Update Report

Water quality in New Zealand: Land use and nutrient pollution

June 2015

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

Contents

Introduction

Over recent years, public concern has grown about the quality of the water in many of New Zealand's rivers and streams, lakes, wetlands, estuaries, and aquifers. For Māori, this concern is very strong, because the relationship with particular awa and roto is central to identity.

In November 2013, the Parliamentary Commissioner for the Environment released a report titled *Water quality in New Zealand: Land use change and nutrient pollution*. The report followed an investigation into the relationship between land use and two nutrient pollutants – nitrogen and phosphorus. On land, nitrogen and phosphorus are valuable nutrients, but in water they can cause excessive growth of weeds, slime and algae.

Nutrient losses from land are, to a large extent, dependent on how the land is used. Losses of both nitrogen and phosphorus are low from land that is covered in forest or scrub, but are much higher from pastoral and arable land.

The 2013 report revealed a clear correlation between large-scale land use change to dairy farming and increases in the nitrogen 'stress' on waterways.

This is an update to the 2013 report. It summarises reactions to the original report and presents new information on land use that was not available in 2013. Recent changes in farm productivity and mitigation are described, and trends in nutrient concentrations and water quality are presented.

Reaction to the 2013 report

The level of engagement and debate that followed the release of the report was encouraging, and it is evident the debate about water policy has now become more sharply focused on the key challenge of dealing with declines in water quality coming from changing land use.[1]

The Government's view was that agricultural production could be increased while maintaining or improving water quality. The Prime Minister, Rt Hon John Key said: *"I don't think we should assume that we're in a static position where we won't use greater science or other techniques to reduce the environmental impacts as we look to increase farm output"*.[2]

In a joint press release the Minister for the Environment, Hon Amy Adams, and the Minister for Primary Industries, Hon Nathan Guy, welcomed the report.[3] Hon Adams said it underlines"… *the importance of the Government's freshwater reform programme, by showing just what could happen with our water quality if we do not have good policy in place…"*. However, she was confident that *"we will see significant water quality gains within a generation"*.

Other Parliamentarians were less sanguine.

Labour Party environment spokesperson Moana Mackey said "*The message is clear – business as usual, even assuming mitigation strategies are employed, will see further degradation of our waterways."*[4]

Green Party water spokesperson Eugenie Sage urged the Government to *"reconsider its proposed weak bottom lines for water quality and set tougher standards to ensure all our rivers are safe for swimming"*.[5]

Maori Party co-leader Te Ururoa Flavell said the report had raised *"crucial issues"* including the changing use of land from forestry to farming.[6]

Federated Farmers welcomed the report, acknowledging the importance of good science to underpin policy development, but questioned some of the assumptions of the modelling.[7] Dairy chairman Willy Leferink said the report was *"a wake-up call"*, but the modelling was *"a worst case if we collectively do nothing"*.[8] Other agriculture commentators also took the view that the modelling did not take adequate account of existing and planned mitigation on farms or of the Government's new freshwater policy.[9]

Fonterra responded to the report by stating its commitment to improve water quality, with Todd Muller, Group Director Cooperative Affairs, saying *"We share the Parliamentary Commissioner's concerns about the pressure on New Zealand's waterways and recognise the role we have to play in improving water quality."*[10] In an address to Fonterra's Annual General Meeting, Chief Executive Theo Spierings said the report was "*in the past and looking backwards*", although Fonterra "*needed to lift its game*".[11]

Forest & Bird called for moderation of dairy conversions, with Advocacy Manager Kevin Hackwell saying "*This report must mark a turning point in the rate at which dairy conversions are polluting our waterways.*"[12] Fish & Game Chief Executive, Bryce Johnson, said that the report "… *serves as a stark warning that the nation is at a crossroads.*"[13]

In an Opinion-Editorial published in the New Zealand Herald, Sir David Skegg, the President of the Royal Society of New Zealand wrote:

"Dr Jan Wright's advice is worded diplomatically, but her message is blunt. Unless New Zealand takes urgent steps to slow the expansion of dairying, many more rivers and lakes will be degraded. None of the steps being taken to lessen environmental impacts can reverse this trend in the near future."[14]

The Royal Society's Science Media Centre sought comment on the report from several scientists.[15]

Professor Jenny Webster-Brown, Director of the Waterways Centre for Freshwater Management, University of Canterbury & Lincoln University wrote:

"The modelling approach that has been used here is valid, in my opinion. The assumptions that have been made in the modelling scenarios are reasonable and defensible."

Professor David Hamilton, President of the NZ Freshwater Sciences Society, wrote that the report *"… clearly highlights the enormous challenge that we face as a nation: how to meet the government's goals of doubling the value of agricultural exports by 2025 whilst meeting the 2011 National Policy Statement for Freshwater Management which requires that the 'overall quality of freshwater' in all regions of the country be maintained or improved."*

Dr Rich McDowell from AgResearch and Dr Mike Scarsbrook from DairyNZ queried the assumptions about mitigation and said that the impact of the Government's new fresh water policies had not been given due consideration.

Under standing orders, reports from the Commissioner are first tabled in Parliament, and then referred to the Local Government and Environment Committee. In reporting back to the House, the Committee said: *"We are keen to see progress in the area of water quality in New Zealand, and encourage the relevant committee of the 51st Parliament to closely observe future developments on this topic."*[16]

The Committee also said that two things would be helpful in future reports on the subject – *"solid statistical data"* on the relationship between land uses and water quality, and recommendations from the Commissioner.

This committee's request has prompted the preparation of not only this update report, which contains additional data, but also an examination of the Government's National Policy Statement for Freshwater Management which the Commissioner is releasing at the same time. That report contains six recommendations.

3

Changing land use

The Commissioner's report *Water quality in New Zealand: Land use and nutrient pollution* linked a model of land use change and a model of nutrient losses from land into water. The modelling predicted changes in land use and consequential changes in nutrient loads between 2008 and 2020.

With regard to land use, the modelling predicted that the amount of land used for sheep/beef farming would continue to decline. It also predicted that dairy conversions would continue, and less productive sheep/beef land would be planted in forest or left to revert to scrub.[17]

Table 3.1 shows how land use has changed between 2008 and 2012 using satellite photographs that have recently become available.[18]

Table 3.1. *Actual* changes in land use between 2008 and 2012 (rounded to the nearest 100 hectares).

Region	Sheep / Beef	Dairy	Plantation Forestry	Scrub
Northland	-3,900	5,500	-900	300
Auckland	-2,000	400	-100	1,800
Waikato	-7,500	28,400	-18,700	1,400
Bay of Plenty	1,100	2,800	-4,300	-400
Gisborne	-14,000	200	6,000	7,000
Hawke's Bay	-7,400	2,000	1,400	3,400
Taranaki	-1,100	4,600	2,500	-2,200
Manawatu-Wanganui	-9,300	6,200	3,200	1,800
Wellington	-4,400	200	3,400	-200
Nelson and Tasman	1,700	200	-1,000	1,100
Marlborough	-1,900	400	1,400	600
West Coast	200	5,100	-2,500	-1,500
Canterbury	-50,100	50,200	-4,200	-1,000
Otago	-17,400	12,700	2,400	-600
Southland	-35,700	38,900	1,700	-5,000
New Zealand	**-151,700**	**157,900**	**-9,600**	**6,600**

At the national level, the loss of sheep/beef land is almost matched by the increase in dairy land. This is consistent with the predictions in the 2013 report.

The modelling in the 2013 report predicted a large increase in both forest and scrub land by 2020. However, between 2008 and 2012, the area of plantation forest has actually decreased, and the increase in scrub land has been small.

The projections of land use change in the model are largely driven by forecasts of commodity prices and interest rates. The actual prices over recent years have differed somewhat from the official forecast prices used in the modelling.[19]

The biggest changes in land use between 2008 and 2012 have occurred in Waikato, Canterbury, Otago, and Southland.

In Waikato, large areas of new dairy land have come from the felling of forest on the Volcanic Plateau. This will lead to big increases in nutrient losses into water in the upper Waikato catchment.

Nearly 70% of the increase in dairying land has taken place in the east of the South Island – in Canterbury, Otago, and Southland.

That land planted in forest or left to revert to scrub has not increased in line with the predictions of the modelling is not good news for future water quality. Losses of both nitrogen and phosphorus are low from forested land. Unless there is a big increase in forestry in the next few years, the modelling is likely to have *underpredicted* nutrient loads on waterways in 2020.

Source: Rob Suisted / naturespic.com

Figure 3.1. Forestry to dairy conversion in the Upper Waikato catchment. The actual increase in dairying land in Waikato by 2012 had already exceeded what the modelling predicted for 2020.

Changing productivity and mitigation

The great challenge for farmers is to increase productivity while simultaneously decreasing nutrient losses. This is the focus of much industry, government and scientific effort.

Nutrient losses are affected by changes in farming practice. On one hand, increasing productivity increases nutrient losses when it is driven by using more inputs. On the other hand, increasing mitigation reduces nutrient losses.

The productivity of the sheep/beef sector remains fairly constant, having fallen from its peak in 2007.[20]

In contrast, productivity (milk solids per hectare) continues to increase rapidly in the dairy sector, largely driven by the use of more inputs – water, fertiliser, and supplementary feed.[21] Mitigation is thus required if nutrient losses are to be held steady, let alone be reduced.

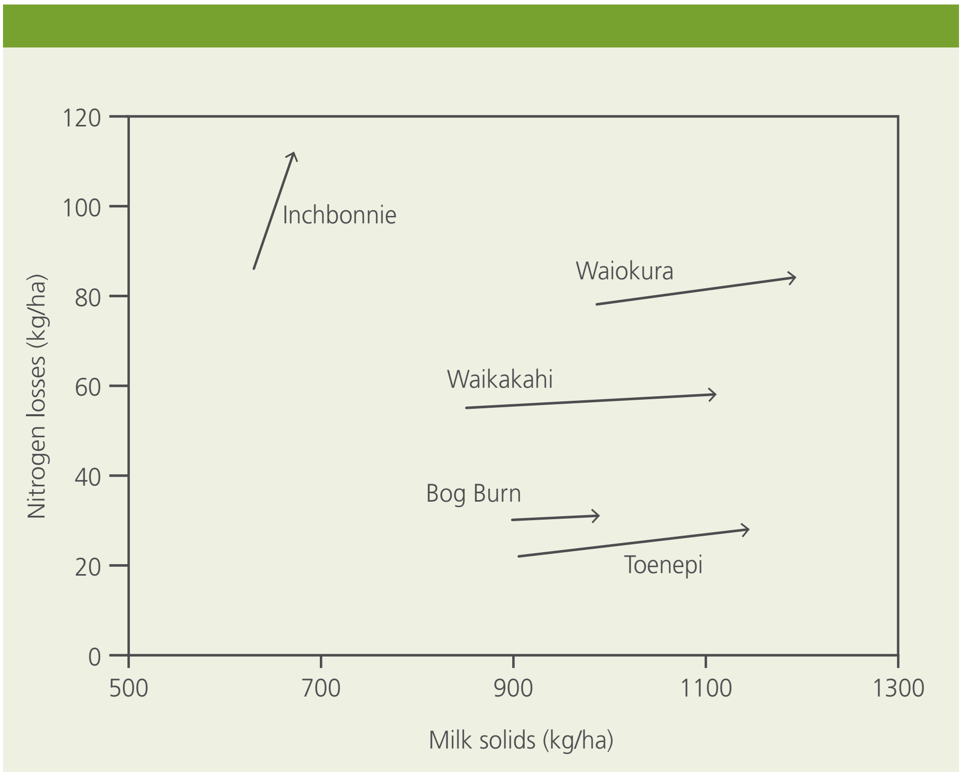
A range of mitigation techniques are increasingly being used on dairy farms to reduce nutrient losses. The Dairying and Clean Stream Accord set up in 2003 was replaced by the Sustainable Dairying: Water Accord in 2013.[22] There has been a great deal of action, especially on the management of shed effluent, bridging waterways, and fencing waterways; as at May 2014, nearly 24,000 kilometres of waterways had been fenced.[23] In other areas, such as keeping stock out of wetlands and the provision of nutrient management data, progress has been much slower.[24]

Keeping nitrogen out of water is particularly difficult because it leaves land in chemical forms that are highly soluble. 'Standard' mitigation techniques such as applying shed effluent as fertiliser on land, keeping stock out of waterways, and riparian planting all help reduce nitrogen losses, but are more effective at keeping phosphorus (and pathogens and sediment) out of waterways.[25]

The 'nitrogen challenge' can be seen in Figure 4.1. A study of five regionally representative catchments predominantly used for dairy farming was begun in 2001.[26] In all five catchments, farm productivity increased over a number of years. At the same time, dairy shed effluent was increasingly applied to land and more streams were fenced. However, this 'standard' mitigation was not enough to keep nitrogen losses constant, let alone reduce them.[27]

Experiments on research farms have shown that it is possible to reduce nitrogen losses by as much as 50%, but the most effective techniques are generally expensive.[28]

Encouragingly, some new research is showing the benefit of using a combination of techniques. On the Future farmlet in Waikato, nitrogen losses were reduced by 40 to 50% by using less nitrogen fertiliser, a lower stocking rate, with cows that excrete less nitrogen in their urine and are taken off pasture for defined periods – however, profitability fell by 5%.[29] It is important to note that successful demonstrations on research farmlets are a long way from widespread adoption of these new techniques.



Data source: Monaghan and De Klein, 2014

Figure 4.1. 'Standard' mitigation techniques on dairy farms struggle to keep nitrogen losses from rising as productivity rises.

5

Nutrient loads, concentrations and water quality

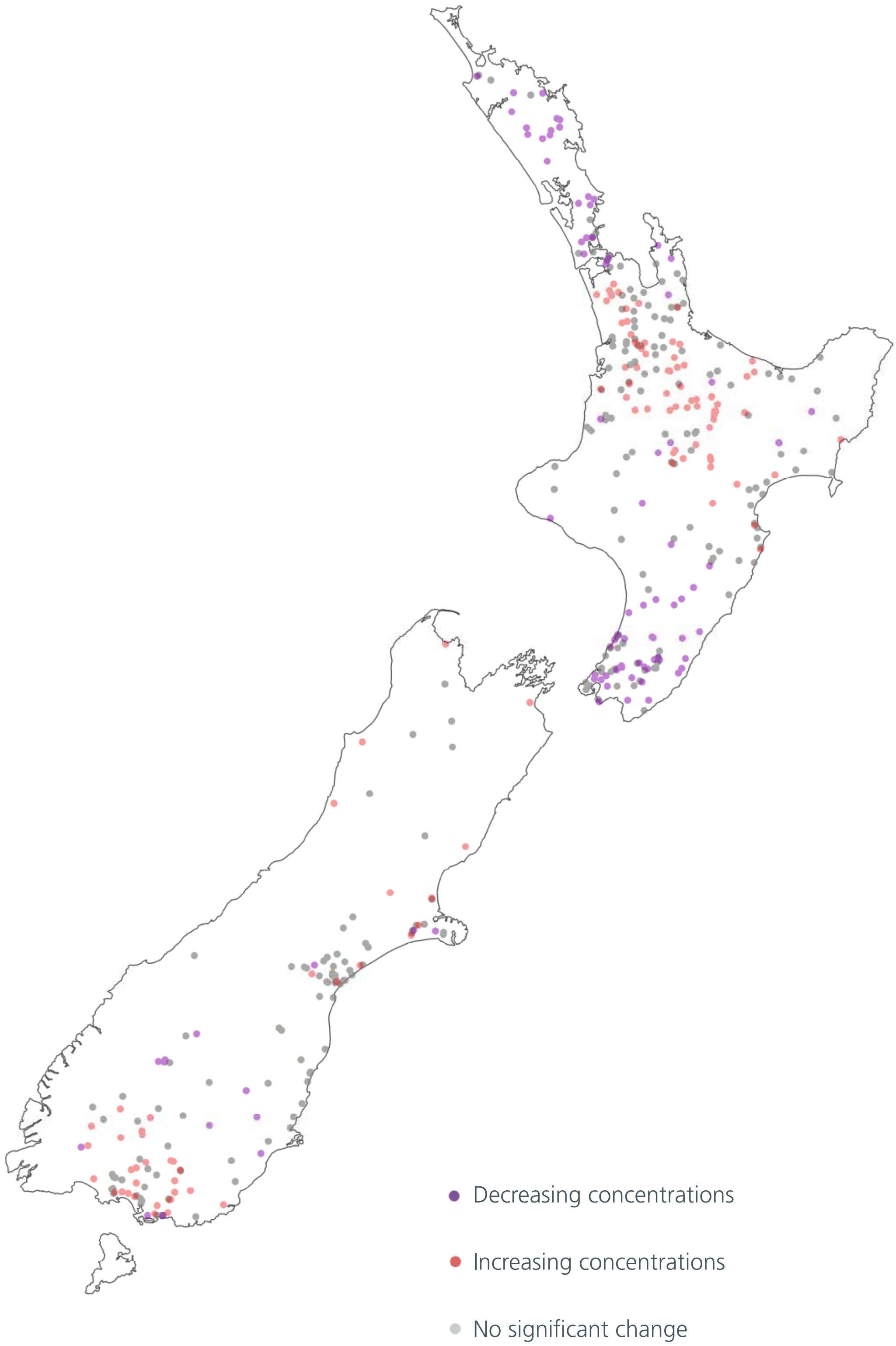
Ongoing and increasing nutrient *loads* will generally lead to higher nutrient *concentrations* and worsening water quality – more degraded lakes, more turbid (cloudy) estuaries, greater frequency and duration of algal blooms, declines in the insects, fish and birds that rely on fresh water ecosystems, and more exceedances of nitrate toxicity limits.

Nutrient concentrations are measured at river sites by NIWA and by regional councils.[30] Changes in nutrient concentrations between 2001 and 2011 at these sites are shown in the maps in Figures 5.1 and 5.2.[31,32]

These maps show the trends in concentrations of the main 'active' forms of nitrogen and phosphorus, that is, the chemical forms that drive the growth of unwanted plants such as invasive weeds, algae and slime. In the case of nitrogen, this is nitrate. In the case of phosphorus, it is dissolved reactive phosphorus (DRP).

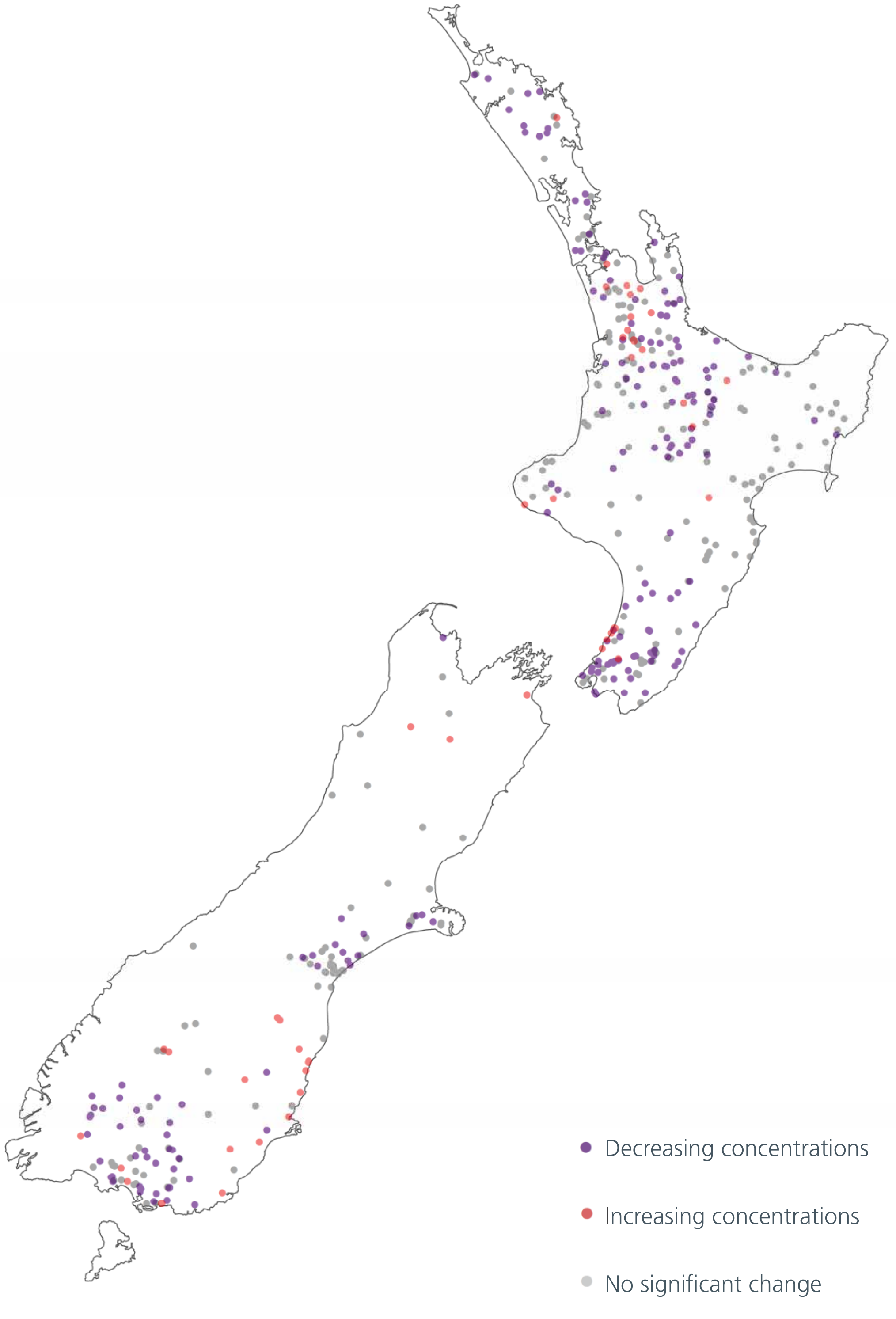
The modelling in the 2013 report showed that rising *nitrogen loads* on waterways are correlated with the expansion of dairy farming. The red dots in Figure 5.1 show that *nitrate concentrations* rose between 2001 and 2011 in regions where dairy farming has expanded on a large scale.

The modelling in the 2013 report predicted that *phosphorus loads* on waterways would remain relatively stable. The red dots in Figure 5.2 show DRP *concentration*s rose at relatively few river sites between 2001 and 2011. Encouragingly, there are considerably more sites shown in the figure where DRP *concentrations* fell over this period.[33]



Data source: MfE website (Environment indicator for fresh water: River condition)

Figure 5.1. Changes in nitrate concentrations between 2001 and 2011 at over 400 river sites monitored by NIWA and by regional councils.



Data source: MfE website (Environment indicator for fresh water: River condition)

Figure 5.2 Changes in concentrations of dissolved reactive phosphorus between 2001 and 2011 at over 400 river sites monitored by NIWA and by regional councils.

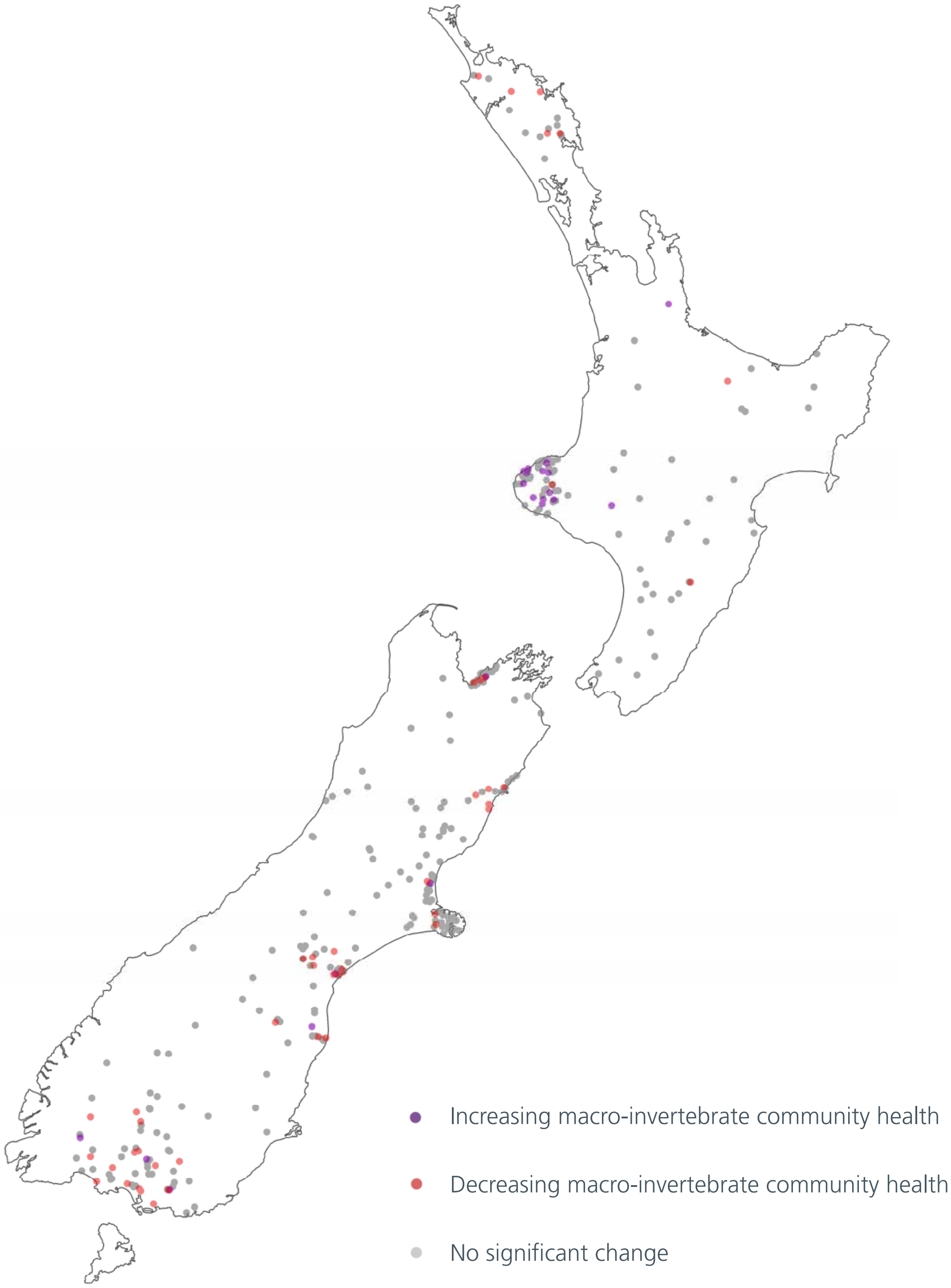
The impact of changing nutrient concentrations on the health of aquatic ecosystems is best measured with bio-indicators. The *macroinvertebrate community index* (MCI) is commonly used in New Zealand for this purpose. Macroinvertebrates are very small animals that have no backbone – they are 'macro' because they can be seen with the naked eye. In New Zealand rivers, the presence of many mayfly and caddisfly larvae is a sign of a healthy river ecosystem, while a preponderance of snails and chironomids indicates the opposite.

Figure 5.3 shows changes in MCI in rivers between 2000 and 2010.[34,35] Most sites show no change over this decade.[36] There are a number of purple dots in Taranaki, where a programme of riparian planting has been underway for many years. On the other hand, the presence of red dots in South Canterbury and Southland indicates a decline in river health.

It is important to note that these sites are only on rivers, so trends in concentrations of nutrients in lakes, estuaries, and groundwater (water bodies that tend to trap pollutants) are not shown.

The complex nature of hydrological systems means that in some areas at least, the effects of land use change will not be fully seen for many years. The legacy of nitrate in groundwater has been termed 'the load to come'.[37] In Canterbury, for instance:

"Research by GNS has shown that nitrate in the groundwaters to the west of Christchurch is 30-to-60 years old and probably dates back to the increased application of fertiliser in the post-World War 2 era. We therefore have another 30-60 years' worth of nitrate still to travel through the groundwater system, affecting drinking water supply and lowland stream quality. It will be very difficult for more intensive irrigation and dairying to occur on the plains without the legacy of nitrate in groundwater increasing for future Cantabrians."[38]



Data source: MfE website (Environment indicator for fresh water: River condition)

Figure 5.3 Changes in macro-invertebrate community health between 2000 and 2010 at over 300 river sites monitored by NIWA and by regional councils.

6 Discussion

Dairy farming is not the only land use responsible for declining water quality – horticulture, arable farming, intensive sheep and beef farming also have relatively high nutrient losses per hectare. But dairy farming is the land use that has continued to expand rapidly, and so is largely the cause of increased nutrient stress on waterways.

The two nutrients – nitrogen and phosphorus – differ in a number of important way, with nitrogen being the greater water quality challenge.

The main source of nitrogen is animal urine. But it is not just *how much* urine animals produce that matters, but *how* they urinate. Sheep urinate in small amounts, so the grass is able to take up much of the nitrogen as fertiliser. Cows, on the other hand, gush litres of urine at a time, overwhelming the ability of the grass to absorb it. Because the nitrogen exists in highly soluble chemical forms, some of the surplus is washed off by rain, but most leaches through soil into groundwater.

The intensification of dairy farming – more milk from each cow and more cows on each hectare – has been enabled by using more nitrogen fertiliser, irrigation in some regions of the country, and by supplementing grass with palm kernel extract and other stock food. The increase in nitrogen concentrations in waterways is sometimes attributed to the rapid increase in the amount of nitrogen fertiliser used. But it is not nitrogen fertiliser *per se* that has caused the problem. Rather, it is what it has enabled – a longer grass growing season, and thus, more cows and more urine.

There are many sources of phosphorus, including animal effluent, sewage, and wastewater from freezing works and dairy factories. Much of the phosphorus in fresh water is a legacy of clearing forests on hill country for sheep farming. The erosion that followed (and still continues) took soil containing naturally occurring phosphorus and superphosphate fertiliser into waterways. But the relative insolubility of the forms of phosphorus, and the way in which it tends to stick to soil, makes it easier to mitigate than nitrogen.

While a range of mitigation techniques are increasingly used, significant reductions in nitrogen losses on intensive farms with high inputs generally requires extensive and costlier mitigation techniques.

The volatility of milk prices is leading some to question the high input model that has become increasingly prevalent on New Zealand dairy farms. DairyNZ principal scientist John Roche recently told a forum of farmers that the average dairy farmer is milking a hundred more cows than a decade ago, yet making no more money. Dr Roche believes that the greater use of supplementary feed is undermining the resilience of the system, and that changing the model would reduce nitrate leaching.[39]

7 Conclusion

When nitrogen and phosphorus are lost off land into water, they can lead to degraded water quality. Nutrient losses from land are, to a large extent, dependent on how the land is used.

Nitrogen concentrations in waterways have increased in regions where dairy farming has expanded. In many places water quality has declined as a result.

A large change in land use has been taking place in New Zealand over the last two decades. Many sheep/beef farms and some forests have been converted to dairy farms. The modelling undertaken for the 2013 report, *Water quality in New Zealand: Land use and nutrient pollution*, predicted that this trend would continue to 2020.

This update report contains new information on land use that was not available in 2013. It shows that the conversion of sheep/beef farms to dairy farms has continued. However, the predicted increase in forested land has not begun to occur.

This is not good news for water quality. The modelling in the 2013 report is likely to have underpredicted the nutrients that will be lost from land into water.

This is especially true for nitrogen losses. It is much harder to stop nitrogen being lost from land than it is to stop phosphorus – nitrogen is the 'elusive' nutrient.

Losses of nitrogen and phosphorus from land can be, and are, being changed by farming practices, and this was a major consideration in the 2013 report. Changing practices on dairy farms have broadly gone in two opposing directions. The focus on growing productivity has led to higher stocking rates and greater use of inputs, driving up nutrient losses. But 'standard' mitigation practices struggle to keep nitrogen losses, in particular, from rising.

The dairy industry is facing some big challenges – challenges that are economic as well as environmental. For instance, high stocking rates that rely on importing feed not only lead to high nutrient losses, but also carry greater financial risk. It is encouraging to see the focus on ever-increasing production being questioned, and some win-win strategic thinking occurring.

Notes

1 For example, the Board of Inquiry into the Tukituki Catchment Proposal cited the report in noting the need to more actively address the link between land use changes and water quality. *Final Report and Decisions of the Board of Inquiry into the Tukituki Catchment Proposal*, 18 June 2014, page 42.

2 *Key eyes science solution to water woes*. Bernard Hickey, Hive News. 26 November 2013.

3 *Report reinforces need for Govt's freshwater reforms*. New Zealand Government press release. 21 November 2013

4 *PCE report on nutrient pollution timely*. Labour Party press release. 21 November 2013.

5 *PCE report signals need for strong water rules*. Green Party press release. 21 November 2013.

6 *Maori Party welcomes 'Water quality in New Zealand' Report.* Maori Party press release. 21 November 2013.

7 *Farmers welcome the PCE's water contribution*. Federated Farmers press release. 21 November 2013.

8 *Environment and economy linked*. Willy Leferinck, The Dominion Post. 27 November 2013.

9 See, for instance, *Bryce, Don't forget your rod* Russell MacPherson, The Southland Times. 19 December 2013; *Action well underway to address pollution concerns.* DairyNZ press release. 21 November 2013.

10 *Fonterra Committed to Improving New Zealand Water Quality*. Fonterra press release. 21 November 2013.

11 *Fonterra has to lift its game - CEO*. Fairfax Media. 28 November 2013.

12 *Conclusion from report - dairy conversions need moderating* Royal Forest and Bird Protection Society press release. 21 November 2013.

13 *PCE report shows dairying out of control, Fish & Game NZ*. Fish and Game New Zealand press release. 21 November 2013.

14 David Skegg: We must choose riches or water? *New Zealand Herald*, 10 April 2014

15 *Shifts in farming put pressure on water quality – report.* Science Media Centre. 21 November 2013

16 Report of the Local Government and Environment Committee. Report from the Parliamentary Commissioner for the Environment, 1 August 2014 *Water quality in New Zealand: Land use and nutrient pollution*.

17 The model predicts land use based on official forecasts of the prices of commodities (wool, lamb, beef, milk solids, logs, and carbon), and projected interest rates. When the modelling was done, official forecasts for commodity prices were available up to 2015 and assumed to be constant thereafter. A $5 carbon price was assumed in the modelling. Anastasiadis, S. and Kerr, S. 2013. *Land Use and Farming Intensity: For 1996, 2008 and 2020*. Motu Economic and Public Policy Research.

18 Timar, L., Keller, E. and Le, T. *A regional summary of 2012 land use*. Motu Economic and Public Policy Research. 24 April 2015. The rows in Table 3.1 do not sum to zero because of small changes in other land uses.

19 From 2011 to 2014, the prices paid for wool, lamb, and beef have generally been higher than the prices used in the modelling. (Anastasiadis, S. and Kerr, S. 2013. *Land Use and Farming Intensity: For 1996, 2008 and 2020.* Motu Economic and Public Policy Research. p 9.). In contrast, the prices paid for logs since 2011 have been significantly below the prices used in the modelling. Another factor that has influenced the decline in forestry has been the way in which the Emissions Trading Scheme has operated. A $5 carbon price was assumed in the modelling, but because the NZ scheme allowed the purchase of 'hot air' carbon credits, it has been possible to fell forests while paying carbon prices as low as a few cents per tonne. The policy uncertainty around the Emissions Trading Scheme may also have deterred investment in carbon forests.

20 Based on information from Andrew Burtt, Chief Economist at Beef + Lamb New Zealand Economic Service. See also p. 43 of *Water quality in New Zealand: land use and nutrient pollution.*

21 *"In the decade ending June 2013, higher milk production per hectare has come from increases in quantities of inputs such as capital (cows and infrastructure), and farm working inputs (feed, fertiliser, overheads etc.)"*. DairyNZ Economic Survey 2012-13, p.23.

22 The new Accord includes new commitments and covers all dairy farmers, not just those who supply Fonterra.

23 *Sustainable Dairying: Water Accord. One year on...* First annual progress report. DCANZ and DairyNZ, 2014.

24 Some of the results are awaiting verification and progress in some areas may well be overstated. For instance, the 2011/2012 progress report on the first Accord – the Dairying and Clean Streams Accord – reports that 87% of Fonterra farms exclude stock from Accord waterways, but notes that the assessment *"is based on a non-audited verbal assessment of stock exclusion". ("The Dairying and Clean Streams Accord: Snapshot of Progress 2011/2012"*, p.2). An on-the-ground audit in December 2011 found that 57% of Accord waterways were completely protected from stock. (Sanson, R. & Baxter, W. 2011. Stock Exclusion Survey. MAF Technical Paper No: 2011/102. Prepared for Ministry of Agriculture and Forestry. p.2).

25 See, for instance, McDowell, R., Wilcock B., and Hamilton, D. 2013. *Assessment of Strategies to Mitigate the Impact or Loss of Contaminants from Agricultural Land to Fresh Waters.* Report prepared for MfE. Figures 3 and 4 in this report show the estimated effectiveness and cost of mitigating nitrogen and phosphorus respectively.

26 The five catchments are Toenepi in Waikato, Waiokura in Taranaki, Waikakahi in Canterbury, Bog Burn in Southland, and Inchbonnie on the West Coast. The Inchbonnie catchment study did not begin until 2004. Monaghan, R. and De Klein, C., Integration of measures to mitigate reactive nitrogen losses to the environment from grazed pastoral dairy systems. *Journal of Agricultural Scienc*e, 152, S45–S56 2014.

27 Wilcock, R.J., Monaghan, R.M., Quinn, J.M., Srinivasan, M.S., Houlbrooke, D.J., Duncan, M.J., Wright-Stow, A.E., and Scarsbrook, M.R. 2013. Trends in water quality of five dairy farming streams in response to adoption of best practice and benefits of long-term monitoring at the catchment scale. *Marine and Freshwater Research*, 64, pp. 401–412. Table 2; and Monaghan, R. and De Klein, C. 2014. Integration of measures to mitigate reactive nitrogen losses to the environment from grazed pastoral dairy systems. *Journal of Agricultural Science*, 152, S45–S56. Table 2. The results for the Inchbonnie catchment are puzzling because, as well as a big increase in effluent disposal to land and stream fencing, the average use of nitrogen fertiliser per hectare declined. This might be related to high rainfall.

28 McDowell, R., Wilcock B., and Hamilton, D. 2013. *Assessment of Strategies to Mitigate the Impact or Loss of Contaminants from Agricultural Land to Fresh Waters.* Report prepared for Ministry for the Environment, p23.

29 DairyNZ. *Technical Series. Pastoral 21 – profitable dairy systems, low footprint*. Issue 24. October 2014, pp.1-4. [30] NIWA's National Rivers Water Quality Network comprises 77 measurement sites on 35 rivers.

30 In Figures 4.1 and 4.2 the *purple* dots are sites where nutrient concentrations have *decreased* by an amount that is statistically significant and meaningful; the *red* dots are sites where nutrient concentrations have *increased* by an amount that is statistically significant and meaningful; and the *grey* dots are sites where there has been no statistically significant or meaningful change. NIWA considers a trend to be 'meaningful' if the change is greater than 1% per year.

31 Data from the Ministry for the Enviroment website (Environmental indicator for fresh water: River condition)

32 http://www.mfe.govt.nz/more/environmental-reporting/fresh-water/river-condition-indicator. Downloaded dataset named 'Modelled state, trend and long term change data' Worksheet named 'Trends WQ' was used was used for Figures 4.1 and 4.2.

33 The reasons for this remain unclear. *"This may may reflect improving environmental management practices, such as wastewater treatment and riparian planting… Because similar patterns occurred over all land covers, another possibility is that the trends are unrelated to management but from a widespread background influence such as long duration climate variation."* Ministry for the Environment, 2013. River condition indicator.

34 In Figure 5.3 the *purple* dots are sites where the macro-invertebrate community index has *increased* by an amount that is statistically significant and meaningful; the *red* dots are sites where the macro-invertebrate community index has *decreased* by an amount that is statistically significant and meaningful; and the *grey* dots are sites where there has been no statistically significant or meaningful change. NIWA considers a trend to be 'meaningful' if the change is greater than 1% per year.

35 Data from the Ministry for the Enviroment website (Environmental indicator for fresh water: River condition)

http://www.mfe.govt.nz/more/environmental-reporting/fresh-water/river-condition-indicator. Downloaded dataset named 'Modelled state, trend and long term change data'. The worksheet named 'Trends Invertebrates' was used for Figure 5.3.

36 Note, however, that MCI has been measured at very few sites in Waikato.

37 See, for example, Howard-Williams, C., Davies-Colley, R., Rutherford, K., and Wilcock, R. 2010. *Diffuse pollution and freshwater degradation: New Zealand Perspectives.* 14th International Conference IWA Diffuse Pollution Specialist Group. p. 131.

38 Professor Jenny Webster-Brown, Director of Waterways, Lincoln University quoted in *"Call for Cantabs to think about future of water"*, Lincoln University Press Release, 13 April 2015.

39 Dominion Post, 7 May, 2015, *"More cows, more milk, but no more profit"*. Roche, J. and Horan, B., 2015, *"Resilient farming systems – surviving volatility"*.