Research Findings Brief

National SCIENCE Challenges
OUR LAND AND WATER
Toitū te Whenua, Toiora te Wai

Using cause and effect relationships to enhance freshwater management

WHO IS THIS RESEARCH BRIEF FOR?

- Regional councils
- Freshwater managers
- Catchment groups
- Farm advisors
- Policy makers
- Scientists

RESEARCHERS

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PROJECT TIMELINE

June 2016 – December 2019

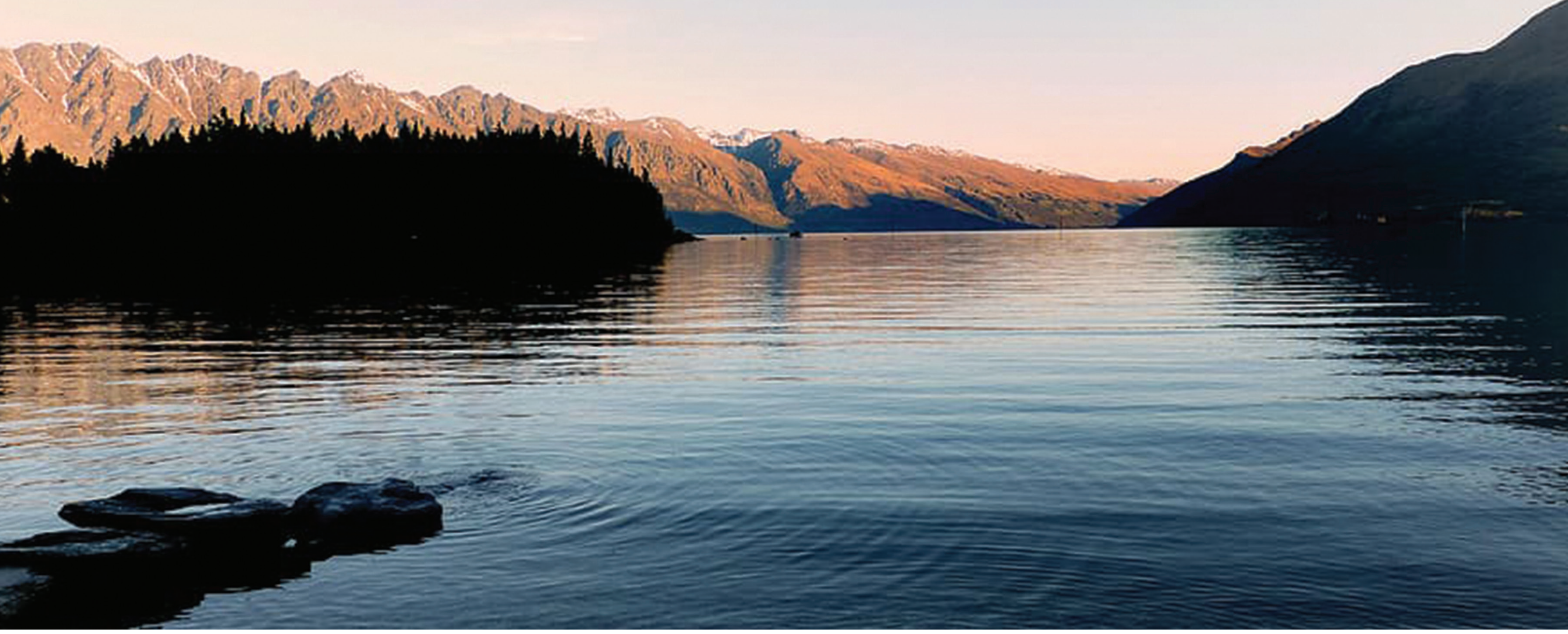
Key points

Degradation of freshwater bodies can be more effectively prevented or reversed by understanding the cause and effect (stressor-response) relationships impacting them, and by locating their position on stressor-response relationship curves.

Stressor-response curves can help regional councils more accurately predict responses to changes in stressors, and use this information to help develop water quality policies.

Stressor-response relationships seem to vary by lake (or river) type, which has important implications for freshwater management.

This research has developed a method to help identify the most appropriate freshwater management actions, based on stressor-response relationships. The method is outlined, using lakes as an example.



How can research be used?

The stressor-response framework can help identify the most appropriate management actions for waterbodies at risk of degradation due to increased stressor levels, and also to predict and characterise recovery as stressor levels decline.

Knowing the extent of water quality degradation across fresh waters nationally can help in setting restoration objectives and in reducing nutrient loads.

Environmental management applications include regulating contaminant discharges, evaluating restoration projects, and predicting effects of changes in stressor levels in unmonitored locations and in the future.

Why was this research needed?

Many lakes, rivers, estuaries and other waterbodies in New Zealand are degraded, and at times affected by algal blooms. Protecting and restoring these waterbodies is important to the people of New Zealand now, and for future generations.

To prevent and reverse degradation in freshwater bodies caused by contaminants (such as the plant nutrients nitrogen and phosphorus) and other land-based stressors it may be necessary to alter what is occurring on land.

In New Zealand, most management and restoration activities occur after significant degradation. These activities often rely on solutions which may not be desirable for some people and/or may have unintended consequences.

A proactive approach to lake management, such as the stressor-response framework, looks at the bigger picture, linking land use, contaminant levels in water and impacts on ecological and socio-economic values (*Figure 1*). It encourages a deeper understanding of ecosystem dynamics and early management actions, enabling more effective responses and avoiding more costly, undesirable ones.

Understanding a stressor-response relationship curve and identifying where a waterbody sits on the curve can help prioritise actions to prevent and reverse degradation.

Understanding stressor-response relationships can help identify land use intensity levels at which stressor levels become excessive and degrade ecological values and can also help forecast the impacts of land use change.

Water quality targets have associated time frames, but most stressor-response relationships are not simple (linear). Water quality may respond more or less quickly to changes in stressors, depending on the stressor-response relationship curve. Water quality can become legally challengeable or fail if stressor-response relationships, both linear or complex (non-linear), are not understood.

Stressor-response framework

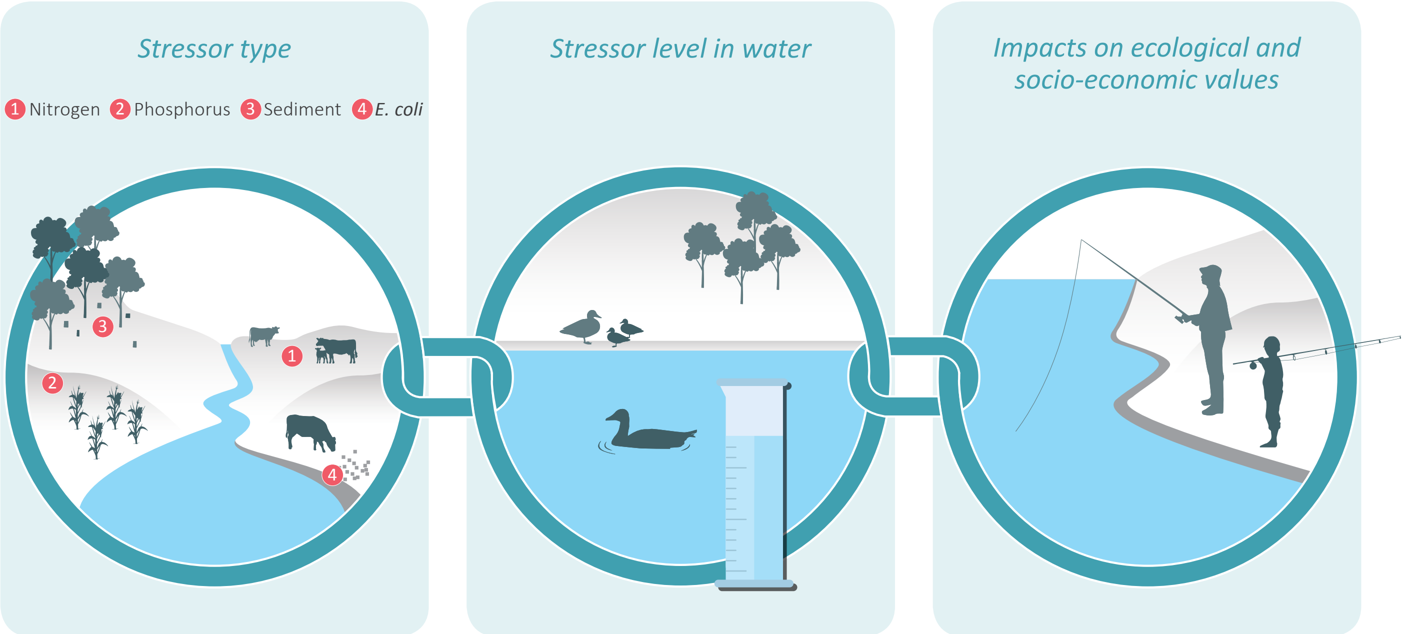


Figure 1: *Illustrating the relationship between land use, stressor type, stressor level and impacts.*

What did we do?

We outlined a method for using stressor-response relationships to help identify the most appropriate management actions, using nutrient-enriched Lake Hayes in Otago as an example (McDowell et al, 2018). The management actions for Lake Hayes serve as an example only, and have not necessarily been implemented *(see 'Method for using stressor-response relationships to plan management actions').*

Using lakes as an example, we helped transform freshwater ecosystem dynamics theory into a stressor-response framework for managing and restoring fresh water, outlined the stressor-response framework for freshwater managers, and presented three case studies of lakes where the framework has been used to understand and manage algae issues – Lake Taupō in Waikato, Waituna Lagoon in Southland, and Lake Hayes in Otago (Larned et al, 2019; Schallenberg 2020).

We also developed models to predict the reference concentrations (prior to human-caused effects) of total nitrogen and total phosphorus for a nationally representative sample of lakes, so the magnitude of human-caused algal growth could be calculated (Abell et al, 2019).

We used the pressure-state-impact framework to assess evidence (published quantitative and categorical associations linking land use pressures to state changes and ecological impacts in freshwater bodies) of land use's effects on fresh water (Larned et al, 2020).

What did we find?

Assessing lakes using the stressor-response framework can help managers identify potential vulnerabilities and tipping points in healthy lakes (when a slight increase in a stressor creates a disproportionate response) as well as situations where degraded lakes may be resistant to restoration efforts.

Lakes with some inherent resistance to nutrient inputs tend to eventually exhibit tipping points. If these lakes become degraded, they may also be resistant to restoration by nutrient reduction, necessitating greater restoration efforts to return them to a stable, healthy condition[2].

Different types of lakes appear to have different stressor-response relationship 'curves', which has important implications for their management (*Figure 2*). For example, very clear lakes like Lake Taupo are sensitive to nutrient inputs, whereas shallow lakes with extensive native plant communities can assimilate higher nutrient loads before degradation occurs.

Stressor-response curves observed in lakes

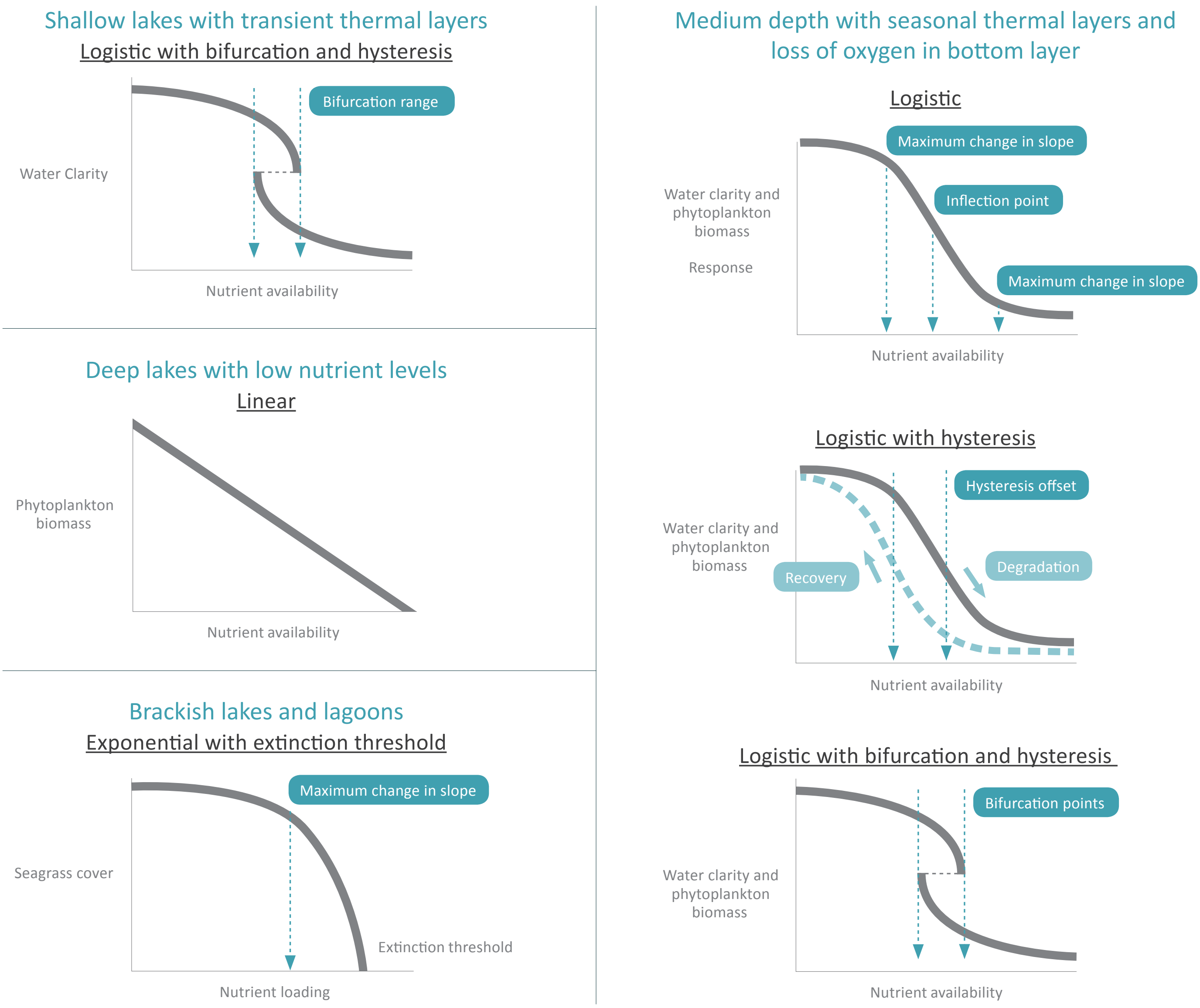


Figure 2: Examples of stressor-response curves observed in New Zealand lake types (S. Larned et al, 2019)

Method for using stressor-response relationships to plan management actions

Applying the method to Lake Hayes*

Step 1

Set water quality objective

- Prevent degradation or start recovery?
- Include desired numerical value of the response variable for the contaminant/s.

To ensure recovery by reducing phosphorus loading (the nutrient that controls phytoplankton growth), achieving a low phytoplankton concentration and improved water clarity.

Step 2

Identify stressor-response curve and current position on curve

- Select curve based on receiving environment and contaminant/s.
- Calculate score for current position of receiving environment using: *response score x stressor score x sensitivity of system*.
- See McDowell et al, 2018

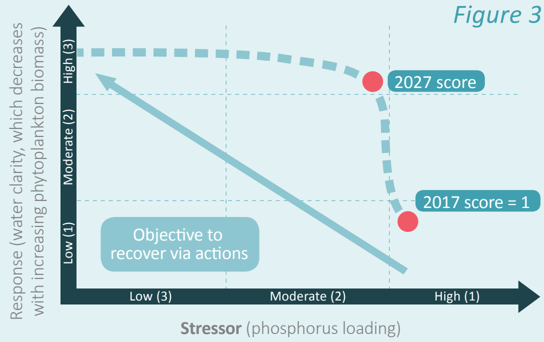
Response score x stressor score x sensitivity of system

1 (lake's current phosphorus loading is high) x 1 (lake in poor state) x 1 (sensitive to small changes in phosphorus) = 1

Stressor-response curve for Lake Hayes

Stressor-response curve for phosphorus and phytoplankton in Lake Hayes showing the scoring of response, stressor and sensitivity of the lake in 2017 and prediction for 2027

Figure 3



Step 3

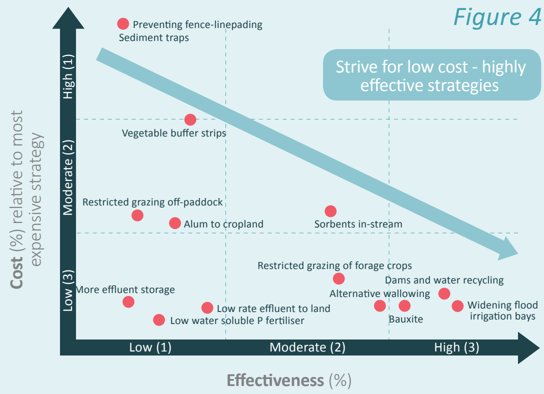
Score potential management actions

- Identify and score management actions based on cost, effectiveness, treatment speed and applicability for local conditions.
- See Key See McDowell et al, 2018

Cost-effectiveness of actions

The relationship between mean cost and effectiveness of phosphorus mitigation and management actions (McDowell et al, 2018)

Figure 4



Step 4

Assess benefit of actions

- Divide each action score by the receiving environment score. In recovery, a high score is good.
- Rank each action against ability to implement action (considering factors such as timing, placement, longevity, co-benefits and unintended consequences).

Action	*Action score*	*Benefit score*
Stream fencing	27	27
Restricted grazing of forage crops	18	18
Alum to pasture	12	12
Alum to grazed forage crops	12	12
Optimum soil test phosphorus concentration	3-9	3-9
Preventing fence-line pacing	6	6
Vegetated buffer strips	6	6
Sediment traps	3	3
Phosphorus inactivation or flocculation	18	18
Lake hydraulic flushing	6-18	6-18
Aeration, oxygenation, and destratification	9	9

**The management actions for Lake Hayes are an example only and have not been implemented.*

Next steps

Our Land and Water's Land Use Opportunities: Whitiwhiti Ora research programme (2020-2023) will build on this research, which was part of the Land Use Suitability Programme (2016-2019). Land Use Opportunities research will expand the scope of land use assessments to consider a broader range of constraints and pressures, including greenhouse gas emissions, and a much wider range of benefits.

Further study to validate the lake typology proposed (and augment this with river typologies, for example via the River Environment Classification) could improve the prediction of responses to increases or decreases in stressors.

The extension of stressor-response relationships to include multiple interacting stressors and responses would improve the ability to predict responses.

The National Policy Statement for Freshwater Management (September 2020) should accelerate regional councils' identification of stressor-response curves for local water bodies.

Key publications

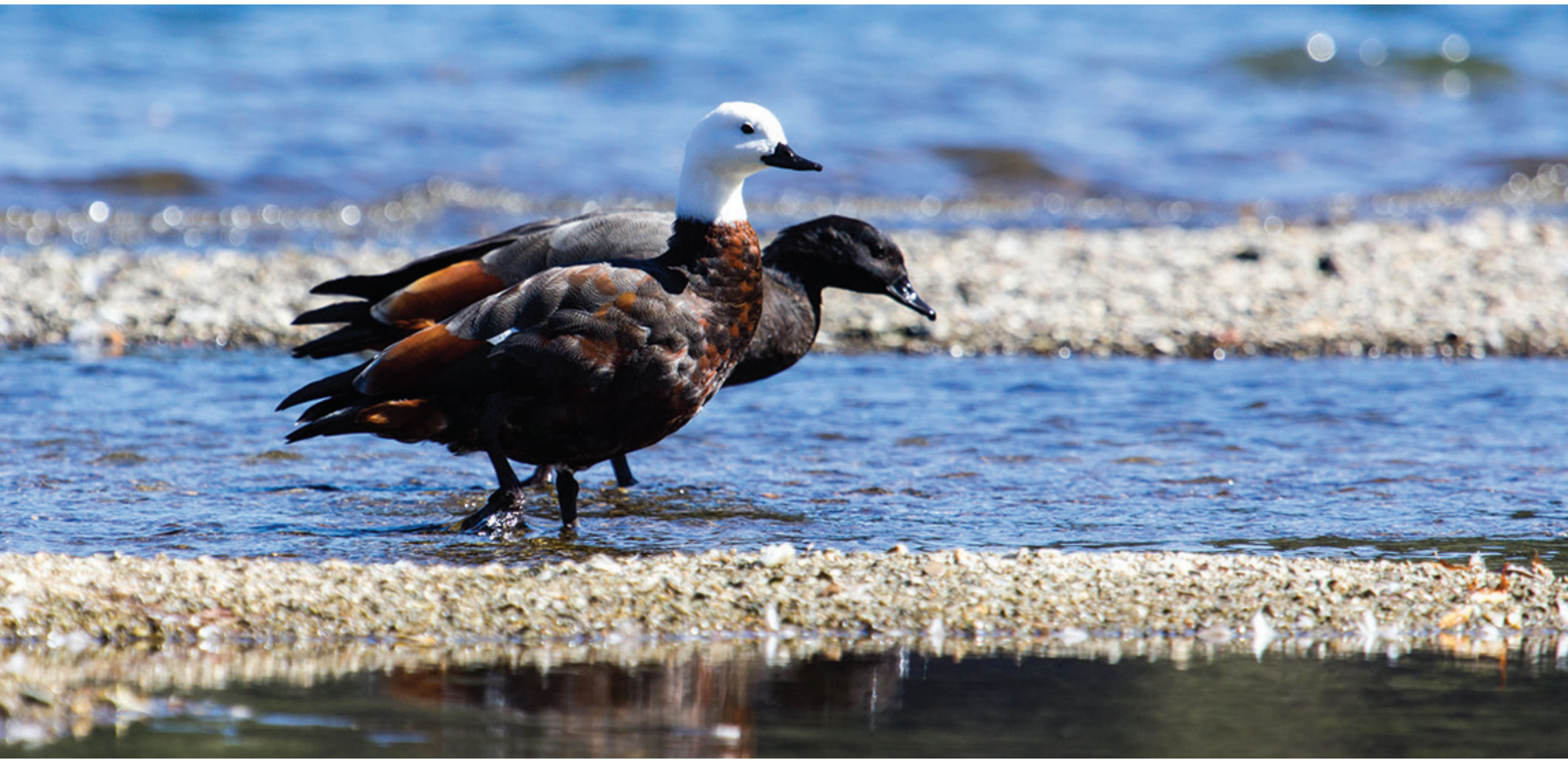
R. W. McDowell, M. Schallenberg, S. Larned, A strategy for optimizing catchment management actions to stressor-response relationships in freshwaters (*Ecosphere 2018)* **doi.org/10.1002/ecs2.2482**

S. Larned & M. Schallenberg, Stressor-response relationships and the prospective management of aquatic ecosystems *(New Zealand Journal of Marine and Freshwater Research* 2019, 53:4, 489-512) **doi.org/10.1080/00288330.2018.1524388**

M. Schallenberg, The application of stressor-response relationships in the management of lake eutrophication (*Inland Waters* 2020) **doi.org/10.1080/20442041.2020.1765714**

J. M. Abell, D. Özkundakci, D. P. Hamilton, P. van Dam-Bates & R. W. McDowell, Quantifying the Extent of Anthropogenic Eutrophication of Lakes at a National Scale in New Zealand (*Environmental Science & Technology* 2019; 53:9439-9452) **doi.org/10.1021/acs.est.9b03120**

S. Larned, J. Moores, J. Gadd, B. Baillie & M. Schallenberg, Evidence for the effects of land use on freshwater ecosystems in New Zealand *(New Zealand Journal of Marine and Freshwater Research* 2020; 54:3, 551-591) **doi.org/10.1080/00288330.2019.1695634**



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National SCIENCE Challenges

Our Land and Water (Toitū te Whenua, Toiora te Wai) is working towards an agri-food and fibre system that enhances the vitality of te Taiao with a diverse mosaic of land uses that improve the health of land, water and people.

Our Land and Water is one of 11 National Science Challenges that focus on defined issues of national importance identified by the New Zealand public.

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