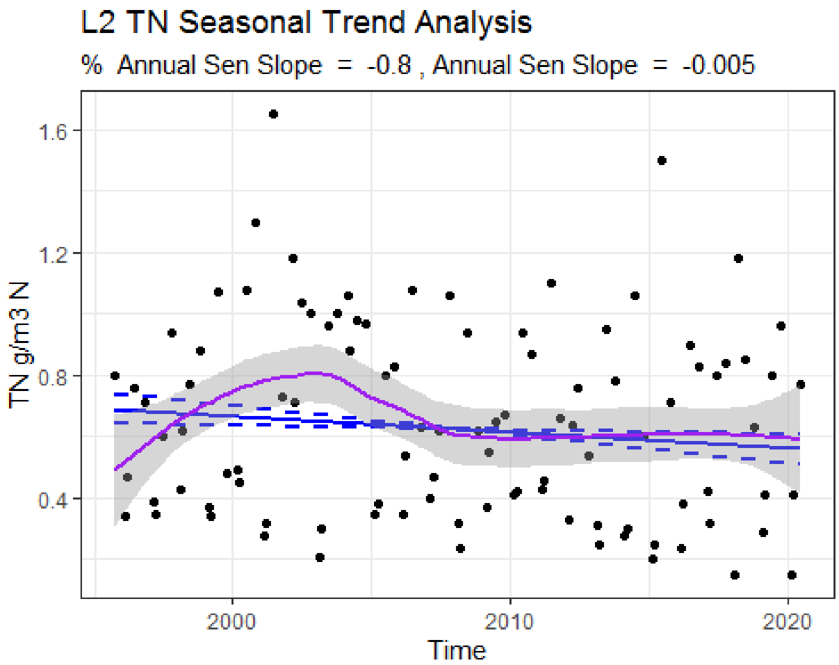

L2 COND Seasonal Trend Analysis
% Annual Sen Slope = 0.2 , Annual Sen Slope = 2.76
COND µS/cm
1500
1000
2000
2010
2020
Time

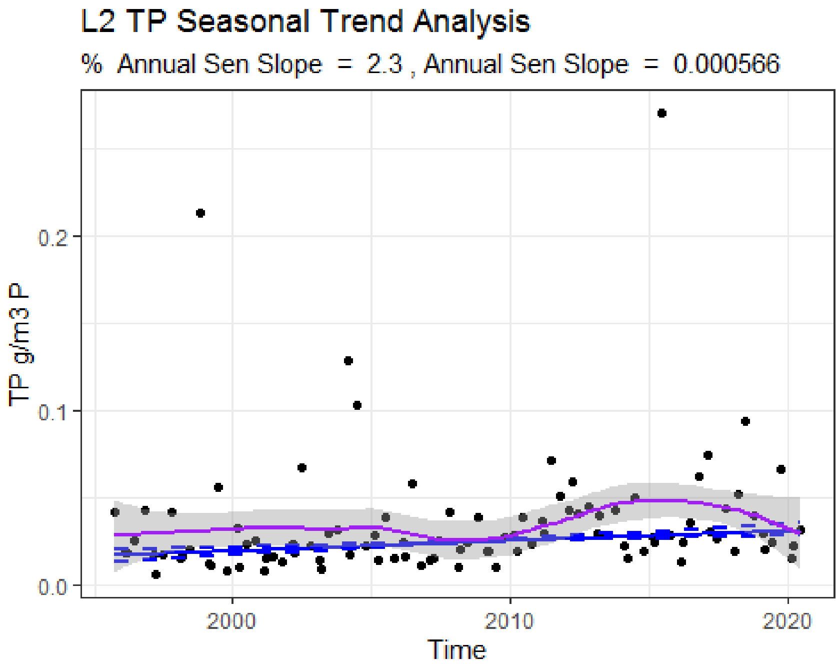

L2 DRP Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
DRP g/m3 P
0.015
0.010
0.005
2000
2010
2020
Time

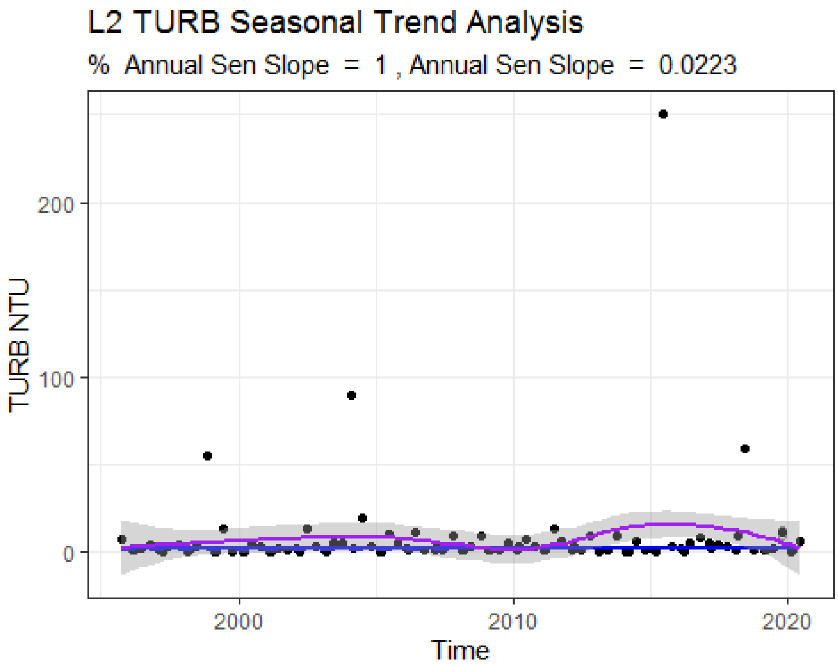

L2 NH4 Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
NH4 g/m3 N
0.3
0.2
0.1
0.0
2000
2010
2020
Time

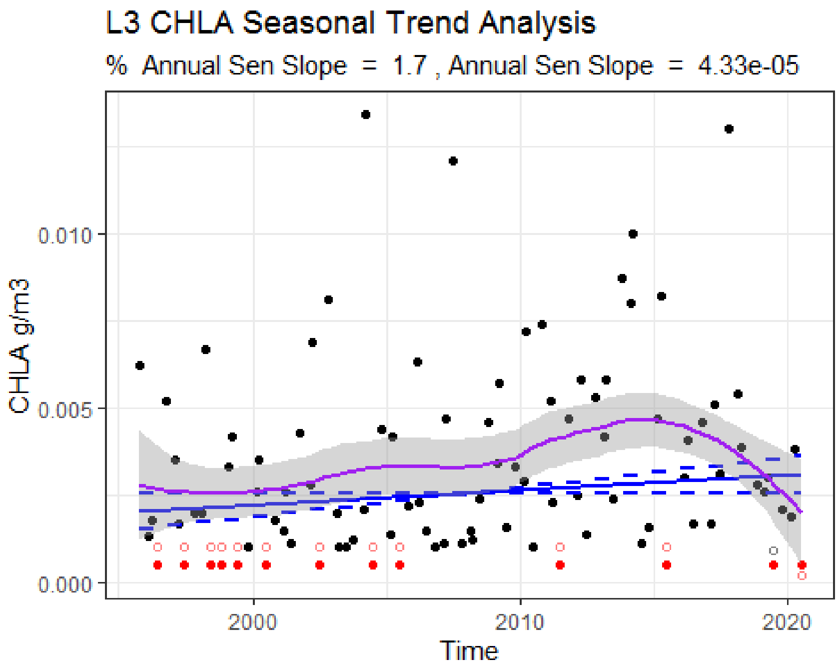

L2 NNN Seasonal Trend Analysis
% Annual Sen Slope = -0.4 , Annual Sen Slope = -0.00138
NNN g/m3 N
1.00
0.75
0.50
0.25
0.00
2000
2005
2010
2015
2020
Time

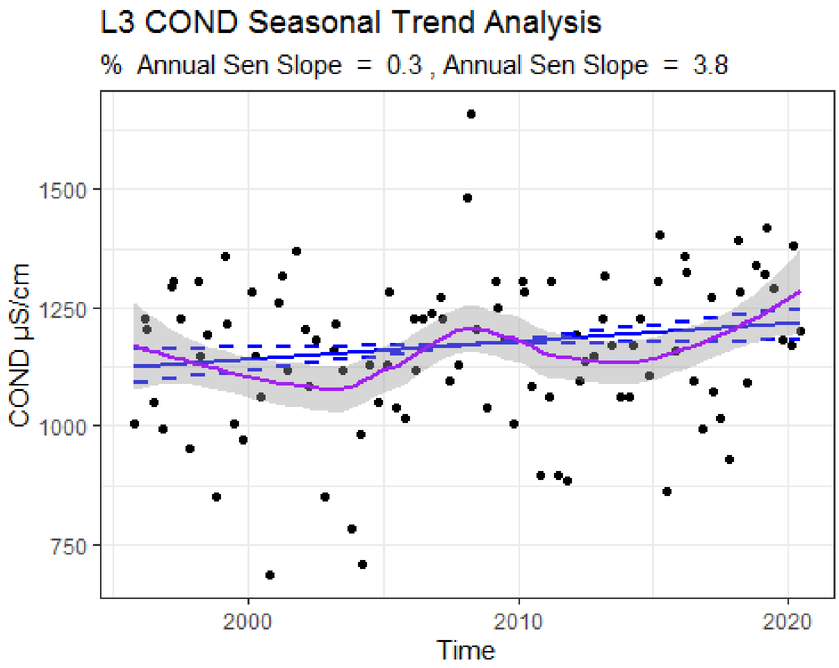

L2 SECCHI Seasonal Trend Analysis
% Annual Sen Slope = -0.3 , Annual Sen Slope = -0.00892
SECCHI m
5
4
3
2
1
0
2000
2010
2020
Time

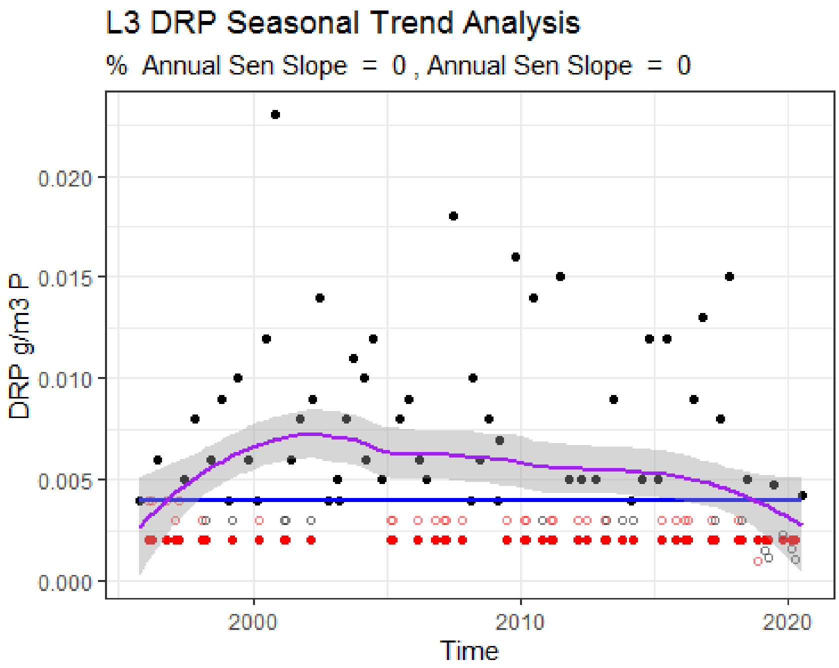

L2 TN Seasonal Trend Analysis
% Annual Sen Slope = -0.8 , Annual Sen Slope = -0.005
TN g/m3 N
1.6
1.2
0.8
0.4
2000
2010
2020
Time

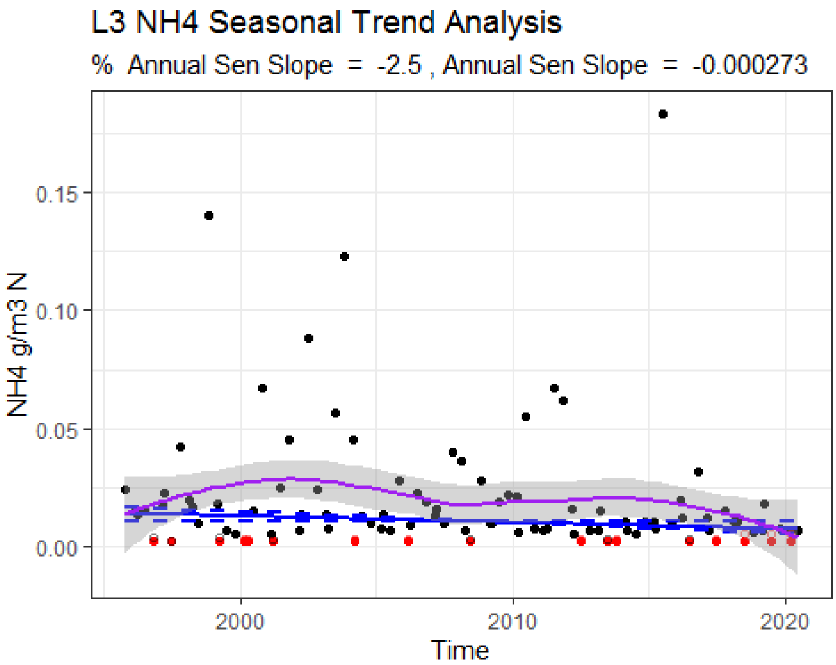

L2 TP Seasonal Trend Analysis
% Annual Sen Slope = 2.3 , Annual Sen Slope = 0.000566
TP g/m3 P
0.2
0.1
0.0
2000
2010
2020
Time

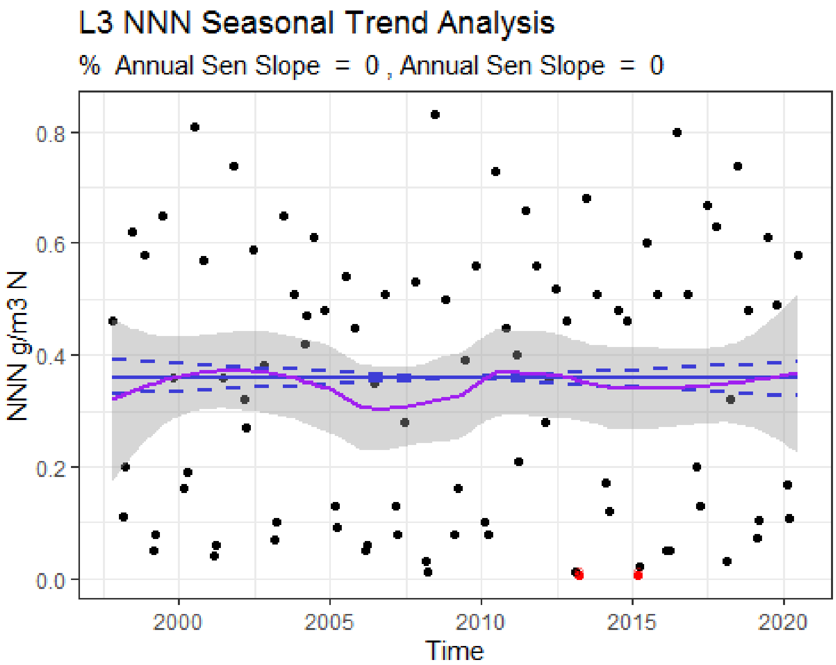

L2 TURB Seasonal Trend Analysis
% Annual Sen Slope = 1 , Annual Sen Slope = 0.0223
TURB NTU
200
100
0
2000
2010
2020
Time

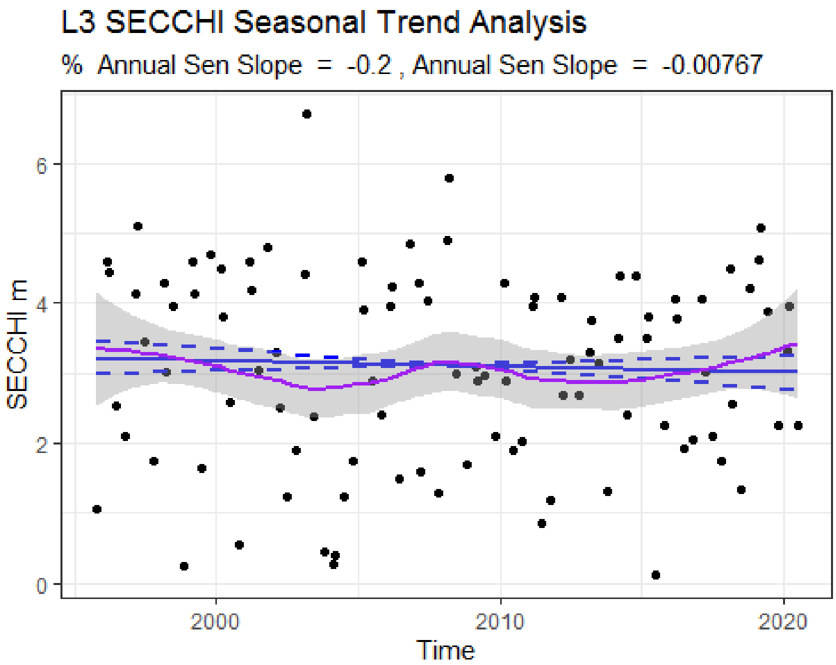

L3 CHLA Seasonal Trend Analysis
% Annual Sen Slope = 1.7 , Annual Sen Slope = 4.33e-05
CHLA g/m3
0.010
0.005
0.000
2000
2010
2020
Time

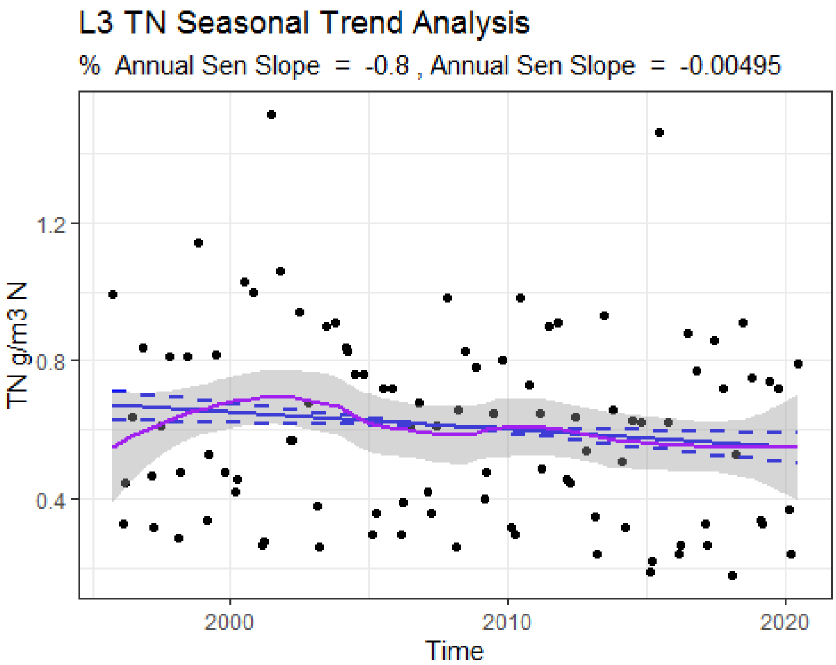

L3 COND Seasonal Trend Analysis
% Annual Sen Slope = 0.3 , Annual Sen Slope = 3.8
COND µS/cm
1500
1250
1000
750
2000
2010
2020
Time

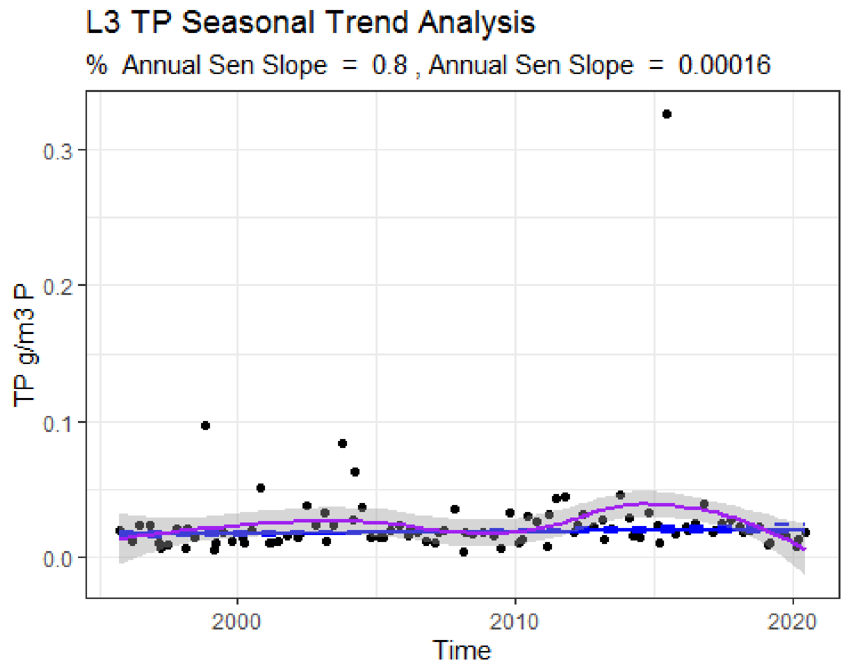

L3 DRP Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
DRP g/m3 P
0.020
0.015
0.010
0.005
0.000
2000
2010
2020
Time

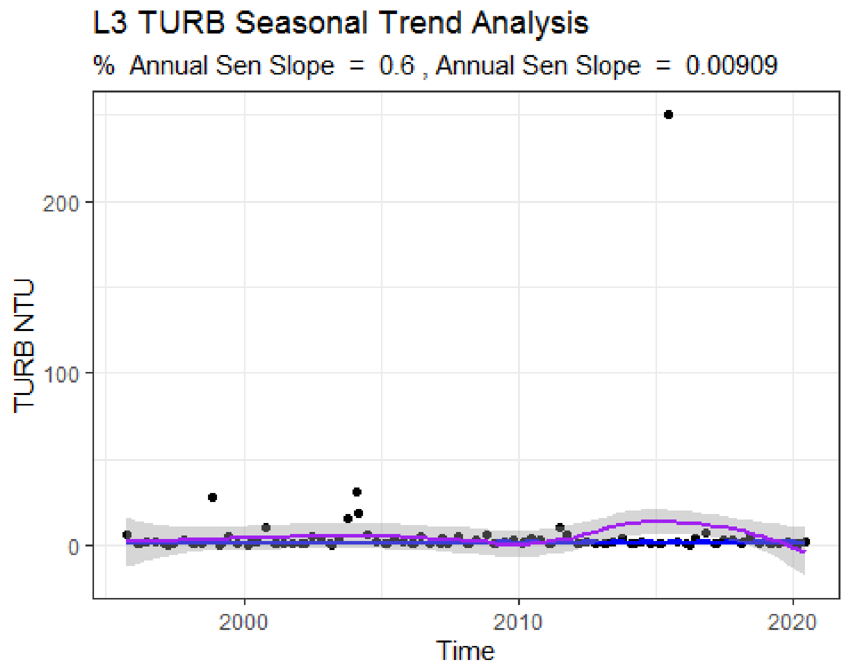

L3 NH4 Seasonal Trend Analysis
% Annual Sen Slope = -2.5 , Annual Sen Slope = -0.000273
NH4 g/m3 N
0.15
0.10
0.05
0.00
2000
2010
2020
Time

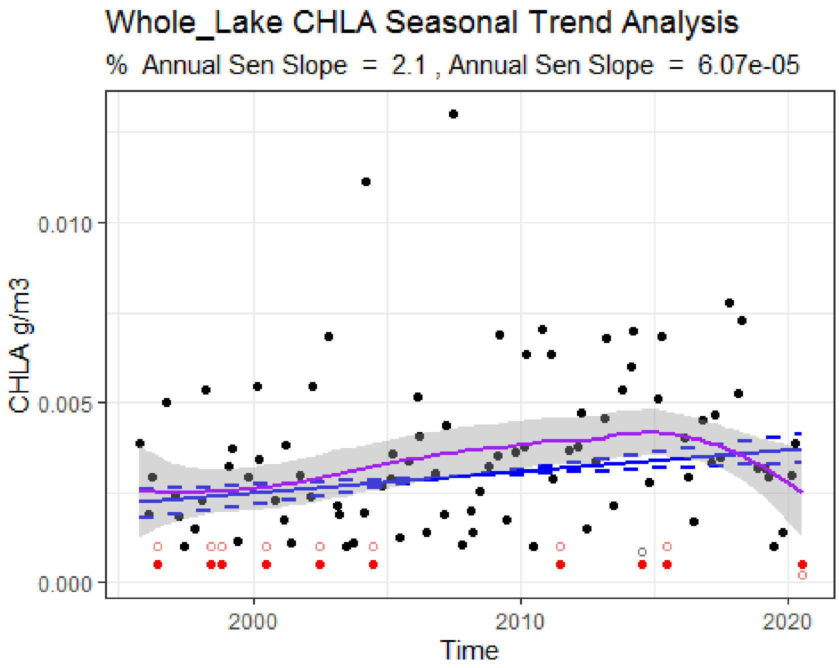

L3 NNN Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
NNN g/m3 N
0.8
0.6
0.4
0.2
0.0
2000
2005
2010
2015
2020
Time

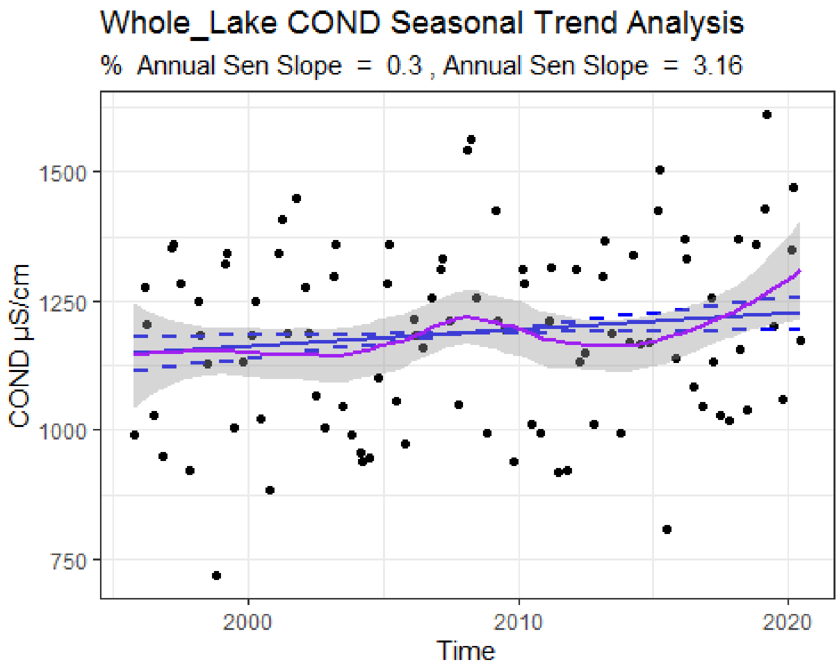

L3 SECCHI Seasonal Trend Analysis
% Annual Sen Slope = -0.2 , Annual Sen Slope = -0.00767
SECCHI m
0
2
4
6
2000
2010
2020
Time

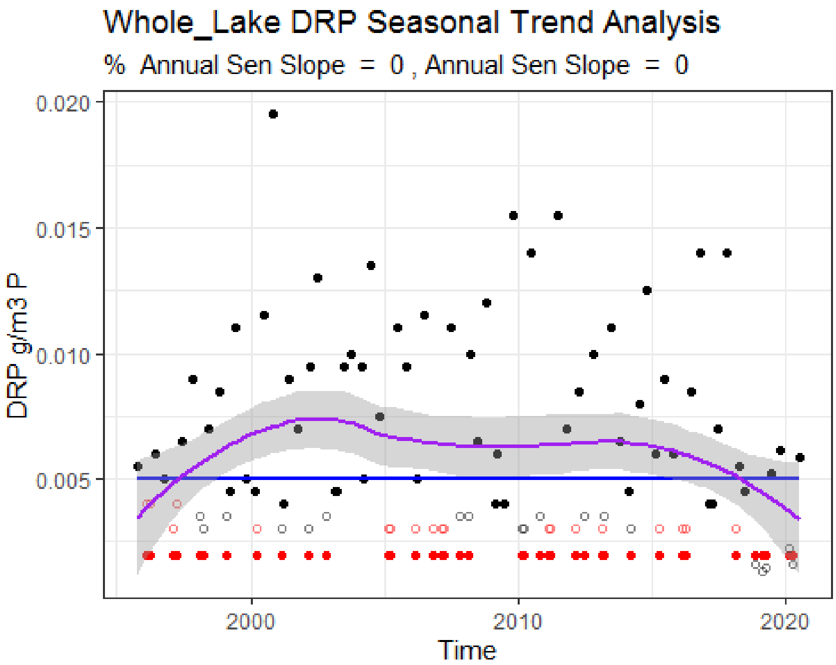

L3 TN Seasonal Trend Analysis
% Annual Sen Slope = -0.8 , Annual Sen Slope = -0.00495
TN g/m3 N
0.4
0.8
1.2
2000
2010
2020
Time

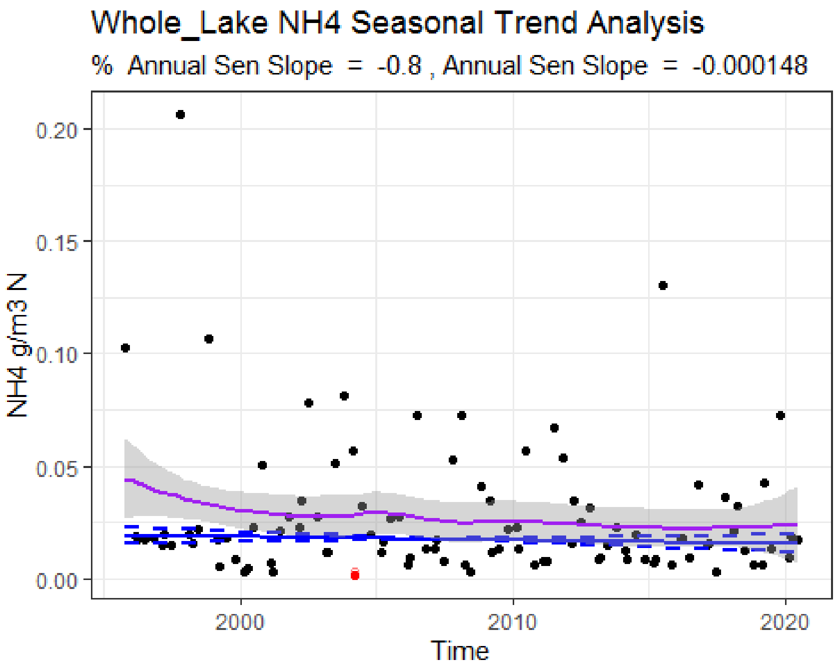

L3 TP Seasonal Trend Analysis
% Annual Sen Slope = 0.8 , Annual Sen Slope = 0.00016
TP g/m3 P
0.3
0.2
0.1
0.0
2000
2010
2020
Time

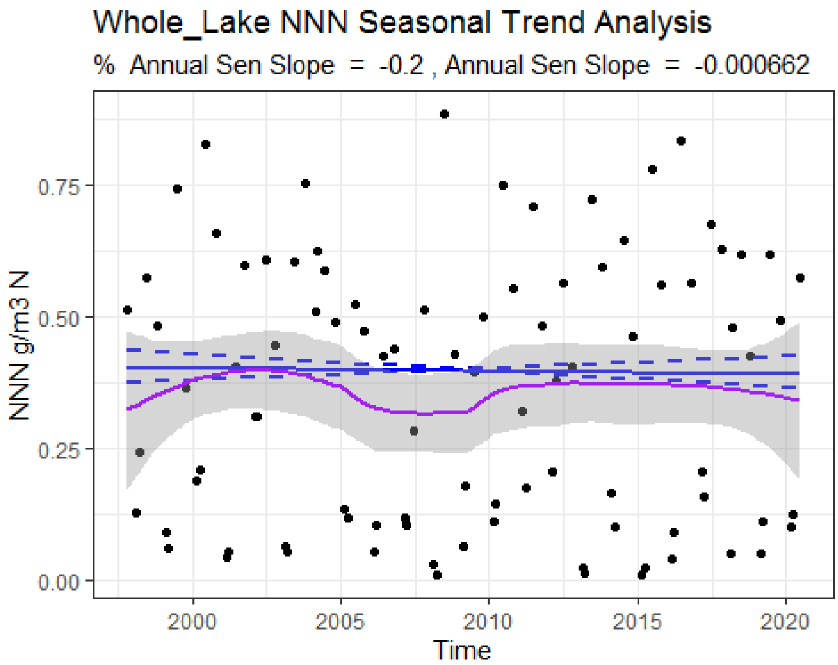

L3 TURB Seasonal Trend Analysis
% Annual Sen Slope = 0.6 , Annual Sen Slope = 0.00909
TURB NTU
200
100
0
2000
2010
2020
Time

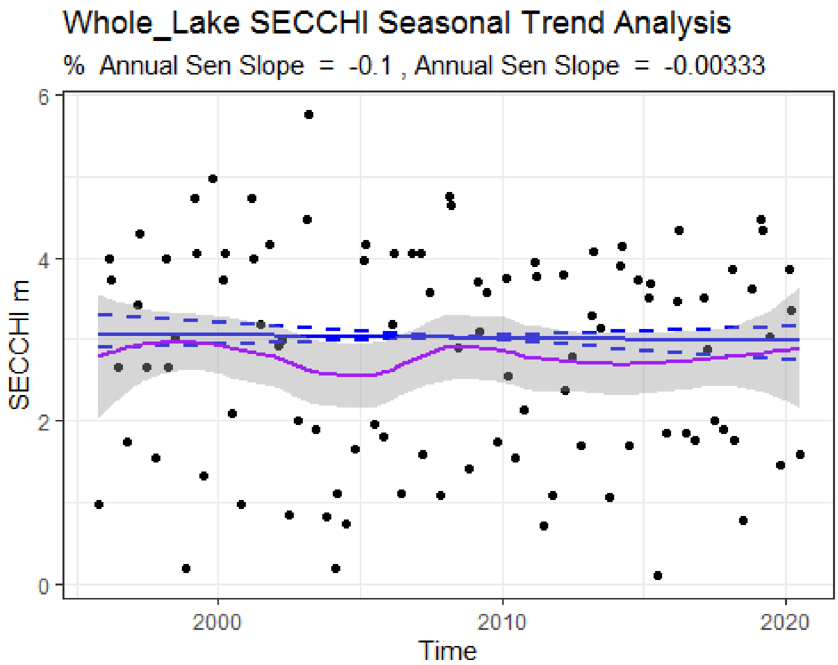

Whole_Lake CHLA Seasonal Trend Analysis
% Annual Sen Slope = 2.1 , Annual Sen Slope = 6.07e-05
CHLA g/m3
0.010
0.005
0.000
2000
2010
2020
Time

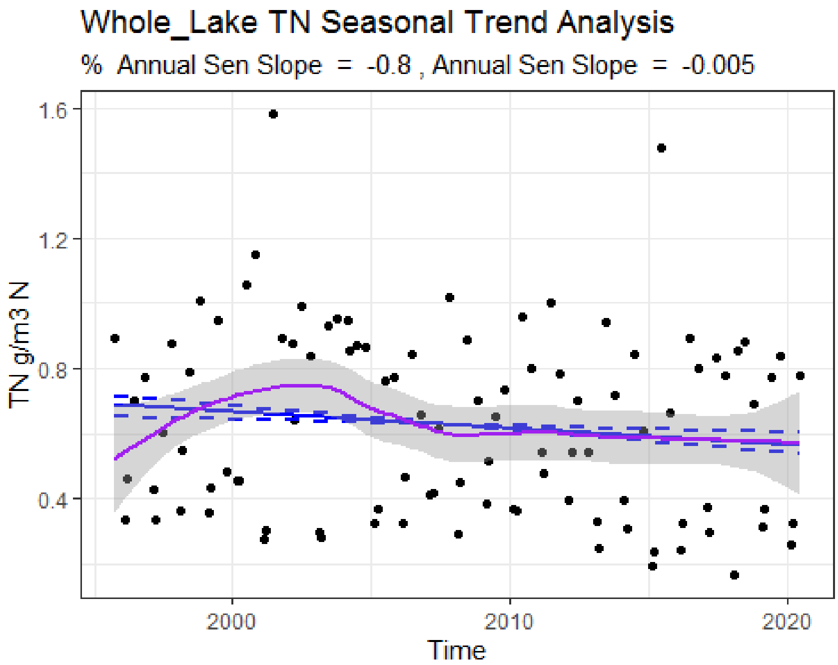

Whole_Lake COND Seasonal Trend Analysis
% Annual Sen Slope = 0.3 , Annual Sen Slope = 3.16
COND µS/cm
1500
1250
1000
750
2000
2010
2020
Time

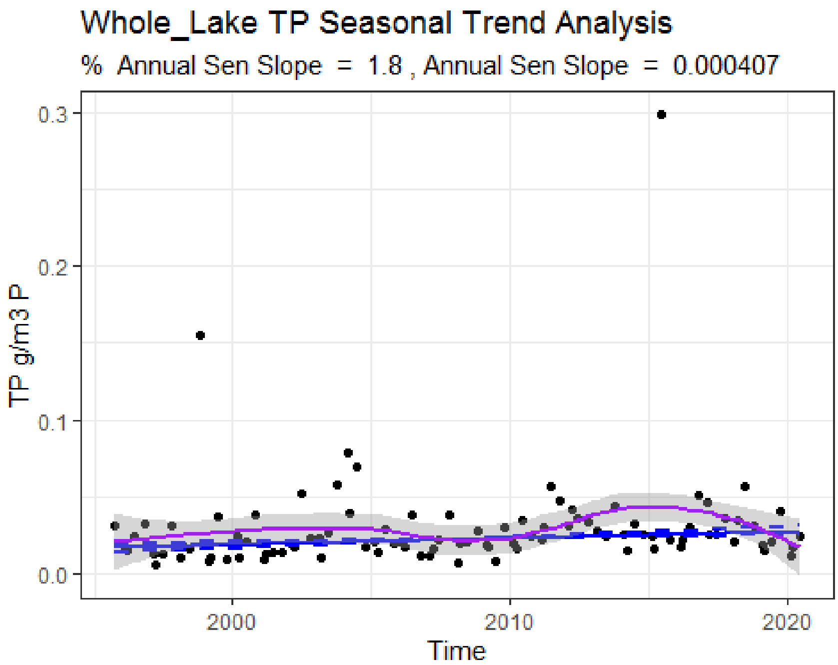

Whole_Lake DRP Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
DRP g/m3 P
0.020
0.015
0.010
0.005
2000
2010
2020
Time

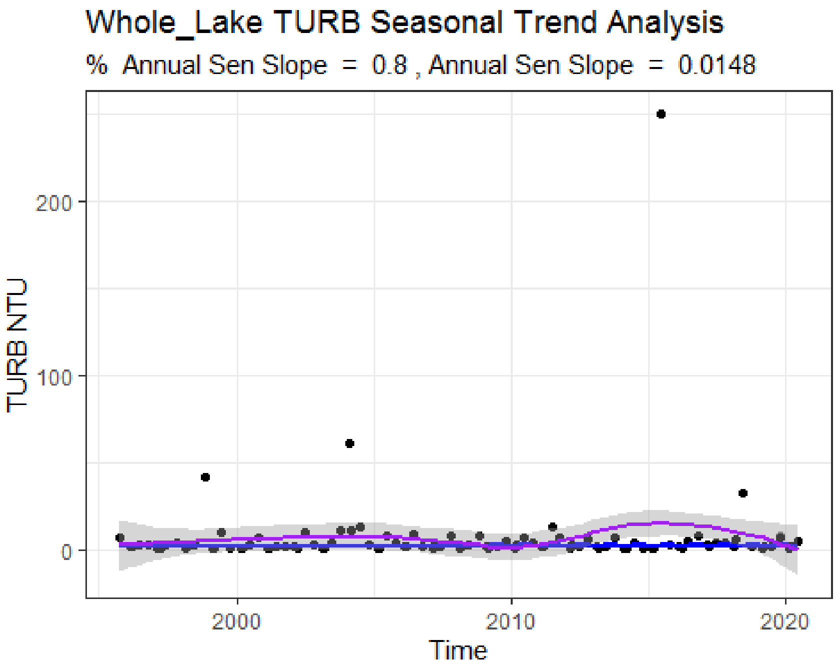

Whole_Lake NH4 Seasonal Trend Analysis
% Annual Sen Slope = -0.8 , Annual Sen Slope = -0.000148
NH4 g/m3 N
0.20
0.15
0.10
0.05
0.00
2000
2010
2020
Time


Whole_Lake NNN Seasonal Trend Analysis
% Annual Sen Slope = -0.2 , Annual Sen Slope = -0.000662
NNN g/m3 N
0.75
0.50
0.25
0.00
2000
2005
2010
2015
2020
Time


Whole_Lake SECCHI Seasonal Trend Analysis
% Annual Sen Slope = -0.1 , Annual Sen Slope = -0.00333
SECCHI m
6
4
2
0
2000
2010
2020
Time


Whole_Lake TN Seasonal Trend Analysis
% Annual Sen Slope = -0.8 , Annual Sen Slope = -0.005
TN g/m3 N
1.6
1.2
0.8
0.4
2000
2010
2020
Time

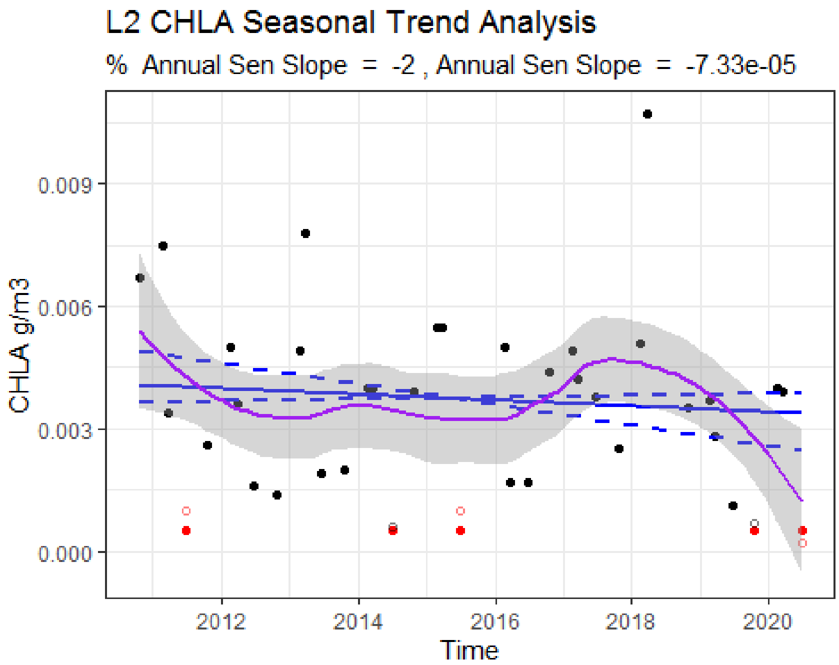

Whole_Lake TP Seasonal Trend Analysis
% Annual Sen Slope = 1.8 , Annual Sen Slope = 0.000407
TP g/m3 P
0.3
0.2
0.1
0.0
2000
2010
2020
Time

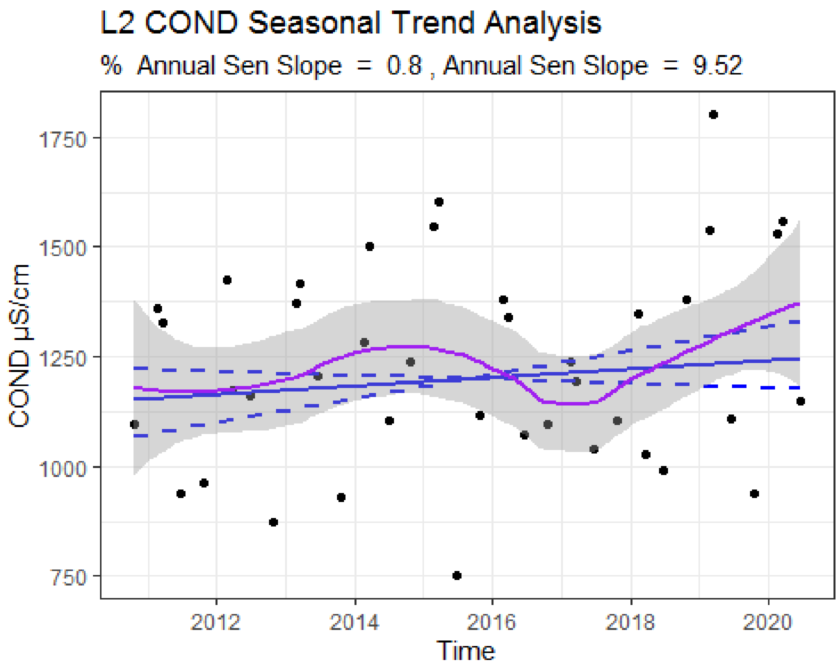

Whole_Lake TURB Seasonal Trend Analysis
% Annual Sen Slope = 0.8 , Annual Sen Slope = 0.0148
TURB NTU
200
100
0
2000
2010
2020
Time

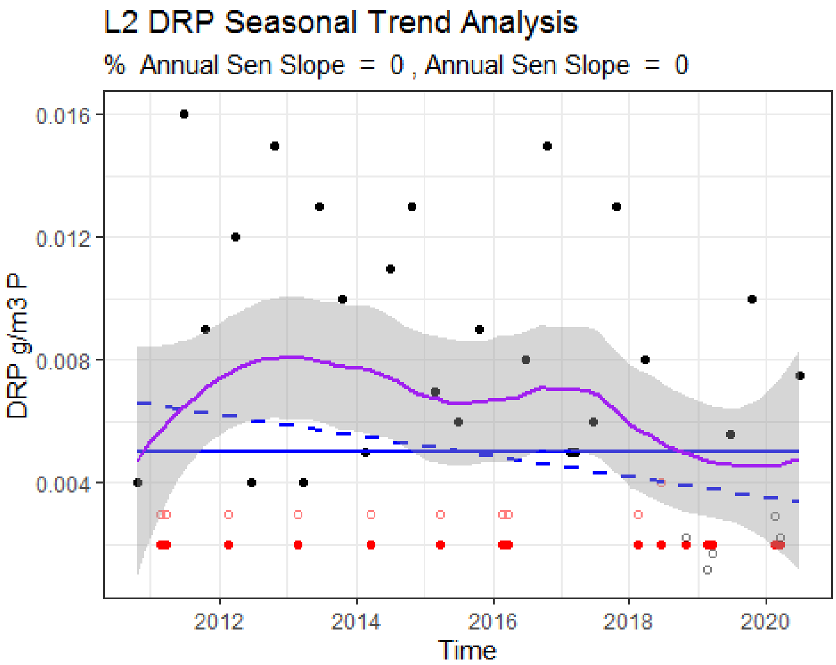
# Appendix V

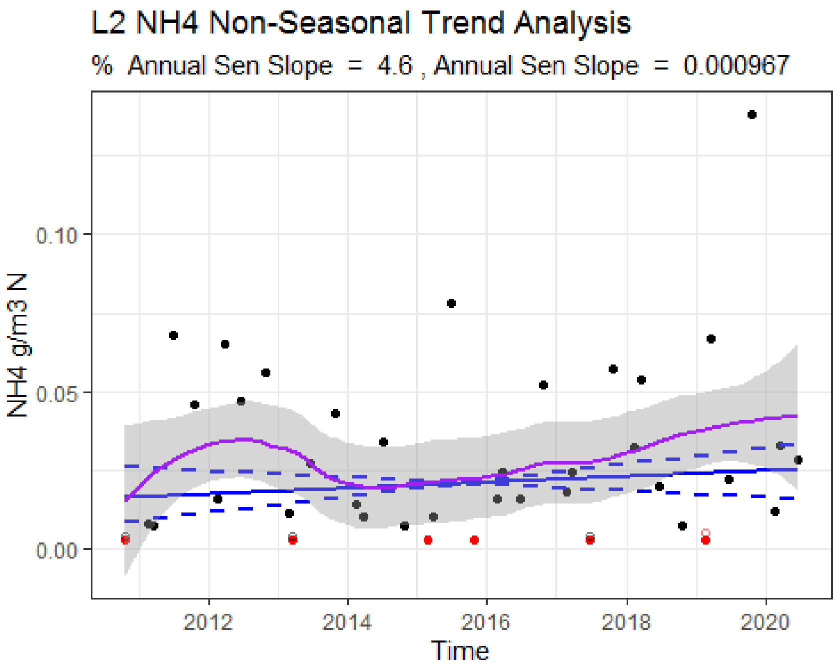
# Trend plots for the period 2011-2020

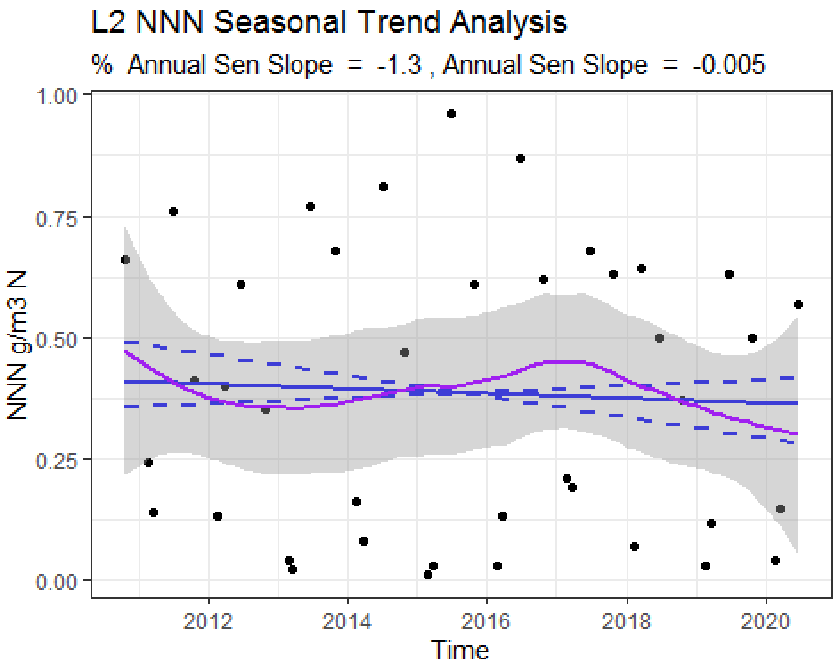
Legend for all trend plots:

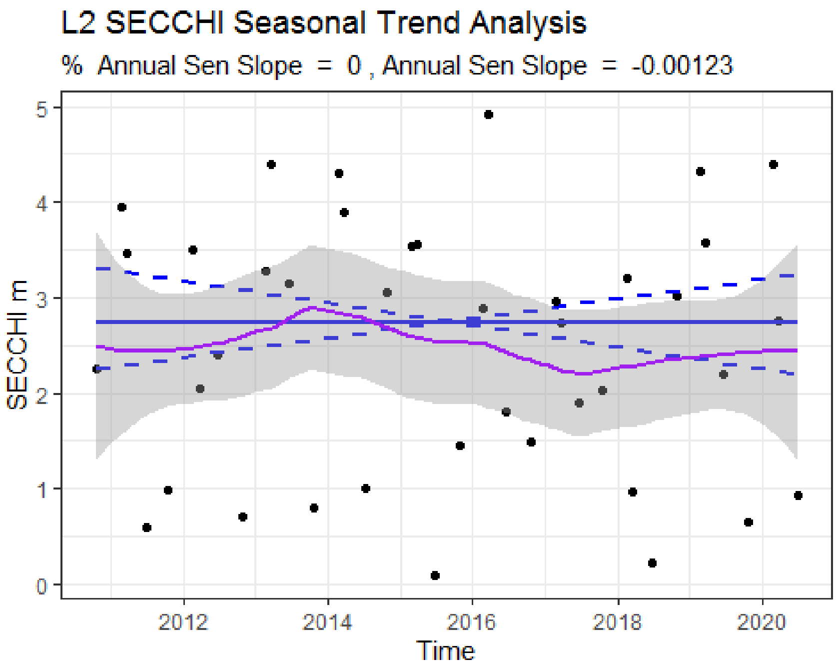

L2 CHLA Seasonal Trend Analysis
% Annual Sen Slope = -2 , Annual Sen Slope = -7.33e-05
CHLA g/m3
0.009
0.006
0.003
0.000
2012
2014
2016
2018
2020
Time

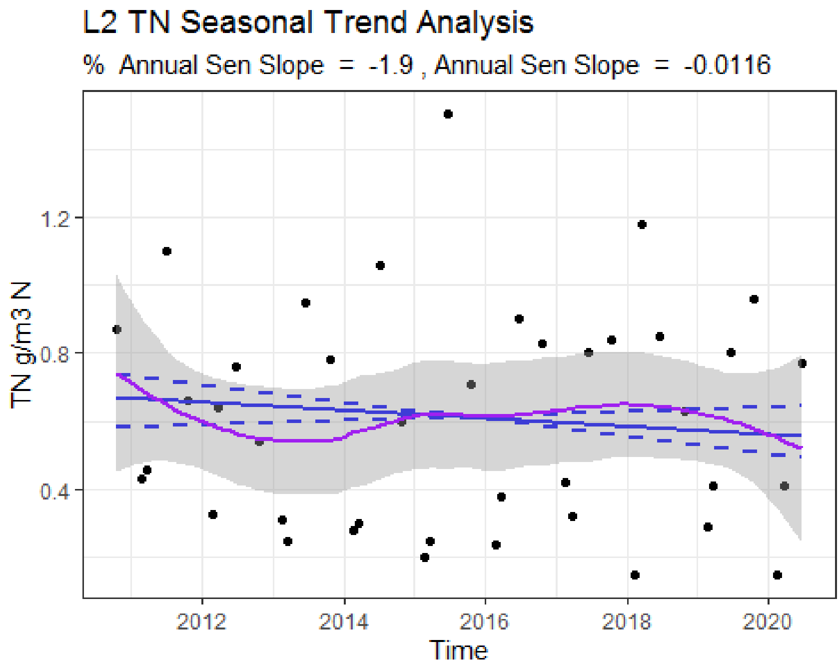

L2 COND Seasonal Trend Analysis
% Annual Sen Slope = 0.8 , Annual Sen Slope = 9.52
COND µS/cm
1750
1500
1250
1000
750
2012
2014
2016
2018
2020
Time

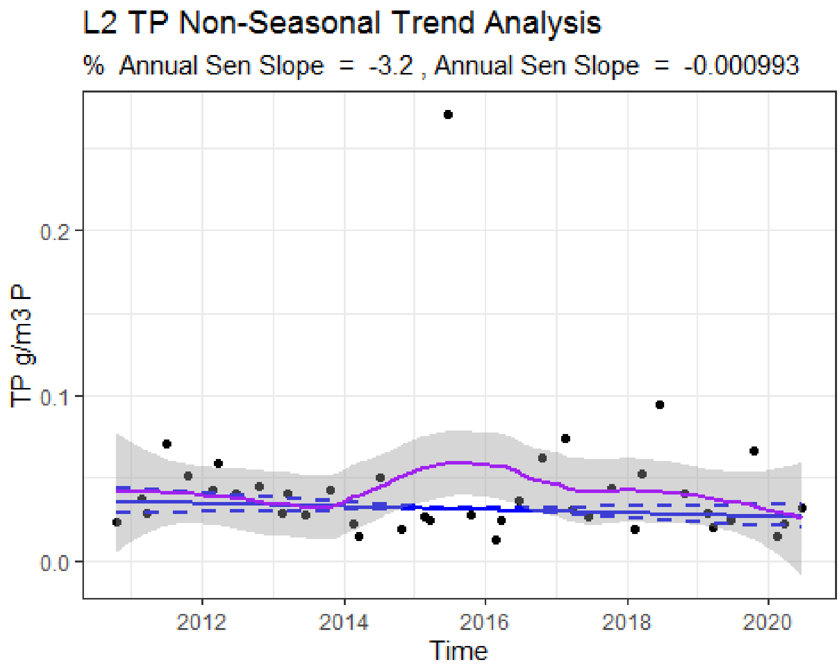

L2 DRP Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
DRP g/m3 P
0.016
0.012
0.008
0.004
2012
2014
2016
2018
2020
Time

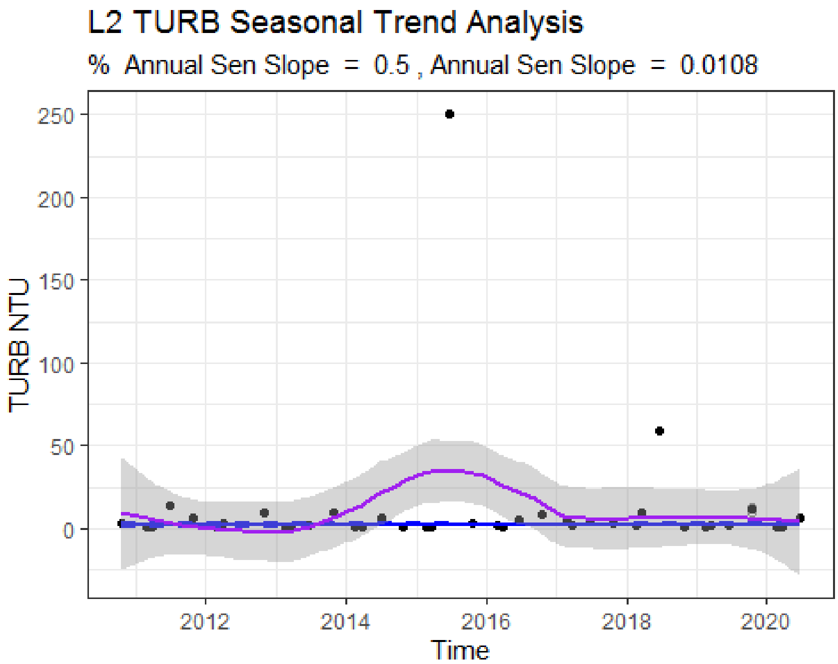

L2 NH4 Non-Seasonal Trend Analysis
% Annual Sen Slope = 4.6 , Annual Sen Slope = 0.000967
NH4 g/m3 N
0.10
0.05
0.00
2012
2014
2016
2018
2020
Time

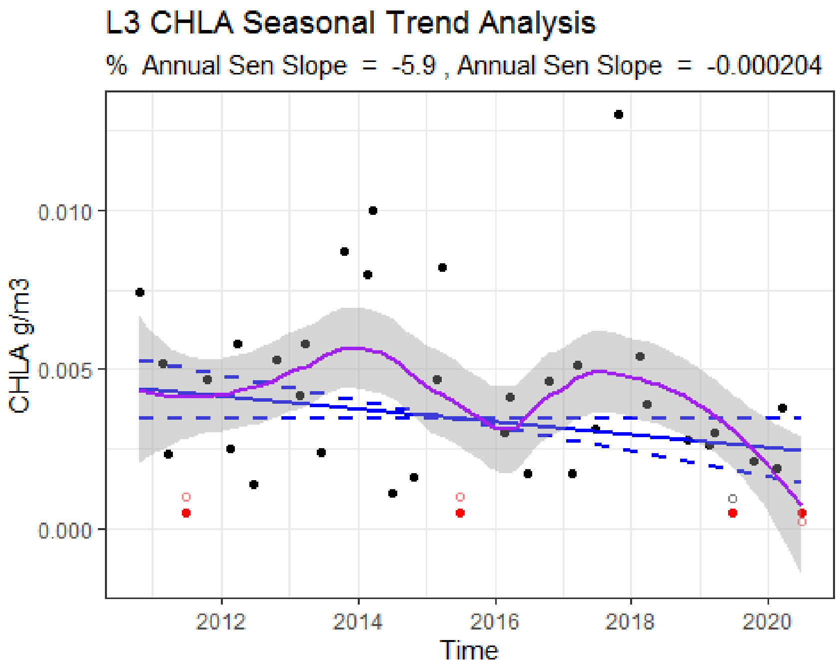

L2 NNN Seasonal Trend Analysis
% Annual Sen Slope = -1.3 , Annual Sen Slope = -0.005
NNN g/m3 N
1.00
0.75
0.50
0.25
0.00
2012
2014
2016
2018
2020
Time

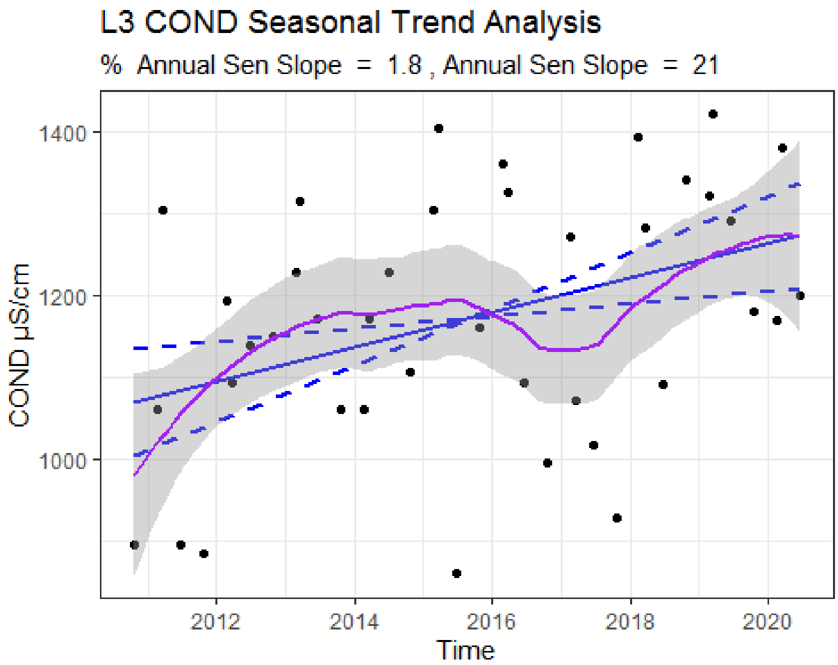

L2 SECCHI Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = -0.00123
SECCHI m
5
4
3
2
1
0
2012
2014
2016
2018
2020
Time

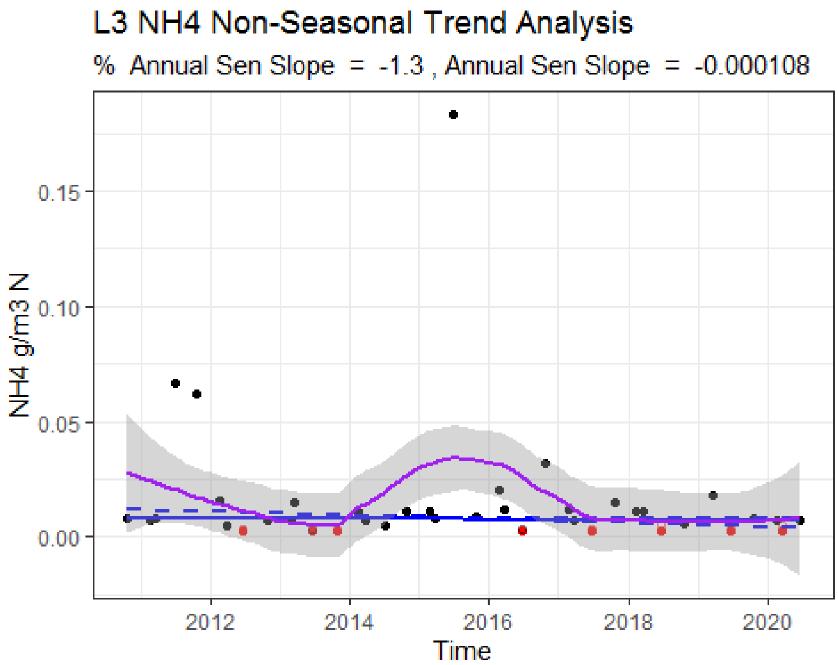

L2 TN Seasonal Trend Analysis
% Annual Sen Slope = -1.9 , Annual Sen Slope = -0.0116
TN g/m3 N
1.2
0.8
0.4
2012
2014
2016
2018
2020
Time


L2 TP Non-Seasonal Trend Analysis
% Annual Sen Slope = -3.2 , Annual Sen Slope = -0.000993
TP g/m3 P
0.2
0.1
0.0
2012
2014
2016
2018
2020
Time


L2 TURB Seasonal Trend Analysis
% Annual Sen Slope = 0.5 , Annual Sen Slope = 0.0108
TURB NTU
250
200
150
100
50
0
2012
2014
2016
2018
2020
Time

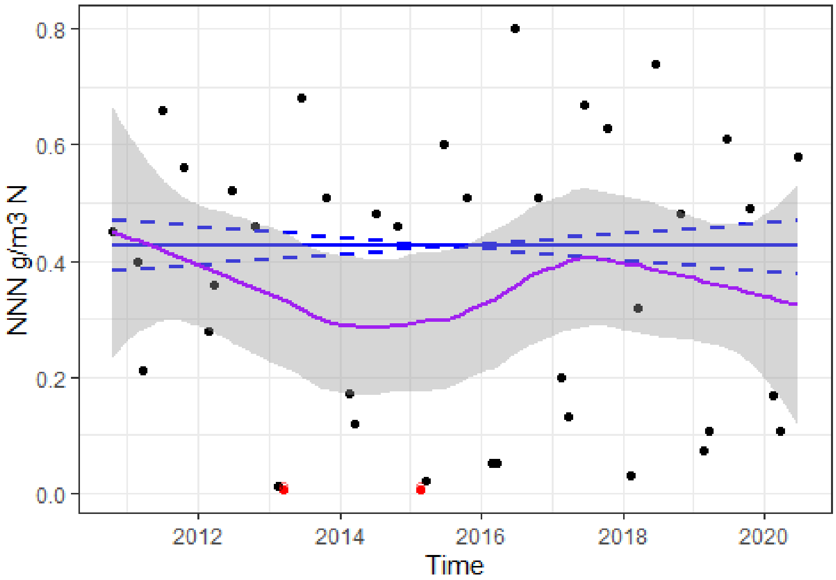

L3 CHLA Seasonal Trend Analysis
% Annual Sen Slope = -5.9 , Annual Sen Slope = -0.000204
CHLA g/m3
0.010
0.005
0.000
2012
2014
2016
2018
2020
Time


L3 COND Seasonal Trend Analysis
% Annual Sen Slope = 1.8 , Annual Sen Slope = 21
COND µS/cm
1400
1200
1000
2012
2014
2016
2018
2020
Time


L3 NH4 Non-Seasonal Trend Analysis
% Annual Sen Slope = -1.3 , Annual Sen Slope = -0.000108
NH4 g/m3 N
0.15
0.10
0.05
0.00
2012
2014
2016
2018
2020
Time

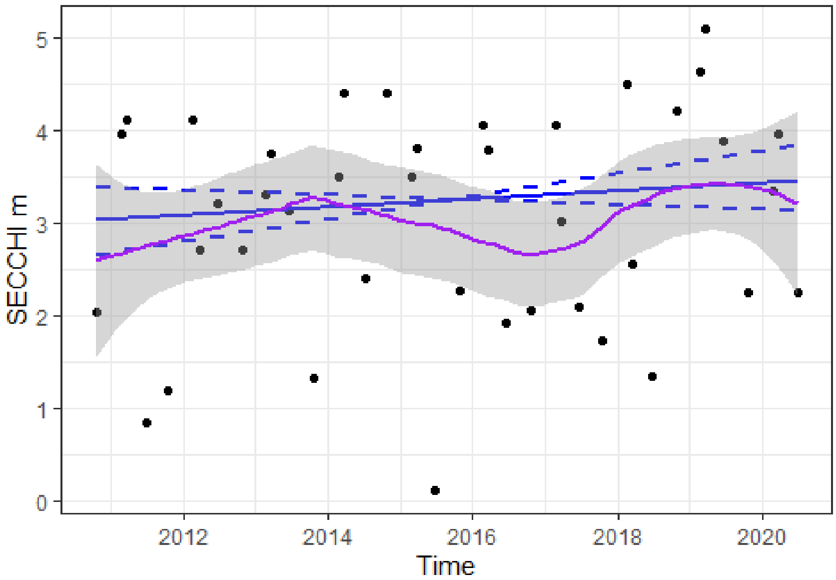
L3 NNN Seasonal Trend Analysis

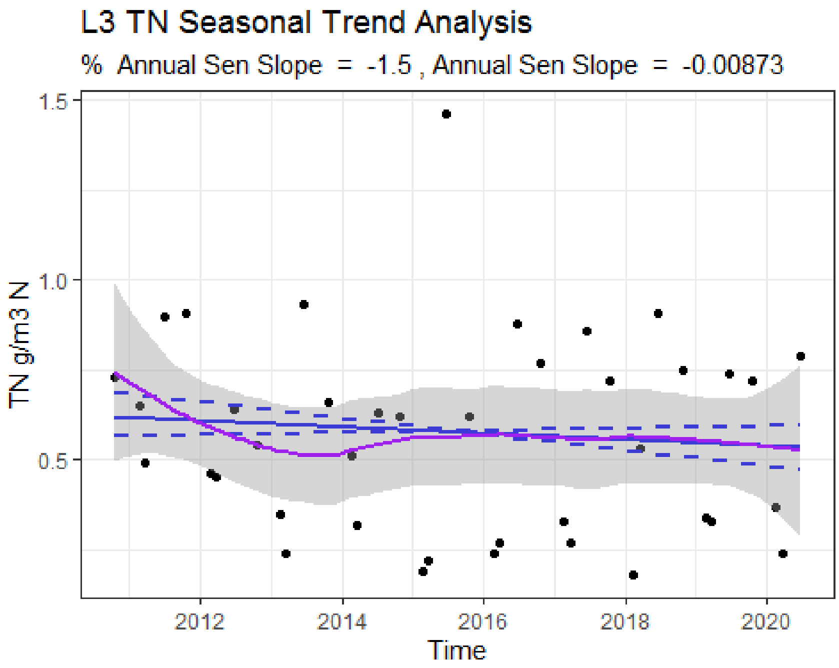
% Annual Sen Slope = 0 , Annual Sen Slope = 0

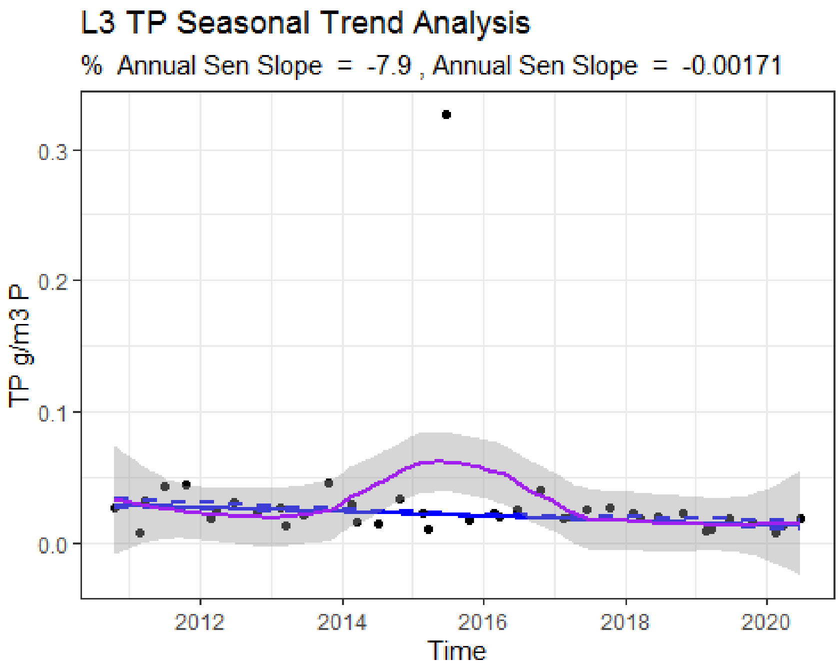


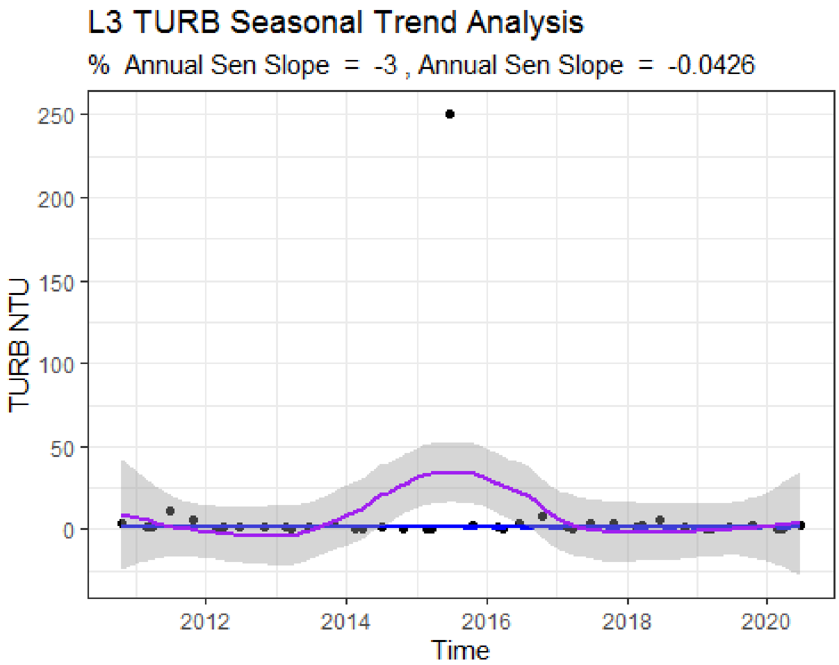

L3 SECCHI Seasonal Trend Analysis

% Annual Sen Slope = 1.4 , Annual Sen Slope = 0.0442

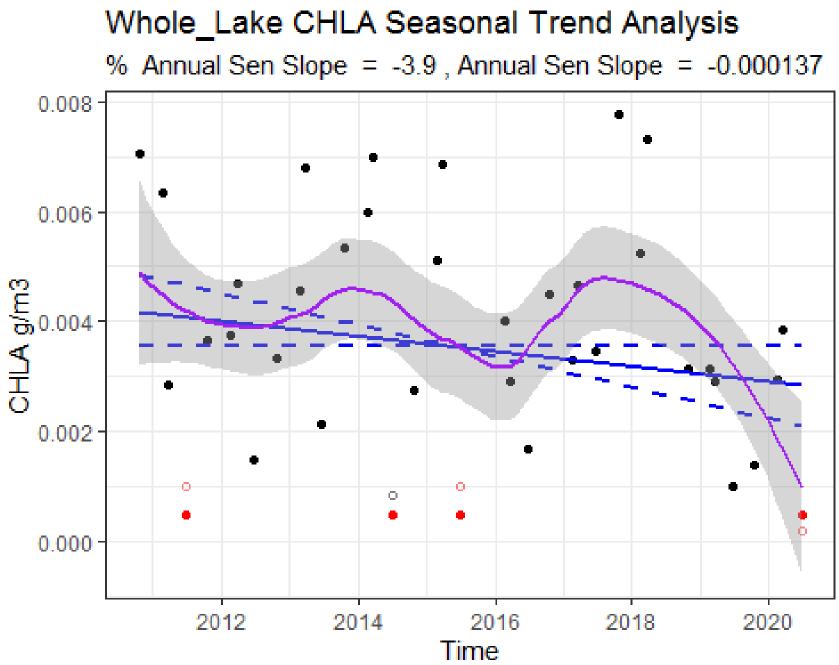



L3 TN Seasonal Trend Analysis
% Annual Sen Slope = -1.5 , Annual Sen Slope = -0.00873
TN g/m3 N
1.5
1.0
0.5
2012
2014
2016
2018
2020
Time

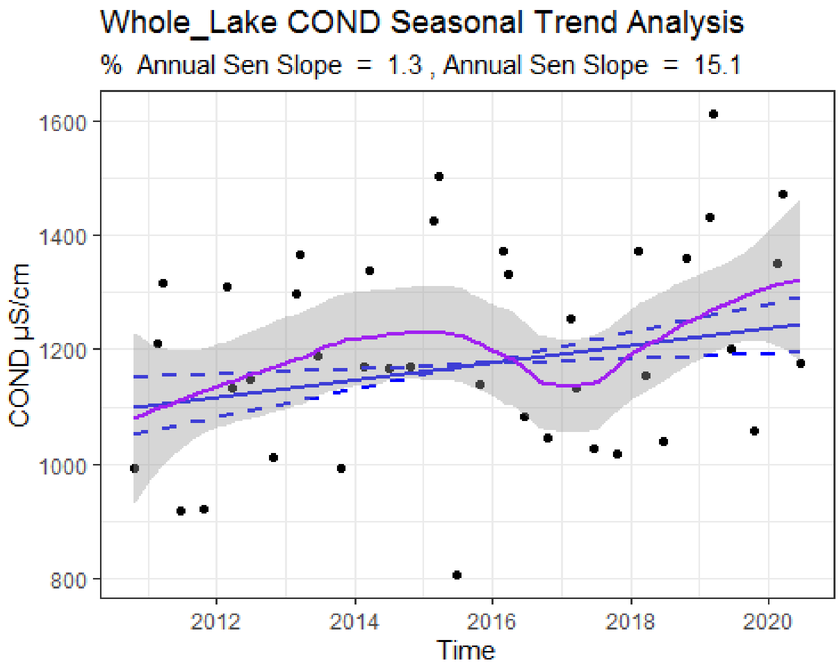

L3 TP Seasonal Trend Analysis
% Annual Sen Slope = -7.9 , Annual Sen Slope = -0.00171
TP g/m3 P
0.3
0.2
0.1
0.0
2012
2014
2016
2018
2020
Time

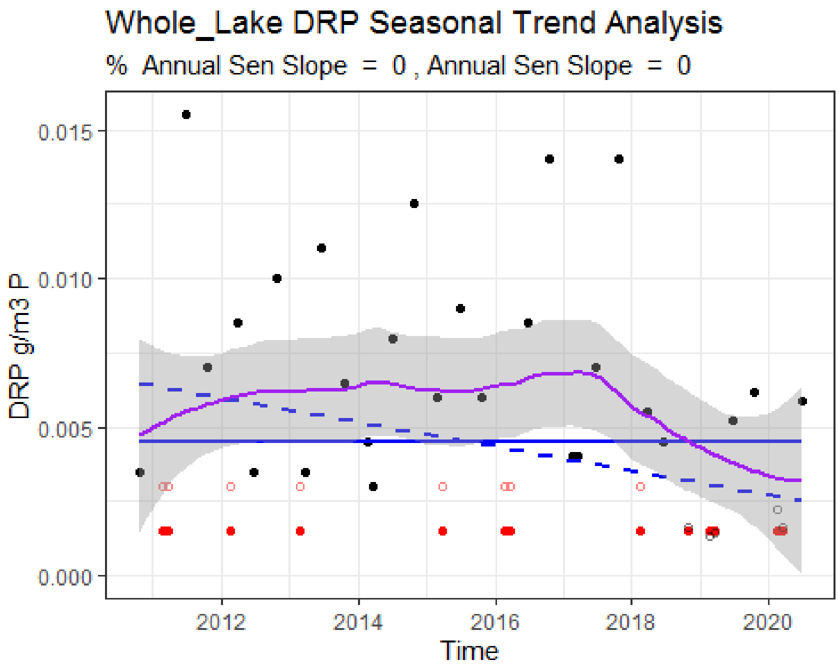


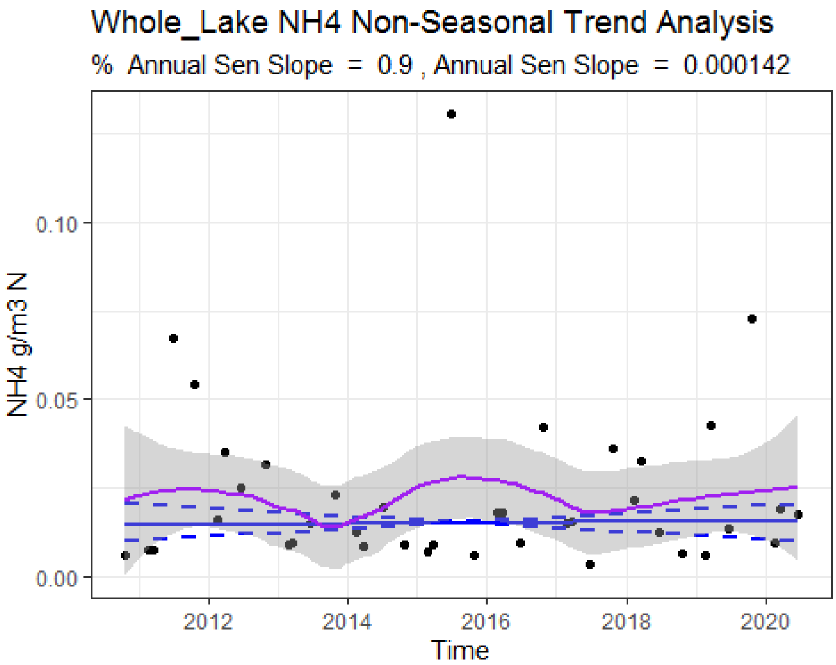
L3 TURB Seasonal Trend Analysis
% Annual Sen Slope = -3 , Annual Sen Slope = -0.0426
TURB NTU
250
200
150
100
50
0
2012
2014
2016
2018
2020
Time

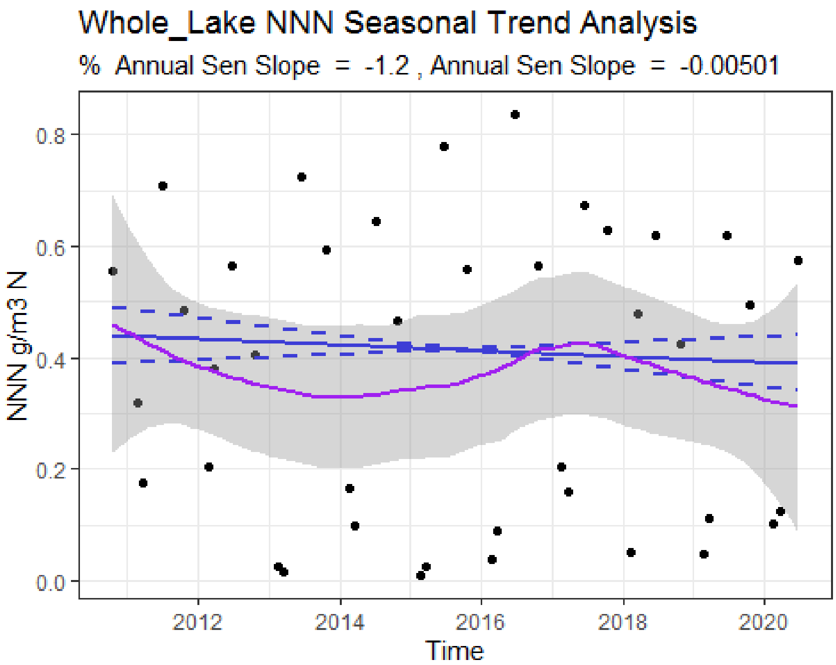



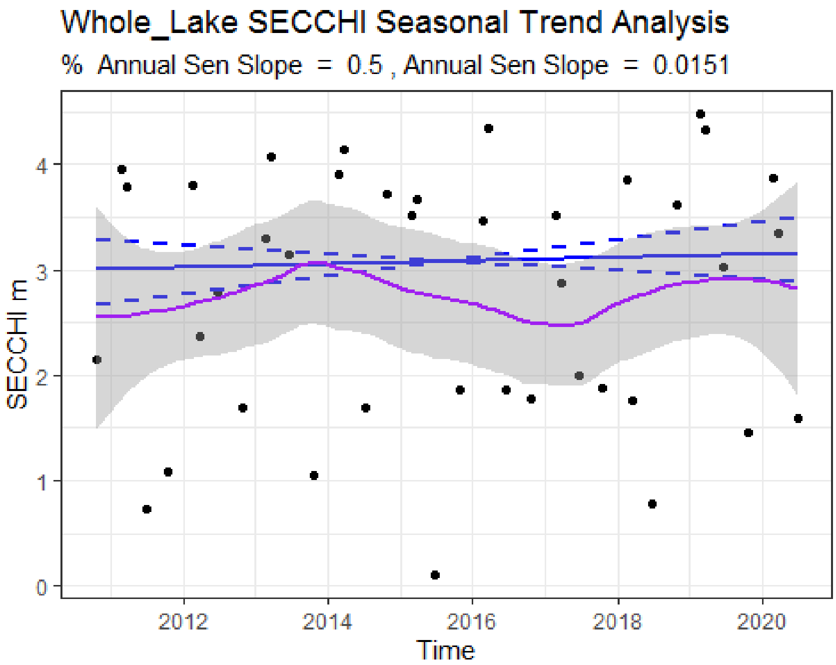
Whole_Lake CHLA Seasonal Trend Analysis
% Annual Sen Slope = -3.9 , Annual Sen Slope = -0.000137
CHLA g/m3
0.008
0.006
0.004
0.002
0.000
2012
2014
2016
2018
2020
Time

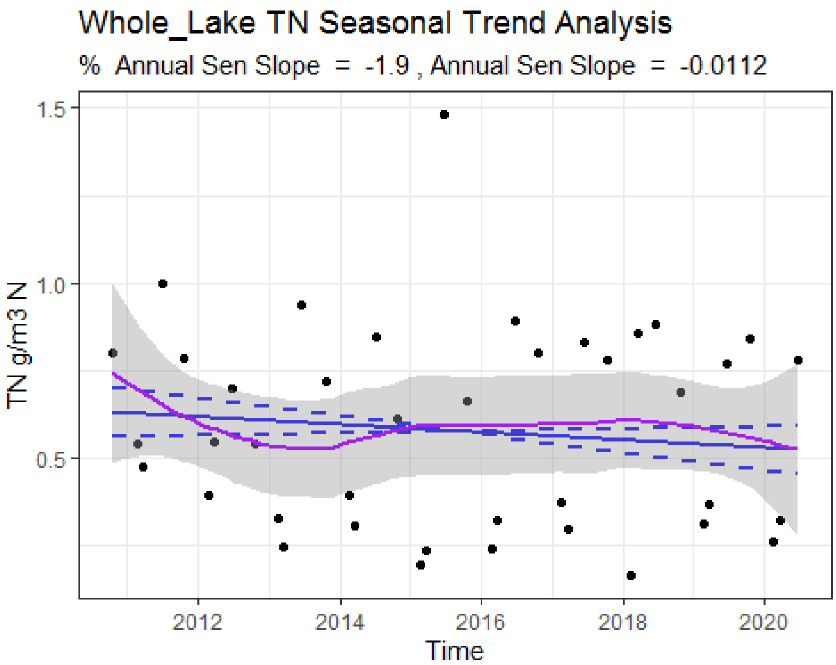

Whole_Lake COND Seasonal Trend Analysis
% Annual Sen Slope = 1.3 , Annual Sen Slope = 15.1
COND µS/cm
1600
1400
1200
1000
800
2012
2014
2016
2018
2020
Time

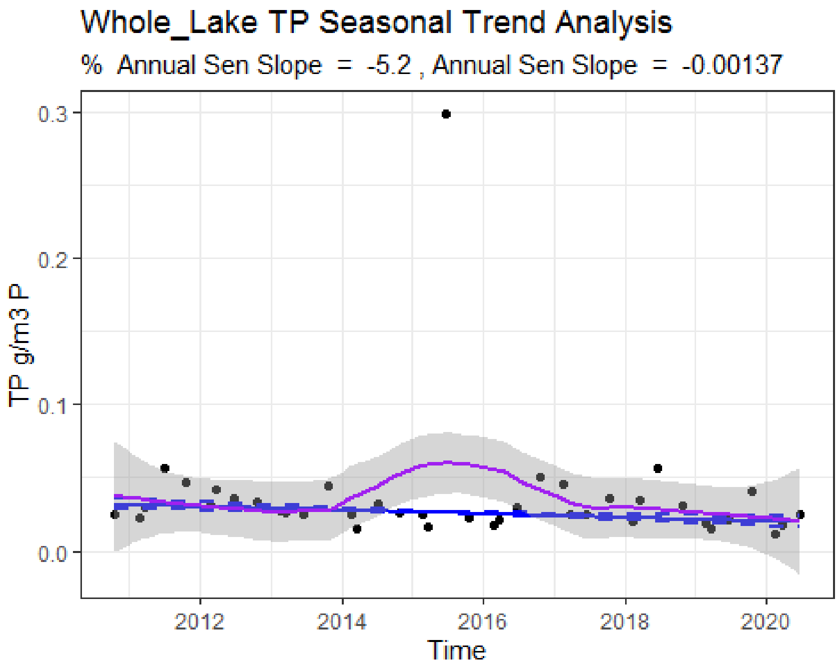

Whole_Lake DRP Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
DRP g/m3 P
0.015
0.010
0.005
0.000
2012
2014
2016
2018
2020
Time


Whole_Lake NH4 Non-Seasonal Trend Analysis
% Annual Sen Slope = 0.9 , Annual Sen Slope = 0.000142
NH4 g/m3 N
0.00
0.05
0.10
2012
2014
2016
2018
2020
Time

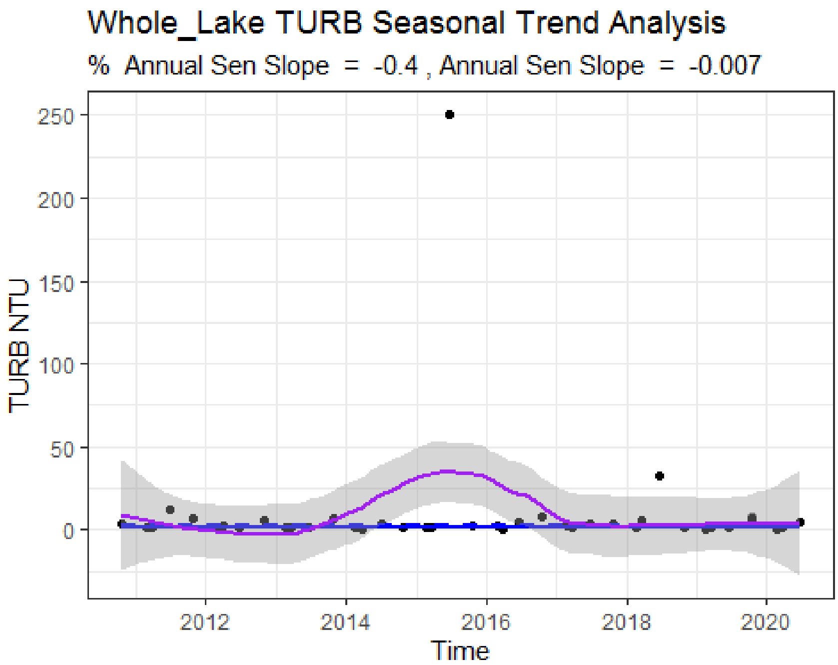

Whole_Lake NNN Seasonal Trend Analysis
% Annual Sen Slope = -1.2 , Annual Sen Slope = -0.00501
NNN g/m3 N
0.0
0.2
0.4
0.6
0.8
2012
2014
2016
2018
2020
Time


Whole_Lake SECCHI Seasonal Trend Analysis
% Annual Sen Slope = 0.5 , Annual Sen Slope = 0.0151
SECCHI m
0
1
2
3
4
2012
2014
2016
2018
2020
Time


Whole_Lake TN Seasonal Trend Analysis
% Annual Sen Slope = -1.9 , Annual Sen Slope = -0.0112
TN g/m3 N
0.5
1.0
1.5
2012
2014
2016
2018
2020
Time



Whole_Lake TP Seasonal Trend Analysis
% Annual Sen Slope = -5.2 , Annual Sen Slope = -0.00137
TP g/m3 P
0.0
0.1
0.2
0.3
2012
2014
2016
2018
2020
Time

Whole_Lake TURB Seasonal Trend Analysis
% Annual Sen Slope = -0.4 , Annual Sen Slope = -0.007
TURB NTU
0
50
100
150
200
250
2012
2014
2016
2018
2020
Time

# Appendix VI

# Comparison of trends reported using a significance based and a confidence based interpretation

Comparison between the results of the confidence grading system and the previous p-value based significance method. Significant trends based on p-values are identified in green text, while trends with high confidence are identified in red (increasing trend) or green (decreasing trend) text

| Site | No. of Surveys | Seasonality | Proportion Censored | Analysis Note | S Stat | tau | p-value | Median Sen Slope | Percent Annual Change | Trend Direction | Confidence Trend Decreasing |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **CHLA** | | | | | | | | | | | |
| L2 | 98 | Seasonal | 0.16 | | 217 | 0.188 | 0.00809 | 0.00005 | 1.79 | Increasing | Exceptionally unlikely |
| L3 | 98 | Seasonal | 0.13 | | 211 | 0.183 | 0.00996 | 0.00004 | 1.70 | Increasing | Exceptionally unlikely |
| Whole Lake | 98 | Seasonal | 0.10 | | 269 | 0.234 | 0.00114 | 0.00006 | 2.06 | Increasing | Exceptionally unlikely |
| **COND** | | | | | | | | | | | |
| L2 | 100 | Seasonal | 0.00 | | 106 | 0.088 | 0.21933 | 0.27599 | 0.23 | Increasing | Unlikely |
| L3 | 100 | Seasonal | 0.00 | | 190 | 0.158 | 0.02697 | 0.37984 | 0.32 | Increasing | Extremely unlikely |
| Whole Lake | 100 | Seasonal | 0.00 | | 190 | 0.158 | 0.02713 | 0.31594 | 0.27 | Increasing | Extremely unlikely |
| **DRP** | | | | | | | | | | | |
| L2 | 100 | Seasonal | 0.34 | Sen slope influenced by censored values | -11 | -0.009 | 0.89908 | 0.00000 | 0.00 | Decreasing | As likely as not |
| L3 | 100 | Seasonal | 0.45 | Sen slope influenced by censored values | -108 | -0.090 | 0.15455 | 0.00000 | 0.00 | Decreasing | Very likely |
| Whole Lake | 100 | Seasonal | 0.38 | Sen slope influenced by censored values | -23 | -0.019 | 0.77688 | 0.00000 | 0.00 | Decreasing | As likely as not |
| **NH4** | | | | | | | | | | | |
| L2 | 100 | Seasonal | 0.10 | Sen slope influenced by censored values | 0 | 0.000 | 1 | 0.00000 | 0.00 | Indeterminant | As likely as not |
| L3 | 100 | Seasonal | 0.17 | | -184 | -0.153 | 0.0308 | -0.00027 | -2.48 | Decreasing | Extremely likely |
| Whole Lake | 100 | Seasonal | 0.01 | | -71 | -0.059 | 0.4134 | -0.00015 | -0.85 | Decreasing | Likely |
| **NNN** | | | | | | | | | | | |
| L2 | 92 | Seasonal | 0.00 | | -60 | -0.059 | 0.43498 | -0.00138 | -0.37 | Decreasing | Likely |
| L3 | 92 | Seasonal | 0.02 | Sen slope based on tied non-censored values | -3 | -0.003 | 0.97886 | 0.00000 | 0.00 | Decreasing | As likely as not |

| Site | No. of Surveys | Seasonality | Proportion Censored | Analysis Note | S Stat | tau | p-value | Median Sen Slope | Percent Annual Change | Trend Direction | Confidence Trend Decreasing |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Whole Lake | 92 | Seasonal | 0.00 | | -25 | -0.025 | 0.75115 | -0.00066 | -0.17 | Decreasing | As likely as not |
| **SECCHI** | | | | | | | | | | | |
| L2 | 100 | Seasonal | 0.00 | | -55 | -0.046 | 0.52812 | -0.00892 | -0.33 | Decreasing | Likely |
| L3 | 100 | Seasonal | 0.00 | | -63 | -0.052 | 0.46845 | -0.00767 | -0.25 | Decreasing | Likely |
| Whole Lake | 100 | Seasonal | 0.00 | | -25 | -0.021 | 0.77923 | -0.00333 | -0.11 | Decreasing | As likely as not |
| **TN** | | | | | | | | | | | |
| L2 | 100 | Seasonal | 0.00 | | -194 | -0.162 | 0.02399 | -0.00500 | -0.80 | Decreasing | Extremely likely |
| L3 | 100 | Seasonal | 0.00 | | -198 | -0.165 | 0.02122 | -0.00495 | -0.81 | Decreasing | Extremely likely |
| Whole Lake | 100 | Seasonal | 0.00 | | -223 | -0.186 | 0.00949 | -0.00500 | -0.80 | Decreasing | Virtually certain |
| **TP** | | | | | | | | | | | |
| L2 | 100 | Seasonal | 0.00 | | 325 | 0.271 | 0.00015 | 0.00057 | 2.31 | Increasing | Exceptionally unlikely |
| L3 | 100 | Seasonal | 0.00 | | 129 | 0.108 | 0.13393 | 0.00016 | 0.84 | Increasing | Very unlikely |
| Whole Lake | 100 | Seasonal | 0.00 | | 256 | 0.213 | 0.00288 | 0.00041 | 1.79 | Increasing | Exceptionally unlikely |
| **TURB** | | | | | | | | | | | |
| L2 | 100 | Seasonal | 0.00 | | 140 | 0.117 | 0.10411 | 0.02227 | 0.97 | Increasing | Very unlikely |
| L3 | 100 | Seasonal | 0.00 | | 95 | 0.079 | 0.27172 | 0.00909 | 0.61 | Increasing | Unlikely |
| Whole Lake | 100 | Seasonal | 0.00 | | 128 | 0.107 | 0.13778 | 0.01484 | 0.82 | Increasing | Very unlikely |

# Appendix VII

# Comparison of currently and previously reported trends

Significant changes to the data analysis methodology have been made in the current report. Previously LakeWatch software has been used for analysis and it is no longer being supported. Moving away from using the LakeWatch analysis software has provided the opportunity to review and update the analytical methods used. The main changes can be summarised as follows:

1. The data period used for the full record has been taken as beginning in the 1996 monitoring year, while previously the record used began in 1990. This change has been made due to changes to the monitoring being standardised in 1996. The monitoring programme has remained relatively unchanged since this time. Differences in the timing of data collection prior to 1996 means that the sampling was not consistently targeting the stratification conditions that the programme was designed around.
2. The annual period for the calculation of TLI has been shifted from the calendar year to align with the monitoring year (July-June). This change provides a more robust assessment of the trophic level of the lake, which should be assessed on complete stratification cycles (Burns, 2000). Previously, the period of one stratification cycle would have been split across two years. Because the nature of stratification does not allow for mixing between layers of the water column, particular changes in the water chemistry occur in a predictable fashion during the stratified period. This means that these cyclical changes were not incorporated into the annual TLI value in a holistic manner. Furthermore, this change has aligned the period over which the TLI is calculated with the reporting period used by the Council, so that reporting of TLI and trend analyses are no longer calculated for only the first half of the reporting period. Although Burns et al., (2000) and Schallenberg & van der Zon (2021) recommend using a September to August calculation period to best align with the stratification cycle, in this instance the standardised sampling regime used in Lake Rotorangi does not include sampling between July-October. Because of this the calculation on the existing dataset will provide the same result whether the annual period starts in July or September.
3. A Mann-Kendall or seasonal Kendall test is now used for trend analysis (dependent on the results of a Kruskal-Wallis test for seasonality). This has replaced a seasonal linear regression. This change has been made due to the non-normal distribution of the data studied. Linear regression is a parametric technique, which relies on the data being (approximately) normally distributed. It is thus more appropriate to use non-parametric analytical methods.
4. Previous interpretation of the linear regression was made using the p-value for the f-statistic, which tests whole regression fit. To test change over time, it is more appropriate to test the p-value of the regression slope. Doing so in the past would also have given linear regression results that are more similar to those of the Mann-Kendall test (see Appendix V for a comparison).
5. Left censored data (data points below detection limits) were previously analysed by replacing these values with half the detection limit. In the current period, censored data has been replaced using a regression on order statistics (ROS) model when calculating summary statistics. This creates a distribution of the censored data based on the data above the detection limit. While this is a more robust method, care should be taken when interpreting statistics below the detection limit. For this reason, suspended solids for which approximately two-thirds of the data is censored, has been excluded from the analysis.
6. Epilimnion data is now used in trend analysis. Although Lakewatch stated that epilimnion data was trended during stratified periods and all data during isothermal periods, subsequent discrepancies in data have revealed that previously all data from all lake layers was being included in trend analysis. The trend analysis has been updated to include only epilimnetic data for the majority of variables, which is consistent with national reporting (Larned et al. 2015).

Overall, these changes have had the effect that the parameters for which a significant trend has been reported have changed. A comparison between the results of the confidence grading system and the previous p-value based significance method is also given in Appendix V. This analysis shows that the confidence based system identifies the same trends as the significance based system, when the statistical output is interpreted correctly. A further analysis is provided in the table below, identifying the changes in reported trends compared to previous reporting periods where the p-value of the f-statistic was incorrectly reported. This shows that between the two periods there are few similarities in reported trends, with only chlorophyll-a at all sites, TLI at site L2 and total phosphorus for the whole lake showing increasing trends in both analyses. Previous reporting did not detect any decreasing trends, which is due to the interpretation of trends in previous years. It should also be noted that the parameters used in the trend analysis have changed slightly, with turbidity now included in the analysis and suspended solids, dissolved oxygen and temperature no longer trended.

Comparison of trends reported in the 2018-2019 using previous methodology and interpretation with trends reported in the current period using updated methodology

| Parameter | Site | Previous Reporting | | | Current Reporting | | | |
|---|---|---|---|---|---|---|---|---|
| | | p-value | R | Trend Categorisation | Median Sen Slop | Percent Annual Change | Trend Category | Confidence (%) |
| CHLA | L2 | 0.02 | 0.23 | Significant Deterioration | 0.00005 | 1.79 | Very Likely Degrading | 99.60 |
| | L3 | 0.04 | 0.20 | Significant Deterioration | 0.00004 | 1.70 | Very Likely Degrading | 99.50 |
| | Whole Lake | 0.002 | 0.21 | Highly Significant Deterioration | 0.00006 | 2.06 | Very Likely Degrading | 99.94 |
| COND | L2 | 0.66 | 0.03 | | 0.27599 | 0.23 | Likely Degrading | 89.03 |
| | L3 | 0.31 | 0.08 | | 0.37984 | 0.32 | Very Likely Degrading | 98.65 |
| | Whole Lake | 0.33 | 0.05 | | 0.31594 | 0.27 | Very Likely Degrading | 98.68 |
| DRP | L2 | 0.49 | 0.06 | | 0.00000 | 0.00 | Indeterminate | 55.05 |
| | L3 | 0.48 | -0.06 | | 0.00000 | 0.00 | Very Likely Improving | 92.27 |
| | Whole Lake | 0.98 | -0.00 | | 0.00000 | 0.00 | Indeterminate | 61.16 |
| **NH4** | L2 | 0.84 | -0.02 | | 0.00000 | 0.00 | Indeterminate | 50.00 |
| | L3 | 0.83 | 0.02 | | -0.00027 | -2.48 | Very Likely Improving | 98.46 |
| | Whole Lake | 0.98 | -0.00 | | -0.00015 | -0.85 | Likely Improving | 79.33 |
| NNN | L2 | 0.0008 | 0.29 | Highly Significant Deterioration | -0.00138 | -0.37 | Likely Improving | 78.25 |
| | L3 | 0.0008 | 0.29 | Highly Significant Deterioration | 0.00000 | 0.00 | Indeterminate | 51.06 |
| | Whole Lake | 0.000002 | 0.29 | Highly Significant Deterioration | -0.00066 | -0.17 | Indeterminate | 62.44 |
| SECCHI | L2 | 0.98 | -0.00 | | -0.00892 | -0.33 | Likely Improving | 73.59 |

| Parameter | Site | Previous Reporting | | | Current Reporting | | | |
|---|---|---|---|---|---|---|---|---|
| | | p-value | R | Trend Categorisation | Median Sen Slop | Percent Annual Change | Trend Category | Confidence (%) |
| | L3 | 0.36 | -0.09 | | -0.00767 | -0.25 | Likely Improving | 76.58 |
| | Whole Lake | 0.48 | -0.05 | | -0.00333 | -0.11 | Indeterminate | 61.04 |
| TN | L2 | 0.58 | 0.05 | | -0.00500 | -0.80 | Very Likely Improving | 98.80 |
| | L3 | 0.94 | -0.01 | | -0.00495 | -0.81 | Very Likely Improving | 98.94 |
| | Whole Lake | 0.75 | 0.02 | | -0.00500 | -0.80 | Very Likely Improving | 99.53 |
| TP | L2 | 0.09 | 0.15 | | 0.00057 | 2.31 | Very Likely Degrading | 99.99 |
| | L3 | 0.17 | 0.13 | | 0.00016 | 0.84 | Very Likely Degrading | 93.30 |
| | Whole Lake | 0.03 | 0.14 | Significant Deterioration | 0.00041 | 1.79 | Very Likely Degrading | 99.86 |
| TURB | L2 | Not analysed | | | 0.02227 | 0.97 | Very Likely Degrading | 94.79 |
| | L3 | Not analysed | | | 0.00909 | 0.61 | Likely Degrading | 86.41 |
| | Whole Lake | Not analysed | | | 0.01484 | 0.82 | Very Likely Degrading | 93.11 |
| TLI | L2 | 0.03 | 0.20 | Significant Deterioration | 0.01047 | 0.25 | Very Likely Degrading | 95.59 |
| | L3 | 0.01 | 0.26 | Significant Deterioration | 0.01204 | 0.29 | Very Likely Degrading | 91.59 |
| | Whole Lake | 0.009 | 0.24 | Highly Significant Deterioration | 0.01342 | 0.32 | Very Likely Degrading | 93.55 |

# Lake Rotorangi

State of the Environment Monitoring

Annual Report

2020-2021

Technical Report 2021-63

Working with people | caring for Taranaki

Taranaki Regional Council

Taranaki Regional Council
Private Bag 713
Stratford

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November 2021

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## Annual Report
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# Executive summary

Lake Rotorangi was formed in May 1984 by the construction of an earth fill dam on the Patea River for hydroelectric power generation. In recognition of both the regionally significant recreational resource created, and the considerable environmental impacts which might occur, a comprehensive monitoring programme was developed and implemented for the lake. This report presents the results of monitoring for the period July 2020-June 2021.

Four water quality surveys were undertaken at two sites during the period under review. One site is located in the mid reaches of the lake, while the second site is located nearer the dam.

Thermal stratification is when the upper and lower water columns separate into different layers within the lake. Processes occurring within these layers can cause substantial differences in water quality between the layers. Stratification was beginning to form in the spring survey, was fully developed in the later summer and early autumn surveys, and had overturned by the winter survey. Oxygen depletion was evident in the late summer and early autumn surveys, and persisted at the lower lake site in the winter survey despite the uniform water temperatures throughout the water column. This pattern has been typical of Lake Rotorangi since monitoring began.

Physicochemical monitoring showed that lake water chemistry largely remained within the range which has been typical of the lake over the past 25 years. *E. coli* levels were within the 'surveillance' level (green traffic light) under contact recreational guidelines for the entire period in the lower lake (site L3), and in the mid lake (site L2) in late summer and early autumn, while in spring and winter the 'action' level (red traffic light) was reached at this site.

The trend analysis methodology implemented for this report was updated in the 2019-2020 period. This has resulted in changes to the results when compared to those previously reported. The methodology is briefly described in Section 2.4, with more detail provided in Appendix I.

Increasing trends in chlorophyll-a, conductivity and total phosphorus were detected, while total nitrogen showed a decreasing trend for the period 1996-2021. When analysed over the most recent ten year period, decreasing trends in dissolved reactive phosphorus, total phosphorus and chlorophyll-a, and an increasing trend in conductivity were detected.

National Objectives Framework (NOF) attributes for ammonia and phytoplankton classify the lake in the 'B' band, or as being slightly impacted compared to reference conditions, while total nitrogen concentrations classify the lake as being in the 'C' band, or moderately impacted compared to reference conditions. Total phosphorus classifies the upper lake as moderately impacted and the lower lake as mildly impacted.

The trophic state of the lake remains eutrophic, while on the basis of individual sites L2 is eutrophic and site L3 is mesotrophic.

The monitoring of Lake Rotorangi will continue in its present format for the 2021-2022 monitoring year, with the triennial biological monitoring next due for inclusion in the 2023-2024 year. This report also includes recommendations for the 2021-2022 monitoring year.

# Table of contents

Page

1 Introduction 1

1.1 General 1

1.2 Lake Rotorangi 1

1.2.1 Lake stratification processes 2

2 Monitoring methodology 3

2.1 Physicochemical monitoring 5

2.2 Biological monitoring 5

2.3 Trophic state 5

2.4 Analysis 6

3 Results 8

3.1 General observations/hydrological conditions 8

3.2 Physicochemical 10

3.2.1 Stratification 10

3.2.2 Water chemistry 12

3.3 Biological 20

3.3.1 Phytoplankton 20

3.3.2 Benthic macroinvertebrates 22

3.3.3 Macrophytes 22

3.4 Trophic state 23

3.5 Temporal trends 25

4 Discussion 29

5 Recommendations 31

Glossary of common terms and abbreviations 32

Bibliography and references 34

Appendix I Trend analysis methodology 37

Appendix II Physicochemical Monitoring Results 2020-2021

Appendix III Macrophyte Survey Report

Appendix IV Trophic Level Index

Appendix V Trend plots for the period 1996-2021

Appendix VI Trend plots for the period 2012-2021

# List of tables


| | | |
|---|---|---|
| Table 1 | Monitoring site locations in Lake Rotorangi | 3 |
| Table 2 | Seasonal sampling and targeted stratification conditions | 3 |
| Table 3 | Physicochemical parameters monitored at each sampling depth in Lake Rotorangi | 5 |
| Table 4 | Confidence categorisation for trend direction results | 7 |
| Table 5 | Observations at Lake Rotorangi monitoring sites on sampling occasions during 2020-2021 | 8 |
| Table 6 | Minimum dissolved oxygen concentrations ($g/m^3$) in Lake Rotorangi assessed against National Objective Framework attributes. | 10 |
| Table 7 | Trophic State of Lake Rotorangi based on total nitrogen and total phosphorus National Objective Framework attributes. (Note that units used in the NOF differ between parameters and from the units primarily used throughout this report) | 17 |
| Table 8 | Phytoplankton attribute state of Lake Rotorangi under the National Objectives Framework. (Note that units used in the NOF differ from the units primarily used throughout this report) | 21 |
| Table 9 | Trophic level and values of key variables defining the trophic status* of Lake Rotorangi in 2020-2021. (Note that units used in the trophic level calculations differ from the units primarily used throughout this report) | 24 |
| Table 10 | Trend analysis of selected variables in Lake Rotorangi for the period 1996-2021. Trends of high confidence are identified in red (degrading trend) or blue (improving trend) | 25 |
| Table 11 | Trend analysis of selected variables in Lake Rotorangi for the period 2012-2021. Trends of high confidence are identified in red (degrading trend) or blue (improving trend) | 27 |


# List of figures


| | | |
|---|---|---|
| Figure 1 | Location of monitoring sites in Lake Rotorangi with inset showing the location and catchment of the lake. Sites L2 and L3 are currently monitored, while monitoring at Site L1 was discontinued in 2010 due to the predominantly riverine nature of the lake at this northern location | 4 |
| Figure 2 | Synthetic inflow at Lake Rotorangi for the period 1 July 2020 to 30 June 2021 | 9 |
| Figure 3 | Temperature (°C) and dissolved oxygen ($g/m^3$) profiles for sites L2 and L3 on sampling occasions in 2020-2021. Sampling depths are indicated by letters (E = epilimnion; H = hypolimnion; B = near benthos) | 11 |
| Figure 4 | Measures of visual clarity in Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the measurement recorded in the period under review is represented as a diamond | 12 |
| Figure 5 | Epilimnetic and hypolimnetic physicochemical parameters in Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond | 13 |
| Figure 6 | *E. coli* measured at the surface of Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the measurement recorded in the period under review is represented as a diamond. The red line indicates the threshold below which data is | |

censored. Statistics below this threshold should be interpreted with caution. Black threshold lines represent guidelines for recreational use 14

Figure 7 Epilimnetic and hypolimnetic nutrient concentrations at site L2 in Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution 15

Figure 8 Epilimnetic and hypolimnetic nutrient concentrations at site L3 in Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution 16

Figure 9 Selected parameters sampled in Lake Rotorangi in the hypolimnion and near the bottom of the water column at site L2. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution 18

Figure 10 Selected parameters sampled in Lake Rotorangi in the hypolimnion and near the bottom of the water column at site L3. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution 19

Figure 11 Seasonal chlorophyll-a concentrations in the photic zone of Lake Rotorangi. Historical summary data is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution 20

Figure 12 Phytoplankton taxa richness at site L2 since 1989 21

Figure 13 Phytoplankton taxa richness at site L3 since 1989 21

Figure 14 Dominant macrophytes recorded in Lake Rotorangi on 16 April 2021 23

Figure 15 Trophic level index in Lake Rotorangi over the period 1996-2021. The four components of the TLI (chlorophyll-a, secchi depth, total nitrogen and total phosphorus) are plotted individually, as well as the overall TLI. The trend shown relates to the overall TLI. The lowess curve for the overall TLI is in purple 24

# 1 Introduction

## 1.1 General

The *Resource Management Act 1991* (RMA) sets out requirements for local authorities to undertake environmental monitoring. Section 35 of the RMA requires local authorities to monitor, among other things, the state of the environment of their region or district, to the extent that is appropriate to enable them to effectively carry out their functions under the Act.

To this effect, the Taranaki Regional Council (Council) has established a state of the environment monitoring (SoE) programme for the region. This programme is outlined in the Council's 'State of the Environment Monitoring Procedures Document', which was prepared in 1997. The monitoring programme is based on the significant resource management issues that were identified in the *Council's Regional Policy Statement for Taranaki (1994)*.

Council's SoE programme encompasses a number of individual monitoring activities, many of which are undertaken and managed on an annual basis (from 1 July to 30 June). Where possible, individual consent monitoring programmes have been integrated within the SoE programme to save duplication of effort and minimise costs. The purpose of SoE reporting is to summarise and interpret regional environmental monitoring activity results and report on any changes (trends) in these data. These reports in turn provide key information for Council's five yearly regional state of environment report, which is due to be published in the first half of 2022. Copies of these reports are made available on Council's website.

## 1.2 Lake Rotorangi

Lake Rotorangi was formed in May 1984 by the construction of an earth fill dam on the Patea River for the purpose of a hydro-electric power scheme. An initial sampling programme was designed to assess the state and environmental consequences of the new lake. The results of this intensive monitoring programme were published in the 'Lake Rotorangi - Monitoring a New Hydro Lake' (Taranaki Catchment Board, 1988) report. Results of monitoring since this time are published in annual reports listed in the references of this report.

This initial monitoring determined that the lake was mildly eutrophic or mesotrophic. Further, the annual thermal stratification cycle which the lake undergoes was identified as the single most important factor influencing water quality within the lake.

Since monitoring began, the trophic state of Lake Rotorangi has been increasing (degrading) at a very slow rate, in the order of 0.02±0.01 units per year. Initial monitoring showed the lake was in a mesotrophic state, and has over time moved to a mildly eutrophic state. Previous analysis has determined that the trophic level is heavily influenced by high turbidity values and therefore not a true indication of actual trophic status (as determined by primary production) of the lake (Burns 2006).

The Patea catchment upstream of the dam covers an area of 86,944 ha. This includes both the Patea River sub-catchment and the Mangaehu River sub-catchment. Approximately 841 ha (1%) of this area is urban, while another 6589 ha (8%) is conservation land. The remainder of the catchment (71,514 ha, 91%) is in pastoral land, with a mixture of dry stock and dairy farming in the catchment. Identifying and implementing actions to address hill country erosion is a significant focus for this catchment. Farm plans addressing land management and sediment issues cover around 43055 ha (50%) of the catchment, primarily in the area where dry stock faming is the dominant land use.

The trophic level of Lake Rotorangi has been increasing at a very slow rate since monitoring began. Initial monitoring showed the lake was in a mesotrophic state, and has over time moved to a mildly eutrophic state. Previous analysis has determined that the trophic level is heavily influenced by high turbidity values and therefore not a true indication of actual trophic status (as determined by primary production) of the lake (Burns 2006).

### 1.2.1 Lake stratification processes

Thermal stratification is a seasonal process, which occurs when the upper water column near the surface warms much faster than the lower water column. Changes in the density of water at differing temperatures creates a physical barrier separating the upper water column (epilimnion) and lower water column (hypolimnion). Biological and chemical processes differ between the epilimnion and hypolimnion, causing substantial differences in water quality between the layers. In Lake Rotorangi, is one of the primary factors impacting observed water quality.

Substantial differences in water quality can occur between the epilimnion and hypolimnion as a result of stratification. Typically, the epilimnion has the majority of primary production because light levels are highest in the upper water column. Organic detritus sinks from the epilimnion though the water column, resulting in the transfer of nutrients to the hypolimnion. Therefore over time, the concentrations of bioavailable nutrients decreases in the epilimnion compared to the hypolimnion.

Oxygen depletion may occur in the hypolimnion, because oxygen consumed by biological and chemical processes cannot be replaced due to the physical separation from the more oxygenated surface waters. Replacement of oxygen in the hypolimnion results from mixing caused by either the natural overturn processes or as a results of flood events in the river inflow.

Furthermore, as oxygen depletion occurs in the hypolimnion, this can in turn alter the pH of the hypolimnion. The increased pH in anoxic waters creates a risk of nutrient release from the lakebed sediment into the water column.

# 2 Monitoring methodology

The current Lake Rotorangi Monitoring programme consists of two primary components; physicochemical and biological monitoring. Sampling is undertaken at two sites along the lake, on four occasions each year. The sampling occasions are timed to target particular conditions with regard to stratification of the lake. Details of the sites are provided in Table 1 and Figure 1.

Table 1 Monitoring site locations in Lake Rotorangi

| Site code | Site | Location |
|---|---|---|
| LRT000300 | L2 (near Tangahoe Valley Road) | E1729856 N5626435 |
| LRT000450 | L3 (near Patea Dam) | E1734948 N5621974 |

The targeted conditions are described in Table 2. Sampling in the specified months is aimed to be undertaken on or near the 20th of the month. The dates sampled in the 2020-2021 year are also provided in Table 2.

Table 2 Seasonal sampling and targeted stratification conditions

| Season | Month | Target conditions | Sampling date |
|---|---|---|---|
| Spring | October | Pre-stratification | 16 Oct 2020 |
| Late Summer | February | Stable stratification | 25 Feb 2021 |
| Early Autumn | March | Pre-overturn | 23 Mar 2021 |
| Winter | June | Post-overturn | 24 Jun 2021 |

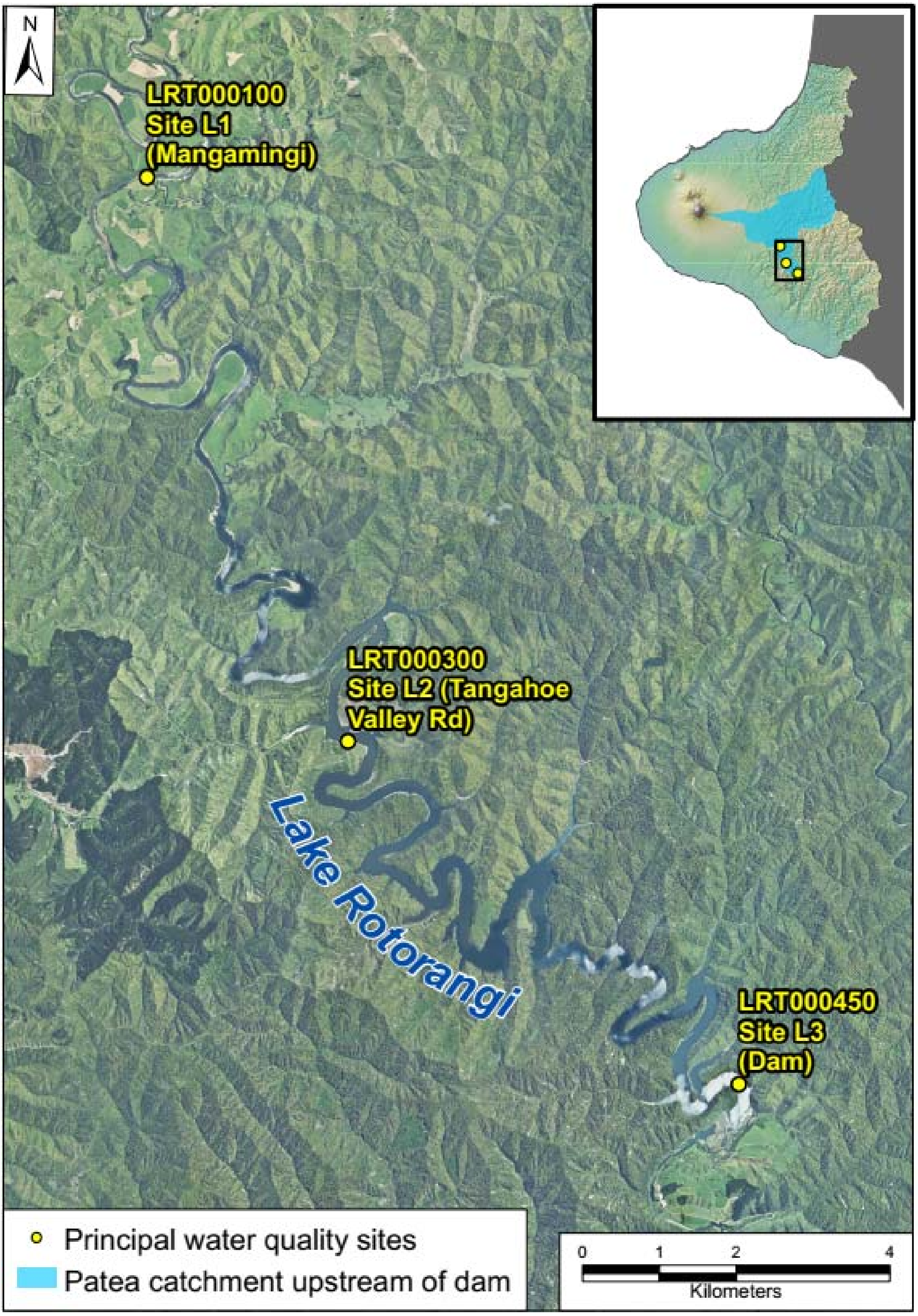


Figure 1 Location of monitoring sites in Lake Rotorangi with inset showing the location and catchment of the lake. Sites L2 and L3 are currently monitored, while monitoring at Site L1 was discontinued in 2010 due to the predominantly riverine nature of the lake at this northern location

## 2.1 Physicochemical monitoring

At each site a depth profile is collected measuring temperature and dissolved oxygen. On all sampling occasions, water samples are collected using a grab sample to reflect conditions at the surface, and using a van-Dorn sampler at points in the water column to represent conditions in the epilimnion and the hypolimnion. In February and March (under stratified conditions), additional water samples are collected near the base of the water column to assess the impact of anoxia at the sediment-water interface.

Table 3 Physicochemical parameters monitored at each sampling depth in Lake Rotorangi

| Parameter | Units | Surface | Epilimnion | Hypolimnion | Lower hypolimnion[1] |
|---|---|---|---|---|---|
| Black disc transparency | m | x | | | |
| Secchi disc transparency | m | x | | | |
| pH | pH units | x | x | x | x |
| Conductivity | µS/cm | x | x | x | |
| Turbidity | FNU | x | x | x | x |
| Suspended solids | $g\ m^{-3}$ | x | x | x | |
| *E. coli* | MPN/100mL | x | | | |
| Dissolved reactive phosphorus | $g\ m^{-3}$ P | | x | x | x |
| Total phosphorus | $g\ m^{-3}$ P | | x | x | x |
| Ammoniacal nitrogen | $g\ m^{-3}$ N | | x | x | x |
| Nitrite nitrogen | $g\ m^{-3}$ N | | x | x | |
| Nitrate nitrogen | $g\ m^{-3}$ N | | x | x | |
| Nitrate and nitrite nitrogen | $g\ m^{-3}$ N | | x | x | x |
| Total Kjeldahl nitrogen | $g\ m^{-3}$ N | | x | x | |
| Total nitrogen | $g\ m^{-3}$ N | | x | x | |

[1] Sampled in late summer and early autumn only

Samples are collected in accordance with the National Environmental Monitoring Standard (NEMS) for discrete lake water quality data (NEMS, 2019).

## 2.2 Biological monitoring

Sampling of the photic zone is undertaken in conjunction with physicochemical monitoring. A depth integrated sample is collected and analysed for chlorophyll-a, and a subsample used to identify the phytoplankton species present.

Triennially, a benthic macroinvertebrate sample is collected at each site in conjunction with the spring physicochemical monitoring. A macrophyte survey is also undertaken triennially in autumn. Both the benthic macroinvertebrate and the macrophyte survey were due to be carried out in the 2020-2021 monitoring year.

## 2.3 Trophic state

The trophic level index (TLI) is calculated for the lake as a whole as well as for individual sites. The equations used vary from those used by Burns (1999), and are consistent with those used by Lakewatch (which was previously used to calculate the TLI). This change to the equation for secchi disc was made after removal of peat-stained lakes, and is appropriate for Lake Rotorangi which is not affected by peat.

Furthermore, following the Lakewatch methodology, the calculation of TLI is dependent on the stratification of the lake. Epilimnetic data is used during stratified periods, while both epilimnetic and hypolimnetic data is used when the lake is isothermal (defined as less than 3°C differences between the surface and lake bottom water temperature). In calculating the TLI, censored values have been treated as the detection limit. Annual average values of the four parameters used are calculated, and are then input into equations to calculate the four components of the TLI as follows:

$$TLc = 2.22 + 2.54 \log (Chla)$$
$$TLs = 5.56 + 2.60 \log ((1/Secchi) - (1/40))$$
$$TLp = 0.218 + 2.92 \log (TP)$$
$$TLn = -3.61 + 3.01 \log (TN)$$

These four component values are then averaged to obtain the overall TLI.

It should be noted that in previous reports the TLI has been calculated per calendar year. In this report an adjustment has been made to this calculation, so that the analysis year is from July-June to align with the reporting period. Furthermore, this change aligns with the recommendation in Burns et al, (2000) and Schallenberg & van der Zon (2021) by ensuring that the calculation year includes an entire period of stratification. Although Burns et al, (2000) and Schallenberg & van der Zon (2021) recommend using a September to August calculation period to best align with the stratification cycle, in this instance the standardised sampling regime used in Lake Rotorangi does not include sampling between July-October. Because of this the calculation on the existing dataset will provide the same result whether the annual period starts in July or September.

## 2.4 Analysis

A number of changes to data analysis methodologies have been implemented in this report. A brief description of the current methods used is given below, with a more detailed discussion in Appendix I. A discussion of how these differ from methods used in previous TRC SEM lake reports is provided in the 2019-2020 Lake Rotorangi report (Taranaki Regional Council 2021).

In this report, trend analysis has been carried out using the LWP-Trends library R package (version 1901), developed by Land Water People Ltd. (Snelder & Fraser, 2019). The methods employed have the primary purpose of establishing the direction and rate of any trend, along with a measure of the uncertainty in the result. The use of the LWP-Trends package represents a major change in trend analysis methodology compared to previous TRC Lake SEM reports, in part due to different methods used in the past, but also due to a recent conceptual shift in how to assess confidence in trend analysis results (Greenland et al. 2016, McBride 2019, Helsel et al. 2020).

The data is assessed using a Kruskal-Wallis test to determine whether the data is seasonal. Either a Mann-Kendall or seasonal Kendall test is used to determine the trend direction. A trend rate and confidence in the trend are also generated using a sen-slope regression. Censored data is handled using the methods of Helsel (2011). A note is included when this is affected by censored data, which generally indicates that the trend rate is smaller than can be detected.

The confidence in the trend direction is assessed following the credible interval assessment method of McBride (2019). The confidence in the reported trend direction (ranging from 50% to 100%) is categorised based on the categories in Table 4.

Table 4 Confidence categorisation for trend direction results

| Confidence Category | Confidence in reported trend direction |
|---|---|
| Very Likely Improving | 90 – 100% |
| Likely Improving | 67 – 90% |
| Indeterminate | 50 – 67% |
| Likely Degrading | 67 – 90% |
| Very Likely Degrading | 90 – 100% |

The trend methods implemented are limited to identifying a single direction (monotonic) trend over time. In many cases, trend in environmental data may fluctuate throughout the time series, due to changes in conditions or individual events resulting in changed trends. A Loess curve has been overlaid on the trend analysis to assist with assessment of non-monotonic trends and investigation into causes of any changes in trends. In addition, a comparison of long term (25 year) and short term (10 year) quantitative trends is undertaken.

In the case of parameters which are sampled at multiple depths within the lake, trend analysis has been carried out on the data from the epilimnion. Differences in the water chemistry between the epilimnion and hypolimnion during the stratified period mean that combining the data from both stratified layers may mask any trends present. For the analysis of the lake as a whole, results taken at different sites, within the same layer of the water column and on the same day, are averaged to provide a single result. These average values are analysed as described above. Both the use of epilimnion data and averaging across the whole lake are consistent with national reporting (Larned et al, 2015).

# 3 Results

## 3.1 General observations/hydrological conditions

Sampling was undertaken on the dates specified in Table 2. General observations made on each of the sampling occasions during the period under review are presented in Table 5.

Table 5 Observations at Lake Rotorangi monitoring sites on sampling occasions during 2020-2021

| Date | Lake level (m asl) | Weather | Wind | | Lake appearance | |
|---|---|---|---|---|---|---|
| | | | L2 | L3 | L2 | L3 |
| 16 Oct 2020 | 76.78 | Fine, rain 3 days prior | Light NE breeze | No wind | Turbid, brown-green; surfaced rippled | Turbid, green-brown; surface rippled |
| 25 Feb 2021 | 76.65 | Fine, dry weather preceding | No wind | Light breeze | Clear, dark green; surface flat | Clear, dark green; surface rippled |
| 23 Mar 2021 | 7.66 | Fog clearing, fine weather preceding | No wind | No wind | Clear, dark green; surface flat | Clear, dark green; surface flat |
| 24 Jun 2021 | 76.56 | Broken cloud, rain week prior | No wind | Light NW | Slightly turbid, brown-green; surface flat | Slightly turbid, brown-green; surface rippled |

The synthetic inflow data for Lake Rotorangi is presented in Figure 2. This synthetic inflow is the flow entering the head of the lake (at Mangamingi) and equates to flows form the Patea River and Mangaehu River catchments above Mangamingi.

The spring and winter surveys were carried out under fresh recession inflow conditions, with two small freshes in the month preceding the spring survey and three small freshes in the month preceding the winter survey. The late summer and early autumn surveys were carried out under baseflow conditions with two minor freshes in the month preceding the late summer survey and one minor fresh in the month preceding the early autumn survey.

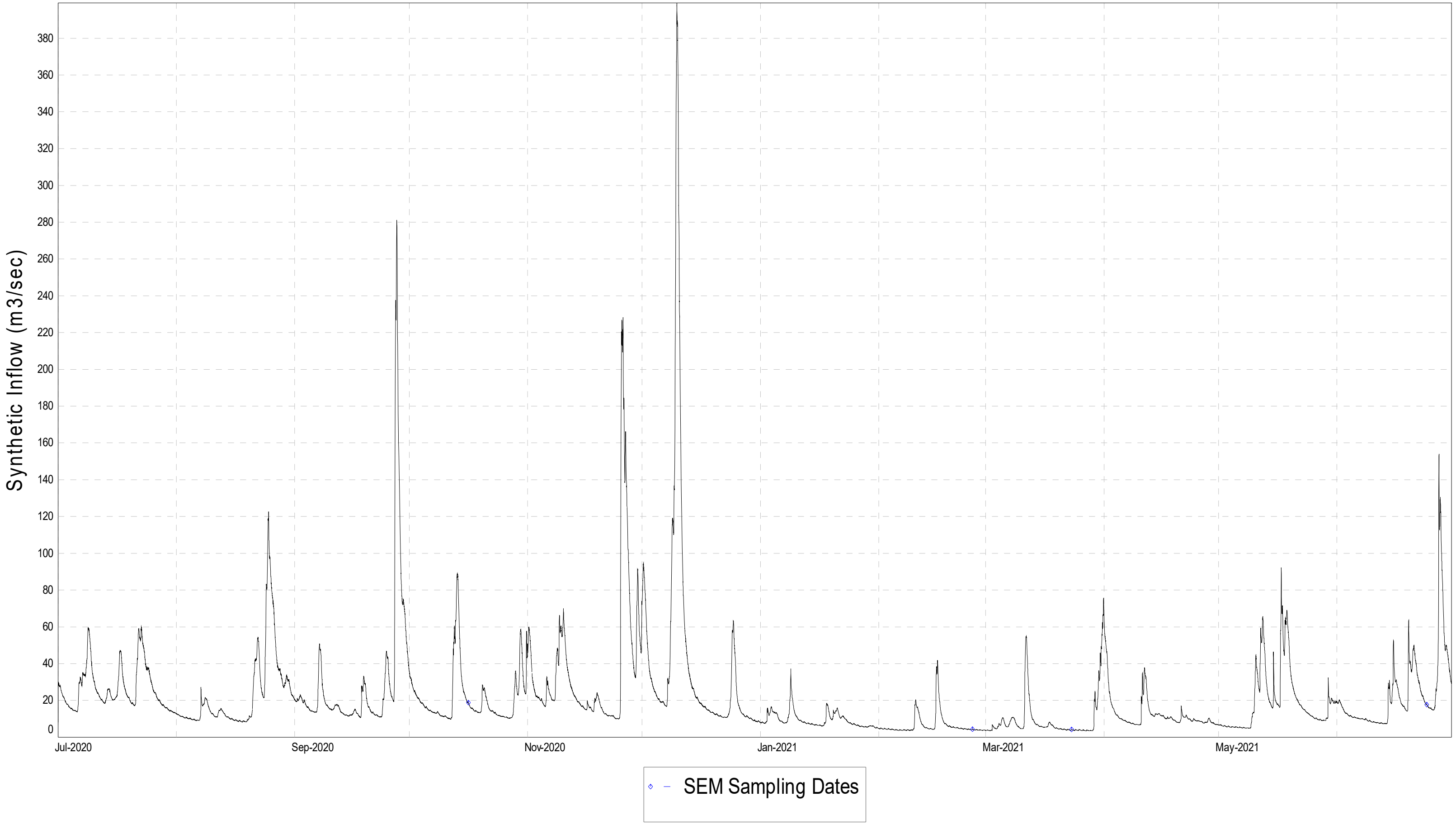


Figure 2 Synthetic inflow at Lake Rotorangi for the period 1 July 2020 to 30 June 2021

## 3.2 Physicochemical

Physicochemical monitoring data collected during the period under review are provided in full in Appendix II.

### 3.2.1 Stratification

Thermal stratification was developed at site L2 and weakly developed at site L3 during the spring sampling. In both the late summer and early autumn sampling, the stratification was strongly developed, and the lake was isothermal during the winter sampling (Figure 3).

Dissolved oxygen stratification was evident at both sites during all four sampling occasions in 2020-2021 (Figure 3). This pattern of dissolved oxygen stratification remaining site L3 has been typical of Lake Rotorangi in previous monitoring years and indicates that although temperatures are similar throughout the water column, vertical mixing of the water column was not complete.

Surface water temperatures were below seasonal medians in 2020-2021, except in the winter sampling. Water temperatures above the lakebed were above median throughout the period under review.

Surface dissolved oxygen concentrations were above medians at site L2 throughout the period under review. Site L3 had lower than typical concentrations in spring and early autumn, and similar to median concentrations in late summer and early autumn. Dissolved oxygen concentrations near the bottom of the water column were below medians at both sites throughout the period under review.

Anoxic conditions, when dissolved oxygen is less than 0.5 g/m$^3$, were observed in the hypolimnion at site L2 below 28 metres in late summer and below 26 metres in early autumn. At site L3, anoxia occurred below 42 metres in late summer, 32 metres in early autumn and below 26 metres in winter.

Assessment of lake-bottom and mid-hypolimnetic dissolved oxygen concentrations against the National Objectives Framework (NOF) numeric attribute state (New Zealand Government, 2020) places both sites in the D band for both attributes (Table 6). This does not meet the National Bottom line. Further work will be required to assess whether this is naturally occurring and if any action should be required as a result.

Table 6 Minimum dissolved oxygen concentrations (g/m$^3$) in Lake Rotorangi assessed against National Objective Framework attributes.

| Site | Minimum | Level | Band | Narrative Attribute State |
|---|---|---|---|---|
| L2 | 0 | Lake-bottom | D | Likelihood from lake-bottom dissolved oxygen of biogeochemical conditions resulting in nutrient release from sediments |
| L3 | 0 | | D | Likelihood from lake-bottom dissolved oxygen of biogeochemical conditions resulting in nutrient release from sediments |
| L2 | 0 | Mid-hypolimnion | D | Significant stress on a range of fish species seeking thermal refuge in the hypolimnion. Likelihood of local extinctions of fish species and loss of ecological integrity |
| L3 | 0 | | D | Significant stress on a range of fish species seeking thermal refuge in the hypolimnion. Likelihood of local extinctions of fish species and loss of ecological integrity |

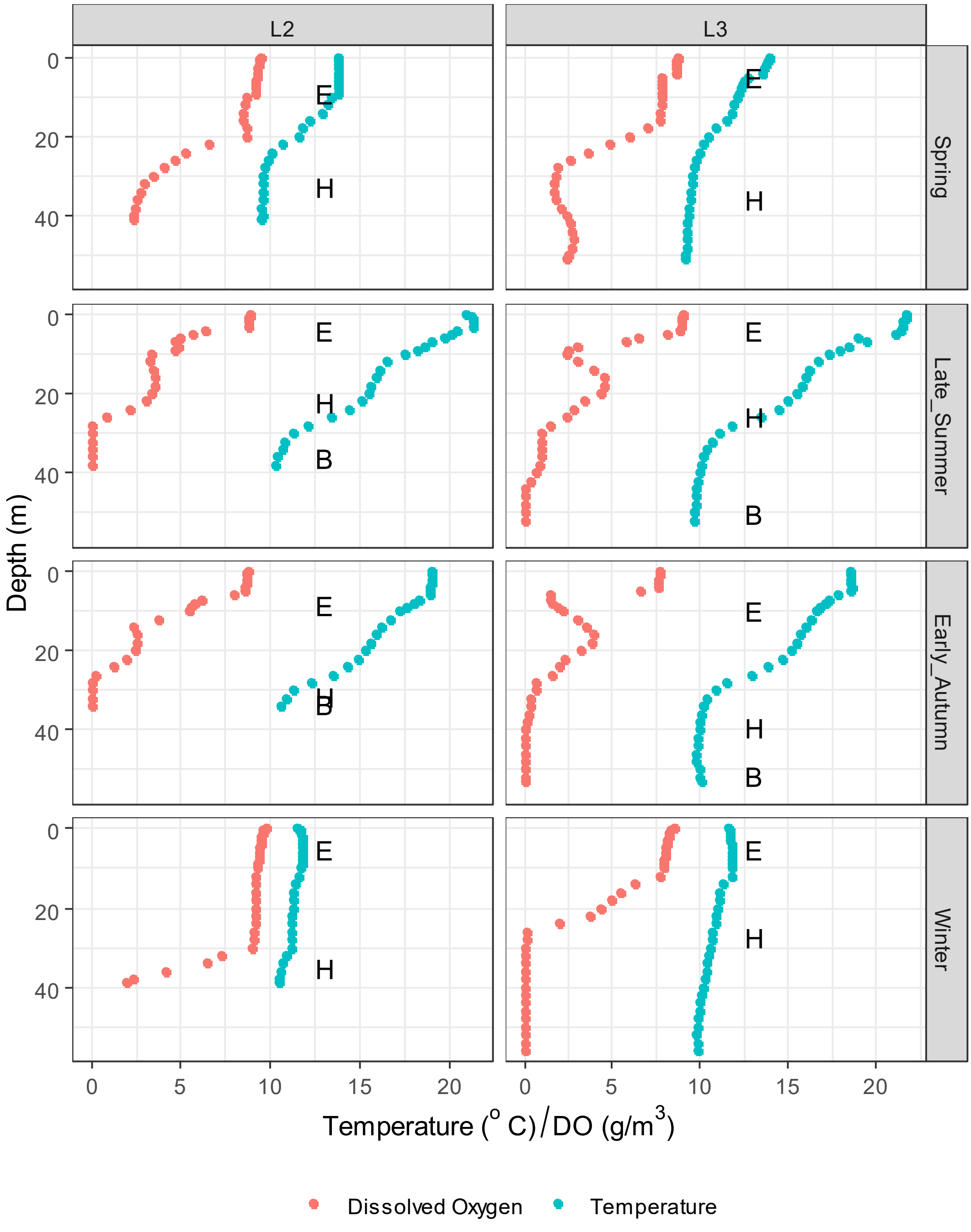


Figure 3 Temperature (°C) and dissolved oxygen (g/m³) profiles for sites L2 and L3 on sampling occasions in 2020-2021. Sampling depths are indicated by letters (E = epilimnion; H = hypolimnion; B = near benthos)

### 3.2.2 Water chemistry

The full physicochemical monitoring results collected during the period under review are provided in Appendix II. Selected results and associated historical data are discussed in more detail below.

Black disc measurements provide an estimate of horizontal water clarity, while secchi disc provides an estimate of vertical water clarity. Together, these measurements can be used to provide information on the penetration of diffuse light into the water column. As might be expected, there is a direct relationship between the two measurements, with the secchi disc greater than the black disc by a ratio of about 1.2:1 in Lake Rotorangi.

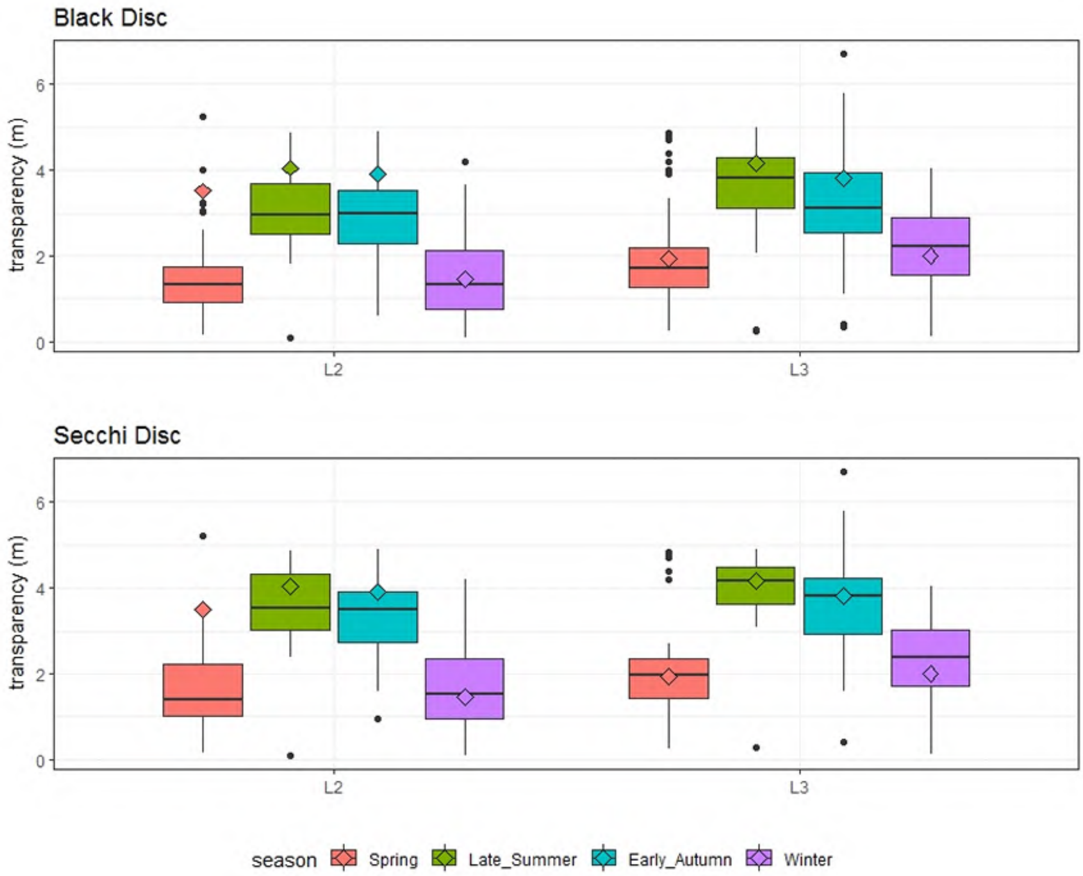


Figure 4 Measures of visual clarity in Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the measurement recorded in the period under review is represented as a diamond

During the period under review, black disc and secchi disc measurements were generally within a typical range. At site L2 in spring, both clarity measurements were higher than usual, albeit within the previously recorded range (Figure 4).

Conductivity at site L2 was generally above median. In late summer, this was particularly pronounced at the surface, while the hypolimnion recorded a lower than typical conductivity. Site L3 recorded lower than median conductivity in the upper water layers in spring. The epilimnion also recorded an atypically low conductivity in early autumn.

Turbidity was generally low at site L2, except in the upper water column in spring. At site L3, turbidity remained below seasonal median values throughout the period under review.

Suspended solids remained at low concentrations at both sites L2 and L3 throughout the period under review. It should be noted that the majority of suspended solids results during this period, including all results from L3, were below the detection limit of this test. Suspended solids data has not been presented in the body of this report due to the extremely high proportion of censored data for this parameter.

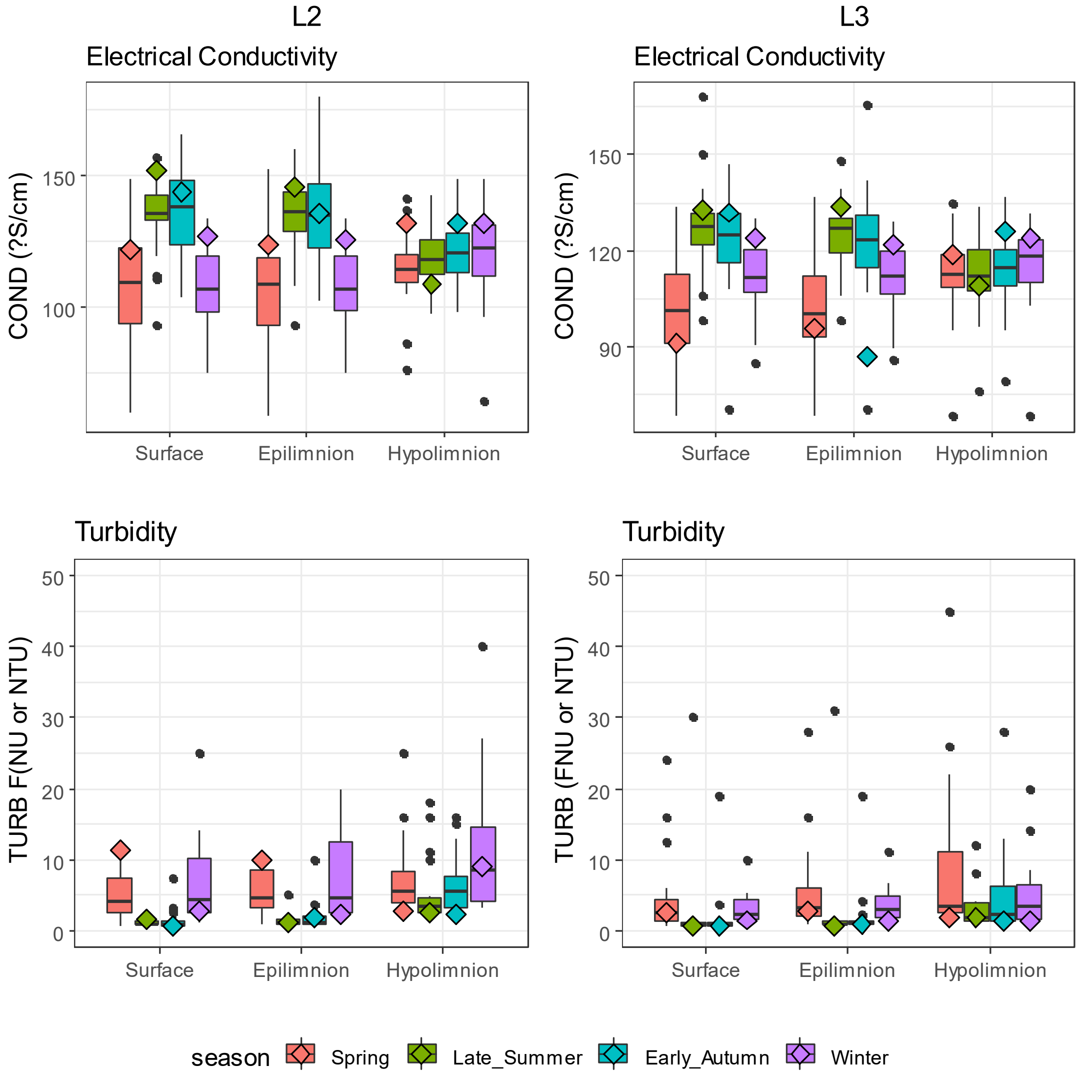


Figure 5 Epilimnetic and hypolimnetic physicochemical parameters in Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond

### 3.2.2.1 Bacteria (E. coli)

In recognition of the recreational uses of Lake Rotorangi (mainly boating and waterskiing at site L2, but also at site L3; see Taranaki Regional Council, 2008a), samples taken at the surface are tested for E. coli. These results are presented in Figure 6. During the period under review, no samples at either site reached the alert level for primary contact recreation (MfE, 2003).

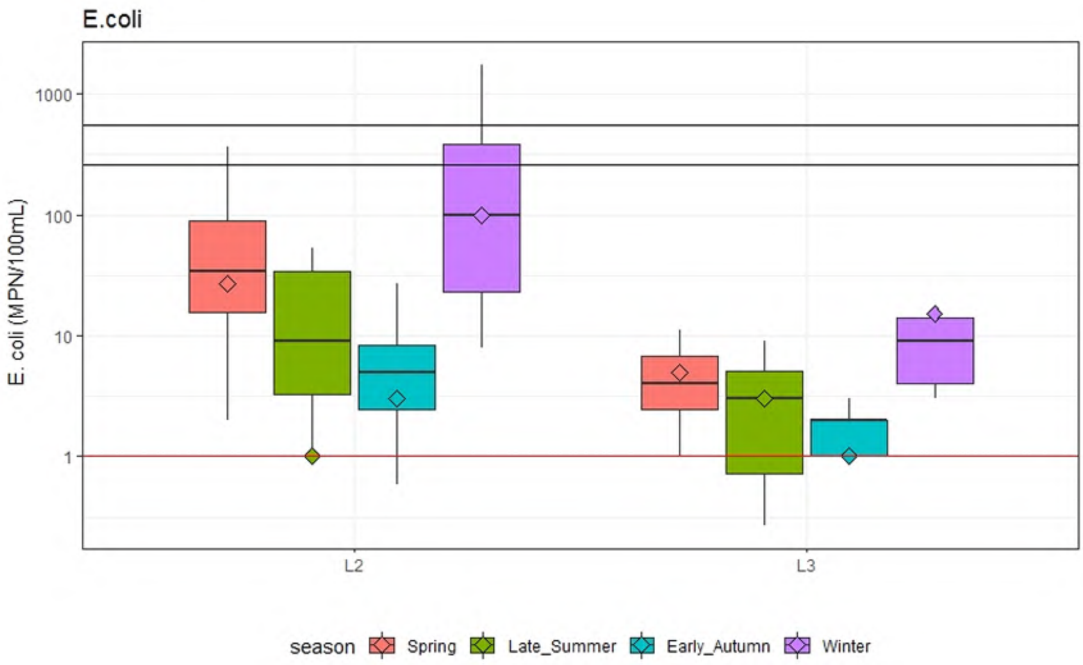


Figure 6 *E. coli* measured at the surface of Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the measurement recorded in the period under review is represented as a diamond. The red line indicates the threshold below which data is censored. Statistics below this threshold should be interpreted with caution. Black threshold lines represent guidelines for recreational use

### 3.2.2.2 Nutrients

Ammoniacal nitrogen was above detection limits at site L2, except in late summer in the hypolimnion (Figure 7). Nitrate-nitrite nitrogen and total nitrogen showed the typical reduction in the epilimnion during the stratified period, while concentrations in the hypolimnion showed a similar, but less pronounced pattern. Total Kjeldahl nitrogen remained at concentrations around the detection limit in the epilimnion, and had slightly higher concentrations in the hypolimnion in early autumn and winter. Dissolved reactive phosphorus was below detection limits in both the hypolimnion and epilimnion during the late summer, and in the hypolimnion in spring. Concentrations were relatively high in the epilimnion in early autumn and the hypolimnion in winter, whilst total phosphorus remained within typical concentrations throughout the period under review.

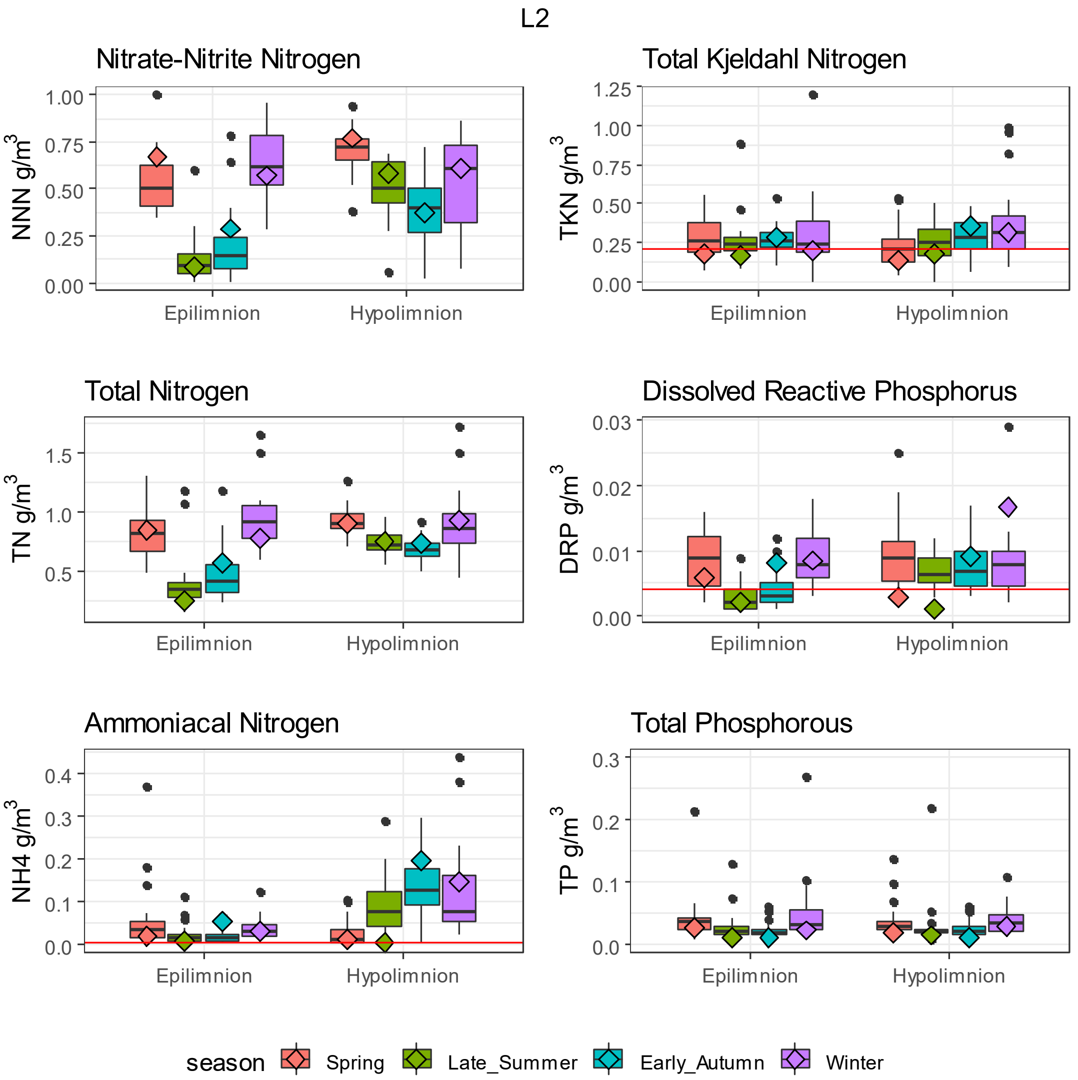


Figure 7 Epilimnetic and hypolimnetic nutrient concentrations at site L2 in Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

Site L3 recorded ammoniacal nitrogen concentrations around the detection limit for the majority of the period under review. Higher concentrations were recorded in the epilimnion in spring, and the hypolimnion in early autumn and winter. The recorded concentration in early autumn was atypically high for that season. Nitrate-nitrite nitrogen and total nitrogen were within a relatively typical range in the hypolimnion; while in the epilimnion the typical decrease during the stratified period was seen only in late summer and not the early autumn sampling. Dissolved reactive phosphorus was below detection limits throughout the period under review, except in the epilimnion in spring. Total phosphorus remained at low concentrations for the entire period under review.

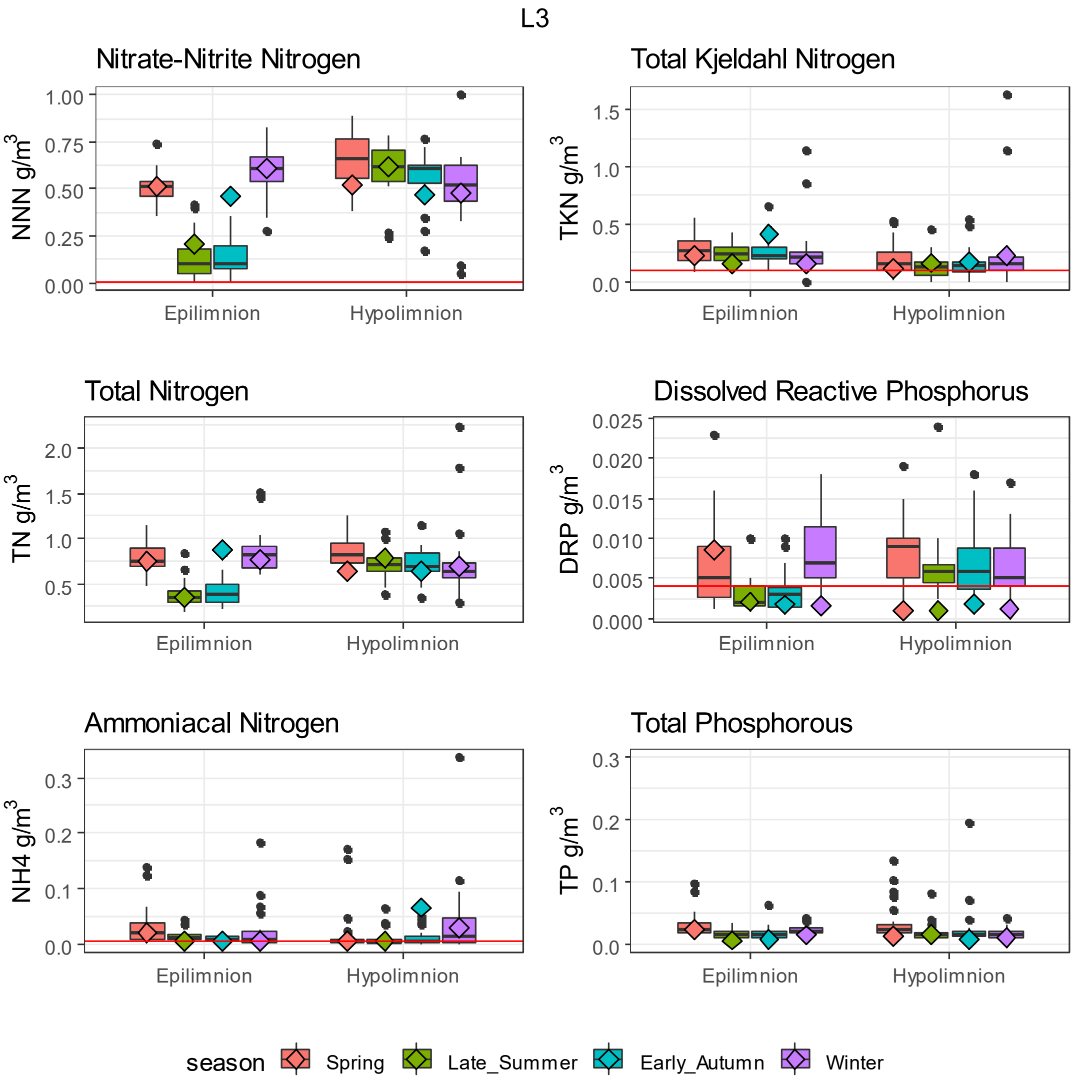


Figure 8 Epilimnetic and hypolimnetic nutrient concentrations at site L3 in Lake Rotorangi. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

Assessment of ammonia, total nitrogen and total phosphorus concentrations against the National Objectives Framework (NOF) numeric attribute state (New Zealand Government, 2020) places both sites in the B band for ammonia and the C band for total nitrogen. Total phosphorus classes site L2 in the C band and site L3 in the B band. It should be noted that Lake Rotorangi is a seasonally stratified lake. This assessment is based on data collected in the epilimnion.

Table 7 Trophic State of Lake Rotorangi based on total nitrogen and total phosphorus National Objective Framework attributes. (Note that units used in the NOF differ between parameters and from the units primarily used throughout this report)

| Parameter (unit) | Site | Median | Maximum | Band | Narrative Attribute State |
|---|---|---|---|---|---|
| NH4 (mg/L) | L2 | 0.011 | 0.062 | B | 95% species protection level: Starts impacting occasionally on the 5% most sensitive species |
| | L3 | 0.004 | 0.009 | B | 95% species protection level: Starts impacting occasionally on the 5% most sensitive species |
| TN ($mg/m^3$) | L2 | 600 | 960 | C | Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes |
| | L3 | 730 | 880 | C | Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes |
| TP ($mg/m^3$) | L2 | 23.0 | 66.0 | C | Lake ecological communities are moderately impacted by additional algal and plant growth arising from nutrient levels that are elevated well above natural reference conditions. Reduced water clarity is likely to affect habitat available for native macrophytes |
| | L3 | 13.5 | 23.0 | B | Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions |

#### 3.2.2.2.1 Sediment/water interface

Anoxia in the lower hypolimnion means the biogeochemical conditions are likely to cause release of nutrients from lakebed sediment into water column during periods of stratification. In recognition of this, water samples have been taken for nutrients at the bottom of the water column during stratified periods since 1996. Over this time period, the data has shown a small increase in ammoniacal nitrogen and a very small decrease in nitrate nitrogen near the lakebed compared to in the hypolimnetic water column. This change may result from the reduction of nitrate to ammonia in the water column or the release of ammonia from anoxic sediments. At site L2 no change has been seen in phosphorus levels, while at site L3 an increase in total phosphorus has been observed near the lakebed, in conjunction with an increase in turbidity. This is likely related to disturbance of the lakebed during sampling rather than hypoxic nutrient release because no such increase in DRP is observed.

Anoxic conditions were present at both sites during the late summer and early autumn sampling in the hypolimnion as well as near the bottom of the water column. During the period under review, nitrate concentrations remained relatively similar near the lakebed compared to higher in hypolimnion at both sites L2 and L3 (Figure 9 and Figure 10). Ammonia concentrations were elevated near the lakebed compared to higher in the hypolimnion in late summer, but were similar in the early autumn sampling for both sites. DRP concentrations remained largely similar, or were at slightly lower concentrations, in the water column near the lakebed compared to higher in the hypolimnion. Both total phosphorus and turbidity were relatively low in the hypolimnion and near the lake bed at both sites. These results provide no evidence of nutrient release or reduction in the anoxic environment.

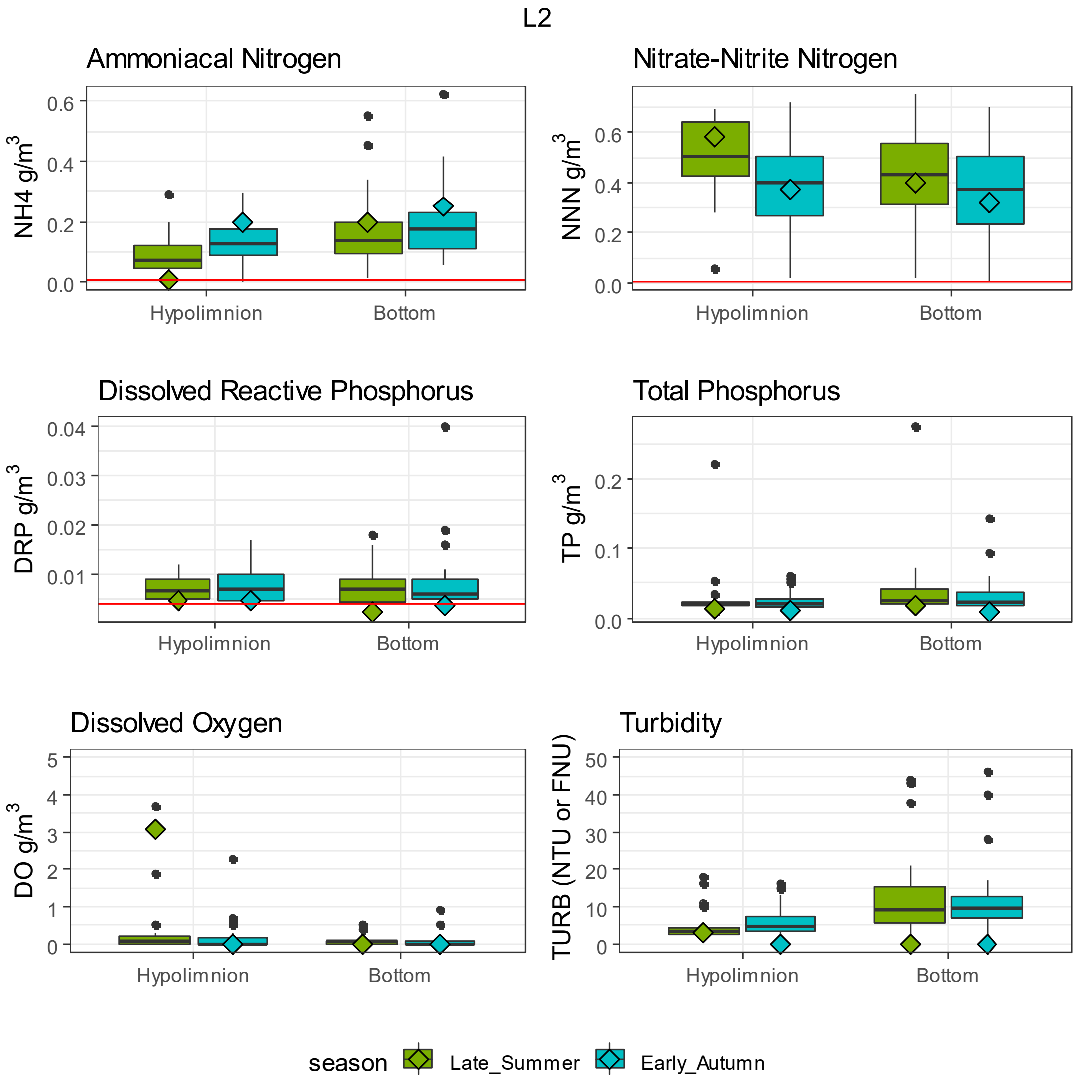


Figure 9 Selected parameters sampled in Lake Rotorangi in the hypolimnion and near the bottom of the water column at site L2. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

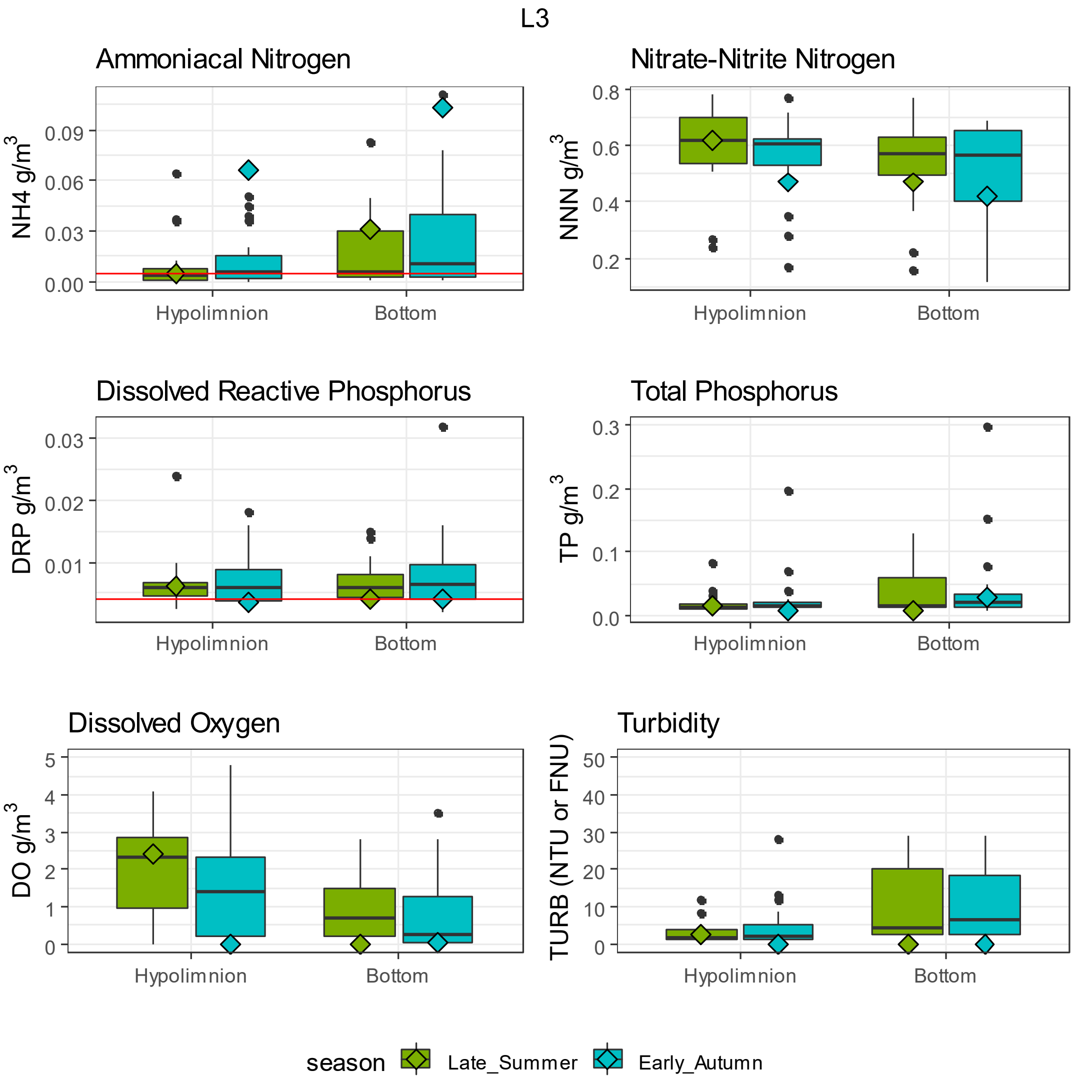


Figure 10 Selected parameters sampled in Lake Rotorangi in the hypolimnion and near the bottom of the water column at site L3. Historical summary data for the period 1996-2020 is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

## 3.3 Biological

### 3.3.1 Phytoplankton

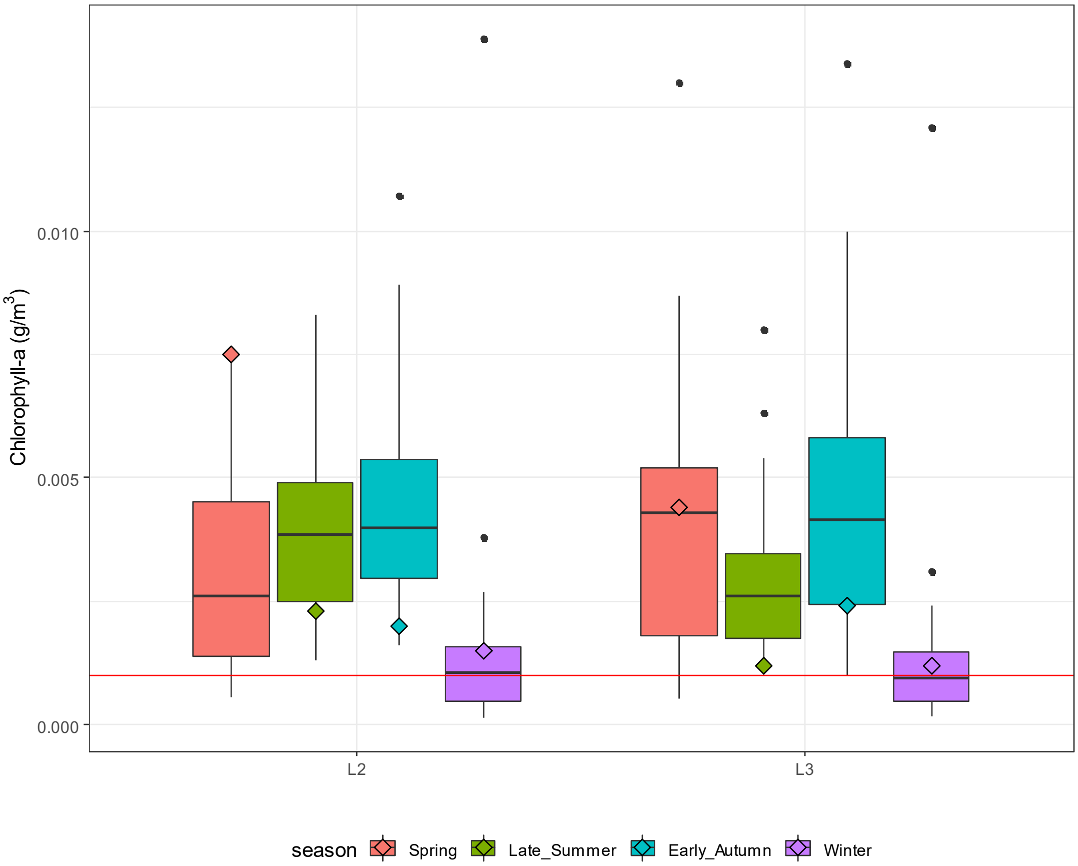


Figure 11 Seasonal chlorophyll-a concentrations in the photic zone of Lake Rotorangi. Historical summary data is represented by boxplots, while the concentration recorded in the period under review is represented as a diamond. Red lines indicate the threshold below which data is censored for each parameter. Statistics below this threshold should be interpreted with caution

Chlorophyll-a concentrations during the period under review were within the previously recorded ranges, except for site L2 in spring which recorded the highest spring chlorophyll concentration to date. Concentrations at both sites in late summer and early autumn were lower than seasonal medians, while spring and winter results were higher than medians.

Assessment of chlorophyll concentrations in Lake Rotorangi is based on three years of data against the phytoplankton NOF attribute places both sites in the B band for phytoplankton (Table 8 and Figure 11) (New Zealand Government, 2020).

Table 8 Phytoplankton attribute state of Lake Rotorangi under the National Objectives Framework. (Note that units used in the NOF differ from the units primarily used throughout this report)

| Site | Median ($mg/m^3$) | Maximum ($mg/m^3$) | Band | Narrative Attribute State |
|---|---|---|---|---|
| L2 | 2.6 | 7.5 | B | Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions |
| L3 | 2.3 | 4.4 | B | Lake ecological communities are slightly impacted by additional algal and/or plant growth arising from nutrient levels that are elevated above natural reference conditions |

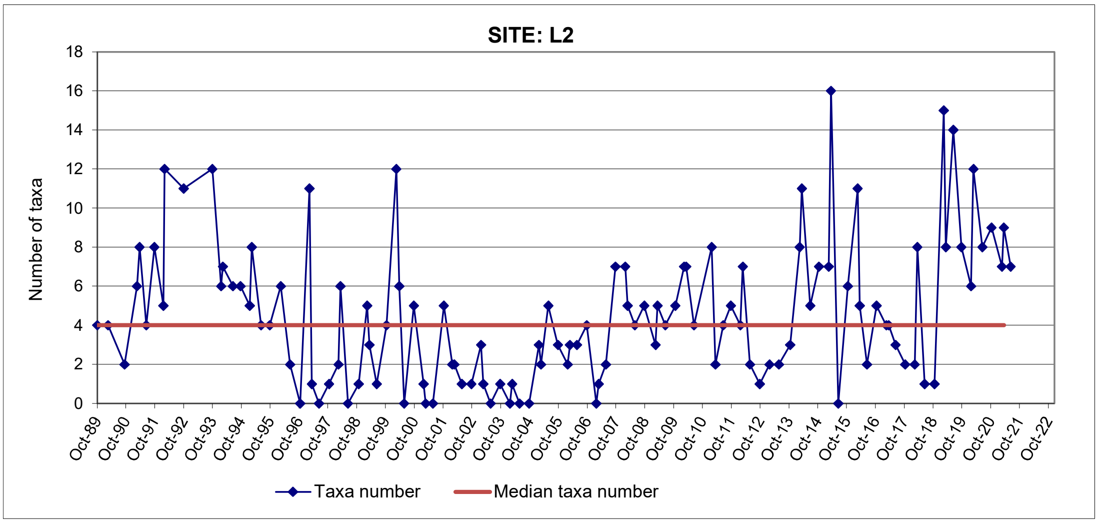


Figure 12 Phytoplankton taxa richness at site L2 since 1989

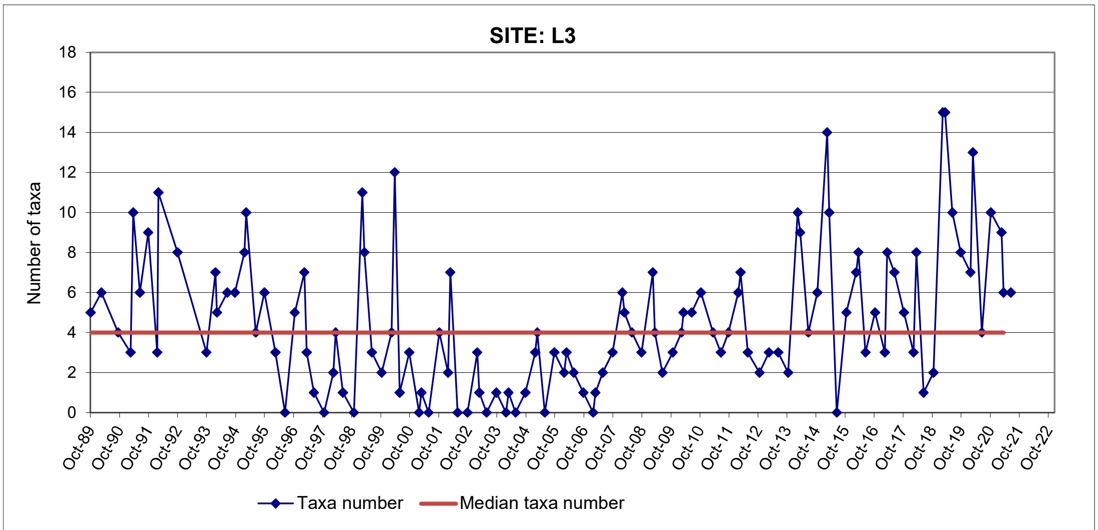


Figure 13 Phytoplankton taxa richness at site L3 since 1989

Phytoplankton taxa richness was higher than has been typical for both sites L2 and L3 during the 2020-2021 period (Figure 12 and Figure 13). Richness was between 7 and 9 taxa at site L2 and 6 and 10 taxa at site L3.

### 3.3.2 Benthic macroinvertebrates

Macroinvertebrate sampling was scheduled to be undertaken in the period under review. This was unable to be undertaken due to sampling equipment failure. Given the paucity of macroinvertebrates that are typically recorded in the benthos at these sites, macroinvertebrate sampling is considered to add negligible value to the lake monitoring. This is likely to primarily relate to the both the depth of the lakebed and the anoxic conditions typical of the lakebed. See TRC 2018 for detailed results of the most recent macroinvertebrate survey.

### 3.3.3 Macrophytes

The scheduled macrophyte survey was undertaken on 16 April 2021. This survey recorded hornwort (*Ceratophyllum demersum*) as the dominant macrophyte in the lake. Hornwort is highly invasive and this has been predicted since it was first recorded in Lake Rotorangi in 2012. Other species recorded included the invasive oxygen weeds *Egeria densa* and *Lagarosiphon major*, and patches of *Nitella hookeri* and *Potamogeton ochreatus*.

The dominance of hornwort is not predicted to cause significant impacts on the ecology of Lake Rotorangi. However, it increases the potential for spread to other lakes in the region. In 2021, hornwort was confirmed to be present in Lake Herengawe, south of Lake Rotorangi for the first time. Hornwort has also reportedly spread to the nearby Lake Rotokare, where the impacts are expected to be much more severe, although this is yet to be confirmed. It may be worthwhile controlling *C. demersum* in the vicinity of boat ramps to help prevent further spread. The usefulness of this may be subject to further investigation by Taranaki Regional Council.

The full report is provided in Appendix III.

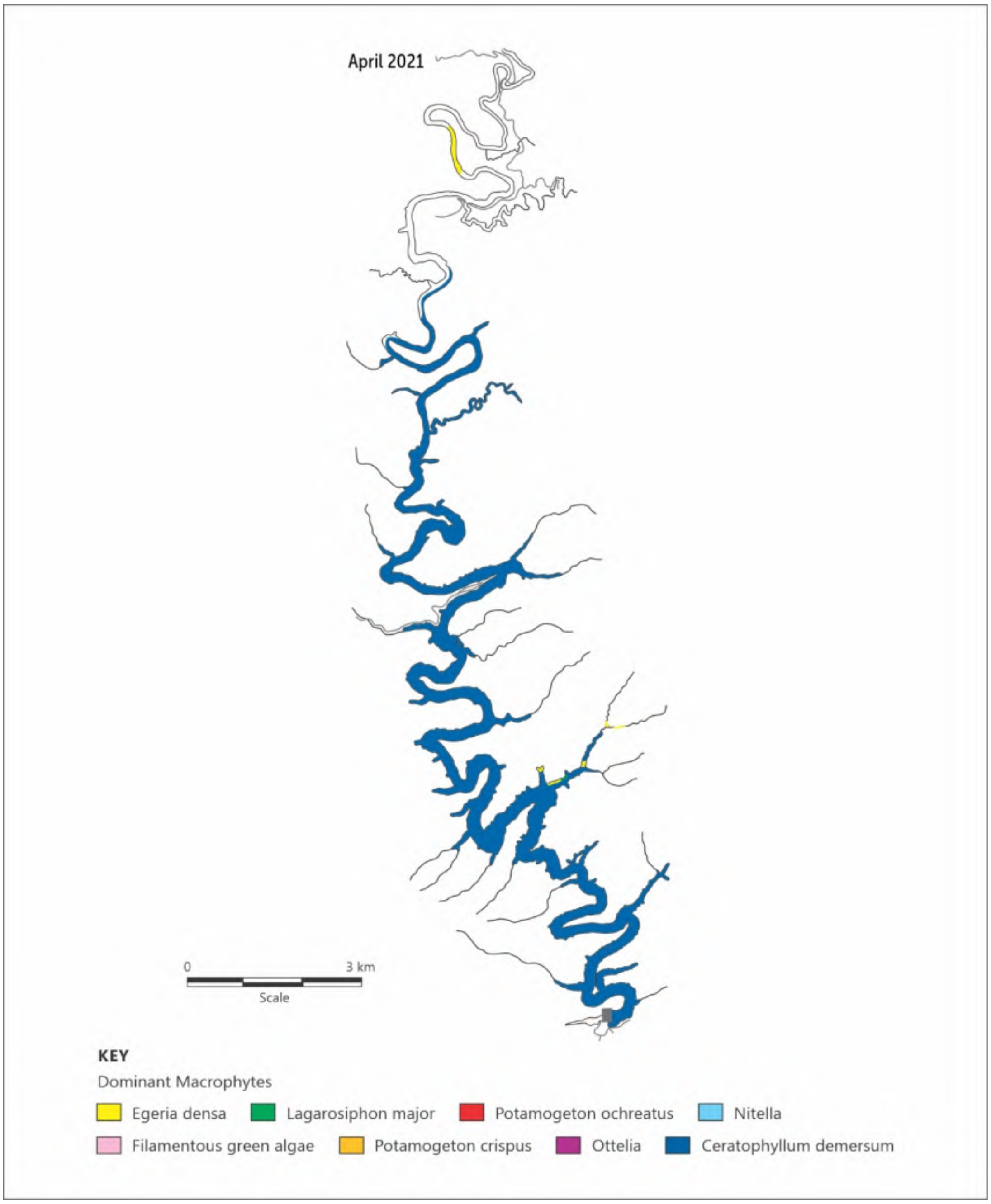


Figure 14 Dominant macrophytes recorded in Lake Rotorangi on 16 April 2021

The full macrophyte survey report is provided in Appendix II.

## 3.4 Trophic state

The trophic state of Lake Rotorangi is shown in Table 8. Annual trophic level values are provided in Appendix II for the lake as a whole and for the individual sites. The trophic level for the year under review was 4.02 TLI units, classifying the lake as eutrophic. When the individual components of the TLI are considered, chlorophyll-a, secchi depth and total phosphorus concentrations categorise the lake as mesotrophic, while total nitrogen categorise the lake as eutrophic.

Table 9 Trophic level and values of key variables defining the trophic status* of Lake Rotorangi in 2020-2021. (Note that units used in the trophic level calculations differ from the units primarily used throughout this report)

| Trophic Level Component | Unit | L2 | L3 | Whole Lake |
|---|---|---|---|---|
| Overall Trophic Status | | Eutrophic | Mesotrophic | Eutrophic |
| Trophic Level | TLI units | 4.10 | 3.92 | 4.02 |
| Chlorophyll a | mg $m^{-3}$ | 3.33 (M) | 2.30 (M) | 2.81 (M) |
| Secchi Depth | m | 3.23 (M) | 2.98 (M) | 3.10 (M) |
| Total Nitrogen | mg N $m^{-3}$ | 676 (E) | 686 (E) | 681 (E) |
| Total Phosphorus | mg P $m^{-3}$ | 16.8 (M) | 12.2 (M) | 14.7 (M) |

* Letters in brackets relate to the trophic status of individual trophic level components. O=Oligotrophic, M=Mesotrophic, E=Eutrophic

The trophic level of Lake Rotorangi has shown an increase over time (Figure 15), albeit at a very slow rate of change (see Table 10). The loess curve shown in Figure 15 shows distinct peaks in 2004 and 2015, both years in which flood inflows affected the water chemistry of the lake, and illustrates the relatively riverine nature of Lake Rotorangi.

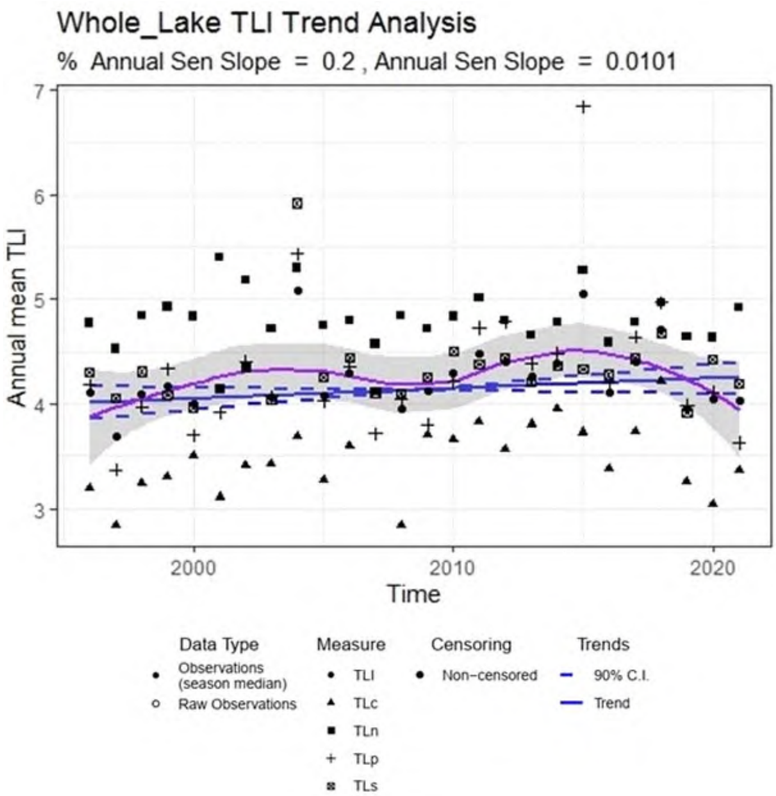


Figure 15 Trophic level index in Lake Rotorangi over the period 1996-2021. The four components of the TLI (chlorophyll-a, secchi depth, total nitrogen and total phosphorus) are plotted individually, as well as the overall TLI. The trend shown relates to the overall TLI. The lowess curve for the overall TLI is in purple

## 3.5 Temporal trends

Where possible, trend analysis is carried out based upon data from the epilimnion. In the case of chlorophyll-a and secchi distance, which are not measured in the epilimnion, data is from the photic zone and surface, respectively. Hypolimnetic data is not trended due to the magnitude of change occurring seasonally as a result of stratification processes, which has the potential to mask changes in the data over longer time frames. This is consistent with national analyses (Larned *et al.*, 2015).

Trend analysis results for the period 1996-2021 are provided in Table 10 and for the most recent ten years (2012-2021) in Table 11. The shorter trend period provides useful information to assess whether changes are consistent over time. This can provide information as to the effectiveness of management actions, or alternatively can show when interventions might be required. Although it is typical to report statistical analysis for a lake holistically, the riverine nature of Lake Rotorangi means that there are substantial differences in water chemistry between the mid and lower lake sites. Therefore, the trend analysis for the whole lake should be interpreted with caution.

Trend plots for each variable are provided in Appendix III for the period 1996-2021 and Appendix IV for the period 2012-2021.

Table 10 Trend analysis of selected variables in Lake Rotorangi for the period 1996-2021. Trends of high confidence are identified in red (degrading trend) or blue (improving trend)

| Measure | Site | No. of Surveys | Seasonality | Proportion censored | Median Slope | Percent Annual Change | Trend | Confidence (%) |
|---|---|---|---|---|---|---|---|---|
| CHLA | L2 | 102 | Seasonal | 0.16 | 0.00004 | 1.46 | Very Likely Increasing | 99.30 |
| | L3 | 102 | Seasonal | 0.13 | 0.00003 | 1.36 | Very Likely Increasing | 98.36 |
| | Whole Lake | 102 | Seasonal | 0.10 | 0.00005 | 1.71 | Very Likely Increasing | 99.79 |
| COND | L2 | 104 | Seasonal | 0.00 | 0.03679 | 0.30 | Very Likely Increasing | 95.65 |
| | L3 | 104 | Seasonal | 0.00 | 0.03678 | 0.31 | Very Likely Increasing | 98.25 |
| | Whole Lake | 104 | Seasonal | 0.00 | 0.03318 | 0.28 | Very Likely Increasing | 99.12 |
| DRP | L2 | 104 | Seasonal | 0.36 | 0.00000 | 0.00 | Likely Decreasing | 76.11 |
| | L3 | 104 | Seasonal | 0.47 | 0.00000 | 0.00 | Very Likely Decreasing | 97.98 |
| | Whole Lake | 104 | Seasonal | 0.39 | 0.00000 | 0.00 | Likely Decreasing | 82.70 |
| NH4 | L2 | 104 | Seasonal | 0.10 | 0.00000 | 0.00 | Indeterminate | 54.84 |
| | L3 | 104 | Seasonal | 0.19 | -0.00031 | -2.86 | Very Likely Decreasing | 99.68 |
| | Whole Lake | 104 | Seasonal | 0.01 | -0.00017 | -0.95 | Likely Decreasing | 85.00 |
| NNN | L2 | 96 | Seasonal | 0.00 | -0.00061 | -0.16 | Indeterminate | 66.37 |

| Measure | Site | No. of Surveys | Seasonality | Proportion censored | Median Slope | Percent Annual Change | Trend | Confidence (%) |
|---|---|---|---|---|---|---|---|---|
| | L3 | 96 | Seasonal | 0.02 | 0.00022 | 0.06 | Indeterminate | 66.85 |
| | Whole Lake | 96 | Seasonal | 0.00 | 0.00000 | 0.00 | Indeterminate | 53.46 |
| SECCHI | L2 | 104 | Seasonal | 0.00 | -0.00216 | -0.08 | Indeterminate | 55.26 |
| | L3 | 104 | Seasonal | 0.00 | -0.00767 | -0.25 | Likely Increasing | 77.35 |
| | Whole Lake | 104 | Seasonal | 0.00 | 0.00000 | 0.00 | Indeterminate | 50.00 |
| TLI | L2 | 26 | NonSeasonal (Annual Mean) | 0.00 | 0.00432 | 0.10 | Likely Increasing | 77.32 |
| | L3 | 26 | NonSeasonal (Annual Mean) | 0.00 | 0.00778 | 0.19 | Very Likely Increasing | 91.41 |
| | Whole Lake | 26 | NonSeasonal (Annual Mean) | 0.00 | 0.01011 | 0.24 | Likely Increasing | 85.50 |
| TN | L2 | 104 | Seasonal | 0.00 | -0.00500 | -0.80 | Very Likely Decreasing | 98.52 |
| | L3 | 104 | Seasonal | 0.00 | -0.00400 | -0.65 | Very Likely Decreasing | 97.59 |
| | Whole Lake | 104 | Seasonal | 0.00 | -0.00464 | -0.72 | Very Likely Decreasing | 99.30 |
| TP | L2 | 104 | Seasonal | 0.00 | 0.00044 | 1.85 | Very Likely Increasing | 99.76 |
| | L3 | 104 | Seasonal | 0.00 | 0.00008 | 0.42 | Likely Increasing | 76.37 |
| | Whole Lake | 104 | Seasonal | 0.00 | 0.00029 | 1.30 | Very Likely Increasing | 97.70 |
| TURB | L2 | 97 | Seasonal | 0.00 | 0.02438 | 1.06 | Very Likely Increasing | 96.57 |
| | L3 | 97 | Seasonal | 0.00 | 0.01272 | 0.85 | Very Likely Increasing | 91.07 |
| | Whole Lake | 97 | Seasonal | 0.00 | 0.01666 | 0.93 | Very Likely Increasing | 94.92 |

Improving trends in total nitrogen were detected with high confidence at both sites L2 and L3 and for the lake as a whole, albeit at a relatively slow rate of change of 0.6 to 0.8 % per year. Dissolved reactive phosphorus and ammonia also showed improving trends with high confidence at site L3 only.

Both sites show a degrading trend in chlorophyll-a, with increases of 1.4-1.5% per year. For the lake as a whole, a similar trend is detected, with a magnitude of 1.7% per year. This long term increasing trend in chlorophyll-a merits further attention, although absolute concentrations remain low.

A degrading trend in conductivity was detected with high confidence at both sites and for the lake as a whole, however the magnitude of this trend is relatively minor at around 0.3 % per year.

Site L2, and the lake as a whole show degrading trends of high confidence for total phosphorus, with an increase of approximately 1.3 % per year for the lake as a whole. Turbidity also showed degrading trends for both sites and for the lake as a whole.

The trophic level index shows an increasing trend of high confidence for site L3, while site L2 and the lake as a whole also show an increasing trend but with a lower level of confidence in the result. It should be noted that because this is a calculation resulting in one annual data point, the ability to detect a trend is reduced compared to parameters which are sampled four times a year. Consequently a ten year trend has not been calculated for the TLI due to insufficient data.

Table 11 Trend analysis of selected variables in Lake Rotorangi for the period 2012-2021. Trends of high confidence are identified in red (degrading trend) or blue (improving trend)

| Measure | Site | No. of Surveys | Seasonality | Proportion censored | Median Slope | Percent Annual Change | Trend | Confidence (%) |
|---|---|---|---|---|---|---|---|---|
| CHLA | L2 | 38 | Seasonal | 0.11 | -0.00007 | -1.89 | Likely Decreasing | 84.54 |
| | L3 | 38 | Seasonal | 0.08 | -0.00029 | -9.57 | Very Likely Decreasing | 99.88 |
| | Whole Lake | 38 | Seasonal | 0.08 | -0.00019 | -5.58 | Very Likely Decreasing | 97.87 |
| COND | L2 | 40 | Seasonal | 0.00 | 0.12835 | 1.04 | Very Likely Increasing | 90.27 |
| | L3 | 40 | Seasonal | 0.00 | 0.11895 | 1.01 | Very Likely Increasing | 93.00 |
| | Whole Lake | 40 | Seasonal | 0.00 | 0.10103 | 0.86 | Very Likely Increasing | 96.69 |
| DRP | L2 | 40 | Seasonal | 0.40 | 0.00000 | 0.00 | Very Likely Decreasing | 97.20 |
| | Whole Lake | 40 | Seasonal | 0.32 | -0.00025 | -5.55 | Very Likely Decreasing | 98.93 |
| NH4 | L2 | 40 | Non-Seasonal | 0.12 | 0.00007 | 0.31 | Indeterminate | 57.41 |
| | L3 | 40 | Seasonal | 0.28 | 0.00000 | 0.00 | Likely Decreasing | 85.53 |
| | Whole Lake | 40 | Non-Seasonal | 0.00 | -0.00025 | -1.49 | Indeterminate | 65.41 |
| NNN | L2 | 40 | Seasonal | 0.00 | 0.00413 | 1.07 | Indeterminate | 63.99 |
| | L3 | 40 | Seasonal | 0.05 | 0.00535 | 1.16 | Likely Increasing | 87.08 |
| | Whole Lake | 40 | Seasonal | 0.00 | 0.00470 | 1.13 | Likely Increasing | 77.69 |
| SECCHI | L2 | 40 | Seasonal | 0.00 | 0.06050 | 2.15 | Likely Decreasing | 77.65 |
| | L3 | 40 | Seasonal | 0.00 | 0.02245 | 0.69 | Likely Decreasing | 77.69 |
| | Whole Lake | 40 | Seasonal | 0.00 | 0.04410 | 1.43 | Likely Decreasing | 88.64 |

| Measure | Site | No. of Surveys | Seasonality | Proportion censored | Median Slope | Percent Annual Change | Trend | Confidence (%) |
|---|---|---|---|---|---|---|---|---|
| TN | L2 | 40 | Seasonal | 0.00 | 0.00211 | 0.34 | Indeterminate | 65.69 |
| | L3 | 40 | Seasonal | 0.00 | 0.00343 | 0.59 | Indeterminate | 64.04 |
| | Whole Lake | 40 | Seasonal | 0.00 | 0.00056 | 0.09 | Indeterminate | 51.79 |
| TP | L2 | 40 | Non-Seasonal | 0.00 | -0.00209 | -7.22 | Very Likely Decreasing | 98.54 |
| | L3 | 40 | Seasonal | 0.00 | -0.00177 | -8.84 | Very Likely Decreasing | 100.00 |
| | Whole Lake | 40 | Seasonal | 0.00 | -0.00193 | -7.57 | Very Likely Decreasing | 99.97 |
| TURB | L2 | 33 | Seasonal | 0.00 | 0.06319 | 2.75 | Indeterminate | 66.00 |
| | L3 | 33 | Seasonal | 0.00 | -0.00743 | -0.53 | Indeterminate | 57.04 |
| | Whole Lake | 33 | Seasonal | 0.00 | 0.02913 | 1.62 | Indeterminate | 59.33 |

A 10 year trend was unable to be carried out for DRP at site L3 due to an insufficient number of unique values in each season.

Over the most recent ten year period, decreasing trends of relatively low confidence were found in chlorophyll-a for the lake as a whole, and at site L3. The magnitude of this trend is relatively large, at approximately 6 % per year for the lake as a whole and 10% per year at site L3. This is in contrast to the long-term increasing trends found in chlorophyll-a.

Conductivity showed a similar pattern in the short term trend as over the longer record, although the magnitude of the trend over the shorter term was much greater, at around 0.8 % for the lake as a whole.

Dissolved reactive phosphorus at site L2 and for the whole lake showed an improving trend of high confidence, with a magnitude of around 5.5% for the lake as a whole.

An improving trend with very high confidence was detected in total phosphorous at site L3, and for the lake as a whole. The magnitude of this trend is significant, with a decrease of approximately 8 % per year at site L3 and for the whole lake. This is in contrast with the 25 year trend where total phosphorus is increasing. This trend is influenced somewhat by some particularly high results in 2015.

# 4 Discussion

During 2020-2021 stratification was recorded in Lake Rotorangi at both the mid and lower sites in late summer and early autumn. Anoxia was recorded in the hypolimnion in both late summer and early autumn. Overturn was complete at site L2 and only partially complete at site L3 at the time of the winter sampling.

The anoxic conditions in the lower hypolimnion have the potential to result in the release of nutrients from the lakebed sediments, particularly during periods when the lake is stratified. Monitoring of the water column near the lakebed during the stratified period shows very slight increases in ammonia concentrations and very slight decreases in nitrate concentrations compared to higher in the hypolimnion. Dissolved reactive phosphorus concentrations do not show any increase lower in the water column. It is unclear whether the increase in ammonia results from hypoxic nutrient release, or simply occurs due to anoxia causing the reduction of nitrate in the water column to ammonia. A lack of hypoxic nutrient release would indicate that nutrient concentrations in the lakebed sediments remain relatively low (Burns 2006). There is insufficient evidence to conclude whether hypoxic nutrient release is occurring in Lake Rotorangi, however given the small magnitude of the changes in water chemistry this is considered unlikely. For both lake-bottom and mid-hypolimnetic dissolved oxygen attributes, Lake Rotorangi does not meet minimum standards (national bottom line) as set out in the NPS-FM.

Total nitrogen was improving at both sites, while total phosphorus shows a degrading trend at L2. Dissolved reactive phosphorus and ammonia both showed an improving trend at L3 over the twenty five year period. All other nutrients measured did not show any trend over time at individual sites. It is worth noting that because of the low nutrient concentrations in Lake Rotorangi, several parameters have a large amount of censored data, impacting upon the ability to determine the change over time. This is particularly relevant for suspended solids, which has been removed from the trend analysis because approximately two-thirds of the data is censored.

When only the most recent ten years of data is considered, dissolved reactive phosphorus was decreasing at site L2, and total phosphorus was decreasing at both sites. A trend was unable to be calculated for dissolved reactive phosphorus at site L3 due to insufficient unique values. This indicates that concentrations likely remain stable. The remainder of the nutrients did not show a trend with any confidence at an individual site over this period.

Chlorophyll concentrations in Lake Rotorangi remain relatively low, as does phytoplankton species diversity. However, trend analysis indicates that chlorophyll- a concentrations are increasing over time at both sites L2 and L3. The rate of change at both sites is less than 2 % per year, and based on the current annual medians, at site L3 chlorophyll-a concentrations would need to increase by more than double to reach eutrophic status based on this parameter (Burns, 1999; Appendix III). Site L2 currently has chlorophyll-a concentrations around the oligotrophic/mesotrophic boundary. The shorter term trend shows improving chlorophyll-a concentrations in Lake Rotorangi, with a high level of confidence at site L3. It is unclear what is driving this change.

The trends for Lake Rotorangi have been calculated for the lake as a whole as well as for the individual sites. It is typical to analyse lakes holistically, however Lake Rotorangi is quite riverine in nature and this is more pronounced at the mid lake site compared to the lower lake site. This leads to differences in the water chemistry and ecology between the sites which makes the individual site analysis potentially more insightful than the analyses of the whole lake.

The trends for the lake as a whole showed degrading chlorophyll-a, conductivity and total phosphorus; and improving total nitrogen over the 25 year record. In contrast, the most recent ten year period shows a degrading trend in conductivity and improving trends in dissolved reactive phosphorus and total phosphorus over this period. Drivers of lake water quality are complex. It is plausible that the total phosphorus levels are related to the suspended sediment within the water column, however, the high amount of censored data for suspended solids prevents analysis of any correlation between these parameters.

The trophic level index is increasing over time. However, the magnitude of this change is almost imperceptible, meaning that this trend is of minor ecological importance.

Ecosystem health is assessed against NOF attributes. Ammonia and chlorophyll-a concentrations classify the lake as being in a mildly impacted state, while total nitrogen classifies the lake as moderately impacted. Total phosphorus classes the upper lake as moderately impacted and the lower lake as mildly impacted.

The macrophyte survey, carried out in April 2021, recorded several invasive species. Hornwort (*Ceratophyllum demersum*) continued to spread, and is now the dominant macrophyte in a large portion on the lake. While the effects on the ecology of Lake Rotorangi and the hydroelectric scheme are not anticipated to be significant, there is the potential for spread to other lakes where the effects may be more severe. Appropriate warning signage regarding the potential problems caused by aquatic weeds and the responsibilities of recreational lake users are in place at the three principal boat ramps in Lake Rotorangi. These were updated in the 2015-2016 monitoring year to include specific reference to hornwort.

The triennial macroinvertebrate survey was not undertaken during the period under review for logistical reasons. Given the anoxic conditions at the lakebed, and the paucity of fauna recorded in previous surveys, the value of this survey is considered to be negligible. It is therefore recommended that this component of the monitoring is discontinued.

The frequency of reporting the results of Lake Rotorangi monitoring should also be reviewed. It is recommended that the frequency of the technical report is reduced to triennial, and is aligned with the triennial biological components of the monitoring programme. The report would next be undertaken in the 2023-2024 year, covering the period 2021-2024. Results would continue to be updated annually on LAWA.

# 5 Recommendations

The following recommendations are based on the results of the 2020-2021 water quality and biological monitoring programmes and the contractual requirements of the resource consents held by Trustpower for the Patea Hydro Electric Power Scheme on Lake Rotorangi:

1. THAT the Lake Rotorangi physicochemical and biological water quality monitoring programme continue on an annual basis as a component of Council's State of the Environment monitoring programme, with every third year of the programme also undertaken in conjunction with the Patea Hydro Electric Power Scheme – aquatic monitoring plan (next in 2023-2024).
2. THAT the triennial benthic macroinvertebrate survey be discontinued due to negligible value provided by the resulting data.
3. THAT in future the Lake Rotorangi physicochemical and biological water quality monitoring programme is reported on a triennial basis, in the year in which the triennial biological components are undertaken (next in 2023-2024).

# Glossary of common terms and abbreviations

The following abbreviations and terms are used within this report:

| | |
|---|---|
| anoxia | absence of dissolved oxygen (defined as dissolved oxygen concentrations less than 0.5 $g/m^3$) |
| aquatic macrophyte | water plants |
| benthic | bottom living |
| black/secchi disc | measurement of visual clarity (metres) through the water (horizontally/vertically) |
| biomonitoring | assessing the health of the environment using aquatic organisms |
| chlorophyll-a | productivity using measurement of phytoplankton pigment ($mg/m^3$) |
| cumec | volumetric measure of flow (cubic metre per second) |
| conductivity | Conductivity, an indication of the level of dissolved salts in a sample, usually measured at 25°C and expressed in µS/cm |
| DO | dissolved oxygen measured as $g/m^3$ (or saturation (%)) |
| DRP | dissolved reactive phosphorus |
| *E.coli* | *Escherichia coli*, an indicator of the possible presence of faecal material and pathological micro-organisms. Expressed as the number of organisms per 100ml |
| epilimnion | lake zone above the thermocline (mixed surface layer) |
| Faecal coliforms | an indicator of the possible presence of faecal material and pathological micro-organisms. Expressed as the number of organisms per 100ml |
| FNU | formazin nephelometric unit, a measure of the turbidity of water |
| fresh | elevated flow in a stream, such as after heavy rainfall |
| $g/m^3$ | grammes per cubic metre, and equivalent to milligrammes per litre (mg/L). In water, this is also equivalent to parts per million (ppm), but the same does not apply to gaseous mixtures |
| hypolimnion | zone below the thermocline in a stratified lake |
| imputed value | a calculated estimate of value produced when an exact value cannot be obtained |
| isothermal | thermally mixed lake; defined in this report as less 3°C difference in water temperature between the lake surface and lake bottom |
| L/s | litres per second |
| mesotrophic | intermediate condition of nutrient enrichment between oligotrophic and eutrophic in lakes |
| mS/m | millisiemens per metre |
| µS/cm | microsiemens per centimetre. |
| $NH_4$ | ammonium, normally expressed in terms of the mass of nitrogen (N) |
| $NO_3$ | nitrate, normally expressed in terms of the mass of nitrogen (N) |
| NTU | Nephelometric Turbidity Unit, a measure of the turbidity of water |
| overturn | remixing of a lake after stratification |

| | |
|---|---|
| pH | a numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline. The scale is logarithmic i.e. a change of 1 represents a ten-fold change in strength. For example, a pH of 4 is ten times more acidic than a pH of 5 |
| photic zone | upper section of lake penetrated by light |
| physicochemical | measurement of both physical properties(e.g. temperature, clarity, density) and chemical determinants ( e.g. metals and nutrients) to characterise the state of an environment |
| plankton | Small and microscopic plants and animals living in the water column |
| resource consent | refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15) |
| RMA | Resource Management Act 1991 and subsequent amendments |
| SS | suspended solids |
| stratification | formation of thermal layers in lakes |
| temp | temperature, measured in ˚C (degrees Celsius) |
| thermocline | zone of most rapid temperature change in stratified lakes |
| TLI | trophic level index, a method of measuring the trophic level of a lake |
| trophic level | amount of nutrient enrichment of a lake |
| turb | turbidity, expressed in NTU or FNU |
| UI | Unauthorised Incident |
| UIR | Unauthorised Incident Register – contains a list of events recorded by the Council on the basis that they may have the potential or actual environmental consequences that may represent a breach of a consent or provision in a Regional Plan |
| VHOD | Volumetric hypolimnetic oxygen depletion. The note of dissolved oxygen decrease in the lower layer of the lake under stratified conditions. A measure of lake productivity |
| water column | water overlying the lake bed |

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# Appendix I

# Trend analysis methodology

A number of changes to data analysis methodologies have been implemented in this report. A brief description of the current methods used is given below, while a discussion of how these differ from methods used in previous TRC SEM lake reports is given in Section 4.1 and Appendix VI of this report.

When assessing point (state) statistics, such as those used to construct the boxplots in this report, censored data has been handled using the NADA R package (vers. 1.6-1.1; Lopaka Lee, 2020). Left censored data has been replaced with imputed values using regression on order statistics (ROS). This method fits a distribution to the non-censored values in the data record and uses the resulting model to impute replacement values for the censored data. The resulting calculated summary statistics and boxplots are more robust than those used in previous reports, where summary statistics were biased by censored data being replaced with a value equal to half the censor limit. Even with this improved method of handling censored data, however, summary statistics (e.g. 25$^{th}$ percentile, median) that are less than the highest common censor limit, should not be directly interpreted.

In this report, trend analysis has been carried out using the LWP-Trends library R package (version 1901), developed by Land Water People Ltd. (Snelder & Fraser, 2019). The methods employed have the primary purpose of establishing the direction and rate of any trend, along with a measure of the uncertainty in the result. The use of the LWP-Trends package represents a major change in trend analysis methodology compared to previous TRC Lake SEM reports, in part due to different methods used in the past, but also due to a recent conceptual shift in how to assess confidence in trend analysis results (Greenland et al. 2016, McBride 2019, Helsel et al. 2020).

As a first step in the trend analysis, a visual inspection of the raw time-series data is undertaken, giving a view of the proportion and temporal distribution of censored data. A Kruskal-Wallis test, using a threshold of $\alpha$=0.05, is employed to determine whether data is seasonal or not over the four separate annual samplings.

Depending on the result of the seasonality test, a non-parametric Mann-Kendall or seasonal Kendall test is used to determine the direction of a monotonic trend through the time-series data. Trend rate and the confidence in trend rate are evaluated using Sen-slope regression of observations against time. This is a non-parametric regression procedure, where the Sen-slope estimate (SSE) is taken as the median of all possible inter-observation slopes (Hirsch et al. 1982). In calculating the Kendall S statistic, censored data are dealt with as robustly as possible, following the methods of Helsel (2011), this allows inter-observation increases and decreases to be identified whenever possible (Snelder and Fraser, 2019). In calculating the SSE, censored data are replaced by a value 0.5 times the highest common censor limit. While this biases inter-observation slopes associated with censored data, in most cases with a small proportion of censored data, the median slope will be unaffected. A note is included in the reported results when the median Sen-slope is affected by censored data. In general, when the SSE is affected by censored data, this usually indicates that the trend rate is smaller than can be detected. Trends noted as being affected by censored data are critically analysed to assess if the resulting statistics are meaningful or not. In a small number of cases, trend assessment is not carried out due to insufficient unique data. This occurs when there are <5 non-censored data, or if there are 3 or less unique non-censored values.

While past trend analysis has reported on the 'significance' of any reported trend, in this report the assessment of confidence in a trend direction moves away from the traditional null hypothesis significance testing (NHST) approach and instead follows the recommended credible interval assessment method of McBride (2019). As a result of this change, the confidence in the reported trend direction (ranging from 50 to 100%) is now categorised as in Table 4. A comparison between the results of the confidence grading system and the previous p-value based significance method is given in Appendix V.

Table 1 Confidence categorisation for trend direction results

| Confidence Category | Confidence in reported trend direction |
|---|---|
| Very Likely Improving | 90 – 100% |
| Likely Improving | 67 – 90% |
| Indeterminate | 50 – 67% |
| Likely Degrading | 67 – 90% |
| Very Likely Degrading | 90 – 100% |

It is noted that the trend analysis methods implemented above are constrained to identifying a monotonic (single direction) trend through any time-series. In many cases, however, environmental time-series data is not monotonic, with a change of conditions or individual events resulting in changes of behaviour at monitoring sites. To account for this, a Loess curve has been overlaid on trend-analysis plots to allow for a qualitative assessment of any non-monotonic trends, and further investigation into the possible cause of any change of behaviour. In addition, a comparison of long term (25 year) and short term (10 year) quantitative trends is undertaken.

In the case of parameters which are sampled at multiple depths within the lake, trend analysis has been carried out on the data from the epilimnion. Differences in the water chemistry between the epilimnion and hypolimnion during the stratified period mean that combining the data from both stratified layers may mask any trends present. Furthermore, the magnitude of the seasonal change in the hypolimnion is greater for many parameters, and the magnitude of seasonal variation may hinder the ability to detect the trend over time. The use of epilimnion data in trend analysis is consistent with national reporting (Larned et al, 2015).

For the analysis of the lake as a whole, results taken at different sites, within the same layer of the water column and on the same day, are averaged to provide a single result. These average values are analysed as described above. This is consistent with the methodology used in Larned et al, 2015).

# Appendix II

# Physicochemical Monitoring Results 2020-2021

Physicochemical monitoring results collected at Lake Rotorangi on 16 October 2020

| Parameter | Unit | L2 | | | | | L3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Photic | Epilimnion | Hypolimnion | Near benthos | Surface | Photic | Epilimnion | Hypolimnion | Near benthos |
| Sample depth | m | 0 | 8.75 | 8.75 | 32.5 | N/S | 0 | 4.83 | 4.5 | 35.5 | N/S |
| Temperature | ° C | 13.8 | - | 13.8 | 9.6 | N/S | 13.9 | - | 13.5 | 9.4 | N/S |
| Black disc transparency | m | 1.43 | - | - | - | N/S | 1.26 | - | - | - | N/S |
| Secchi disc transparency | m | 3.51 | - | - | - | N/S | 1.93 | - | - | - | N/S |
| Dissolved oxygen | $g/m^3$ | 9.46 | - | 9.16 | 2.92 | N/S | 8.76 | - | 8.63 | 1.79 | N/S |
| pH | pH units | 7.1 | - | 7 | 6.8 | N/S | 6.8 | - | 6.9 | 6.7 | N/S |
| Conductivity | µS/cm | 122 | - | 124 | 132 | N/S | 91 | - | 96 | 119 | N/S |
| Turbidity | FNU | 2.3 | - | 2.7 | 3.3 | N/S | 3.6 | - | 3.8 | 1.75 | N/S |
| Suspended solids | $g/m^3$ | < 3 | - | < 3 | < 3 | N/S | < 3 | - | < 3 | < 3 | N/S |
| *E. coli* | MPN/100mL | 27 | - | - | - | N/S | 5 | - | - | - | N/S |
| Dissolved reactive phosphorus | $g/m^3$ P | - | - | 0.0038 | 0.0036 | N/S | - | - | 0.0026 | 0.0023 | N/S |
| Total phosphorus | $g/m^3$ P | - | - | 0.025 | 0.019 | N/S | - | - | 0.023 | 0.013 | N/S |
| Ammoniacal nitrogen | $g/m^3$ N | - | - | 0.018 | 0.012 | N/S | - | - | 0.021 | < 0.005 | N/S |
| Nitrite nitrogen | $g/m^3$ N | - | - | 0.0059 | 0.0029 | N/S | - | - | 0.0086 | < 0.0010 | N/S |
| Nitrate nitrogen | $g/m^3$ N | - | - | 0.67 | 0.77 | N/S | - | - | 0.51 | 0.52 | N/S |
| Nitrate and nitrite nitrogen | $g/m^3$ N | - | - | 0.67 | 0.77 | N/S | - | - | 0.51 | 0.52 | N/S |
| Total Kjeldahl nitrogen | $g/m^3$ N | - | - | 0.18 | 0.13 | N/S | - | - | 0.23 | 0.11 | N/S |
| Total nitrogen | $g/m^3$ N | - | - | 0.85 | 0.9 | N/S | - | - | 0.74 | 0.63 | N/S |
| Chlorophyll-a | $g/m^3$ | - | 0.0075 | - | - | N/S | - | 0.0044 | - | - | N/S |

N/S = not sampled

Physicochemical monitoring results collected at Lake Rotorangi on 25 February 2021

| Parameter | Unit | L2 | | | | | L3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Photic | Epilimnion | Hypolimnion | Near benthos | Surface | Photic | Epilimnion | Hypolimnion | Near benthos |
| Sample depth | m | 0 | 10.1 | 3.6 | 22 | 36 | 0 | 10.4 | 3.6 | 25.5 | 50 |
| Temperature | ° C | 20.9 | - | 20.4 | 15.1 | 10.4 | 21.7 | - | 21.4 | 13.4 | 9.7 |
| Black disc transparency | m | 1.86 | - | - | - | - | 2.52 | - | - | - | - |
| Secchi disc transparency | m | 4.05 | - | - | - | - | 4.16 | - | - | - | - |
| Dissolved oxygen | $g/m^3$ | 8.87 | - | 6.4 | 3.06 | 0 | 9.02 | - | 8.84 | 2.42 | 0 |
| pH | pH units | 7.7 | - | 7.6 | 7 | 7.2 | 7.7 | - | 7.5 | 6.9 | 7 |
| Conductivity | µS/cm | - | - | 146 | 109 | - | 133 | - | 134 | 109 | - |
| Turbidity | FNU | 0.95 | - | 1.03 | 3.3 | 10.1 | 0.95 | - | 0.85 | 4 | 2.6 |
| Suspended solids | $g/m^3$ | - | - | < 3 | < 3 | - | < 3 | - | < 3 | < 3 | - |
| *E. coli* | MPN/100mL | No result | - | - | - | - | 3 | - | - | - | - |
| Dissolved reactive phosphorus | $g/m^3$ P | < 0.0010 | - | < 0.0010 | 0.0046 | 0.0021 | - | - | 0.0014 | 0.0061 | 0.004 |
| Total phosphorus | $g/m^3$ P | 0.006 | - | 0.009 | 0.014 | 0.017 | - | - | 0.006 | 0.015 | 0.009 |
| Ammoniacal nitrogen | $g/m^3$ N | 0.005 | - | 0.006 | < 0.005 | 0.2 | - | - | < 0.005 | < 0.005 | 0.031 |
| Nitrite nitrogen | $g/m^3$ N | - | - | 0.0021 | 0.0011 | - | - | - | 0.0021 | < 0.0010 | - |
| Nitrate nitrogen | $g/m^3$ N | - | - | 0.081 | 0.58 | - | - | - | 0.21 | 0.62 | - |
| Nitrate and nitrite nitrogen | $g/m^3$ N | 0.069 | - | 0.083 | 0.58 | 0.4 | - | - | 0.21 | 0.62 | 0.47 |
| Total Kjeldahl nitrogen | $g/m^3$ N | - | - | 0.17 | 0.18 | - | - | - | 0.15 | 0.16 | - |
| Total nitrogen | $g/m^3$ N | - | - | 0.25 | 0.75 | - | - | - | 0.35 | 0.78 | - |
| Chlorophyll-a | $g/m^3$ | - | 0.0023 | - | - | - | - | 0.0012 | - | - | - |

Physicochemical monitoring results collected at Lake Rotorangi on 23 March 2021

| Parameter | Unit | L2 | | | | | L3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Photic | Epilimnion | Hypolimnion | Near benthos | Surface | Photic | Epilimnion | Hypolimnion | Near benthos |
| Sample depth | m | 0 | 7.7 | 8 | 31 | 33 | 0 | 9.5 | 9.5 | 39 | 51 |
| Temperature | ° C | 19 | - | 18 | 11.3 | 10.6 | 18.5 | - | 16.6 | 10 | 10 |
| Black disc transparency | m | 3.09 | - | - | - | - | 2.47 | - | - | - | - |
| Secchi disc transparency | m | 3.91 | - | - | - | - | 3.81 | - | - | - | - |
| Dissolved oxygen | $g/m^3$ | 8.73 | - | 5.75 | 0 | 0 | 7.74 | - | 2.22 | 0 | 0.05 |
| pH | pH units | 7.5 | - | 7.1 | 6.9 | 6.9 | 7.4 | - | 6.7 | 6.9 | 6.7 |
| Conductivity | µS/cm | 144 | - | 136 | 132 | - | 132 | - | 87 | 126 | - |
| Turbidity | FNU | 0.97 | - | 2 | 3.5 | 5.5 | 0.95 | - | 2.5 | 3.4 | 24 |
| Suspended solids | $g/m^3$ | < 3 | - | < 3 | < 3 | - | < 3 | - | < 3 | < 3 | - |
| *E. coli* | MPN/100mL | 3 | - | - | - | - | 1 | - | - | - | - |
| Dissolved reactive phosphorus | $g/m^3$ P | - | - | 0.0027 | 0.0045 | 0.0035 | - | - | 0.0015 | 0.0036 | 0.004 |
| Total phosphorus | $g/m^3$ P | - | - | 0.01 | 0.01 | 0.008 | - | - | 0.008 | 0.008 | 0.029 |
| Ammoniacal nitrogen | $g/m^3$ N | - | - | 0.053 | 0.197 | 0.25 | - | - | < 0.005 | 0.066 | 0.103 |
| Nitrite nitrogen | $g/m^3$ N | - | - | 0.0081 | 0.0092 | - | - | - | 0.0017 | 0.0018 | - |
| Nitrate nitrogen | $g/m^3$ N | - | - | 0.28 | 0.36 | - | - | - | 0.46 | 0.47 | - |
| Nitrate and nitrite nitrogen | $g/m^3$ N | - | - | 0.29 | 0.37 | 0.32 | - | - | 0.46 | 0.47 | 0.42 |
| Total Kjeldahl nitrogen | $g/m^3$ N | - | - | 0.28 | 0.36 | - | - | - | 0.41 | 0.17 | |
| Total nitrogen | $g/m^3$ N | - | - | 0.57 | 0.73 | - | - | - | 0.88 | 0.64 | - |
| Chlorophyll-a | $g/m^3$ | - | 0.002 | - | - | - | - | 0.0024 | - | - | - |

Physicochemical monitoring results collected at Lake Rotorangi on 24 June 2021

| Parameter | Unit | L2 | | | | | L3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Surface | Photic | Epilimnion | Hypolimnion | Near benthos | Surface | Photic | Epilimnion | Hypolimnion | Near benthos |
| Sample depth | m | 0 | 3.65 | 5 | 34.5 | N/S | 0 | 5 | 5 | 27 | N/S |
| Temperature | ° C | 11.5 | - | 11.8 | 10.7 | N/S | 11.6 | - | 11.8 | 10.7 | N/S |
| Black disc transparency | m | 1.04 | - | - | - | N/S | 1.82 | - | - | - | N/S |
| Secchi disc transparency | m | 1.46 | - | - | - | N/S | 2.01 | - | - | - | N/S |
| Dissolved oxygen | $g/m^3$ | 9.79 | - | 9.41 | 6.43 | N/S | 8.57 | - | 8.04 | 0.2 | N/S |
| pH | pH units | 6.8 | - | 7.1 | 6.7 | N/S | 7.1 | - | 7 | 6.7 | N/S |
| Conductivity | µS/cm | 127 | - | 126 | 132 | N/S | 124 | - | 122 | 124 | N/S |
| Turbidity | FNU | 3.7 | - | 4.4 | 9.8 | N/S | 2.6 | - | 2.5 | 1.85 | N/S |
| Suspended solids | $g/m^3$ | < 3 | - | < 3 | 3 | N/S | < 3 | - | < 3 | < 3 | N/S |
| *E. coli* | MPN/100mL | 99 | - | - | - | N/S | 15 | - | - | - | N/S |
| Dissolved reactive phosphorus | $g/m^3$ P | - | - | 0.0073 | 0.0062 | N/S | - | - | 0.0032 | 0.0032 | N/S |
| Total phosphorus | $g/m^3$ P | - | - | 0.022 | 0.029 | N/S | - | - | 0.014 | 0.01 | N/S |
| Ammoniacal nitrogen | $g/m^3$ N | - | - | 0.03 | 0.145 | N/S | - | - | < 0.005 | 0.028 | N/S |
| Nitrite nitrogen | $g/m^3$ N | - | - | 0.0085 | 0.0167 | N/S | - | - | 0.0016 | 0.0012 | N/S |
| Nitrate nitrogen | $g/m^3$ N | - | - | 0.56 | 0.6 | N/S | - | - | 0.61 | 0.48 | N/S |
| Nitrate and nitrite nitrogen | $g/m^3$ N | - | - | 0.57 | 0.61 | N/S | - | - | 0.61 | 0.48 | N/S |
| Total Kjeldahl nitrogen | $g/m^3$ N | - | - | 0.2 | 0.31 | N/S | - | - | 0.15 | 0.22 | N/S |
| Total nitrogen | $g/m^3$ N | - | - | 0.78 | 0.93 | N/S | - | - | 0.76 | 0.7 | N/S |
| Chlorophyll-a | $g/m^3$ | - | 0.0015 | - | - | N/S | - | 0.0012 | - | - | N/S |

N/S = not sampled

# Appendix III

# Macrophyte Survey Report

| | |
|---|---|
| **To** | Job Manager, Katie Blakemore |
| **From** | Environmental Scientist – Freshwater Ecology, Katie Blakemore |
| **Document** | 2763233 |
| **Date** | 28 April 2021 |

# Aquatic macrophyte survey of Lake Rotorangi, April 2021

A survey of the aquatic macrophytes in Lake Rotorangi was carried out on 16 April 2021. The survey was undertaken by the Taranaki Regional Council under contract to Trustpower Ltd. The survey began at the Patea Dam boat ramp and the true left of the lake was surveyed on the way up the lake to Mangamingi. The true right of the lake was surveyed on the return to the Patea Dam. Larger arms of the lake were entered in order to identify the macrophytes present. Despite these arms making up a small proportion of the lake area, they are generally shallower than the main body of the lake and as such provide a disproportionately large habitat for macrophytes. At regular intervals the macrophyte species seen on the lake edges were recorded on a map of Lake Rotorangi, and the dominant species noted. The dominant taxa were then colour coded and their distributions are shown in Figure 1, with previous data shown in Figure 2. Surveys are now undertaken as a requirement of consent 0489-2, which requires the survey to be undertaken every three years (commencing in 2012). The last survey was conducted in April 2018.

Previous macrophyte monitoring, which began in March 1987, found *Egeria densa* dominating the greatest proportion of the lake edges, increasing as time progressed (Figure 2). Since then, *E. densa* has dominated the lake in most previous surveys, with the exception of the 2005 and 2008 surveys, when *Lagarosiphon major* was dominant. In surveys prior to 2018, *E. densa* has always dominated the upper end of the lake. In 2018, macrophytes were not recorded in the upper end of the lake, whilst *E. densa* was recorded only in the lower lake. It should be noted that the 2018 survey was impacted by high turbidity. The current survey recorded *E. densa* as the dominant macrophyte in the upper lake, while in the lower lake it was not the dominant macrophyte but it was still present. Five species of macrophyte were recorded in the current survey (Table 1). *Lagarosiphon major* was present, but as in the April 2018 survey, was not dominant in any part of the lake.

The macrophyte survey undertaken in 2012 was the first to document *Ceratophyllum demersum* (hornwort) in Lake Rotorangi. Since this survey, when *C. demersum* was only dominant on the true left bank downstream of the Hawera water ski club rooms, its distribution has increased markedly, as predicted in a report prepared by NIWA[1]. In the two most recent surveys, *C. demersum* was the dominant macrophyte, and it should be noted that although the April 2018 survey recorded no macrophytes through the mid-section of the lake, it is possible that it may have been present and obscured by high turbidity.

*E. densa*, *L. major* and *C. demersum* are introduced aquatic plants which are listed in the Pest Plant Accord[2] and are thereby considered an 'unwanted organism'. This means that it is illegal to sell, propagate or distribute these plants in New Zealand. All three species are distributed throughout the North Island, and *C. demersum* especially can have significant impacts on hydroelectric schemes. Trustpower commissioned NIWA to perform an assessment of *C. demersum*, and its potential impact on the scheme and ecology of the lake. They concluded that due to a number of factors, there was unlikely to be a significant impact on the hydroelectric scheme or the ecology of the lake.

*E. densa* tends to thrive in turbid and enriched waters of lakes, whereas *L. major* is more common in clear water of low fertility. In is interesting to note that *L. major* has typically been dominant in the middle and

[1] Lake Rotorangi hornwort assessment. Prepared for Trustpower by NIWA (Rohan Wells). NIWA client report No. HAM2012-062.

[2] The National Pest Plant Accord (NPPA) is a cooperative agreement between the Nursery and Garden Industry Association, regional councils and government departments with biosecurity responsibilities.

lower reaches of the lake, which tend to have clearer water. *E. densa* is more dominant in the more riverine upper reaches, and has in the past been often associated with clumps of filamentous green algae, indicating a more enriched environment in these reaches. The upper reaches are also more regularly affected by flooding in the Patea River upstream of the lake, and are generally more turbid than the lower reaches.

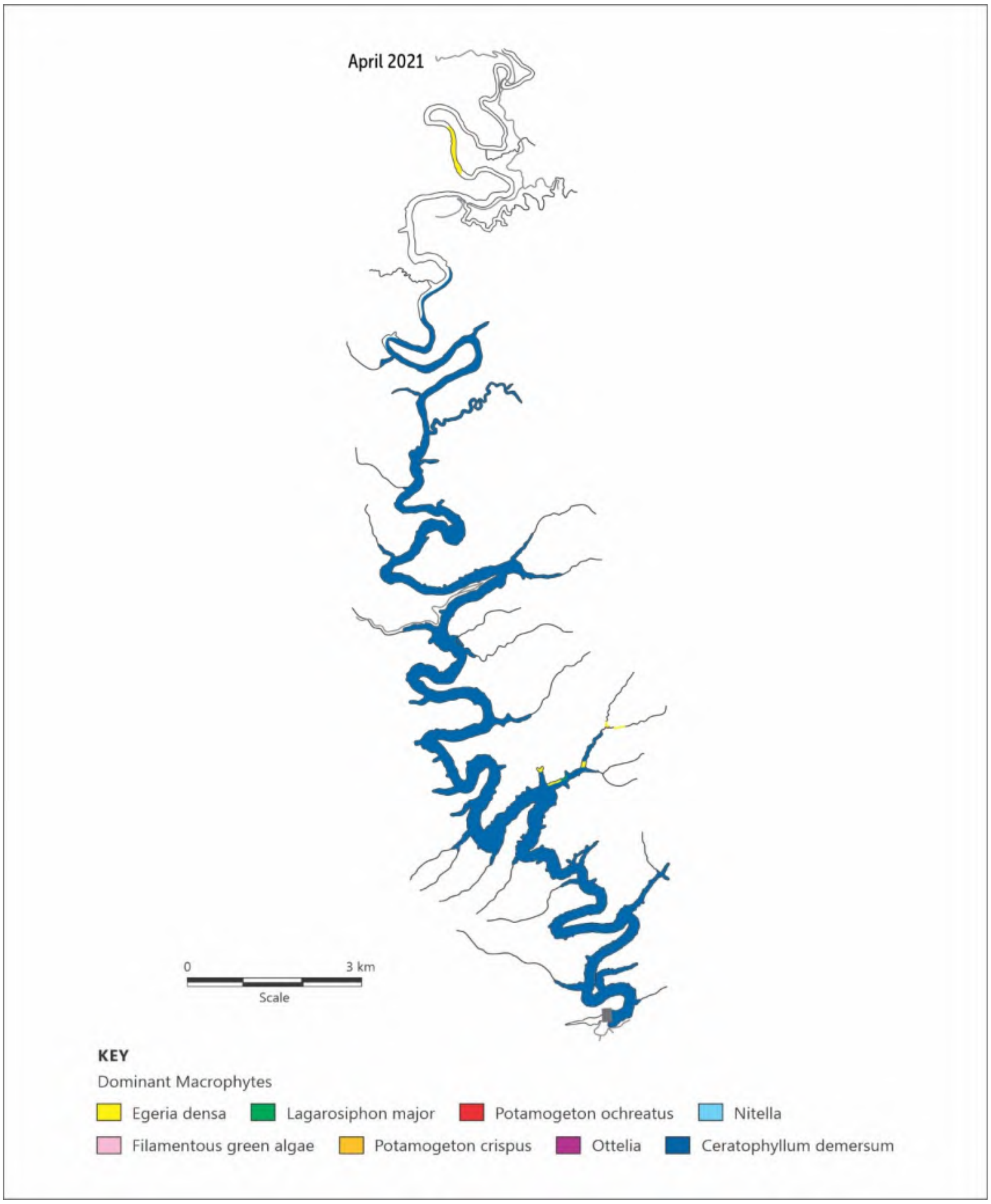



Figure 1 Dominant macrophytes recorded in Lake Rotorangi on 16 April 2021

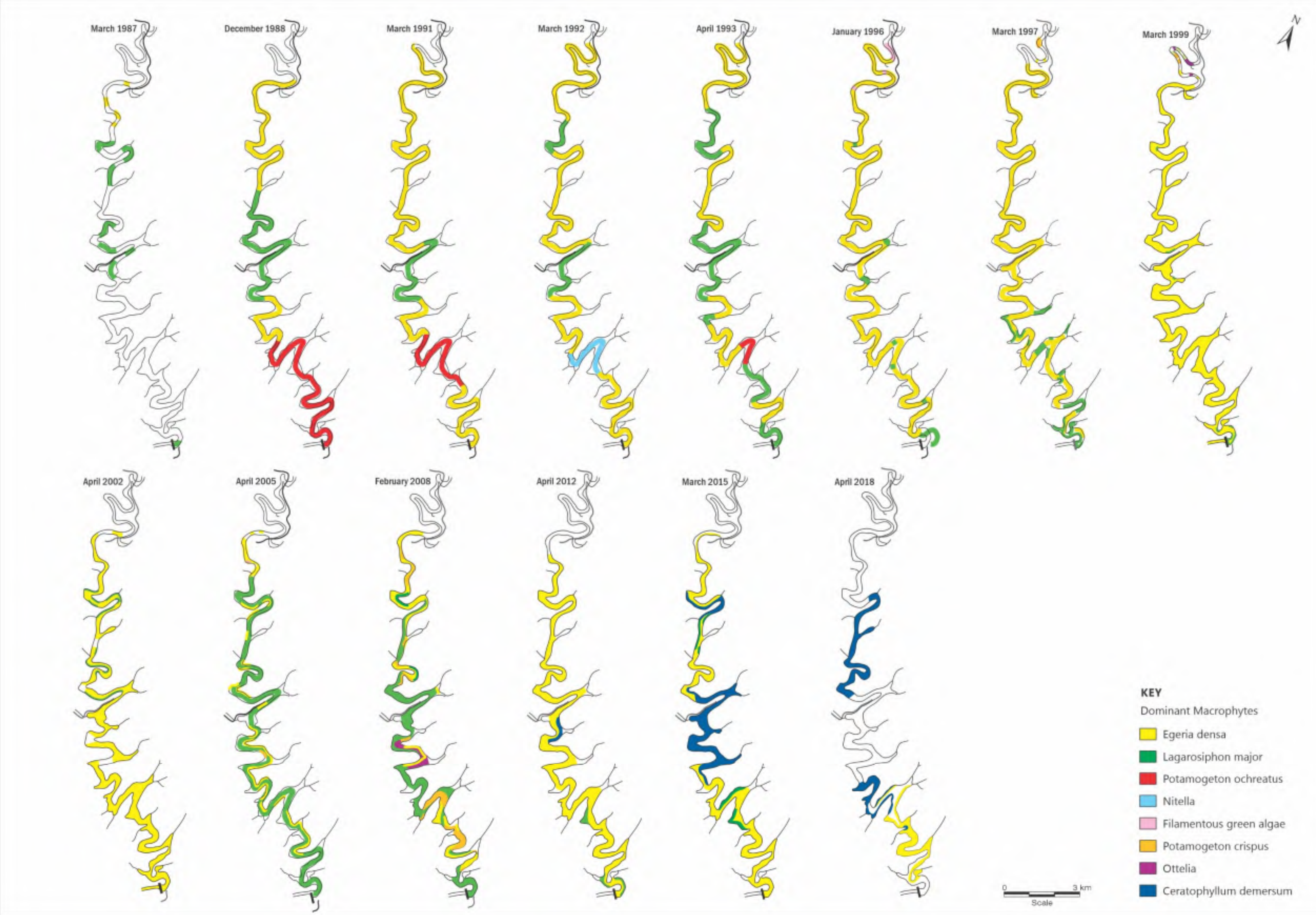



Figure 2 Dominant macrophytes recorded in Lake Rotorangi from 1987 to 2018

Actual coverage of macrophytes throughout the lake remains restricted to the edges of the lake and extends further into the middle of the lake only on the inside of large wide bends where shallow areas permit the spread of these macrophytes. In areas where the banks drop away quickly the macrophytes have been previously recorded in patches rather than large continuous thick growths. However, the presence of *C. demersum* is causing this to change, as this species can grow taller and in deeper water than *E. densa* and *l. major*, enabling it to colonise more of the lakebed. *C. demersum* has been observed growing as deep as 8 metres. Despite this, in the areas with the steepest banks there are still patches of lakebed clear of macrophytes. In the current survey, species diversity was greatest in the inlets at the lower end of the lake.

A summary of the aquatic macrophyte species found in Lake Rotorangi by the summer-autumn surveys performed between 1986 and 2021 is presented in Table 1.

Table 1 Aquatic macrophytes recorded in Lake Rotorangi between 1986 and 2021

| Species | Date | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mar 86 | Mar 87 | Dec 88 | Mar 91 | Mar 92 | Apr 93 | Jan 96 | Mar 97 | Mar 99 | Apr 02 | Apr 05 | Feb 08 | Mar 12 | Mar 15 | Apr 18 | Apr 21 |
| *Aponogeton distachyon* | ✓ | ✓ | | | | | | | | | | | | | | |
| *Ceratophyllum demersum* | | | | | | | | | | | | | ✓ | ✓ | ✓ | ✓ |
| *Chara australis* | | | | | | | | | | | | | ✓* | | | |
| *Egeria densa* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| *Elodea canadensis* | | | | | | | | | | | | ✓ | | | | |
| *Glossostigma elatinoides* | | | | | | | | | | | | | ✓ | ✓ | ✓ | |
| *Lagarosiphon major* | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| *Lilaeopsis ruthiana* | | | | | | | | | | | | | ✓* | | | |
| *Nasturtium officinale* | | | | | | ✓ | | | | | | | | | | |
| *Nitella cristata* | | | | | | | | | | | | | ✓* | | | |
| *Nitella hookeri* | | | | | ✓ | | | | | | | | | | | ✓ |
| *Ottelia ovalifolia* | | | | ✓ | | ✓ | | | ✓ | ✓ | ✓ | ✓ | | ✓ | | |
| *Potamogeton cheesmanii* | ✓ | ✓ | ✓ | | | | | | | | | | | | | |
| *Potamogeton crispus* | ✓ | ✓ | | ✓ | | ✓ | | ✓ | | ✓ | ✓ | ✓ | | ✓ | | |
| *Potamogeton ochreatus* | | | | ✓ | ✓ | ✓ | | | | | | | | | | ✓ |
| *Potamogeton pectinatus* | ✓ | ✓ | | | | | | | | | | | | | | |
| Filamentous green algae | | | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | | |

* Recorded by NIWA in April 2012

A total of 16 aquatic macrophytes have been recorded in Lake Rotorangi over the thirty-five year record. Only *E. densa* has been recorded on all survey occasions, although *L. major* has been recorded on all occasions except the 2018 survey. It is likely that *L. major* was present on this occasion but was not recorded due to high turbidity at the time of this survey. Another species frequently recorded is *Potamogeton crispus*, with this species even dominating parts of the lake in 2008. However in the 2015 survey, this species was recorded only at the head of the lake, and not in abundance. It has not been recorded in the most recent two surveys. *Potamogeton ochreatus* was recorded, although this was only noted in one small patch and was not dominant in any part of the lake. The distribution of *Potamogeton* spp. may be influenced by the large rudd (*Scardinius erythrophthalmus*) population in the lake. A 2002 study[3] found that rudd preferred eating *P. ochreatus* over *E. densa* and *l. major*, while *C. demersum* was least

[3] Lake MD, Hicks BJ, Wells RDS & Dugdale TM. 2002. Consumption of submerged aquatic macrophytes by rudd (*Scardinius erythrophthalmus* L.) in New Zealand. Hydrobiologia 470: 13-22.

preferred. Although *P. crispus* was not included in this study, its similar appearance to *P. ochreatus* indicates that it also would be preferentially eaten by rudd, explaining the reduced abundance of *Potamogeton* spp. in Lake Rotorangi in recent years.

A survey undertaken by NIWA in 2012 recorded four species that had not previously been recorded in Lake Rotorangi. It is unlikely that these species were new additions to the lake. Rather, these species were either not widespread, had growth habits that caused them to be relatively discreet eg. low growing plants that inhabit deep water. These species were only recorded when the boat was stationary (*G. elatinoides*) or by divers (*C. australis*, *L. ruthiana* and *N. cristata*). It is unlikely that these species will ever become abundant.

*C. demersum* is considered highly invasive, and as predicted is becoming dominant in the lake. While this is not expected to cause significant impacts on the ecology of Lake Rotorangi, there is now greater potential for it to spread to nearby lakes where such impacts could be much more severe. In 2021, hornwort was recorded in Lake Herengawe, south of Lake Rotorangi, for the first time. Considering the proximity of Lake Rotokare to the Glen Nui boat ramp, it may be worthwhile controlling *C. demersum* in the vicinity of the Glen Nui boat ramp to help prevent its spread. The usefulness of this may be subject to further investigation by the Taranaki Regional Council.

# Appendix IV

# Trophic Level Index

Trophic level and state, with trophic level components and annual average values used in to calculate the trophic level of Lake Rotorangi as a whole

| Monitoring Year | Chlorophyll-a (mg $m^{-3}$) | Secchi Depth (m) | Total Nitrogen (mg $m^{-3}$) | Total Phosphorus (mg $m^{-3}$) | TLc | TLs | TLn | TLp | TLI | Trophic State |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 2.29 | 2.84 | 610 | 22.8 | 3.13 | 4.3 | 4.77 | 4.18 | 4.1 | Eutrophic |
| 1997 | 1.67 | 3.46 | 505 | 12 | 2.78 | 4.06 | 4.53 | 3.37 | 3.68 | Mesotrophic |
| 1998 | 2.35 | 2.81 | 643.75 | 19.38 | 3.16 | 4.31 | 4.84 | 3.98 | 4.07 | Eutrophic |
| 1999 | 2.6 | 3.38 | 687.5 | 25.75 | 3.27 | 4.09 | 4.93 | 4.34 | 4.16 | Eutrophic |
| 2000 | 3.06 | 3.71 | 641 | 15.6 | 3.45 | 3.97 | 4.84 | 3.7 | 3.99 | Mesotrophic |
| 2001 | 2.24 | 3.22 | 989 | 18.5 | 3.11 | 4.14 | 5.41 | 3.92 | 4.14 | Eutrophic |
| 2002 | 2.83 | 2.73 | 836 | 27.1 | 3.37 | 4.35 | 5.19 | 4.4 | 4.32 | Eutrophic |
| 2003 | 2.91 | 3.52 | 586.25 | 20.88 | 3.4 | 4.03 | 4.72 | 4.07 | 4.06 | Eutrophic |
| 2004 | 3.61 | 0.71 | 914 | 61.2 | 3.64 | 5.92 | 5.3 | 5.44 | 5.07 | Supertrophic |
| 2005 | 2.52 | 2.94 | 601 | 20.2 | 3.24 | 4.26 | 4.75 | 4.03 | 4.07 | Eutrophic |
| 2006 | 3.49 | 2.53 | 624 | 26.2 | 3.6 | 4.44 | 4.8 | 4.36 | 4.3 | Eutrophic |
| 2007 | 5.56 | 3.32 | 523.75 | 15.75 | 4.11 | 4.11 | 4.57 | 3.71 | 4.13 | Eutrophic |
| 2008 | 1.69 | 3.34 | 643 | 20.4 | 2.8 | 4.1 | 4.84 | 4.04 | 3.94 | Mesotrophic |
| 2009 | 3.84 | 2.95 | 586 | 16.8 | 3.7 | 4.25 | 4.72 | 3.8 | 4.12 | Eutrophic |
| 2010 | 3.61 | 2.4 | 640 | 23.3 | 3.64 | 4.5 | 4.84 | 4.21 | 4.3 | Eutrophic |
| 2011 | 4.19 | 2.65 | 732 | 35 | 3.8 | 4.38 | 5.01 | 4.73 | 4.48 | Eutrophic |
| 2012 | 3.4 | 2.52 | 621 | 36.7 | 3.57 | 4.45 | 4.8 | 4.79 | 4.4 | Eutrophic |
| 2013 | 4.21 | 3.05 | 558 | 26.8 | 3.81 | 4.21 | 4.66 | 4.39 | 4.27 | Eutrophic |
| 2014 | 4.8 | 2.7 | 616 | 28.8 | 3.95 | 4.36 | 4.79 | 4.48 | 4.39 | Eutrophic |
| 2015 | 3.8 | 2.76 | 900 | 186.2 | 3.69 | 4.33 | 5.28 | 6.85 | 5.04 | Supertrophic |
| 2016 | 2.87 | 2.88 | 530 | 23.12 | 3.38 | 4.28 | 4.59 | 4.2 | 4.11 | Eutrophic |
| 2017 | 3.98 | 2.54 | 614 | 32.7 | 3.74 | 4.43 | 4.78 | 4.64 | 4.4 | Eutrophic |
| 2018 | 5.58 | 2.07 | 707 | 42.4 | 4.12 | 4.68 | 4.97 | 4.97 | 4.68 | Eutrophic |
| 2019 | 2.55 | 3.86 | 552 | 19.5 | 3.25 | 3.92 | 4.64 | 3.98 | 3.95 | Mesotrophic |
| 2020 | 2.08 | 2.57 | 549 | 21.6 | 3.03 | 4.42 | 4.64 | 4.11 | 4.05 | Eutrophic |
| 2021 | 2.81 | 3.1 | 681 | 14.73 | 3.36 | 4.19 | 4.92 | 3.63 | 4.02 | Eutrophic |

Trophic level and state, with trophic level components and annual average values used in to calculate the trophic level at site L2 in Lake Rotorangi

| Monitoring Year | Chlorophyll-a (mg m$^{-3}$) | Secchi Depth (m) | Total Nitrogen (mg m$^{-3}$) | Total Phosphorus (mg m$^{-3}$) | TLc | TLs | TLn | TLp | TLI | Trophic State |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 2.12 | 2.51 | 620 | 28 | 3.05 | 4.45 | 4.8 | 4.44 | 4.18 | Eutrophic |
| 1997 | 1.43 | 2.68 | 520 | 15.75 | 2.62 | 4.37 | 4.57 | 3.71 | 3.82 | Mesotrophic |
| 1998 | 1.9 | 2.36 | 690 | 23.25 | 2.93 | 4.52 | 4.93 | 4.21 | 4.15 | Eutrophic |
| 1999 | 2.02 | 2.5 | 728 | 72.8 | 3 | 4.45 | 5.01 | 5.66 | 4.53 | Eutrophic |
| 2000 | 4.22 | 3.52 | 676 | 18.2 | 3.81 | 4.03 | 4.91 | 3.9 | 4.16 | Eutrophic |
| 2001 | 2.72 | 3.34 | 1010 | 16 | 3.33 | 4.1 | 5.43 | 3.73 | 4.15 | Eutrophic |
| 2002 | 2.02 | 2.5 | 894 | 32.8 | 3 | 4.45 | 5.27 | 4.64 | 4.34 | Eutrophic |
| 2003 | 2.8 | 3.2 | 674 | 24.2 | 3.36 | 4.15 | 4.9 | 4.26 | 4.17 | Eutrophic |
| 2004 | 2.93 | 0.83 | 981.43 | 102.29 | 3.4 | 5.74 | 5.4 | 6.09 | 5.16 | Supertrophic |
| 2005 | 2.42 | 2.59 | 628 | 24.8 | 3.2 | 4.41 | 4.81 | 4.29 | 4.18 | Eutrophic |
| 2006 | 3.9 | 2.04 | 784 | 32.6 | 3.72 | 4.7 | 5.1 | 4.64 | 4.54 | Eutrophic |
| 2007 | 6.4 | 2.94 | 580 | 22.2 | 4.27 | 4.26 | 4.71 | 4.15 | 4.35 | Eutrophic |
| 2008 | 1.83 | 2.94 | 718.33 | 23.67 | 2.88 | 4.26 | 4.99 | 4.23 | 4.09 | Eutrophic |
| 2009 | 3.85 | 3.24 | 578 | 19.8 | 3.71 | 4.14 | 4.7 | 4 | 4.14 | Eutrophic |
| 2010 | 3.62 | 2 | 678 | 27.4 | 3.64 | 4.72 | 4.91 | 4.42 | 4.42 | Eutrophic |
| 2011 | 4.53 | 2.56 | 808 | 43.4 | 3.89 | 4.42 | 5.14 | 5 | 4.61 | Eutrophic |
| 2012 | 3.2 | 2.23 | 628 | 46.4 | 3.5 | 4.59 | 4.81 | 5.08 | 4.5 | Eutrophic |
| 2013 | 4 | 2.88 | 580 | 34 | 3.75 | 4.28 | 4.71 | 4.69 | 4.36 | Eutrophic |
| 2014 | 2.65 | 2.5 | 700 | 35.4 | 3.3 | 4.45 | 4.95 | 4.74 | 4.36 | Eutrophic |
| 2015 | 3.85 | 2.56 | 854 | 159.6 | 3.71 | 4.43 | 5.21 | 6.65 | 5 | Supertrophic |
| 2016 | 2.8 | 2.76 | 644 | 27.6 | 3.36 | 4.33 | 4.84 | 4.43 | 4.24 | Eutrophic |
| 2017 | 4.32 | 2.27 | 638 | 42.6 | 3.84 | 4.57 | 4.83 | 4.98 | 4.55 | Eutrophic |

| Monitoring Year | Chlorophyll-a (mg m$^{-3}$) | Secchi Depth (m) | Total Nitrogen (mg m$^{-3}$) | Total Phosphorus (mg m$^{-3}$) | TLc | TLs | TLn | TLp | TLI | Trophic State |
|---|---|---|---|---|---|---|---|---|---|---|
| 2018 | 5.2 | 1.6 | 780 | 63.4 | 4.04 | 4.98 | 5.1 | 5.48 | 4.9 | Eutrophic |
| 2019 | 2.78 | 3.28 | 532 | 25.4 | 3.35 | 4.12 | 4.59 | 4.32 | 4.1 | Eutrophic |
| 2020 | 2.17 | 2.19 | 574 | 29.8 | 3.08 | 4.61 | 4.69 | 4.52 | 4.23 | Eutrophic |
| 2021 | 3.33 | 3.23 | 676 | 16.83 | 3.55 | 4.14 | 4.91 | 3.8 | 4.1 | Eutrophic |

Trophic level and state, with trophic level components and annual average values used in to calculate the trophic level at site L3 in Lake Rotorangi

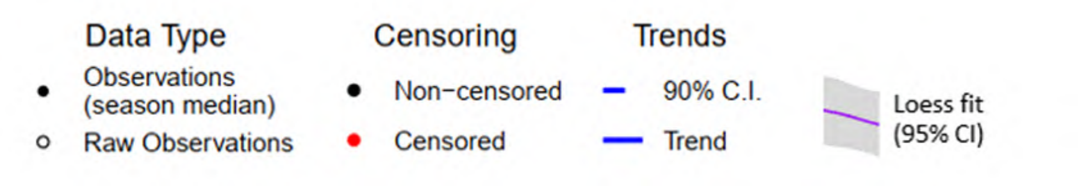
| Monitoring Year | Chlorophyll-a (mg m$^{-3}$) | Secchi Depth (m) | Total Nitrogen (mg m$^{-3}$) | Total Phosphorus (mg m$^{-3}$) | TLc | TLs | TLn | TLp | TLI | Trophic State |
|---|---|---|---|---|---|---|---|---|---|---|
| 1996 | 2.45 | 3.16 | 600 | 17.6 | 3.21 | 4.17 | 4.75 | 3.85 | 4 | Eutrophic |
| 1997 | 2.72 | 3.7 | 560 | 11.2 | 3.33 | 3.97 | 4.66 | 3.28 | 3.81 | Mesotrophic |
| 1998 | 2.8 | 3.26 | 604 | 14 | 3.36 | 4.13 | 4.76 | 3.56 | 3.95 | Mesotrophic |
| 1999 | 2.67 | 3.47 | 685 | 13.75 | 3.3 | 4.05 | 4.93 | 3.54 | 3.96 | Mesotrophic |
| 2000 | 1.9 | 3.9 | 606 | 13 | 2.93 | 3.91 | 4.77 | 3.47 | 3.77 | Mesotrophic |
| 2001 | 1.75 | 3.1 | 968 | 21 | 2.84 | 4.19 | 5.38 | 4.08 | 4.12 | Eutrophic |
| 2002 | 3.62 | 2.96 | 778 | 21.4 | 3.64 | 4.25 | 5.09 | 4.1 | 4.27 | Eutrophic |
| 2003 | 3.02 | 3.85 | 555 | 23 | 3.44 | 3.92 | 4.65 | 4.19 | 4.05 | Eutrophic |
| 2004 | 4.3 | 0.59 | 840 | 50.8 | 3.83 | 6.13 | 5.19 | 5.2 | 5.09 | Supertrophic |
| 2005 | 2.62 | 3.28 | 574 | 15.6 | 3.28 | 4.12 | 4.69 | 3.7 | 3.95 | Mesotrophic |
| 2006 | 3.08 | 3.03 | 464 | 19.8 | 3.46 | 4.22 | 4.42 | 4 | 4.02 | Eutrophic |
| 2007 | 4.72 | 3.7 | 517.5 | 15.25 | 3.93 | 3.97 | 4.56 | 3.67 | 4.03 | Eutrophic |
| 2008 | 1.55 | 3.75 | 634 | 17.8 | 2.7 | 3.96 | 4.82 | 3.87 | 3.84 | Mesotrophic |
| 2009 | 3.83 | 2.66 | 594 | 13.8 | 3.7 | 4.38 | 4.74 | 3.55 | 4.09 | Eutrophic |
| 2010 | 3.6 | 2.8 | 602 | 19.2 | 3.63 | 4.32 | 4.76 | 3.97 | 4.17 | Eutrophic |
| 2011 | 3.85 | 2.73 | 656 | 26.6 | 3.71 | 4.34 | 4.87 | 4.38 | 4.32 | Eutrophic |
| 2012 | 3.6 | 2.8 | 614 | 27 | 3.63 | 4.32 | 4.78 | 4.4 | 4.28 | Eutrophic |
| 2013 | 4.42 | 3.22 | 536 | 19.6 | 3.86 | 4.14 | 4.6 | 3.99 | 4.15 | Eutrophic |
| 2014 | 6.95 | 2.91 | 532 | 22.2 | 4.36 | 4.27 | 4.59 | 4.15 | 4.34 | Eutrophic |
| 2015 | 3.75 | 2.96 | 946 | 212.8 | 3.68 | 4.25 | 5.35 | 7.02 | 5.07 | Supertrophic |
| 2016 | 2.93 | 3.01 | 502.5 | 21 | 3.41 | 4.23 | 4.52 | 4.08 | 4.06 | Eutrophic |
| 2017 | 3.62 | 2.81 | 590 | 22.8 | 3.64 | 4.31 | 4.73 | 4.18 | 4.22 | Eutrophic |

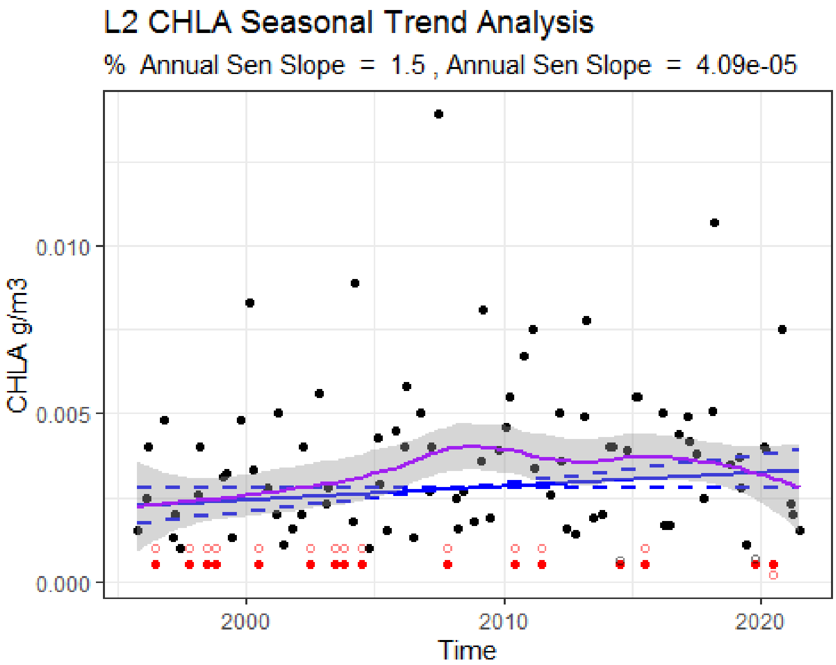
| Monitoring Year | Chlorophyll-a (mg $m^{-3}$) | Secchi Depth (m) | Total Nitrogen (mg $m^{-3}$) | Total Phosphorus (mg $m^{-3}$) | TLc | TLs | TLn | TLp | TLI | Trophic State |
|---|---|---|---|---|---|---|---|---|---|---|
| 2018 | 5.95 | 2.54 | 634 | 21.4 | 4.19 | 4.44 | 4.82 | 4.1 | 4.39 | Eutrophic |
| 2019 | 2.33 | 4.45 | 572 | 13.6 | 3.15 | 3.74 | 4.69 | 3.53 | 3.78 | Mesotrophic |
| 2020 | 1.97 | 2.95 | 524 | 13.4 | 2.97 | 4.25 | 4.58 | 3.51 | 3.83 | Mesotrophic |
| 2021 | 2.3 | 2.98 | 686 | 12.2 | 3.14 | 4.24 | 4.93 | 3.39 | 3.92 | Mesotrophic |

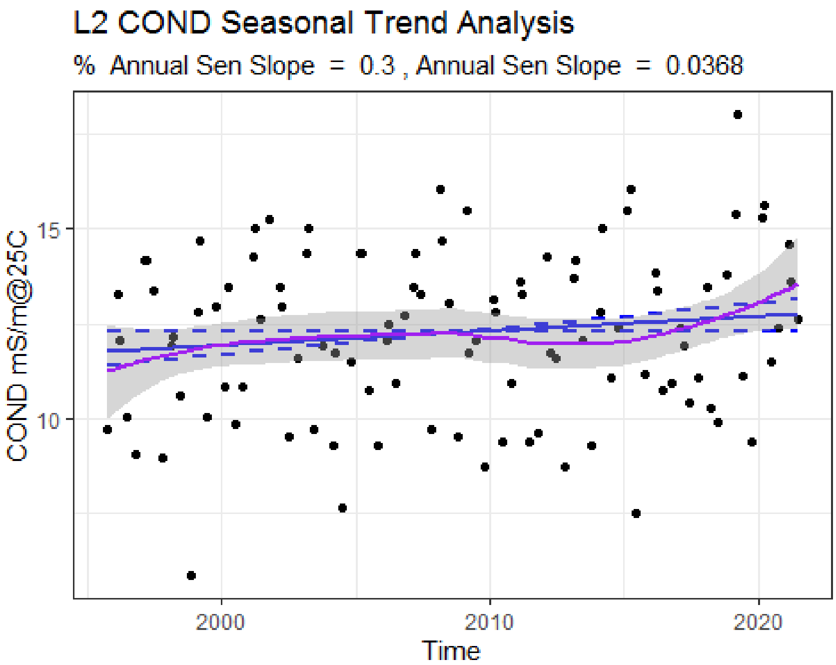
# Appendix V

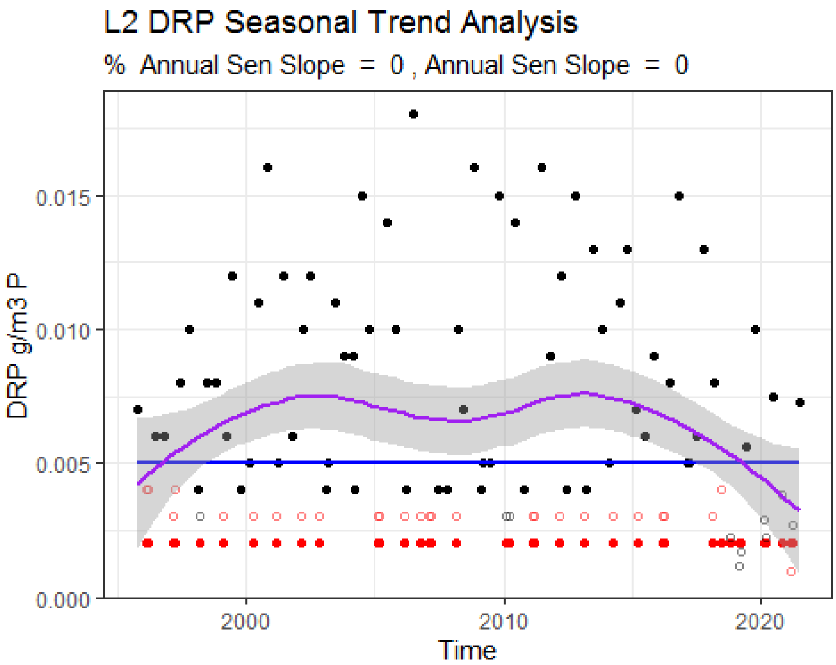
# Trend plots for the period 1996-2021

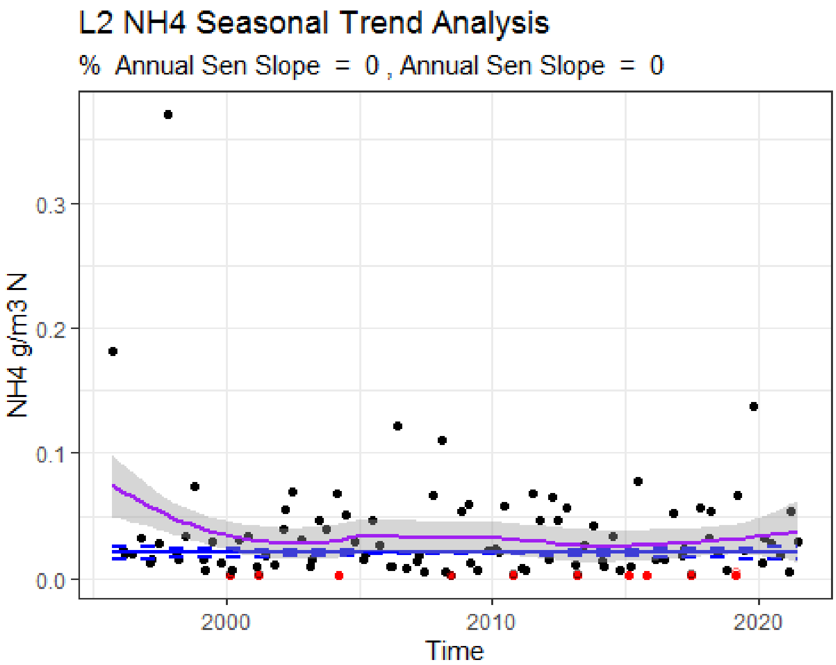
Legend for all trend plots:

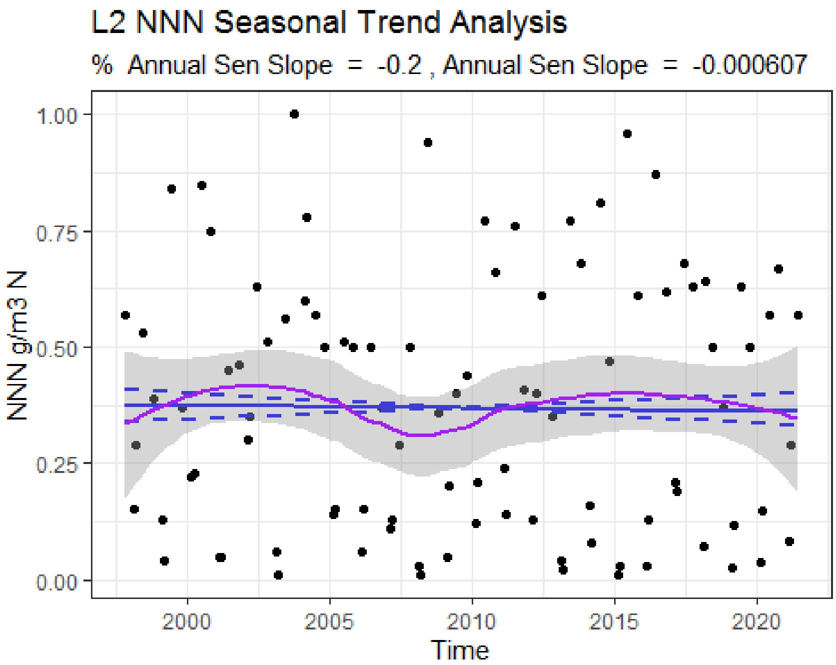


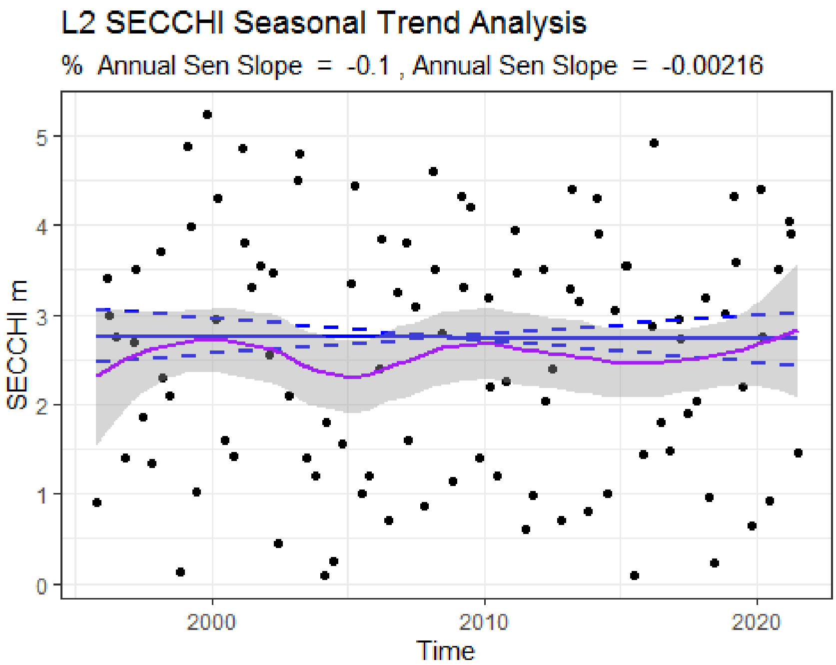

L2 CHLA Seasonal Trend Analysis
% Annual Sen Slope = 1.5 , Annual Sen Slope = 4.09e-05
CHLA g/m3
0.010
0.005
0.000
2000
2010
2020
Time

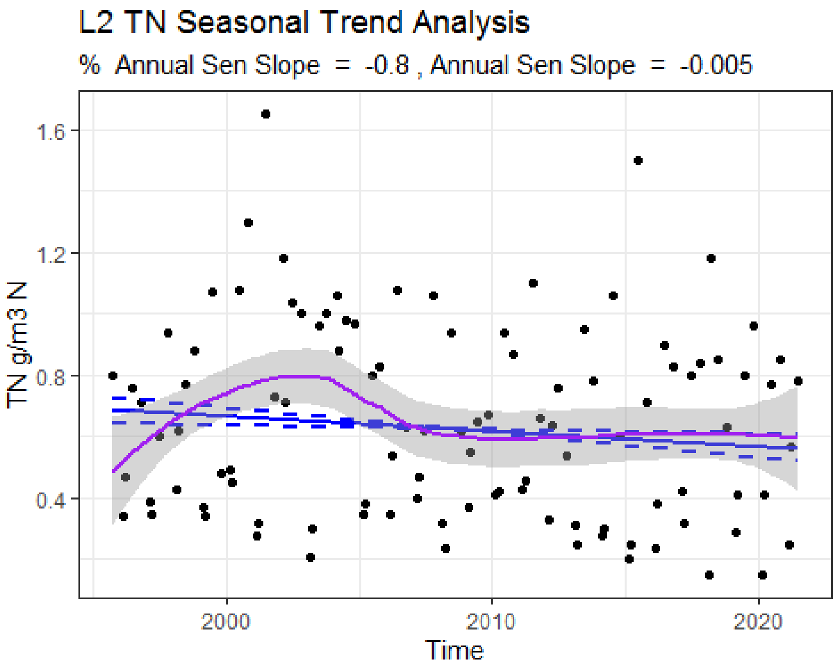

L2 COND Seasonal Trend Analysis
% Annual Sen Slope = 0.3 , Annual Sen Slope = 0.0368
COND mS/m@25C
15
10
2000
2010
2020
Time

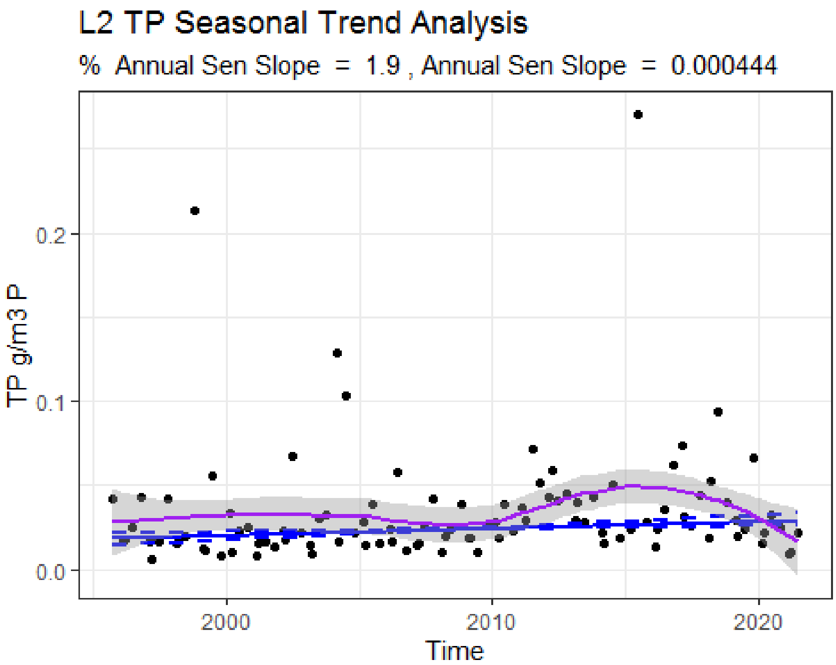

L2 DRP Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
DRP g/m3 P
0.000
0.005
0.010
0.015
2000
2010
2020
Time

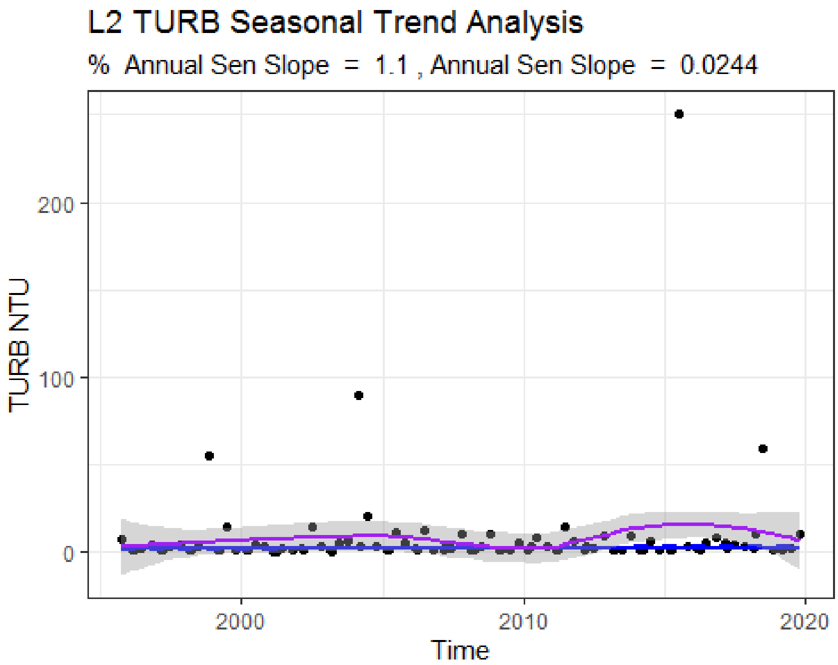

L2 NH4 Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
NH4 g/m3 N
0.0
0.1
0.2
0.3
2000
2010
2020
Time

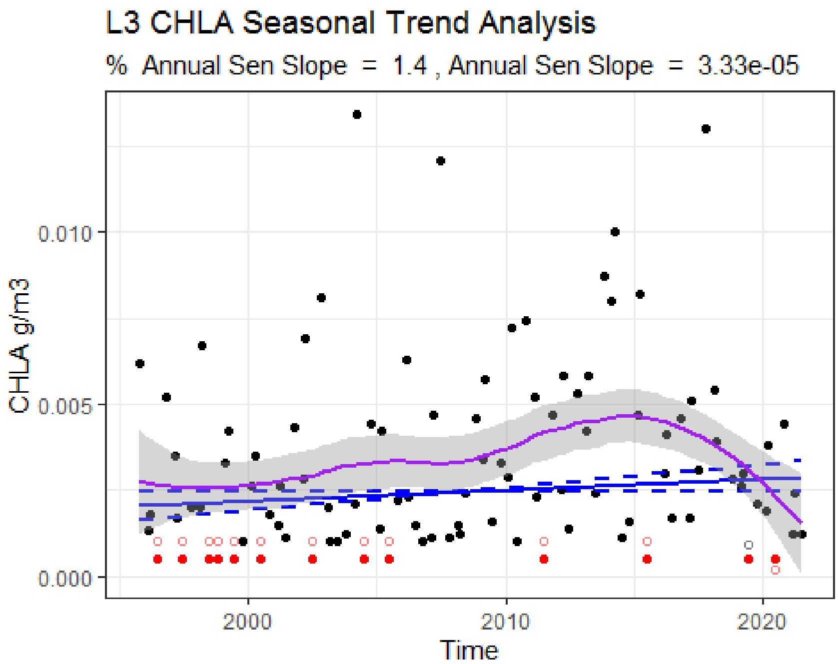

L2 NNN Seasonal Trend Analysis
% Annual Sen Slope = -0.2 , Annual Sen Slope = -0.000607
NNN g/m3 N
1.00
0.75
0.50
0.25
0.00
2000
2005
2010
2015
2020
Time

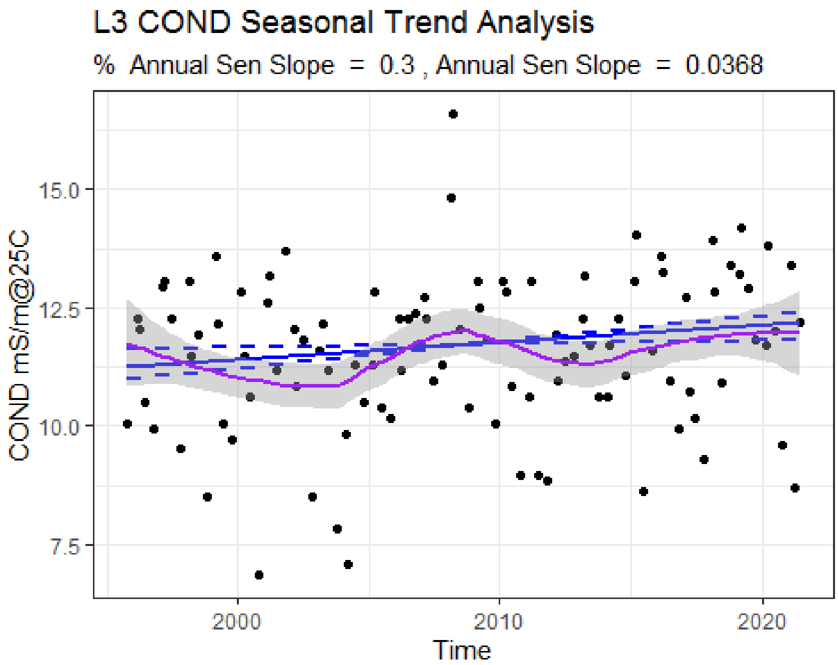

L2 SECCHI Seasonal Trend Analysis
% Annual Sen Slope = -0.1 , Annual Sen Slope = -0.00216
SECCHI m
5
4
3
2
1
0
2000
2010
2020
Time

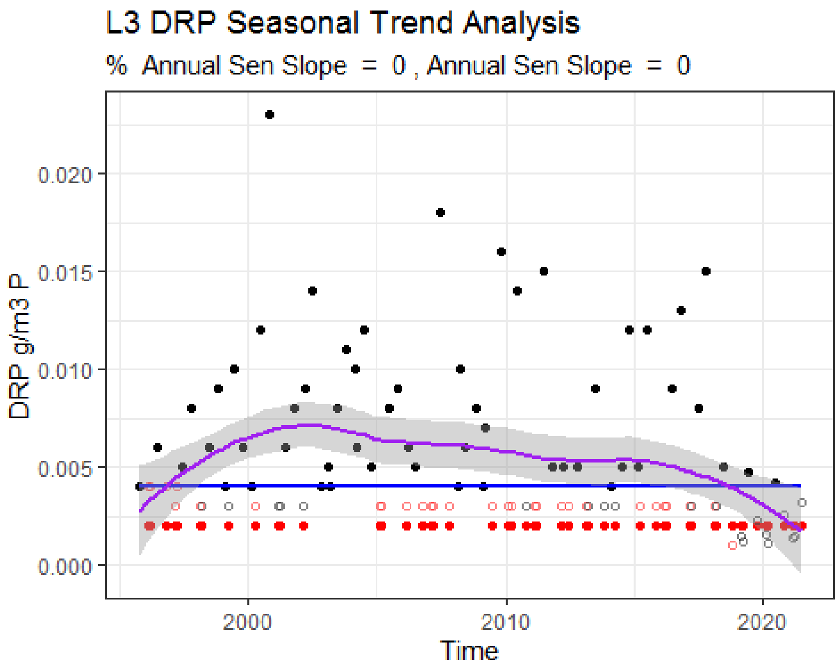

L2 TN Seasonal Trend Analysis
% Annual Sen Slope = -0.8 , Annual Sen Slope = -0.005
TN g/m3 N
1.6
1.2
0.8
0.4
2000
2010
2020
Time

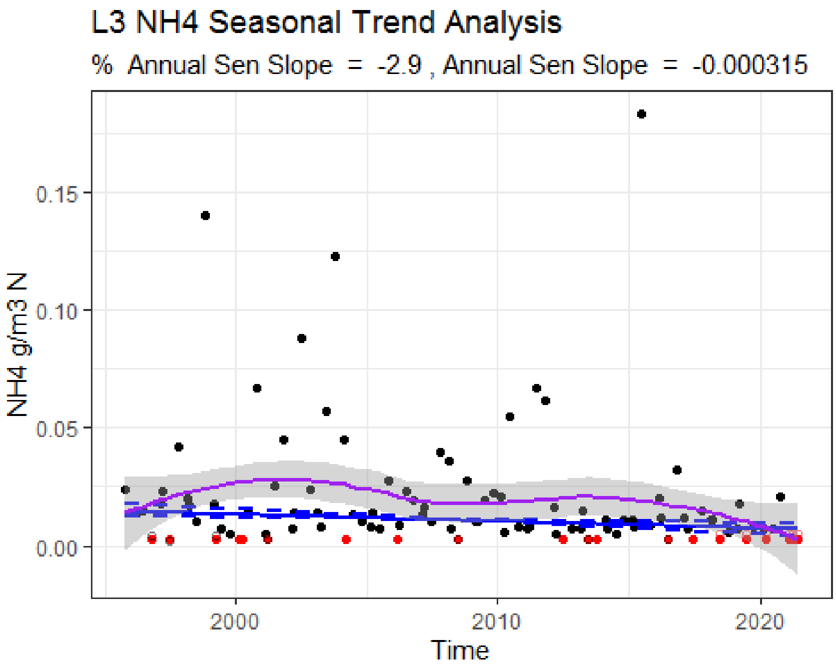

L2 TP Seasonal Trend Analysis
% Annual Sen Slope = 1.9 , Annual Sen Slope = 0.000444
TP g/m3 P
0.2
0.1
0.0
2000
2010
2020
Time

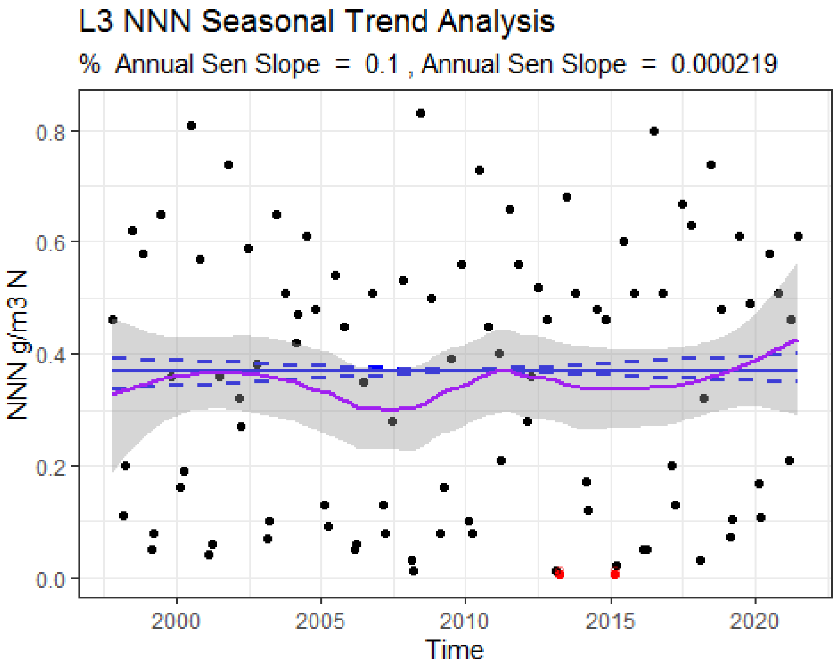

L2 TURB Seasonal Trend Analysis
% Annual Sen Slope = 1.1 , Annual Sen Slope = 0.0244
TURB NTU
200
100
0
2000
2010
2020
Time

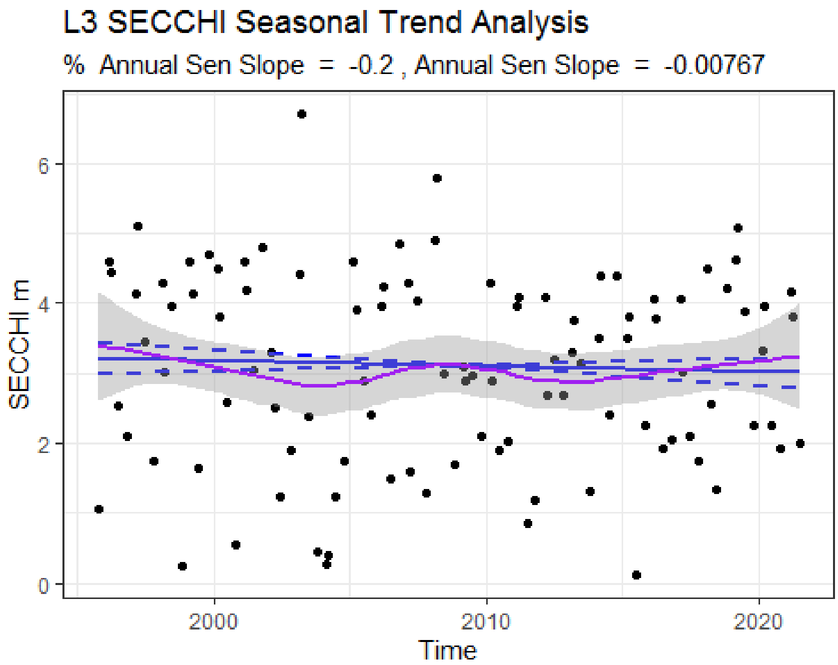

L3 CHLA Seasonal Trend Analysis
% Annual Sen Slope = 1.4 , Annual Sen Slope = 3.33e-05
CHLA g/m3
0.010
0.005
0.000
2000
2010
2020
Time

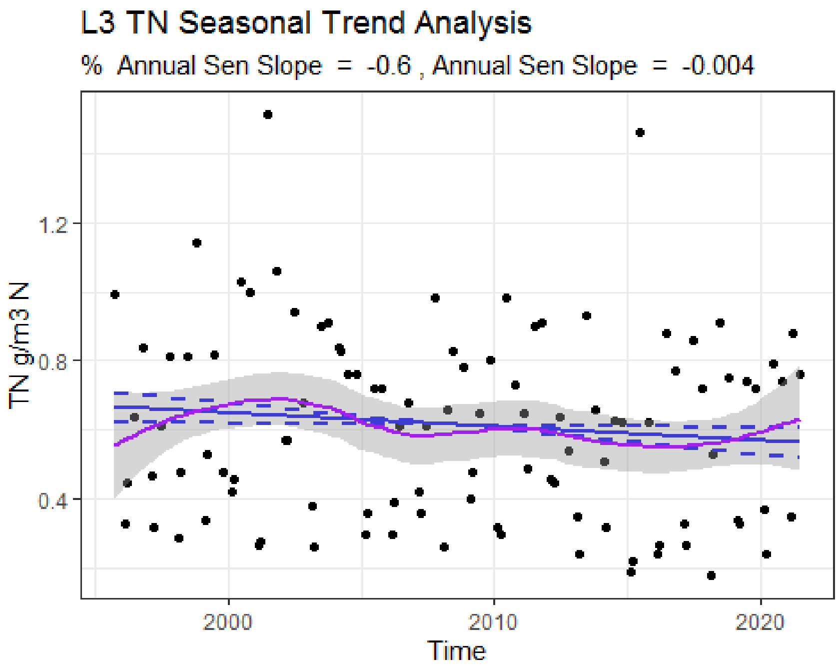

L3 COND Seasonal Trend Analysis
% Annual Sen Slope = 0.3 , Annual Sen Slope = 0.0368
COND mS/m@25C
15.0
12.5
10.0
7.5
2000
2010
2020
Time

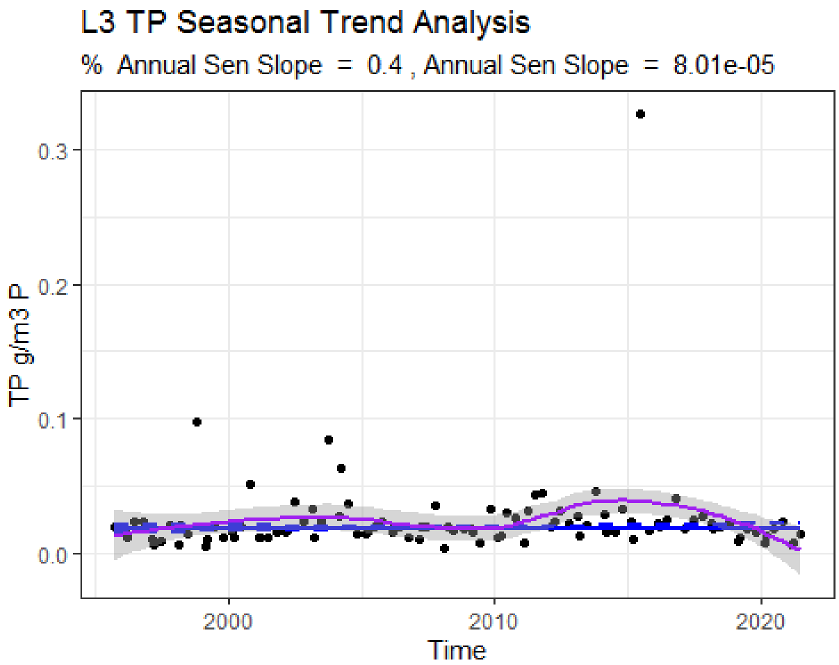

L3 DRP Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
DRP g/m3 P
0.020
0.015
0.010
0.005
0.000
2000
2010
2020
Time

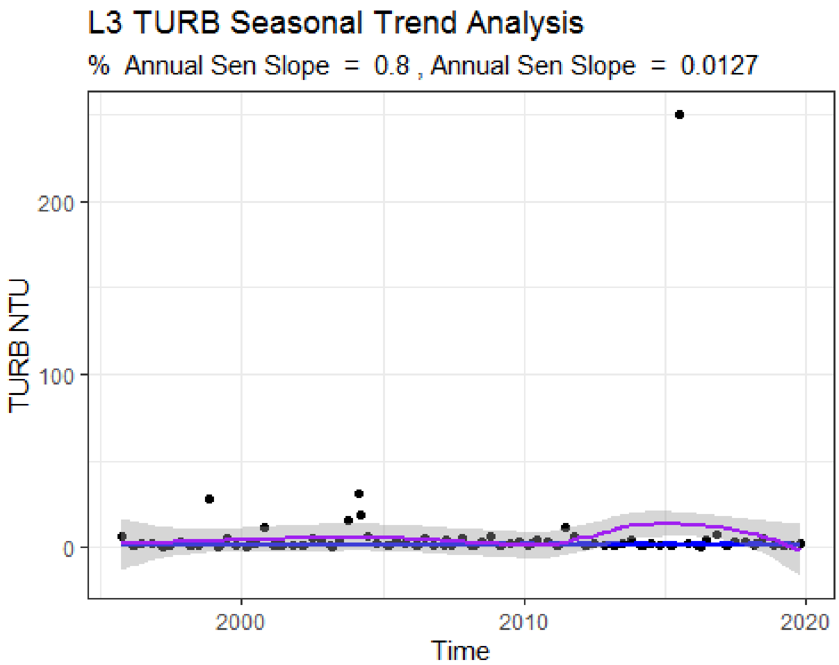

L3 NH4 Seasonal Trend Analysis
% Annual Sen Slope = -2.9 , Annual Sen Slope = -0.000315
NH4 g/m3 N
0.15
0.10
0.05
0.00
2000
2010
2020
Time

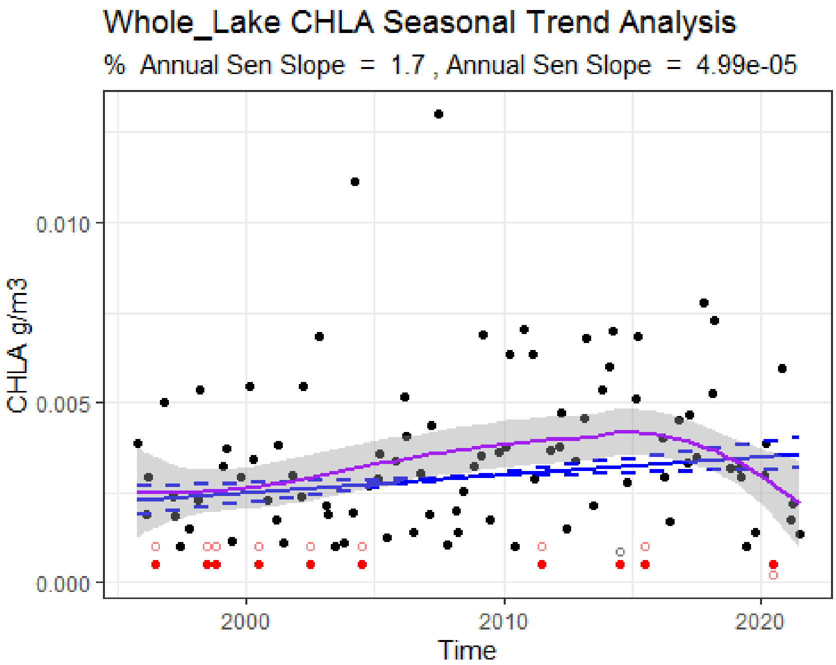

L3 NNN Seasonal Trend Analysis
% Annual Sen Slope = 0.1 , Annual Sen Slope = 0.000219
NNN g/m3 N
0.8
0.6
0.4
0.2
0.0
2000
2005
2010
2015
2020
Time

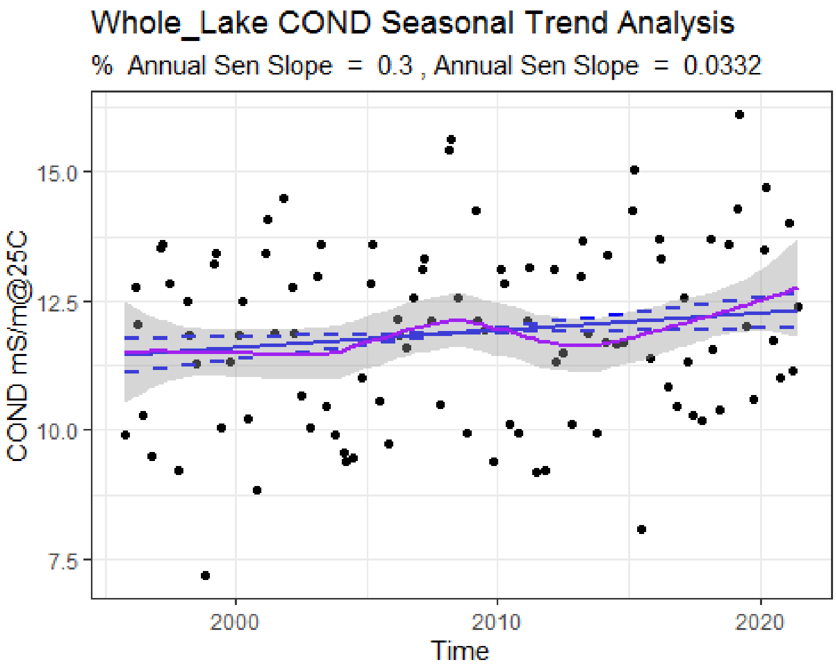

L3 SECCHI Seasonal Trend Analysis
% Annual Sen Slope = -0.2 , Annual Sen Slope = -0.00767
SECCHI m
0
2
4
6
2000
2010
2020
Time

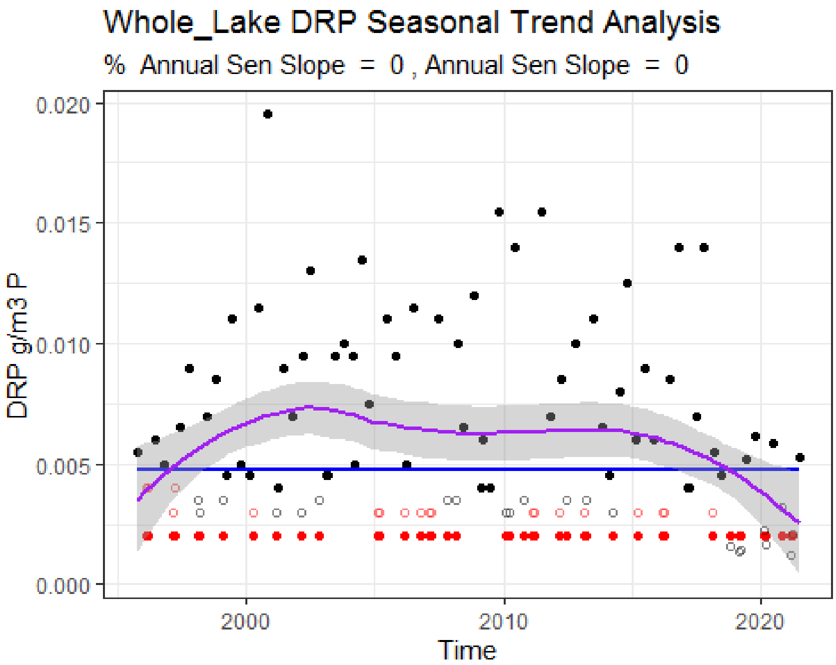

L3 TN Seasonal Trend Analysis
% Annual Sen Slope = -0.6 , Annual Sen Slope = -0.004
TN g/m3 N
0.4
0.8
1.2
2000
2010
2020
Time

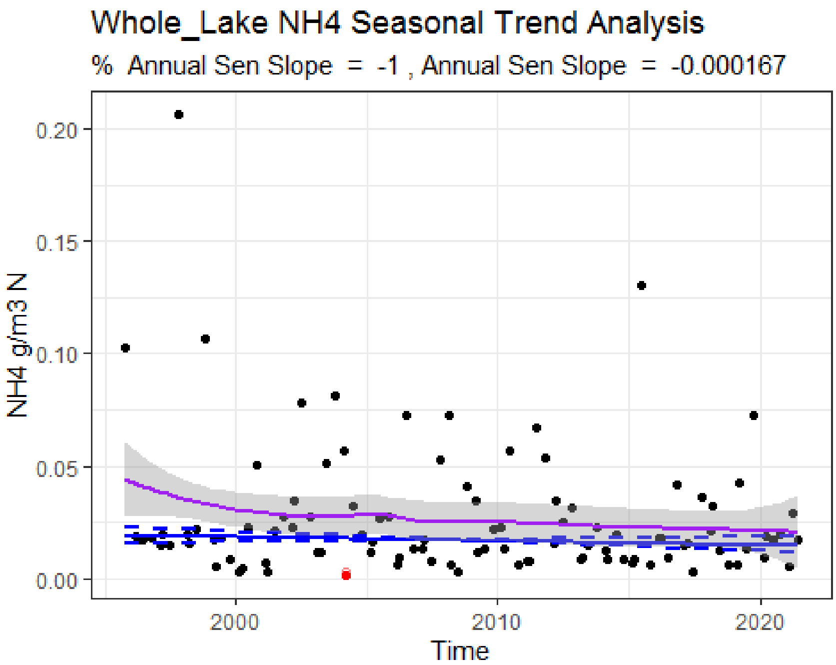

L3 TP Seasonal Trend Analysis
% Annual Sen Slope = 0.4 , Annual Sen Slope = 8.01e-05
TP g/m3 P
0.0
0.1
0.2
0.3
2000
2010
2020
Time

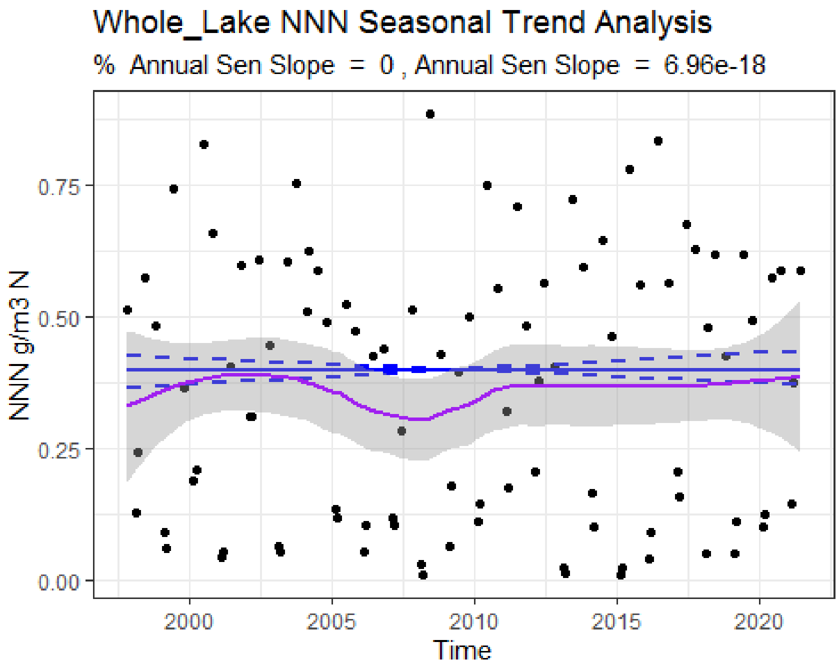

L3 TURB Seasonal Trend Analysis
% Annual Sen Slope = 0.8 , Annual Sen Slope = 0.0127
TURB NTU
0
100
200
2000
2010
2020
Time

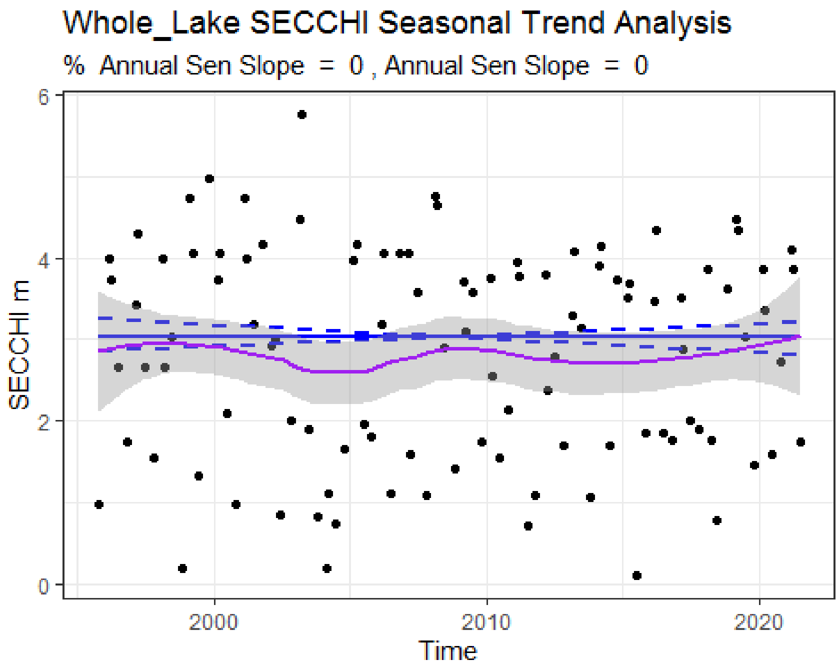

Whole_Lake CHLA Seasonal Trend Analysis
% Annual Sen Slope = 1.7 , Annual Sen Slope = 4.99e-05
CHLA g/m3
0.010
0.005
0.000
2000
2010
2020
Time

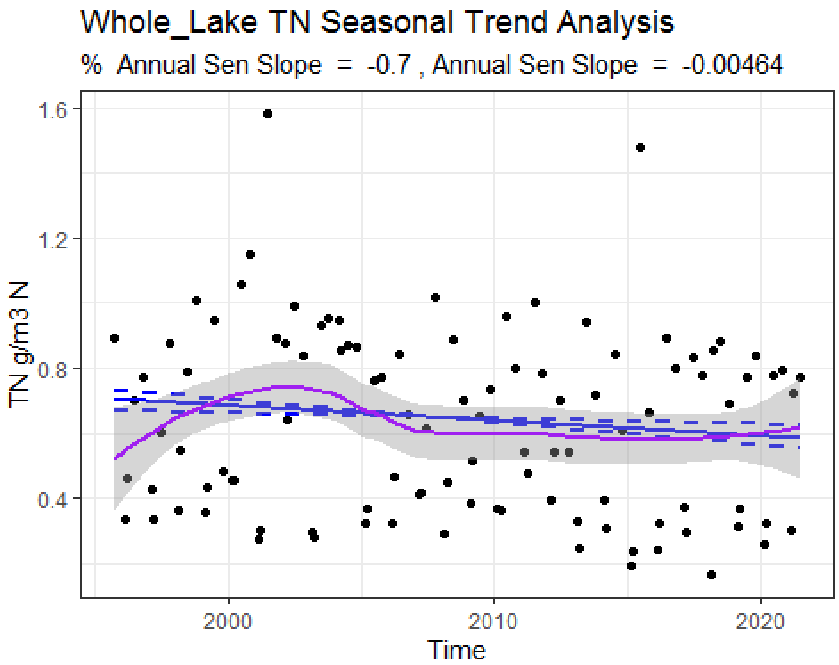

Whole_Lake COND Seasonal Trend Analysis
% Annual Sen Slope = 0.3 , Annual Sen Slope = 0.0332
COND mS/m@25C
15.0
12.5
10.0
7.5
2000
2010
2020
Time

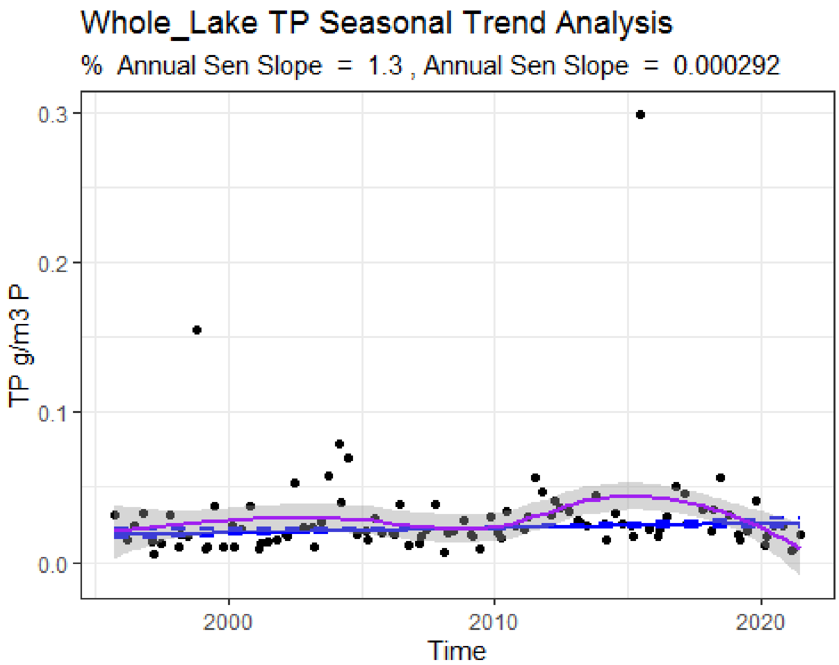

Whole_Lake DRP Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
DRP g/m3 P
0.020
0.015
0.010
0.005
0.000
2000
2010
2020
Time

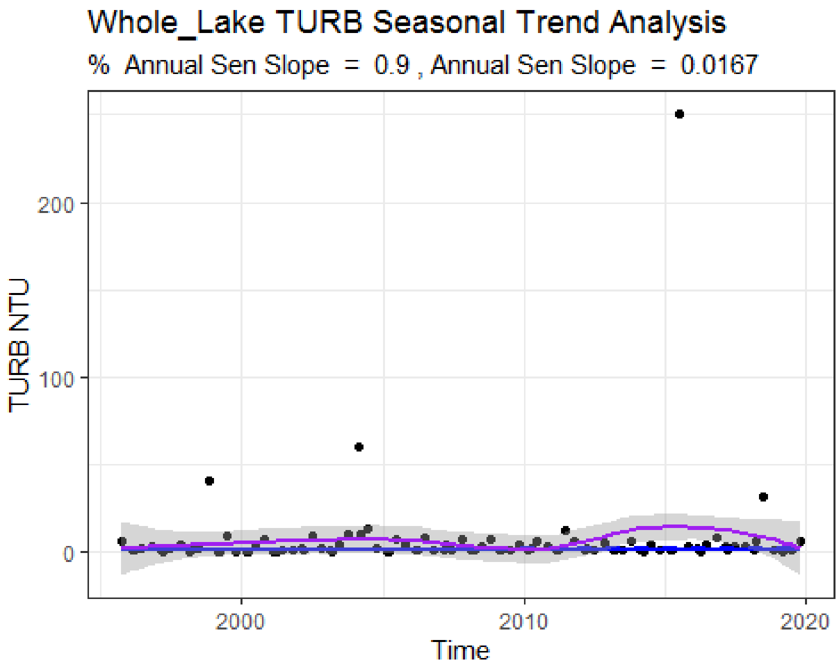

Whole_Lake NH4 Seasonal Trend Analysis
% Annual Sen Slope = -1 , Annual Sen Slope = -0.000167
NH4 g/m3 N
0.20
0.15
0.10
0.05
0.00
2000
2010
2020
Time

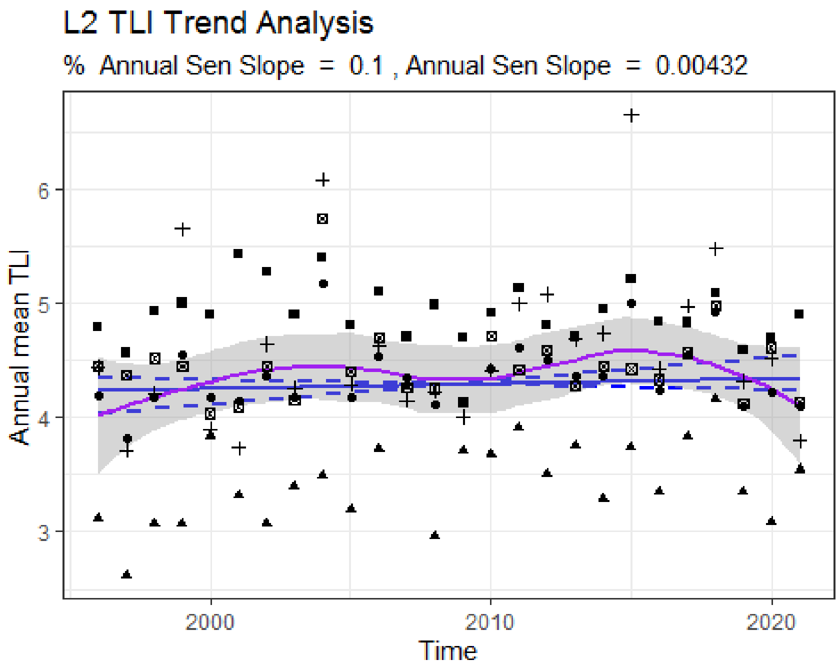

Whole_Lake NNN Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 6.96e-18
NNN g/m3 N
0.00
0.25
0.50
0.75
2000
2005
2010
2015
2020
Time

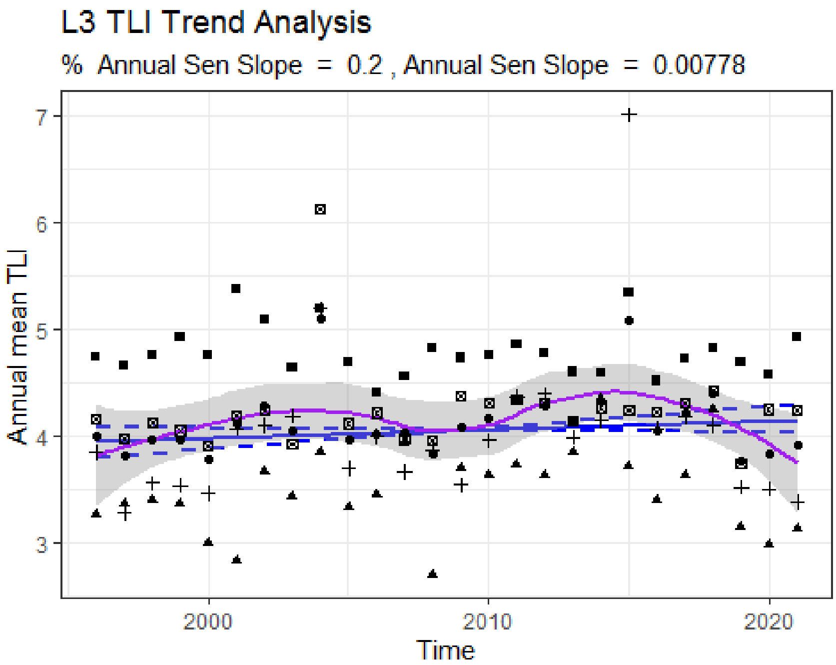

Whole_Lake SECCHI Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
SECCHI m
0
2
4
6
2000
2010
2020
Time

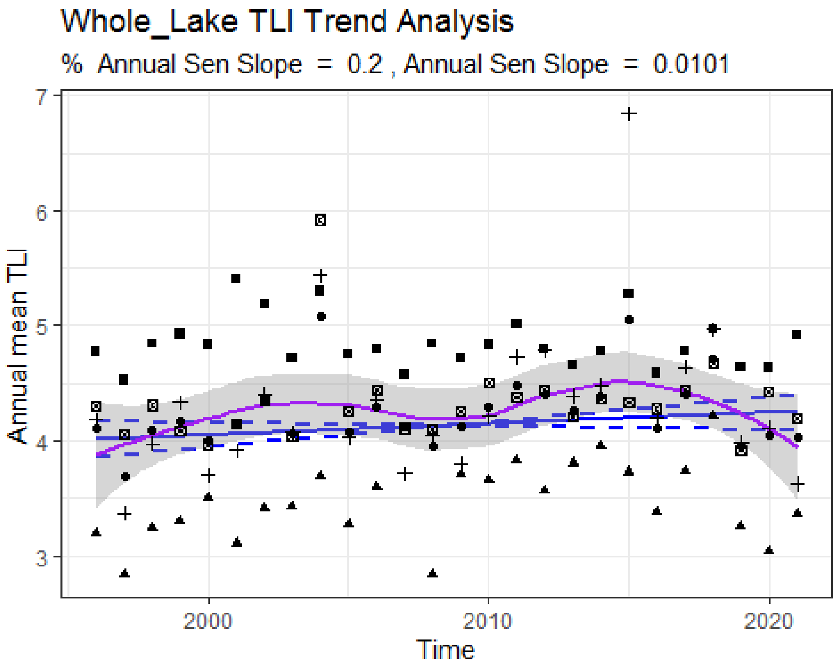

Whole_Lake TN Seasonal Trend Analysis
% Annual Sen Slope = -0.7 , Annual Sen Slope = -0.00464
TN g/m3 N
1.6
1.2
0.8
0.4
2000
2010
2020
Time


Whole_Lake TP Seasonal Trend Analysis
% Annual Sen Slope = 1.3 , Annual Sen Slope = 0.000292
TP g/m3 P
0.3
0.2
0.1
0.0
2000
2010
2020
Time


Whole_Lake TURB Seasonal Trend Analysis
% Annual Sen Slope = 0.9 , Annual Sen Slope = 0.0167
TURB NTU
200
100
0
2000
2010
2020
Time


L2 TLI Trend Analysis
% Annual Sen Slope = 0.1 , Annual Sen Slope = 0.00432
Annual mean TLI
6
5
4
3
2000
2010
2020
Time

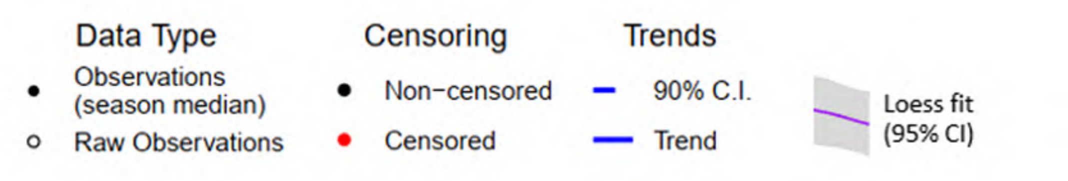

L3 TLI Trend Analysis
% Annual Sen Slope = 0.2 , Annual Sen Slope = 0.00778
Annual mean TLI
7
6
5
4
3
2000
2010
2020
Time

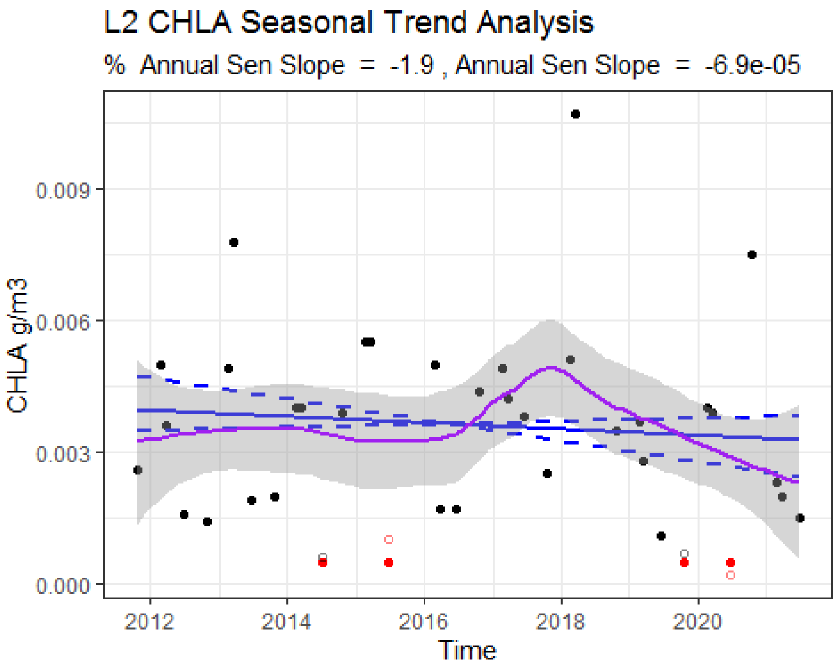

Whole_Lake TLI Trend Analysis
% Annual Sen Slope = 0.2 , Annual Sen Slope = 0.0101
Annual mean TLI
7
6
5
4
3
2000
2010
2020
Time

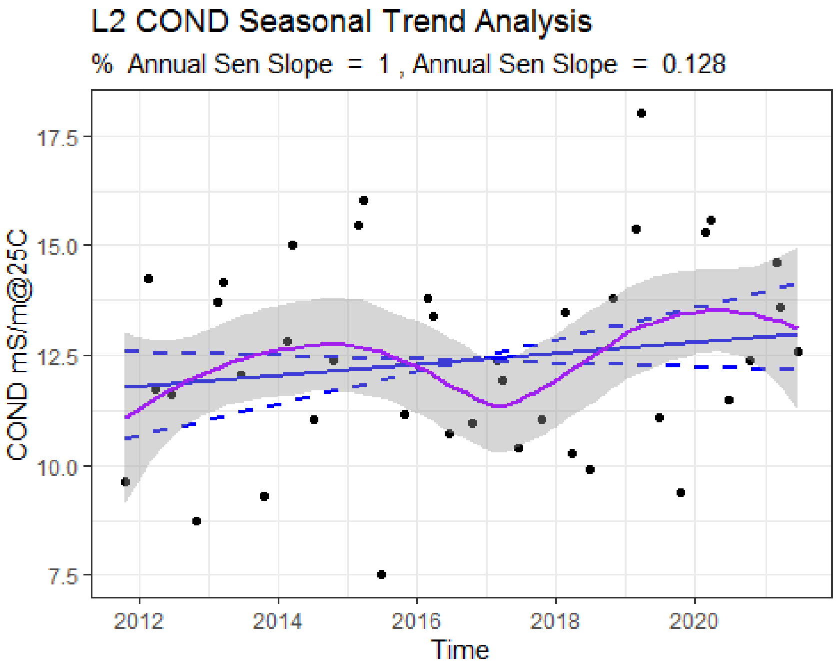
# Appendix VI

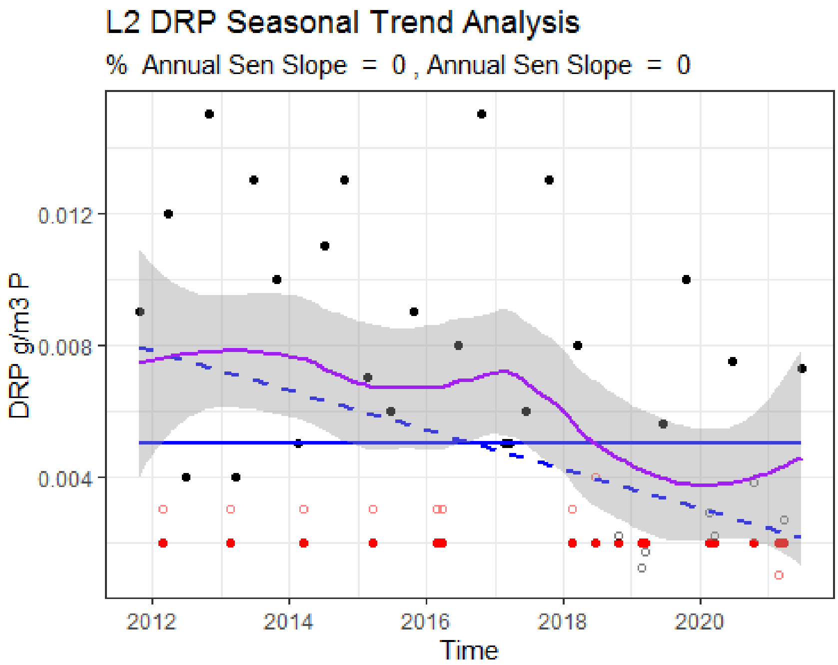
# Trend plots for the period 2012-2021

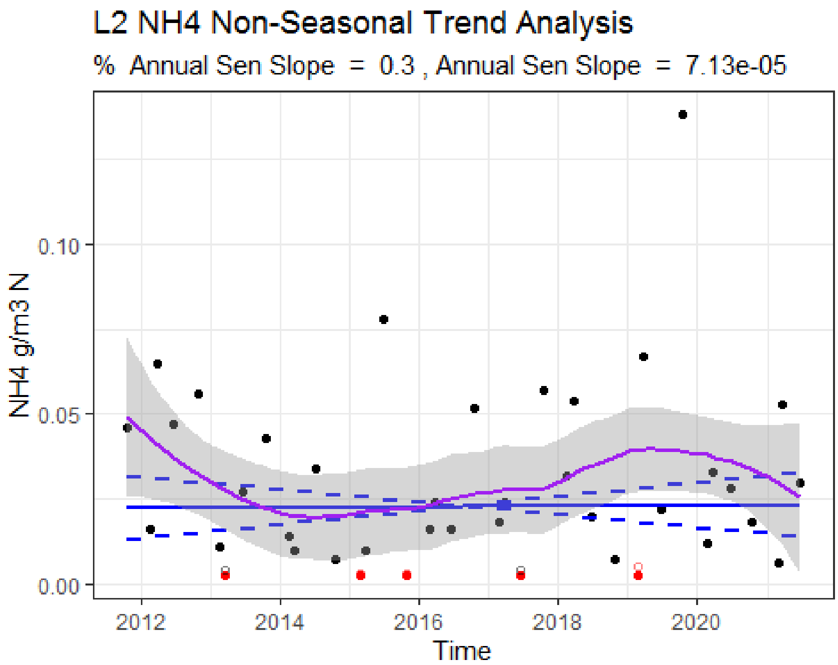
Legend for all trend plots:

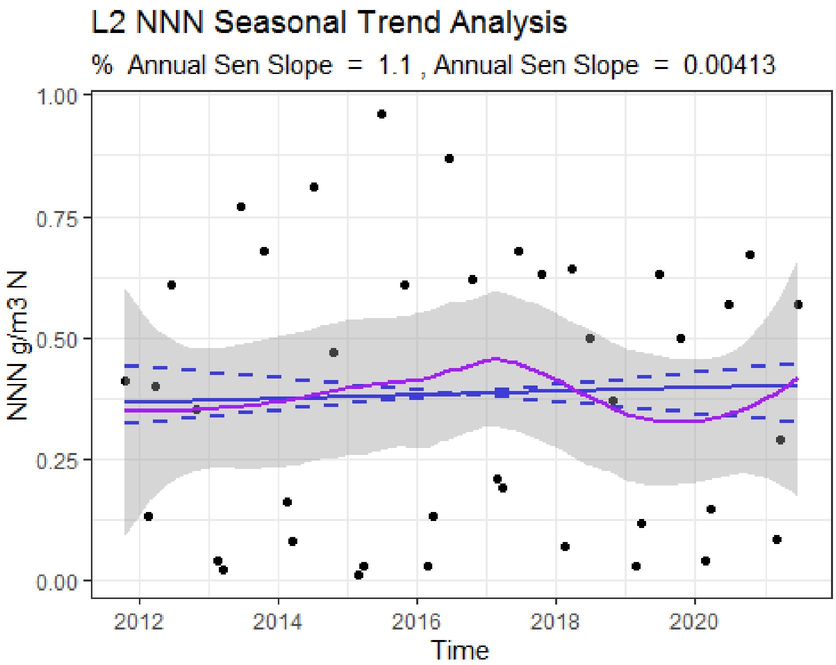


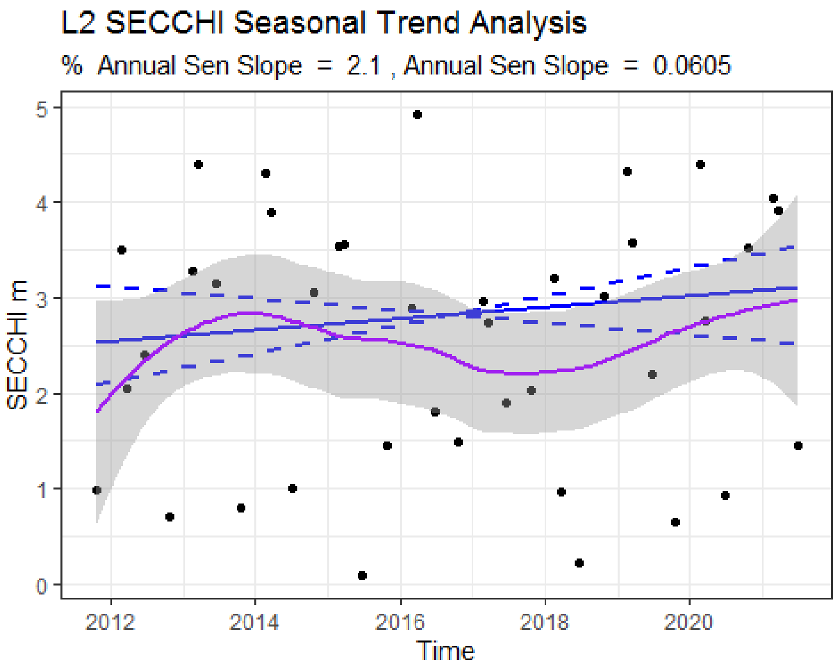

L2 CHLA Seasonal Trend Analysis
% Annual Sen Slope = -1.9 , Annual Sen Slope = -6.9e-05
CHLA g/m3
0.009
0.006
0.003
0.000
2012
2014
2016
2018
2020
Time

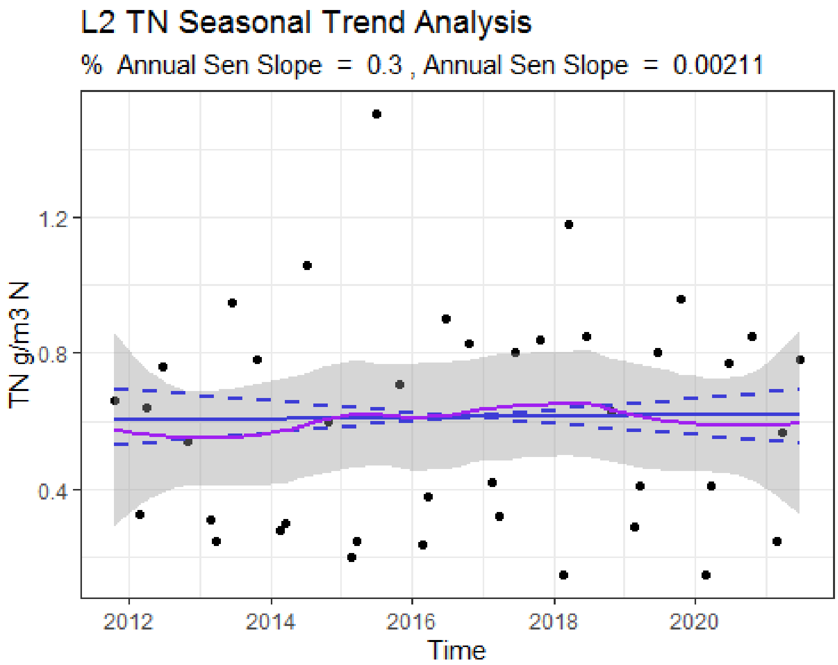

L2 COND Seasonal Trend Analysis
% Annual Sen Slope = 1 , Annual Sen Slope = 0.128
COND mS/m@25C
17.5
15.0
12.5
10.0
7.5
2012
2014
2016
2018
2020
Time

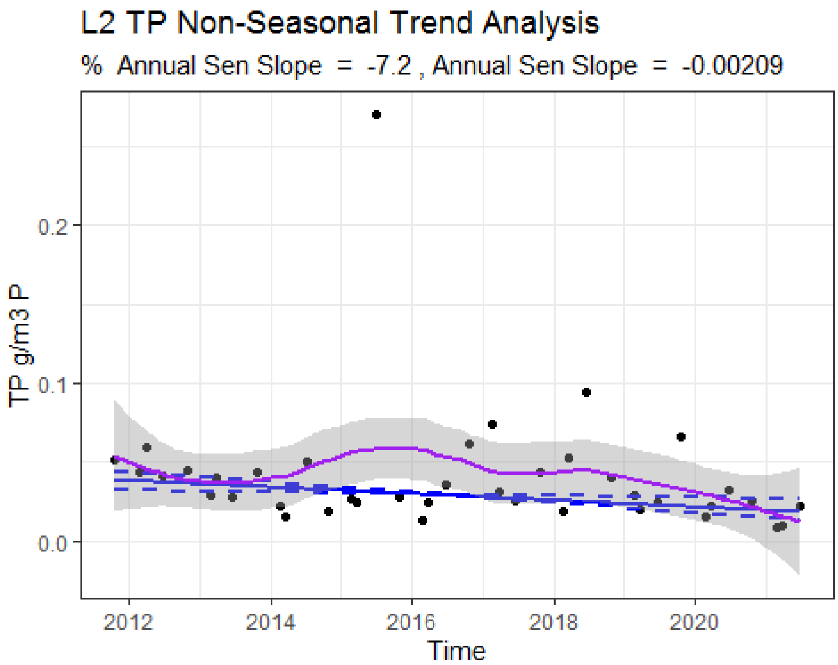

L2 DRP Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
DRP g/m3 P
0.012
0.008
0.004
2012
2014
2016
2018
2020
Time

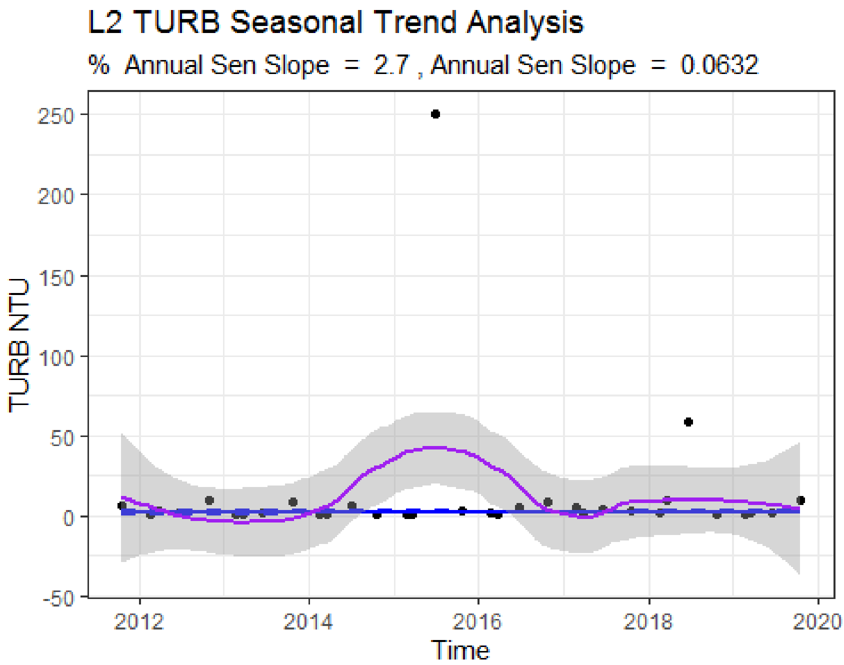

L2 NH4 Non-Seasonal Trend Analysis
% Annual Sen Slope = 0.3 , Annual Sen Slope = 7.13e-05
NH4 g/m3 N
0.10
0.05
0.00
2012
2014
2016
2018
2020
Time

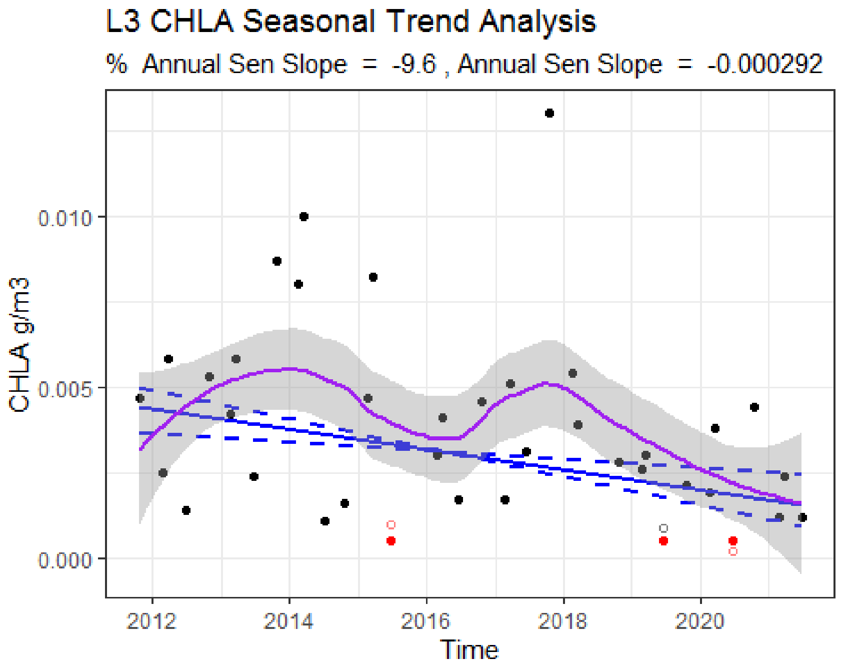

L2 NNN Seasonal Trend Analysis
% Annual Sen Slope = 1.1 , Annual Sen Slope = 0.00413
NNN g/m3 N
1.00
0.75
0.50
0.25
0.00
2012
2014
2016
2018
2020
Time

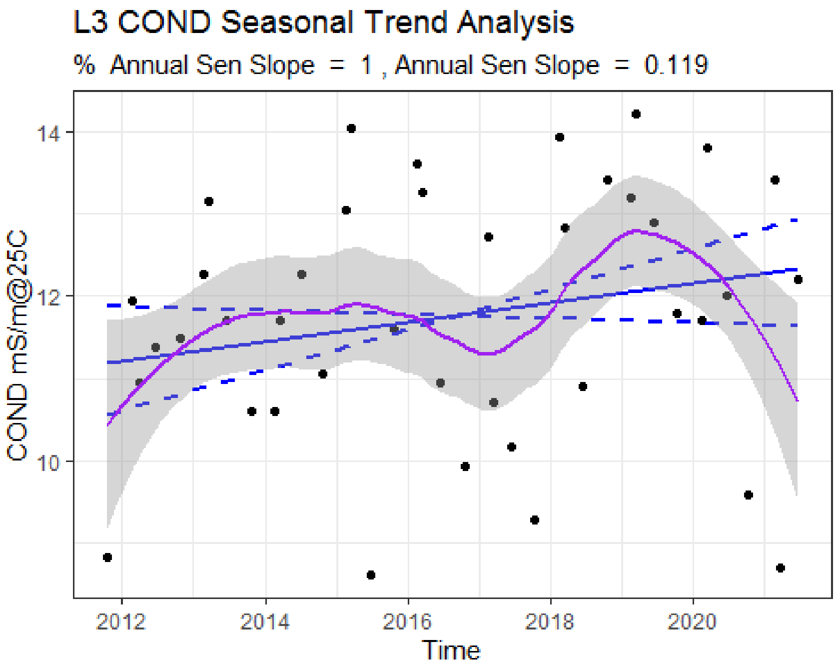

L2 SECCHI Seasonal Trend Analysis
% Annual Sen Slope = 2.1 , Annual Sen Slope = 0.0605
SECCHI m
5
4
3
2
1
0
2012
2014
2016
2018
2020
Time

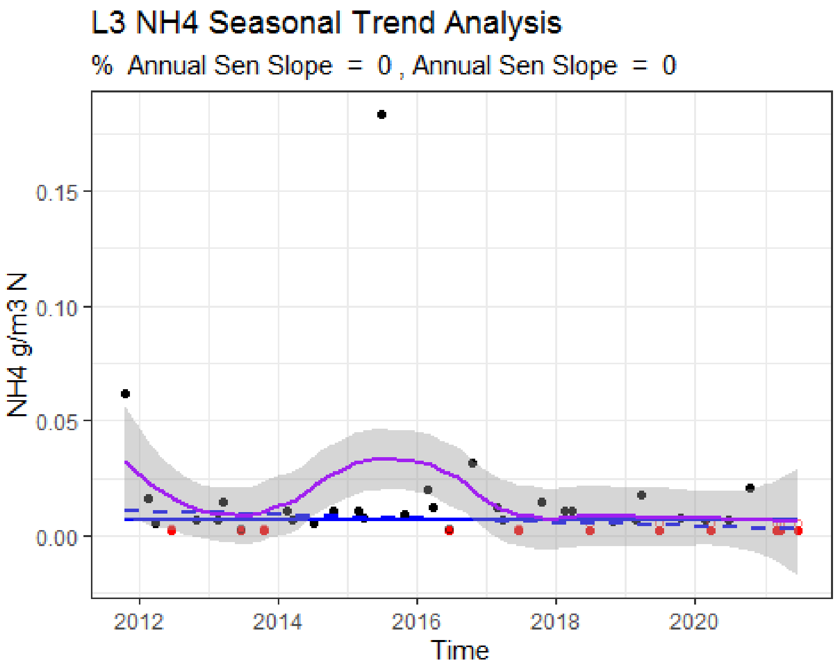

L2 TN Seasonal Trend Analysis
% Annual Sen Slope = 0.3 , Annual Sen Slope = 0.00211
TN g/m3 N
1.2
0.8
0.4
2012
2014
2016
2018
2020
Time

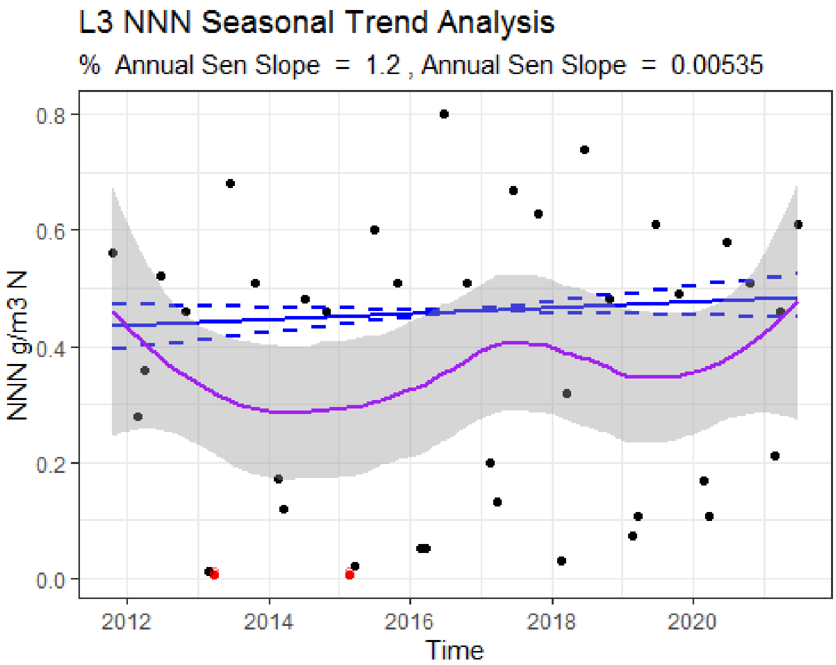

L2 TP Non-Seasonal Trend Analysis
% Annual Sen Slope = -7.2 , Annual Sen Slope = -0.00209
TP g/m3 P
0.2
0.1
0.0
2012
2014
2016
2018
2020
Time

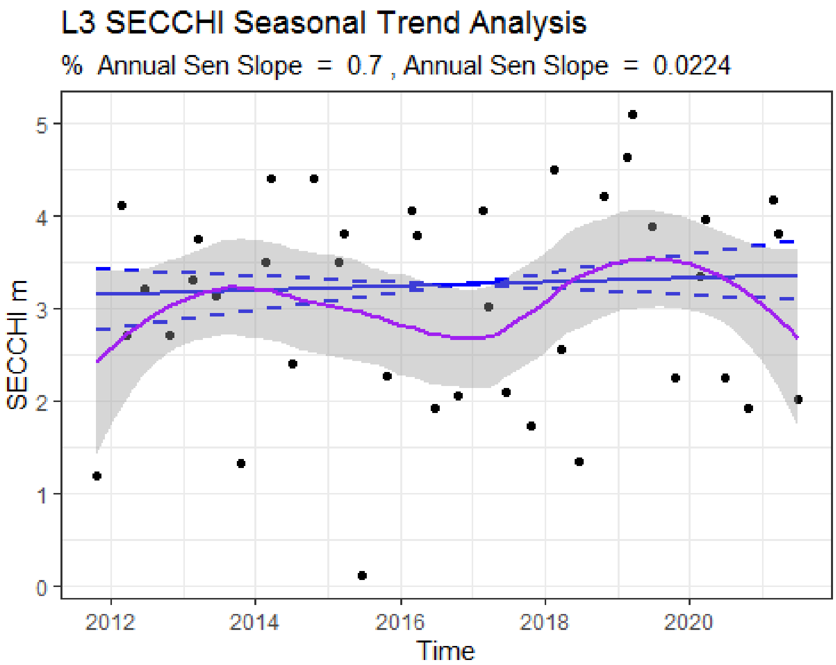

L2 TURB Seasonal Trend Analysis
% Annual Sen Slope = 2.7 , Annual Sen Slope = 0.0632
TURB NTU
250
200
150
100
50
0
-50
2012
2014
2016
2018
2020
Time

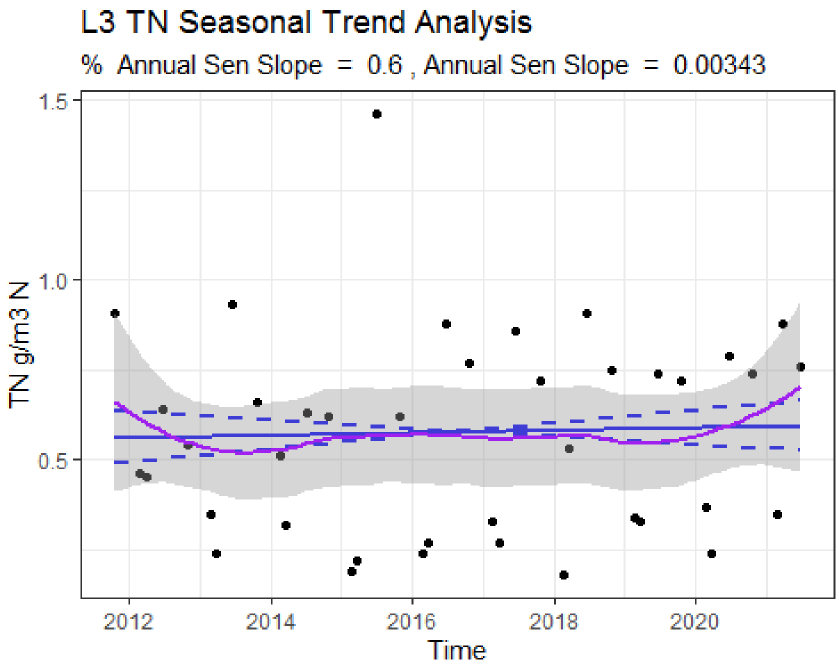

L3 CHLA Seasonal Trend Analysis
% Annual Sen Slope = -9.6 , Annual Sen Slope = -0.000292
CHLA g/m3
0.010
0.005
0.000
2012
2014
2016
2018
2020
Time

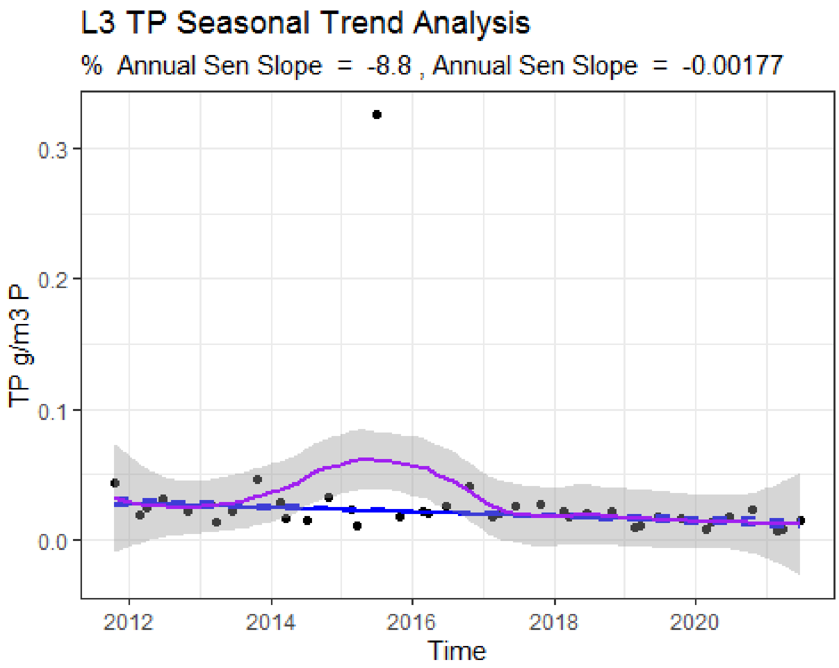

L3 COND Seasonal Trend Analysis
% Annual Sen Slope = 1 , Annual Sen Slope = 0.119
COND mS/m@25C
14
12
10
2012
2014
2016
2018
2020
Time

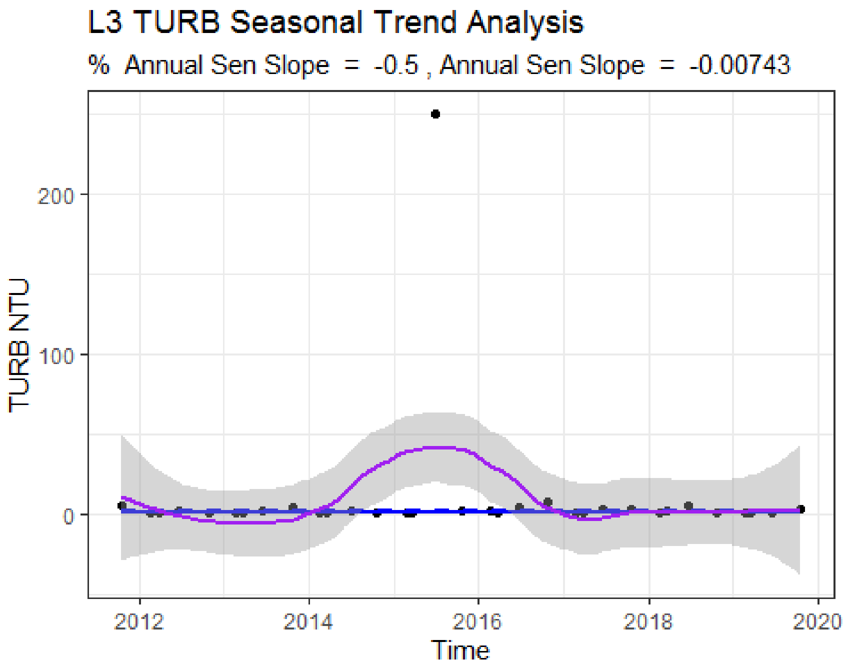

L3 NH4 Seasonal Trend Analysis
% Annual Sen Slope = 0 , Annual Sen Slope = 0
NH4 g/m3 N
0.15
0.10
0.05
0.00
2012
2014
2016
2018
2020
Time

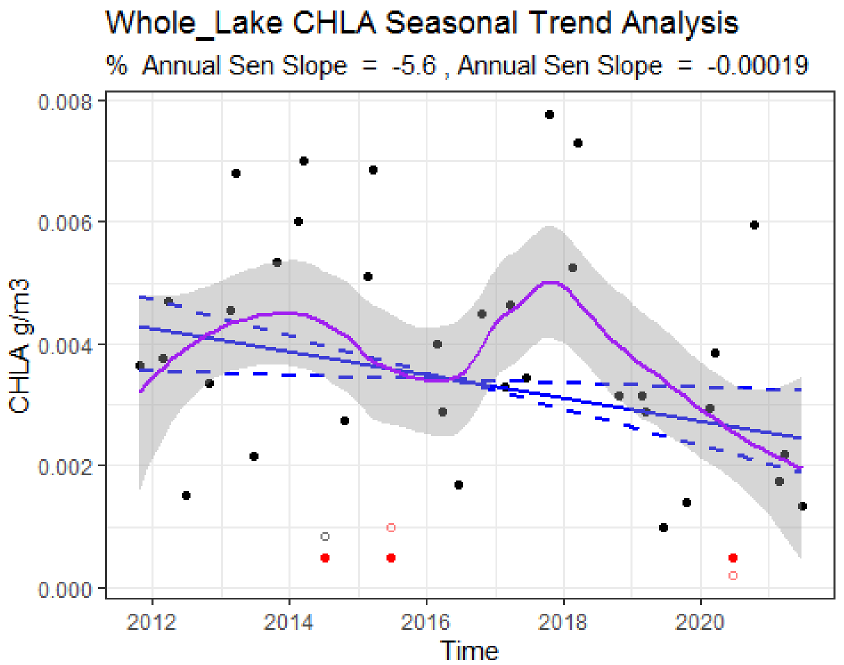

L3 NNN Seasonal Trend Analysis
% Annual Sen Slope = 1.2 , Annual Sen Slope = 0.00535
NNN g/m3 N
0.0
0.2
0.4
0.6
0.8
2012
2014
2016
2018
2020
Time

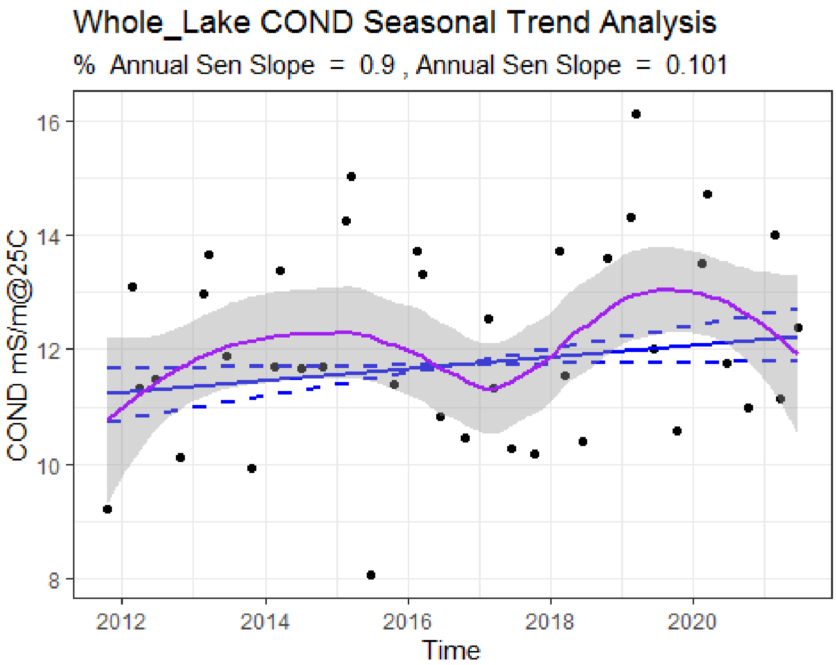

L3 SECCHI Seasonal Trend Analysis
% Annual Sen Slope = 0.7 , Annual Sen Slope = 0.0224
SECCHI m
0
1
2
3
4
5
2012
2014
2016
2018
2020
Time

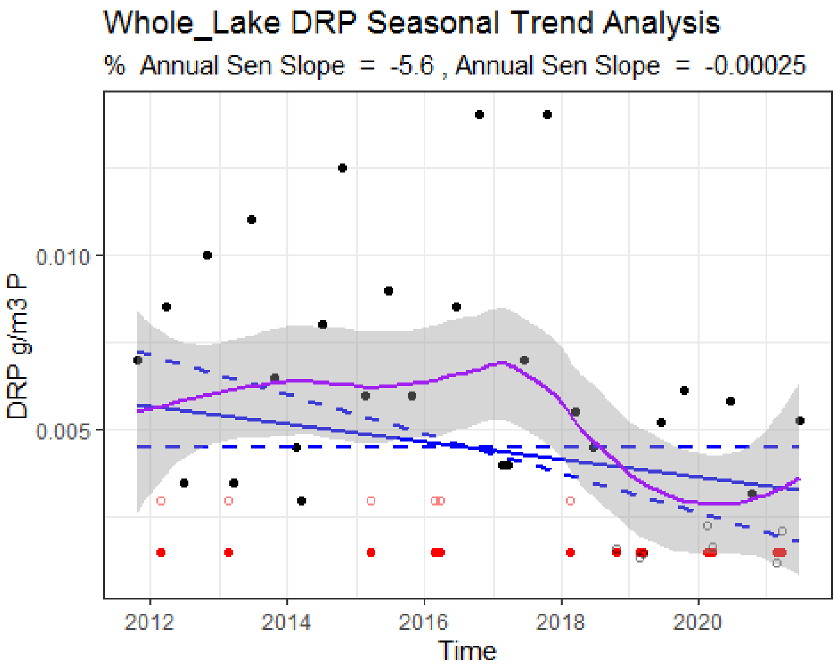

L3 TN Seasonal Trend Analysis
% Annual Sen Slope = 0.6 , Annual Sen Slope = 0.00343
TN g/m3 N
1.5
1.0
0.5
2012
2014
2016
2018
2020
Time

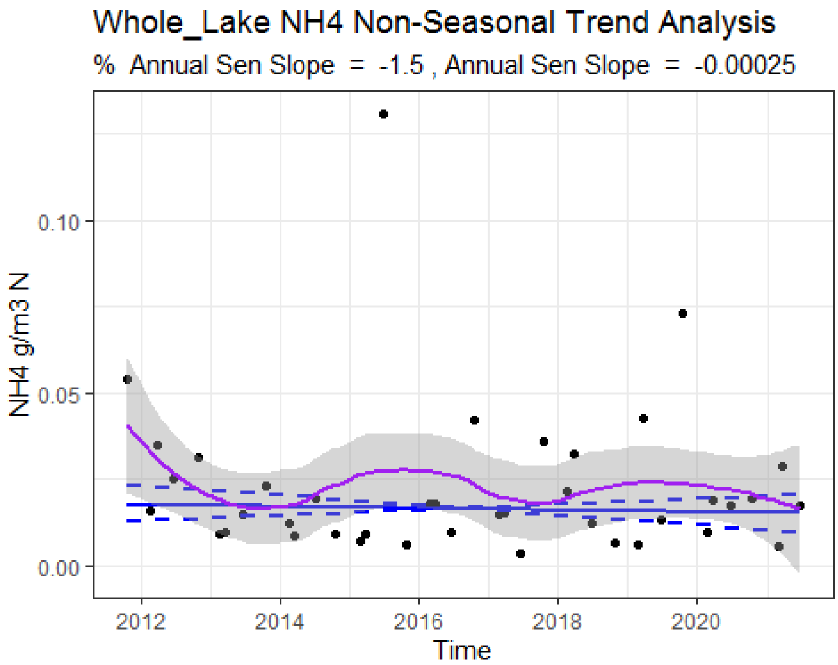

L3 TP Seasonal Trend Analysis
% Annual Sen Slope = -8.8 , Annual Sen Slope = -0.00177
TP g/m3 P
0.3
0.2
0.1
0.0
2012
2014
2016
2018
2020
Time

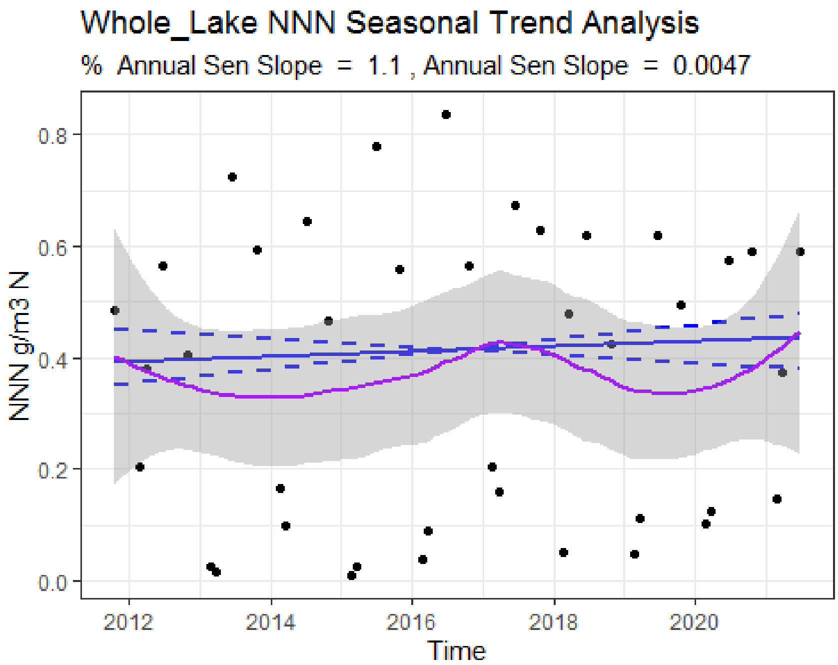

L3 TURB Seasonal Trend Analysis
% Annual Sen Slope = -0.5 , Annual Sen Slope = -0.00743
TURB NTU
200
100
0
2012
2014
2016
2018
2020
Time

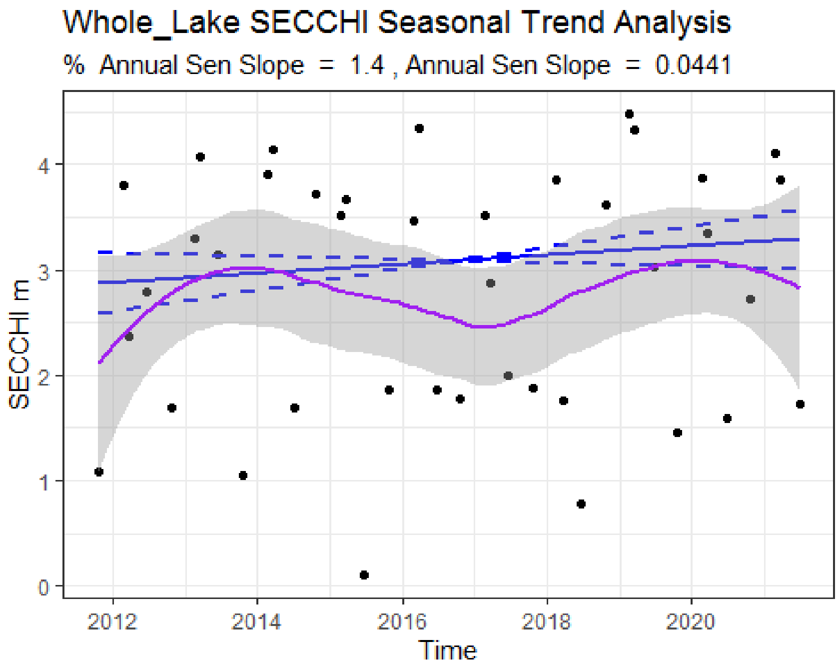

Whole_Lake CHLA Seasonal Trend Analysis
% Annual Sen Slope = -5.6 , Annual Sen Slope = -0.00019
CHLA g/m3
0.008
0.006
0.004
0.002
0.000
2012
2014
2016
2018
2020
Time

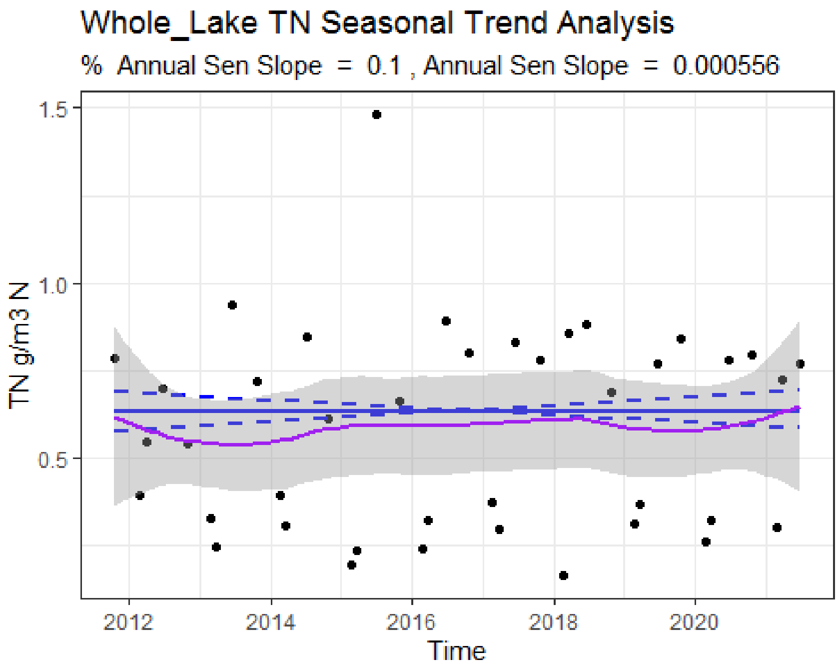

Whole_Lake COND Seasonal Trend Analysis
% Annual Sen Slope = 0.9 , Annual Sen Slope = 0.101
COND mS/m@25C
16
14
12
10
8
2012
2014
2016
2018
2020
Time

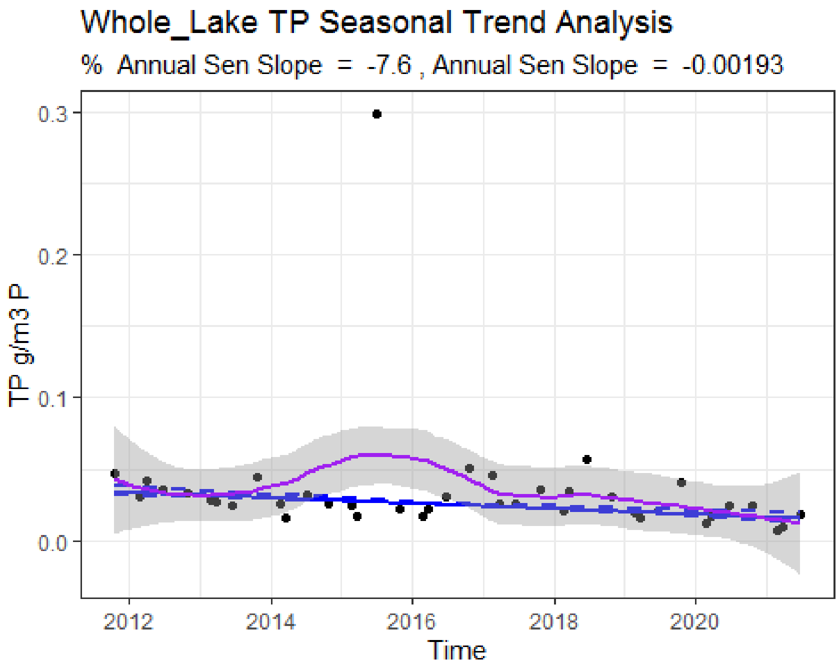

Whole_Lake DRP Seasonal Trend Analysis
% Annual Sen Slope = -5.6 , Annual Sen Slope = -0.00025
DRP g/m3 P
0.010
0.005
2012
2014
2016
2018
2020
Time

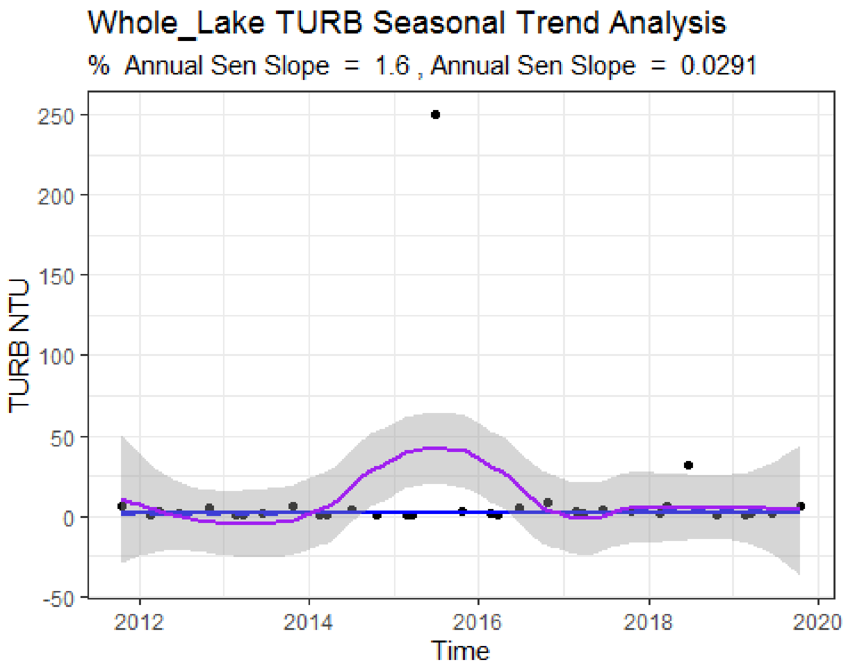

Whole_Lake NH4 Non-Seasonal Trend Analysis
% Annual Sen Slope = -1.5 , Annual Sen Slope = -0.00025
NH4 g/m3 N
0.10
0.05
0.00
2012
2014
2016
2018
2020
Time


Whole_Lake NNN Seasonal Trend Analysis
% Annual Sen Slope = 1.1 , Annual Sen Slope = 0.0047
NNN g/m3 N
0.8
0.6
0.4
0.2
0.0
2012
2014
2016
2018
2020
Time


Whole_Lake SECCHI Seasonal Trend Analysis
% Annual Sen Slope = 1.4 , Annual Sen Slope = 0.0441
SECCHI m
0
1
2
3
4
2012
2014
2016
2018
2020
Time


Whole_Lake TN Seasonal Trend Analysis
% Annual Sen Slope = 0.1 , Annual Sen Slope = 0.000556
TN g/m3 N
0.5
1.0
1.5
2012
2014
2016
2018
2020
Time


Whole_Lake TP Seasonal Trend Analysis
% Annual Sen Slope = -7.6 , Annual Sen Slope = -0.00193
TP g/m3 P
0.0
0.1
0.2
0.3
2012
2014
2016
2018
2020
Time


Whole_Lake TURB Seasonal Trend Analysis
% Annual Sen Slope = 1.6 , Annual Sen Slope = 0.0291
TURB NTU
-50
0
50
100
150
200
250
2012
2014
2016
2018
2020
Time

MEMORANDUM
Policy & Planning

Taranaki Regional Council

**Date** 23 November 2021

## Subject: Natural and Built Environments Bill Select Committee Report

**Approved by:** A D McLay, Director - Resource Management

S J Ruru, Chief Executive

**Document:** 2912802

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### Purpose

1. The purpose of this memorandum is to inform Members of the recent report from the Environment Select Committee on the Exposure Draft for the Natural and Built Environments Bill ("Report" and "the Bill", respectively).

### Executive summary

2. As part of the process of drafting replacement legislation for the Resource Management Act ("RMA"), the government released an Exposure Draft on the Natural and Built Environment Act for comments in June 2021. That Exposure Draft was intended to contain some of the key clauses and provisions to guide potential submitters on government thinking. Council submitted on the Bill, both in its own capacity and as a signatory to a Mayoral Forum submission.
3. The Environment Select Committee has reviewed submissions on the Bill and released its findings in the Report in November. The Select Committee's recommendations were largely focused on a series of changes that would make the Bill more practical and grounded in good practices. Although there was some strengthening of the role for the National Planning Framework ("NPF"), this was somewhat balanced by an acknowledgement of the key role of local government in everything from developing the NPF to supporting local level solutions.

### Recommendation

That the Taranaki Regional Council:

a) <u>receives</u> the memorandum *Natural and Built Environments Bill Select Committee Report.*

### Background

4. The Government announced an intention to reform the Resource Management Act ("RMA") in February 2021. The first major step in that review process was the release of the Exposure Draft for submissions on June 29. Submissions closed on 4 August.

5. A detailed summary of Officers' assessment of the Exposure draft was presented to this Committee at its July meeting (see Agenda item 7 from that meeting). The Committee endorsed Officers' recommendations and instructed them to prepare a submission on the basis of the limited information available to the Council at that time. The Committee also endorsed Officers suggestion of working with the three territorial authorities to prepare a joint submission.
6. The two submissions were prepared and presented to the Committee at the 31 August meeting (see Agenda Item 7 from that meeting).
7. The Environment Select Committee has considered all submissions received, as well as recommendations on how to make the new resource management system "more efficient, proportionate to the risks associated with given activities, more affordable and less complex" than the current system (per terms of reference, item 3). The Select Committee released their report on 1 November 2021.

## Discussion

8. The report is a well-considered and detailed review, comprising some 37 specific recommendations and, at 93 pages, approximately 5 times longer than the Bill itself and longer than the Bill's supporting discussion document. It also contains a marked up version of the original Exposure Draft Bill, containing a number of the Select Committee's specific recommendations.
9. While the Select Committee supports the Bill and the need for the RMA to be reviewed, it may be possible to read into the Report that they view the RMA to be less broken than do the principal sponsors of the Bill. For example, one of the specific recommendations from the Report is to retain as many of the RMA definitions as possible. The Select Committee notes that doing so would enable much of the existing case law to continue, with a resulting level of "consistency" (presumably for resource users).
10. As noted above, another key theme in the recommendations is that the Bill needs to be practical, workable and add positively to environmental outcomes. An example of this type of recommendation is the "rationalisation" of the environmental outcomes, with the Select Committee halving the number and narrowing the focus of the outcomes proposed in the Exposure Draft to outcomes that are focused on what is more typically considered core to environmental sustainability and resource development.
11. The Select Committee also notes the impact of the changes in the legislation on resource users, with a focus in some areas on transitional provisions and attention to possible transition pathways. One key area where this approach is proposed is in the setting of transitional limits in the NPF. These limits would be used where a large step change was required to meet the new baselines – and would have a clearly defined duration before they expired.
12. There was strong support for the proposed purpose of the Bill to include the concept of Te Oranga o te Taiao, with a recommended expansion of the initial drafting of that principle by making it clear that all New Zealanders have relationships with and responsibilities to look after the environment. Officers consider this recommendation a positive change, expanding as it does, a very sound environmental principle to have a very broad applicability.
13. There were also calls to clarify the purpose clauses, including by making the role of the Bill in supporting housing and infrastructure outcomes clearer. A further recommended amendment to the purpose clauses was to clarify that the NPF and regional plans, rather

than consents, to be seen as the main process for protecting and restoring the natural environment. This recommendation may provide an indication as to how the Select Committee sees the guidance and rules in each of those documents being drafted and implemented.

14. The Select Committee gave particular attention to the NPF and the processes behind drafting it. In particular, they called for the NPF to:
    14.1. Have mandated content on all of the environmental outcomes contained in the Bill (although there was no intention to limit the NPF – or plans - solely to these matters);
    14.2. To expand the proposed scope from "integrated direction" on important national and sub-national matters to also include:
        14.2.1. guidance on resolving conflicts on environmental matters; and
        14.2.2. setting environmental limits and providing strategic direction on how to achieve limits and outcomes.
15. Local government's key role in the resource management process was recognised, including specifically:
    15.1. Calling for greater recognition of local government's role in the Treaty partnership;
    15.2. Recognising and supporting a significant role for local government in drafting the NPF – with a recommendation that there is "early engagement" with the sector;
    15.3. Recognising (and calling for greater detail on) local government's crucial role in the revised plan preparation process.
16. Related to the point in paragraph 15.3, the Select Committee endorsed the concept of a single regional plan per region. In giving that endorsement, it noted that the plans "should be able to address sub-regional and local considerations". They did however recognise the significance of the undertakings and the need to address "practical considerations about regional boundaries".
17. As noted, part of the Select Committee's terms of reference was to collate a list of ideas for a number of practical changes to the broader systems around the Bill's implementation. Recommendations made include:
    17.1. Setting the system so that there is greater clarity around the system, enabling more proactive activity by resource uses – which was intended to help reduce reliance on consents;
    17.2. Addressing the widely acknowledged current limits in stakeholder capacity and capability to participate effectively;
    17.3. Working towards principles of co-design of systems with key stakeholders;
    17.4. As noted above, the retention of existing RMA definitions was considered to provide certainty, continuity and reduced the potential for extensive legal action that accompanied the early days of the RMA;
    17.5. Make greater use of "Alternative Dispute Resolution" procedures, including tikanga based dispute resolution;
    17.6. Recognising and reinforcing the role of the Environment Court;

17.7. Making greater use of digital tools, including opportunities for common development of tools across councils; and

17.8. Simplifying consenting processes – including investigating the potential for single national consent templates or coordination of consenting across different councils.

## Overall Assessment of Select Committee Recommendations

18. As an overall tone, the Report recommends changes that would improve the Bill by making it more practical and grounded than the original Exposure Draft recommendation. Officers both support and continue to have concerns with some of the recommendations, although, as an overall position, and recognising the stage that it represents in the overall drafting process, they view the Report as a generally favourable step.
19. The drafting recommendations contained in the Report should also be supported for the numerous calls for greater detail and a more considered approach to drafting the Bill than appeared to be the government's original agenda.
20. The efficiency changes that are proposed are, by and large, positive steps that will contribute positively to the experience of resource management system users. Arguably, these recommendations could actually be pursued ahead of the legislative reform.
21. The recognition that there needs to be a place for local views to be captured and used in any new central system supports the role of councils and the important principle of localism.
22. Achieving a successful national limit setting framework that addresses regional differences and reflects local views, is a very challenging task.

## Financial considerations—LTP/Annual Plan

23. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

## Policy considerations

24. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

## Iwi considerations

25. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

## Community considerations

26. This memorandum and the associated recommendations have considered the views of the community, interested and affected parties and those views have been recognised in the preparation of this memorandum.

## Legal considerations

27. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

## Appendices/Attachments

Inquiry on the Natural and Built Environments Bill: Parliamentary Paper Link:
https://www.parliament.nz/resource/en-NZ/SCR_116599/0935c4f14c63608e55c528b75167a69daee92254

Taranaki Regional Council

MEMORANDUM
Policy & Planning

**Date** 23 November 2021

## Subject: Te Kāhui o Taranaki Trust Taiao Briefing

**Approved by:** S J Ruru, Chief Executive

**Document:** 2884765

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### Purpose

1. The purpose of this memorandum is to enable the Policy and Planning Committee to receive a briefing from the Te Kāhui o Taranaki Trust on the work of their taiao team.

### Executive summary

2. Committee member Peter Moeahu has asked that Taipuni Ruakere be given the opportunity to brief the committee on the work undertaken by the Te Kāhui o Taranaki Trust taiao team.
3. A copy of the presentation can be viewed by following this link https://storymaps.arcgis.com/stories/792ed68215de4df2be6a11800fc30909.

### Recommendations

That the Taranaki Regional Council:

a) receives the memorandum Te Kahui o Taranaki Trust Taiao Briefing.

b) notes that Taipuni Ruakere will provide a verbal briefing on the work undertaken by the Taranaki Iwi taiao team.

### Background

4. Each of the different iwi of Taranaki have staff who undertake a range of environmental work, including advocacy and policy development on behalf of their Iwi.
5. Committee member Moeahu has asked that the Taipuni Ruakere be given an opportunity to brief the committee on the work of the Te Kāhui o Taranaki Trust taiao team.

### Discussion

6. It is envisaged that the briefing will provide the committee with an understanding of the range of work currently undertaken by Iwi environmental staff and the extent to which this might align with the work that that the Policy and Planning Committee is managing on behalf of Council. To the extent that the presentation covers issues that are beyond

the scope of the Policy and Planning Committee delegations it would be appropriate that the information be forwarded to the relevant committee or Council itself.

7. The committee should also note, that in response to discussion on issues relating to the processing of resource consents (and the proposed Mana Whakaho a Rohe agreements) the Consents and Regulatory Committee has asked for a briefing on opportunities for Council to provide support to Maori to meet its obligations under section 81 of the Local Government Act 2002. Some of the issues covered by this request fall within the scope of the Policy and Planning committee.

8. Section 81, is part of the generic decision-making provisions in Part 6 of the Local Government Act 2002. As such these provisions apply to decisions that are made under the Local Government Act 2002 and are subservient to the subject matter specific provisions included in the Resource Management Act 1991.

## Response to Issues Raised

9. The presentation raises a number of environmental issues. Responding to these issues can encompass a mixture of regulatory and non-regulatory responses from Council. Some options, while not exhaustive, are set out in the table below.

| Issue | Environmental indicator | Programme | Council response/ context |
|---|---|---|---|
| Increased nutrient levels | Algal growth and foaming of algal cells under certain conditions<br>Nutrient concentrations, algal (periphyton) biomass and mats/filaments | Science water quality monitoring and research investigations<br>Policy and plan development<br>Riparian management | Nutrient controls on farms from synthetic nitrogen regulations and dairy supplier requirements, and through the implementation of new national policy and regional policy and plan development.<br>Riparian and stream fencing to shelter waterways from sunlight to reduce algal growth. |
| Farm tips | Rubbish entering waterways and reaching the coast | Responding to complaints or arising from riparian programme alerts | Use enforcement provisions to remove material or secure it. Many of these tips are very old. |
| Fish passage barrier | Certain species are absent in waterways or are observed not being able to climb structures | Take enforcement action, where possible.<br>Identify, record and prioritise in-stream structures for remediation or installation of fish passage where required. | Council staff currently scoping a regional work programme to address in-stream structures, a new national policy requirement to address barriers to fish passage.<br>Some instream structures are orphaned with essentially no responsible party, so rely on adjoining landowners to take |

| | | | |
|---|---|---|---|
| | | | action or seek sponsors to remove structures. |
| Poor lake condition | Lake Opunake in poor condition because consents have not been granted for its ongoing operation | Consent process where submitters and applicant are attempting to agree on consent conditions<br>Science monitoring and reporting, research and investigations | Applicant failed to lodge their consent renewal application in time and legally cannot operate the scheme until new consents granted. Iwi involved in the consent process and some water allowed to enter the lake for environmental quality purposes.<br>There are a range of available options for the investigation and remediation of lakes. There may be opportunities to align such investigations with TRC's regional lakes state of environment programme to identify potential options for addressing lake health. |

## Financial considerations—LTP/Annual Plan

10. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

## Policy considerations

11. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

## Iwi considerations

12. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

## Community considerations

13. This memorandum and the associated recommendations have considered the views of the community, interested and affected parties and those views have been recognised in the preparation of this memorandum.

## Legal considerations

14. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

MEMORANDUM
Policy & Planning

**Date** 23 November 2021

## Subject: Towards Predator-Free Taranaki Project

**Approved by:** D Harrison, Director - Operations

S J Ruru, Chief Executive

**Document:** 2917634

### Purpose

1. The purpose of this memorandum is to present for Members' information a quarterly update on the progress of the *Taranaki Taku Tūranga Our Place - Towards Predator-Free Taranaki* project.
2. A presentation will be provided by officers.

### Executive summary

3. On 30 May 2018, the Minister of Conservation launched the *Taranaki Taku Tūranga Our Place -Towards Predator-Free Taranaki* project.
4. *Taranaki Taku Tūranga Our Place -Towards Predator-Free Taranaki* is the first large-scale project with the long term aim of progressing towards removing introduced predators from a region.
5. Three different phases of work are continuing around the mountain, working from north to south. This item reports on the three different elements to the project: urban trapping, rural control, and zero possums.
6. Monitoring work and site-led work is continuing and Council officers have had input into several technological innovations.
7. The project has received a $750,000 funding boost through 'jobs for nature' allocated through Predator Free 2050 Ltd. This has allowed for the employment of four additional internal staff and three additional external staff to be engaged in the project.
8. Roll out of phase 4 of the Rural programme is now underway, continuing to significantly increase the predator control on the western side of the maunga.
9. The Zero Density possum project has hit a significant milestone, with no possums detected within the A block for over 5 months. The mop up phase of the Zero Density possum project is continuing with good downward trends in detections. The trap barrier at Pukeiti is functioning well, with a significant downward trend in possum captures continuing.

10. Roll out of traps within urban areas has been ongoing with good success. The new community liaison roles are proving beneficial, with great community engagement benefits starting to become evident through increased trapping within urban spaces, and the engagement of Community Champions.

11. Agreement for the next FYs funding and research priorities has now been confirmed with Manaaki Whenua/Landcare Research.

## Recommendations

That the Taranaki Regional Council:

a) receives this memorandum *Taranaki Taku Tūranga Our Place - Towards Predator-Free Taranaki project*

b) notes the progress and milestones achieved in respect of the urban, rural and zero density possum projects of the *Taranaki Taku Tūranga Our Place - Towards Predator-Free Taranaki* project.

## Background

12. On 30 May 2018, the Minister of Conservation launched the *Taranaki Taku Tūranga Our Place -Towards Predator-Free Taranaki* project.

13. The *Taranaki Taku Tūranga Our Place -Towards Predator-Free Taranaki* project is the first large-scale project with the long-term aim of progressing towards removing introduced predators from the region. Supported by more than $11 million from Predator Free 2050 Ltd (the company set up by the Government to help New Zealand achieve its predator-free 2050 goals), the Taranaki Regional Council (the Council) aims to restore the sound and movement of our wildlife, rejuvenate native plants in urban and rural Taranaki, and protect agriculture.

14. The project's ultimate aim is to eradicate stoats, rats, and possums across the region by 2050. This ambitious goal has not been attempted before, and the first phases of the project have trialled control methodologies and new tools to inform future implementation. The latest technologies – including remote sensors, wireless nodes and a trapping app - are being used to remove predators and prevent re-infestations. The high-tech equipment makes trapping more efficient, particularly in rural areas, and sends a smartphone alert to the user when the trap goes off.

15. Project work is well underway around the mountain. There are three elements to the project:

    - Rural landscape predator control
    - Urban predator control
    - Zero density possums.

16. There has been a hugely positive response from communities wanting to restore our regional biodiversity by getting behind the *Taranaki Taku Tūranga Our Place -Towards Predator-Free Taranaki* Project as it continues to roll out across the region. Monitoring work and site-led work is well advanced and officers have had input into several technological innovations.

17. Set out below is a summary of key progress and milestones in respect of the main elements of the project and details future work.

## Urban predator control

18. The urban project continues to grow with traps distributed at public workshops, markets, schools and retail outlets in New Plymouth.
19. Community champions are continuing to join the programme and are providing excellent localised support to backyard trappers.
20. Corporate supporters programme is helping to get businesses trapping and engaged with the predator free initiative.
21. Good ongoing support from NPDC through management of the urban track trapping through volunteers and contractor actions.

## Rural landscape predator control

22. Year three has now been completed, with an additional 30,300 ha under the mustelid control programme bringing the total to 72,300 hectares under the mustelid control programme, and an additional 2,051 traps were placed in the Rahotu and Warea areas, bringing the project total to 7,629 (mustelid specific traps).
23. Year four of the project is well underway, with good sign-up and trap placement proceeding.

## Zero-density possums

24. The Kaitake Zero possum project has hit a significant milestone, with no possums detected within the A block (farmland) for over 5 months.
25. The 'mop up' phase of the project is continuing across the Kaitake range. The primary focus of the project within the Kaitake range is still night hunting with possum detection dogs and thermal imaging monocular. The lean trap network based on remote reporting leg-hold traps continues to remove individuals, and the catch rate in this network continues to decline. Possums within the adjacent farmland portion of the project area remain low, with any incursions from the Kaitake range quickly removed following detection.
26. The trap barrier at Pukeiti is functioning well following new magnet sensor upgrades. Catches of possums on the barrier continue to decline, with only 5 possums caught in this quarter.

## Staff changes

27. Following the resignation of Toby Shanley, Sam Haultain has moved from Councils Biosecurity team to take on the role of Predator Free Programme lead.

## Decision-making considerations

28. Part 6 (Planning, decision-making and accountability) of the *Local Government Act 2002* has been considered and documented in the preparation of this agenda item. The recommendations made in this item comply with the decision-making obligations of the *Act*.

## Financial considerations—LTP/Annual Plan

29. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

## Policy considerations

30. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

## Iwi considerations

31. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. All eight iwi provided letters of support for the funding of this project, Council are in regular contact with both Ngāti Tairi and Ngā Mahanga regarding the Zero-density possum operation within their rohe and iwi chairs are updated through the Taranaki Mounga Board.

## Legal considerations

32. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

## Appendices/Attachments

Document 2896463: October 2021 Quarterly report to PF2050.

# PREDATOR FREE 2050 Limited

# LANDSCAPE PROJECTS

## Quarterly reporting

**Project Title:** Towards Predator Free Taranaki

**Report Author:** Sam Haultain

**Project period reported on:** Jul – Sep 2021

**Highlights of overall progress**

*Provide any positive highlights from the reporting period, from technical, social engagement and research activities (200 words max)*

- The Kaitake Zero possum project has hit a significant milestone, with no possums detected within the A block for over 5 months,
- Roll out of phase 4 of the Rural programme is now underway,
- A number of new staff have now been employed under the J4N funding and to fill several vacancies,
- The virtual barrier is functioning well within the Kaitake Zero project, with only 5 possums captured during this reporting period,
- Roll out of traps within urban areas has been ongoing with good success,
- New community liaison roles proving beneficial, with great community engagement benefits starting to become evident through increased trapping within urban spaces,
- Agreement for the next FYs funding and research priorities has now been confirmed with Manaaki Whenua/Landcare Research.

### Part 1 – Reporting against Progress Indicators, Milestones and Decision Points

**1. Current Indicators, Milestones or decision point**

| Code | Description | Due date | Status | Comments |
|---|---|---|---|---|
| TRC UPDP8a | Canopy condition assessment, as per monitoring plan shows recovery of canopy over time | 1-Nov-20 | In progress | Canopy condition monitoring is ongoing. |
| TRC P6 | Payment Invoice Due | 20-Nov-20 | Achieved | This was sent 16/11/2020 |
| TRC TEG4 | Discuss with 'experts' possible extension scenarios for the remainder of the ringfenced funding ($2,432,509) | 20-Apr-21 | In progress | Delayed with COVID |
| TRC SLDP1b | Rodent numbers in 1st extended area of the Pukeiti landscape (100ha) are below a 5% tracking card index. | 1-May-21 | Not achieved | Numbers very high – see notes below. |
| TRC OM1b | A minimum 3:1 funding ratio to be maintained annually throughout the project | 30-May-21 | Completed | Funding maintained |

| | | | | |
|---|---|---|---|---|
| TRC ZDDP7 | Systems in place to maintain zero possum zones into perpetuity Eg inclusions in TRC pest management plan | 30-May-21 | In progress | Further discussions required |
| TRC LSDP10 | New milestones and decision points for Roll out of the rural landscape predator control (as per control and monitoring plan) - year 3 zone | 1-Jun-21 | In progress | Further discussions required |
| TRC LSM11 | Roll out of the rural landscape predator control (as per control and monitoring plan) - year 3 zone | 1-Jun-21 | Completed | Completed as per agreed plan. |
| TRC UPM10a | Traps deployed in private properties throughout Egmont village, Inglewood & Eltham urban areas, as per agreed control plan | 30-Jun-21 | In progress | First year of traps going out in these areas so 1 in 5 not yet achieved, but good progress is being made. |
| TRC ZDM4c | Possums controlled in Block D, as per agreed eradication plan | 30-Jun-21 | Completed | As per agreed plan. RTC has been very low in these buffer areas. |
| TRC TEG5 | Plan for extension completed following discussion with 'experts' | 20-Jul-21 | In progress | Discussions delayed with COVID (is this a duplicate with TRC TEG4?) |
| TRC AR3 | ANNUAL REPORT due | 30-Sep-21 | In progress | Late |

**Commentary** Please see comment sections above.
I have included previous milestones and decision points outside of the reporting period which have not been updated.

Specifically to TRCSLDP1b – Following control, high rat numbers were recorded in Pukeiti which were lower than non-treatment areas, but exceeded the 5% tracking card index required for this decision point. This promoted a review of control techniques for the 2021/2022 season to try to reach this goal in the following year.

**2. Future Indicators, milestones or decision points**

| Code | Description | Due date | Status | Comments |
|---|---|---|---|---|
| TRC TEG2 | Possums eliminated from Zero area (A, B and C) (aligned with an adjustment to earlier decision point ZDDP3) | 20-Oct-21 | In Progress | Numbers are zero for 5 months in A, detections low in B. C detections ongoing but decreasing. Unlikely to meet this goal by the due date. |
| TRC ZDDP3 | Zero possums detected in control blocks A,B,C, as per agreed monitoring plan | 31-Oct-21 | In progress | Numbers zero for 5 months in A, detections low in B. C detections ongoing but decreasing. Unlikely to meet this goal by the due date. |
| TRC UPDP4b | Overall reduction in possum numbers to <2% BMI | 30-Nov-21 | In progress | Possum control delayed with COVID, monitoring will be delayed also. Unlikely to meet this goal by the due date. |

| | | | | |
|---|---|---|---|---|
| TRC ZDDP6b | Evidence that zero possum density is being maintained within Blocks A,B,C; monitoring plan revised (with associated new milestones and decision points) as necessary | 30-Nov-21 | In progress | Zero density is unlikely to be achieved or maintained through all blocks by this due date. |
| **Commentary** Please see comment sections above for each item.<br><br>Very pleased with current tracking of the project towards the next quarter's goals. A number of reports are in preparation to confirm these milestones have been achieved.<br><br>Some variations to timeframes are predicted, but these are being pulled together on the variation request template (to be sent soon after this report). | | | | |

**3. Progress to eradication**

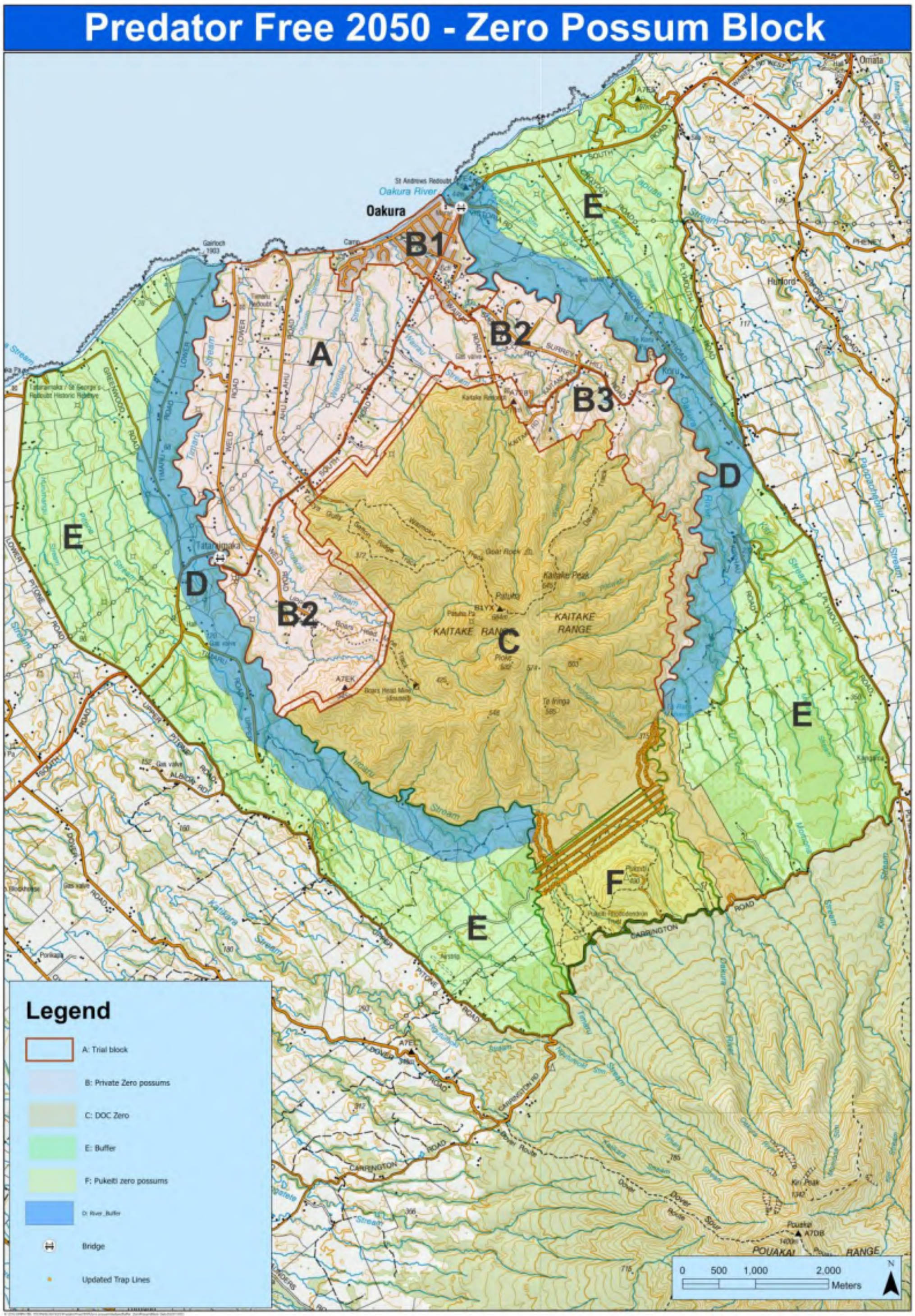
**Commentary**

The Kaitake Zero possum project is progressing well towards eradication. Block A is in an incursion detection and response phase and has had no positive possum detections for almost 6 months. The B block areas are in a survivor mop-up phase and are still harbouring possums, but these numbers are declining monthly. Block C is in a survivor mop-up phase and continues to harbour possums, but numbers are also declining in this area through the use of the lean detection network and the intensive, ongoing use of possum detection dogs and a highly experienced contractor team.

The virtual barrier is preforming well, with only routine battery and magnet sensor issues occurring during the reported period. Five possums were captured during the reported period, comprising of three adult males and two unsexed juveniles.

We have reviewed and revamped our public online possum reporting system, with some additional comms asking for continued reporting of any suspected possums sightings. This system has prompted a number of possum sightings in the B block, as well as the buffer areas, and has allowed us to quickly investigate anything almost immediately after it is reported, even if staff are out in the field, through the use of ArcGIS tools. The survey can be found here https://arcg.is/10019b1.

We are also looking to incorporate ArcGIS tools into other aspects of our eradication work in this space, particularly to streamline and improve reporting of information gathered by contractors undertaking detection work, and to record the details of any actions undertaken by the team to respond to detections or public reports. This work will improve the accuracy of our reporting, and will allow easy data sharing between staff and contractors working on this project, speeding up response times.


Predator Free 2050 - Zero Possum Block
Oakura
Oakura River
A
B1
B2
B3
C
D
E
F
KAITAKE RANGE
Legend
A: Trial block
B: Private Zero possums
C: DOC Zero
E: Buffer
F: Pukeiti zero possums
D: River_Buffer
Bridge
Updated Trap Lines
0
500
1,000
2,000
Meters

## Part 2 – Reporting against other operational aspects

| **1. Health and Safety** |
|---|
| **Commentary** *Provide details of any Health and Safety developments that have been made, or issues that have arisen (particularly 'notifiable events' as defined in the HSWA 2015), during the reporting period. Please include all incidents recorded during the period (attach separately if required).*<br><br>No incidents to report for this period. |

| **2. Risks, issues and opportunities** | |
|---|---|
| **Commentary** *Provide details of any new risks, issues or opportunities in the last quarter (a risk is something that may happen, an issue is something that has happened* | |
| **Type (What is the risk, issue, opportunity?)** | **Mitigation/Comments** |
| **Risks:** Trap supply issues in the future (DOC200 and DOC250 specifically) due to material shortages caused by COVID 19 delays, and increased demand due to surge of new predator free projects. | We're looking to trial alternative traps, specifically the Trapinator mustelid tunnels, which may not be affected by plywood shortages or demand surges, so that we can create an effective contingency plan should this risk come into effect. |
| **Issues:** | |
| **Opportunities:** | |

| **3. Financial performance** |
|---|
| Spreadsheet to be sent separately by TRCs finance team. |
| **Is Project financial performance proceeding as planned?** Yes<br>**If No, please provide details** *(included suggested mitigation)* |

| **4. Innovation, learnings and research** |
|---|
| **Commentary** *Provide details of any project innovations that are additional to your project plan and which are likely to benefit other projects (200 words max).*<br><br>The research priorities for the next FY have been set and agreed to with LCR/MW. |

| **5. Media, communications and events** |
|---|
| **Commentary** *Provide details, if relevant, of any social or environmental events coming up in the next quarter This will help us be proactive with PF2050 community story-telling (200 words max).*<br><br>In-person community events have largely been delayed for this reporting period due to COVID-19 restrictions. However, community engagement through social media and remote engagement from our liaisons has remained high, with some significant gains through this period including the on boarding of |

additional community champions, continued backyard trapping and reporting, and general interest in the project from the public.

| **6. Benefits for Mana whenua** |
|---|
| **Commentary** *Provide details, if relevant in the quarter, of any benefit to Māori including training opportunities (200 words max).*<br><br>Engagement with mana whenua remains positive and is ongoing through the project's relationship with the Taranaki Mounga Project. |

| **7. Benefits to the community** |
|---|
| **Commentary** *Provide details, if relevant in the quarter, of any social or environmental benefit to the community, including training opportunities (200 words max).*<br><br>Community benefits and engagement has remained high, with staff providing ongoing support to interested landowners both inside and outside the project's roll-out boundaries where appropriate. |

| **8. Benefits for the economy** |
|---|
| **Commentary** *Provide details, if relevant in the quarter, of any benefit to the economy e.g eco tourism (200 words max).*<br><br>A reduction in mustelids and possums throughout the project's boundaries has continued to support a reduction in bovine tuberculosis (TB), leptospirosis, and toxoplasmosis vectors. This reduction in vector numbers provides an economic benefit to both the dairy and sheep industry through reduced losses and disease risk, as well as a potential benefit to human health. |

| **Benefits for the environment** |
|---|
| **Commentary** *Provide details, if relevant in the quarter, of any climate change mitigating activities eg Tree planting, protecting, or other environmental benefits (200 words max).*<br><br>This project continues to support substantial environmental benefits through the removal of introduced browsers and restoration of appropriately functioning ecosystems. Targeted control of rats within the boundaries of the project has continued to provide significant long-term benefits through increased seedling success, and general ecosystem restoration. |

Taranaki Regional Council

**AGENDA**
**Policy & Planning**

## Whakataka te hau

***Karakia to open and close meetings***

| | |
|---|---|
| Whakataka te hau ki te uru | Cease the winds from the west |
| Whakataka te hau ki tonga | Cease the winds from the south |
| Kia mākinakina ki uta | Let the breeze blow over the land |
| Kia mātaratara ki tai | Let the breeze blow over the ocean |
| Kia hī ake ana te atakura | Let the red-tipped dawn come with a sharpened air |
| He tio, he huka, he hauhu | A touch of frost, a promise of glorious day |
| Tūturu o whiti whakamaua kia tina. | Let there be certainty |
| Tina! | Secure it! |
| Hui ē! Tāiki ē! | Draw together! Affirm! |

## Nau mai e ngā hua

***Karakia for kai***

| | |
|---|---|
| Nau mai e ngā hua | Welcome the gifts of food |
| o te wao | from the sacred forests |
| o te ngakina | from the cultivated gardens |
| o te wai tai | from the sea |
| o te wai Māori | from the fresh waters |
| Nā Tāne | The food of Tāne |
| Nā Rongo | of Rongo |
| Nā Tangaroa | of Tangaroa |
| Nā Maru | of Maru |
| Ko Ranginui e tū iho nei | I acknowledge Ranginui above and |
| Ko Papatūānuku e takoto ake nei | Papatūānuku below |
| Tūturu o whiti whakamaua kia | Let there be certainty |
| tina | Secure it! |
| Tina! Hui e! Taiki e! | Draw together! Affirm! |