Article

New Zealand's freshwater disaster

Michael K. Joy*
Ecology group – Institute of Agriculture and Environment, Massey University,
Private Bag 11 222, Palmerston North 4442

Freshwater ecosystems in New Zealand have been under considerable and increasing stress since European colonisation. The draining of ninety per cent of wetlands and the removal of a similar amount of indigenous vegetation cover has placed much strain on the health of freshwater bodies. These changes wrought massive impacts through the loss of the crucial hydrologic and biological functions performed by intact wetland and forest ecosystems. These impacts have been exacerbated by the more recent intensification of farming, with the concomitant addition of excess nutrients and sediment to water as well as the effects of urbanisation and introductions of exotic fish species. The cumulative impacts of all these changes can be seen with declining water physicochemical measures and the biological status of freshwater ecosystems. The most obvious impacts are revealed by biological indicators, with seventy-four per cent of the native freshwater fish species listed as threatened, and ninety per cent of lowland waterways and sixty-two per cent of all waterways failing bathing standards. Lowland lakes are under immense pressure; forty-four per cent of monitored lakes are eutrophic or worse and they are mostly the lowland lakes. The legislative response from central and local government to the obvious declines has failed to halt or even slow the deterioration. In contrast, government initiatives to increase farming intensification mean there is no chance of improvement, and further declines will be the future for New Zealand freshwaters.

Introduction

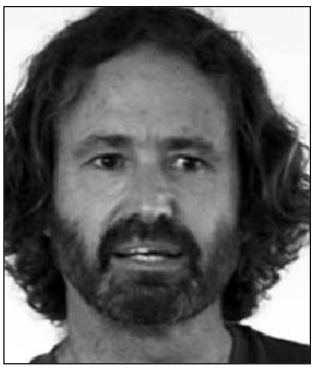
New Zealand's freshwater ecosystems have undergone significant and obvious deterioration both physicochemically and ecologically over the last few centuries, but especially in the last few decades. The decline is revealed in many ways including severe reductions in biodiversity (Joy & Death 2013) as well as by declining physicochemical measures taken at most lowland waterways (Larned *et al.* 2004, Ballantine & Davies-Colley 2014). One of the most stark indications of the extent of the deterioration in freshwater ecosystem health is the fact that New Zealand now has proportionally more threatened freshwater fish species than almost any country globally (IUCN 2010, Goodman *et al.* 2013). While in global terms these freshwater declines in New Zealand are relatively recent, they mirror declines worldwide where the symptoms and drivers of deterioration are similar but have generally occurred over much longer time periods. The primary drivers of decline in New Zealand have been the unrestrained agricultural intensification and indigenous vegetation clearance (Williams 2004, Joy & Death 2013b, Joy 2015) with their attendant increases in nutrients and sediment inevitably entering lakes, rivers and groundwater. These impacts are combined with those of urbanisation (McEwan & Joy 2009), damming of rivers (Jellyman *et al.* 2013) and exotic species introductions (McIntosh 2000, Jellyman *et al.* 2013). Unfortunately, apart from rare exceptions to protect a few iconic waters, there is little indication that the limited government initiatives to halt this erosion in the health of freshwater ecosystems have had any net effect.

*Correspondence: M.K.Joy@massey.ac.nz

Condition of New Zealand rivers and streams

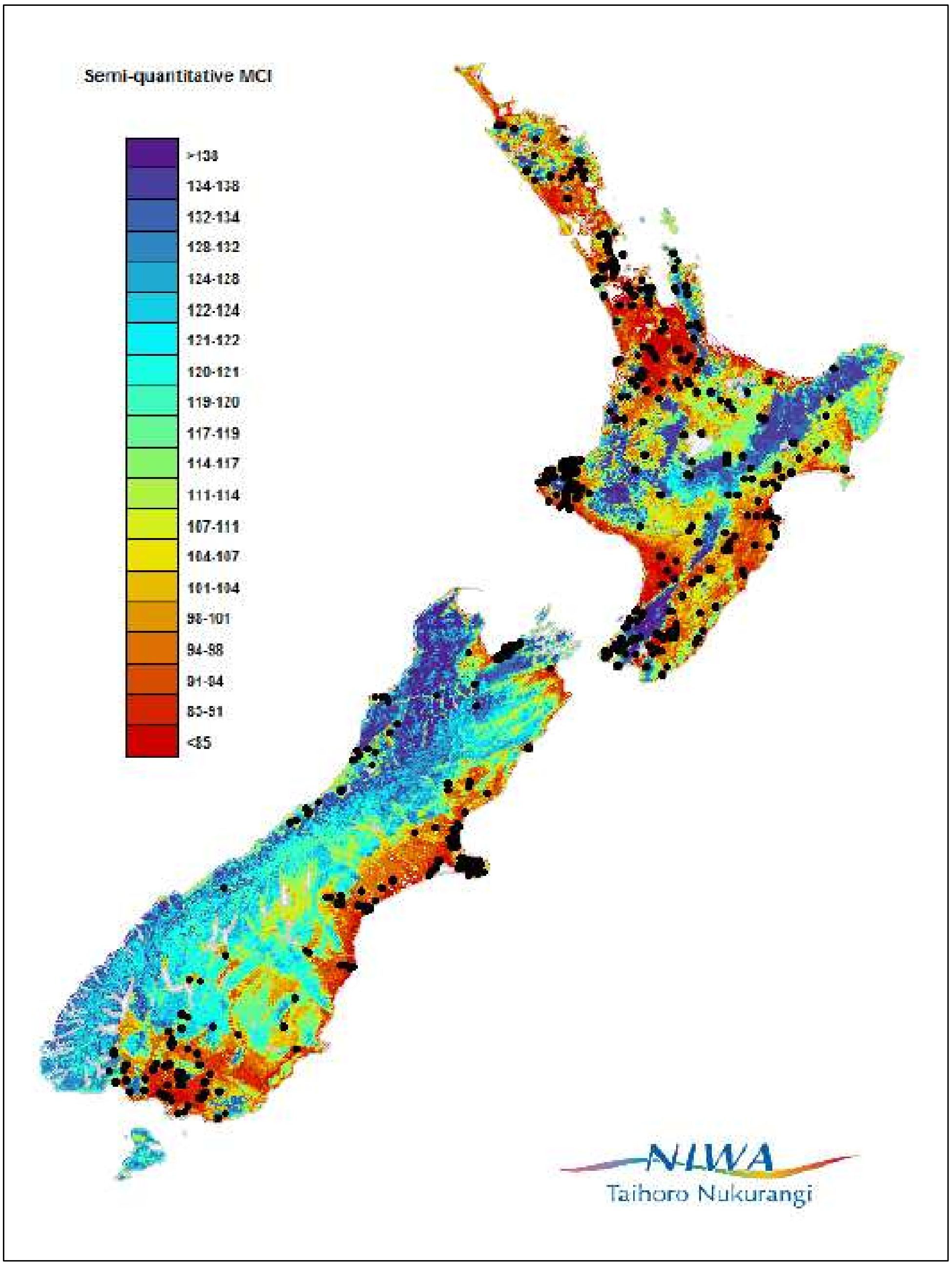
Flowing waters in New Zealand have been regularly monitored since 1990 at a set of seventy-seven river sites known as the National Water Quality Monitoring Network (NRWQN). Analysis of these data reveals the poor state of water quality in most lowland rivers, particularly in those measures related to diffuse nutrient and faecal pollution and sediment (Ballantine & Davies-Colley 2010, 2014). However, the full extent of declines has been masked by the reporting agencies averaging results over control and impact sites. When the water quality variables were correlated with land-use for pastoral and urban land, relationships were mainly positive, indicating that poorer water quality was associated with increasing urban or pastoral cover (Ballantine & Davies-Colley 2014) (although it must be noted that urban catchments make up less than one per cent of land cover).

The commonly used biological measure of water-quality/ecosystem health, the Macroinvertebrate Community Index (MCI), is a measure of organic enrichment based on the response of the individual species to increasing nutrient levels. To give a national picture of the state of water-quality the national MCI scores shown as black dots in Figure 1 were modelled to fill in the gaps and then colour coded. The predictive map shows clearly the areas with poor quality waterways in New Zealand;



Mike Joy is a Senior Lecturer in Ecology and Environmental Science at the Ecology Group, Institute of Natural Resources, at Massey University in Palmerston North. He researches and teaches freshwater ecology, especially freshwater fish ecology and distribution, ecological modelling bio-assessment and environmental science. Dr Joy has developed a number of bioassessment tools and associated software used by many regional councils. He is an outspoken advocate for environmental protection in New Zealand and has received a number of awards including the Ecology in Action award from the New Zealand Ecological Society, the Old Blue award from the Royal Forest and Bird Protection Society, and the 2013 Charles Fleming Award from the Royal Society.

Figure 1. Modelled current state for the Macroinvertebrate Community Index. A score of <80 is severely polluted, and 80–100 is moderately polluted, 100–120 is doubtful water quality and >120 is healthy. Accordingly, dark orange and red waterways are severely or moderately polluted. (From Unwin & Larned 2013).



these areas are mainly located in lowland New Zealand where intensive agriculture occurs. In contrast, the West Coast of the South Island, the East Coast around East Cape, and the Coromandel Peninsular show that healthy waterways do still exist in lowlands without development.

Another dataset of more than 300 lowland waterways collected by local government plus the NRWQN data revealed that ninety-six per cent of the sites in lowland pastoral catchments and all sites in urban catchments showed pathogen levels in excess of the standard considered safe for swimming and more than eighty per cent exceeded nutrient guideline levels (Larned *et al.* 2004). Further analysis and modelling revealed that sixty-two per cent of all waterways would currently fail the human health standard (Unwin & Larned 2013). The human impact of these high levels of pathogen contamination is revealed from estimates by the Ministry of Health that 18,000 to 34,000 people annually contract waterborne diseases (Ball 2006). While damning, these human health impacts occur despite the fact that many lowland waterways and estuaries have health warning signs, and these signs are now a common sight around much of lowland New Zealand.

Temporal trends in water quality and biodiversity

Over the last two decades there were significant increases in nutrients levels at nearly all NRWQN sites, and the worst were nitrogen and phosphate (Figure 2) and the only improvements were in clarity (Ballantine & Davies-Colley 2014). As with the state indicators the strongest temporal patterns of deterioration were at sites with catchments in agricultural and urban land cover.

Trends in freshwater fish biodiversity and the thus freshwater biological health in New Zealand, have been assessed using an Index of Biotic Integrity (IBI) (Joy & Death 2004) which is a measure of the integrity of fish communities commonly used internationally. This methodology was applied to 22546 freshwater fish distribution records collected throughout New Zealand over the last forty years (Joy 2009). A comparison of

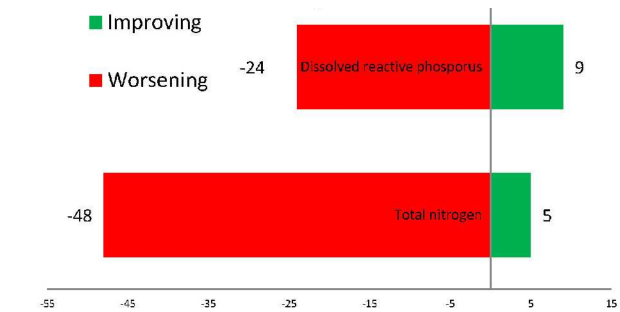


Figure 2. Significant changes in nitrogen and phosphorus at the 77 NZRWQN28 sites over the last 25 years.

these IBI scores in catchments with different land uses revealed significant differences. The IBI scores were significantly lower at sites in tussock, pasture, urban and exotic forest catchments than in native forest and scrub sites. A temporal trend analysis of these IBI scores showed a clear and statistically significant decline in fish communities for all catchment land-use types in New Zealand over the last 40 years, especially in the last decade. Notably the strongest declines however, were at sites with catchments in agricultural and urban land cover (Joy 2009).

Lakes and groundwater

Lakes and groundwaters show deterioration similar to that in flowing waters, in that they suffer from excess nutrient inputs mainly from agricultural intensification as well as urban waste and storm-water inputs. Lakes and groundwater differ from flowing waters, however, in that they are more easily measured but the impacts are longer lasting and harder to fix. The high level of nutrient inputs is revealed by the shocking statistic that forty-four per cent of monitored lakes in New Zealand are now classed as polluted (that is they are now eutrophic or worse) and almost all of these polluted lakes are in lowland areas and in agricultural or urban catchments (Verburg *et al.* 2010). In groundwater, nitrate levels are rising at thirty-nine per cent of monitored sites and groundwater pathogen levels exceeded human drinking standards at twenty-one per cent of monitored sites (Daughney & Wall 2007).

Water quality assessment

What is 'Water-quality'?

The term 'water quality' suggests to many some kind of comprehensive assessment of freshwater condition encompassing aspects of habitat, biodiversity and freshwater health and integrity, but, in reality it is more of a 'managerial' assessment than an ecological assessment. Consideration of the factors currently used to assess 'water quality' reveals that they are more closely related to ease of sampling and presentation of data than any genuine representation of waterway condition. 'Water quality' assessment as prescribed by the Ministry for the Environment and measured by regional authorities generally consists of a suite of 'snap-shot' monthly samples of five physicochemical measures and occasionally some minimal biological assessment. The physicochemical factors are: suspended sediment, nitrogen, phosphorus, temperature and dissolved oxygen, and the biological assessment macro-invertebrate metrics and visual assessment of periphyton (Ballantine & Davies-Colley 2010). Assessment of waterway suitability for bathing and human health is made by measuring faecal bacteria and clarity.

Remarkably, this 'water quality' assessment fails to measure freshwater ecosystem function, habitat quality or biodiversity. What is worse though, is that this limited set of measures are collected as one-off 'snap-shot' samples when it has long been known that the parameters become progressively more variable as impacts accumulate in freshwater systems. For example, oxygen levels are known to fluctuate through diurnal cycles (Figure 3) due to algal photosynthesis and the fluctuations become more extreme as nutrient levels increase with eutrophication.

Another failing is the use of median and mean values for setting limits and presenting water quality measures to the public. While these numbers simplify description and are popular with managers they have no biological reality. For example, the median or mean values for temperature or oxygen are biologically meaningless; rather it's the extremes that are crucial. From a biological perspective, if temperature exceeds the lethal limit or oxygen goes below it even if it's just one per cent of the time, it is fatal.

Importantly, many of the impacts on freshwater biology are not directly related to the water quality parameters that are measured; rather the biological effects are secondary. For example when nutrients in rivers increase, fish are not at first affected directly (although at very high levels these nutrients are toxic), but are affected by the ensuing increase in algal growth which can (if other conditions are conducive) lead to extreme fluctuations in oxygen availability. As a regional example, oxygen saturation fluctuates enormously in the Manawatu River. At one point in the River (Homelands Road below an intensively farmed catchment) oxygen saturation levels in summer vary from less than forty per cent in the early morning to more than one hundred and forty per cent in the late afternoon of the same day (Clapcott & Young 2009). These extremes (both low and high) are potentially lethal for all stream life, or at least harmful, but because guidelines and measurements are based on 'snap-shot' sampling all, this diurnal variability is overlooked, and thus the detrimental consequences are generally not apparent to resource managers.

The other 'water-quality' parameters; nutrient levels, pH, suspended sediments and temperature, also vary in degraded systems, however, unlike oxygen the changes are not always diurnal but vary with flow and biological instream processes. For example the bulk of the phosphorus entering flowing systems occurs during flood events and both phosphorous and nitrogen levels can vary as these nutrients are taken up and released by instream plant life. Obviously assessing such variability using one-off snap-shot sampling is not scientifically robust.

What is not measured?

Crucially, other key indicators of ecological decline are not measured at a national scale, including physical alteration of habitat by deposited sediment, which infills interstitial spaces in the substrate that are known to be crucial to fish and invertebrate life (McEwan & Joy 2011, 2013). As well as the physical instream engineering of rivers for flood control using

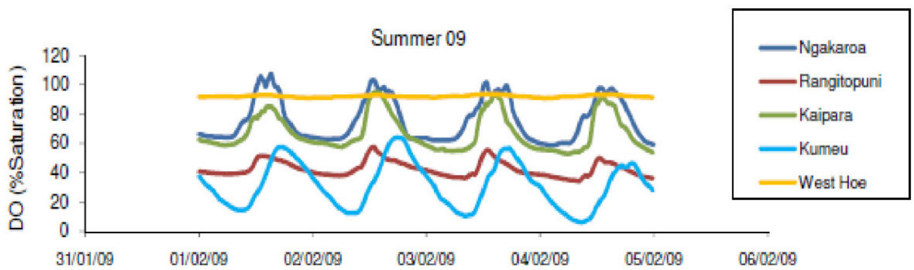


Figure 3. Dissolved oxygen levels in some Auckland Streams (Doehring & Young 2010)

heavy machinery and the associated confining of rivers within stop-banks, there is the loss of habitat to migrating fish and the blockage of downstream passage to complete life-cycles caused by dams for hydro-electricity and irrigation.

Freshwater biodiversity

Any changes in freshwater ecosystem health are ultimately and most comprehensively revealed by changes in freshwater biodiversity. Nationally, native freshwater fish abundance and diversity have been declining for at least the last century but the rate has accelerated over the last 40 years. While only one species (the grayling *Prototroctes oxyrhynchus*) has become extinct, the range and abundance of almost all species has diminished. The declines are revealed by the increase in the number of species listed as threatened over the last twenty years, with the proviso that the criteria for threat rankings change over time and data for the listings inevitably lag behind actual declines. In 1992 the New Zealand Department of Conservation (DOC) recorded 10 species as threatened; by 2002 that number had risen to 16 species (Hitchmough 2002). Three years later, in 2005, 24 species were listed as threatened (Hitchmough &Cromarty 2007). In 2007 a new threat classification scheme was established (Townsend *et al.* 2008) using a reduced set of categories but retaining the key threat descriptors from previous classifications. Under this new system sixty-eight per cent of all extant native taxa and seventy-six per cent of all non-diadromous taxa are considered threatened or at risk (Allibone *et al.* 2010). In 2013 a further analysis found that of the fifty-four resident native taxa, seventy-four per cent (forty) were considered to be threatened or at risk. This proportion of threatened fish species is one of the highest globally and gives a strong indication of the true extent of freshwater ecosystem decline in New Zealand.

These reductions in freshwater fish diversity have been paralleled by declines in invertebrate diversity and distribution. The number of invertebrate taxa that might be considered at risk to some degree increased from sixty-nine in 2002, to one-hundred and thirty-nine in 2005, to two-hundred and ninety-five in 2010 and includes New Zealand's only freshwater crayfish and mussel species. Although, some of this increase in invertebrates listed as declining reflects increasing knowledge of taxonomy and distribution, the number of nationally critical taxa has increased over the same time from four in 2002, to eleven in 2005, to fifty-eight in 2010 (Joy & Death 2013). However, even within this biodiversity assessment there are some clear anomalies, with the two crayfish (*Paranephrops planifrons and P.zealandicus*) listed, but its commensal platyhelminth flatworm (*Temnohaswellia novaezelandiae*) not listed.

Drivers of freshwater declines

The decline of freshwater biodiversity in New Zealand mirrors global declines in biodiversity. Given the fact that the drivers of decline in New Zealand and their impacts on freshwater biodiversity are similar to those occurring globally this is not surprising. These pressures include eutrophication, habitat loss and population isolation caused by the damming of rivers, habitat destruction, species invasions and introductions, over-harvesting, and climate change (Allan & Flecker 1995). While this list of pressures is not complete, it does include the major impacts; however, ascertaining how they interact, particularly the question of whether they are additive or multiplicative, is difficult to assess (Ormerod *et al*. 2010).

In New Zealand it is clear that the declines in the health of freshwaters are dominated by agricultural impacts including excess sediment, phosphorus and nitrogen, as well as by faecal pathogens (Ballantine & Davies-Colley 2010, 2014). Thus, the major contemporary driver of the deterioration in the health of New Zealand's lakes, groundwater, rivers and streams is associated with increases in nutrients, mainly nitrogen from the virtually uncontrolled intensification of dairy production. This escalation in intensity is driven by a farming system based on a strategy of low-cost production which, in the absence of any meaningful leadership from central government, has inevitably led to many unsustainable practices (Baskaran *et al*. 2009). The main issue for freshwaters from this intensification is diffuse-source as opposed to nutrient and pathogen pollution of waterways from the pasture-based livestock farming model (Figure 4). This diffuse pollution is the run-off or seepage through soils of nutrient laden water and urine due to high stocking rates. The remarkable stocking rates now found in New Zealand have been achieved by increasing use of 'off-farm' feed supplements like palm kernel and fossil fuel-derived nitrogenous fertiliser and imported fossil phosphate.

As an example of the magnitude of intensification of dairy farming in New Zealand, between 1990 and 2010 the number of dairy cows in the South Island increased seven-fold, with an obvious massive impact on the quality of lowland streams. During the same period the number of cows in the Waikato River catchment increased by thirty-seven per cent and over that period nitrogen levels in that river increased by forty per cent and phosphorus by twenty-five per cent (NIWA 2010).

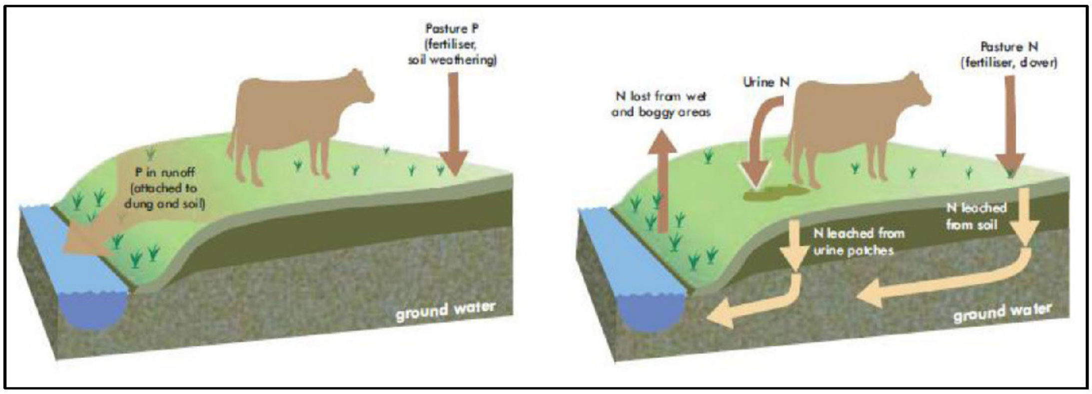


Figure 4. Pathways for nutrients to water. Phosphate and pathogens mostly travel overland attached to sediment, but nitrogen is via urine and travels down and sideways into groundwater or rivers then lakes. (Graphic from Ministry for the Environment)

Dairy cow numbers reached 6.5 million in 2012 (Statistics New Zealand), and given that each cow excretes more waste than 15 humans (Waikato Regional Council 2008) the human-equivalent of the cow population of New Zealand is more than 90 million. The actual human population of New Zealand is less than 4.5 million; these statistics put the relative volume of human versus animal wastes into perspective.

The past

Legislative approaches

At the same time that the Resource Management Act 1991 (RMA) legislation was passed into law, New Zealand committed internationally to halt environmental declines at the United Nations Rio Earth Summit (UN Conference on Environment and Development, Rio de Janeiro, Brazil, 1992). But in the ensuing two decades there has been a comprehensive failure to achieve any of those commitments. The list of failures begins with Principle 16 which declared that "*authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments"* and further that *"the polluter should bear the cost of pollution"*. To date there has not been a fee applied, or any attempt to internalise the costs of the pollution of freshwaters in New Zealand. The only cost for 'out of pipe' (point source) polluters is a one-off consent fee which is essentially an administration charge required by local government. The problem for freshwater health, though, is that the biggest pollution source in New Zealand is not point source, rather it is diffuse and this form of freshwater contamination is not controlled at all. Diffuse pollution is the nutrient, urine and faecal contamination that make their way into lakes and rivers through and over the soil mainly via cow urine patches and washing overland of faeces in rain (Figure 4). The resulting addition of nutrients and microbial contaminants to lakes, rivers and streams has led to many ecological and human health impacts (outlined above), but these are not paid for by the polluters. To date the Lake Taupo catchment is the only one in New Zealand where an attempt has been made to reduce diffuse pollution and protect this iconic lake from nutrient pollution, through regulation using a nitrogen cap and trade system.

Apart from the Lake Taupo example, local authorities have failed to use the capacity they have had under the RMA to control the obvious impacts of farming intensification on freshwaters. Instead they have chosen only to control the much less significant impact of dairy-shed wastewater. The main reason for local government (councils') failure to address the main impact on freshwater quality in New Zealand lies to some extent with the failure of central government to implement a National Policy Statement (NPS) for freshwater management since the inception of the RMA. This was despite a legislative requirement to do so soon after the act was passed. This would undoubtedly have given guidance to regional councils and confidence that they would not be picked off individually as protective legislation was developed.

The NPS was finally put in place in 2011 but it has been criticised as being 'too little and too late' and 'unlikely to produce any improvement in water quality' (Sinner 2011). The only other response from central government around freshwater protection was to set up a stakeholder group known as the Land and Water Forum (LAWF). The LAWF was proposed and set up by central government as a collaborative approach to managing freshwaters into the future. In reality the forum membership was heavily weighted toward very well-resourced stakeholders, with minimal representation from freshwater protectors and conservationists. The LAWF worked through many issues over four years and produced three reports and made many recommendations, but thus far, none that has any chance of halting freshwater declines, has made it into legislation.

In terms of biodiversity declines, ironically, none of the threatened native fish species has any legal protection; indeed, at least five threatened fish species are harvested commercially and recreationally. Absurdly, the Freshwater Fisheries Act 1983 formally protects the extinct grayling last seen in the 1930s, some introduced fish, mainly trout and salmon, but not native fish. The native fish are protected only if they are not used for 'human consumption or scientific purposes'; thus, in reality they have no protection. In addition, four of the five species that make up the whitebait catch (juveniles of the migratory galaxiids; a popular recreational and commercial seasonal harvest in New Zealand) are listed as threatened. To summarise, fifty years after its extinction, a law was passed to protect the endemic grayling, and other native fish species have no legal protection apart from harvesting rules.

Voluntary approaches

Other than the National Policy Statement on freshwater management the only significant response to date from central government to the many freshwater issues was the negotiation of a voluntary accord with the largest dairy company in New Zealand, Fonterra, signed originally in 2003 (and regularly updated since). This agreement, originally called the Clean Streams Accord, was between Fonterra, regional councils and the Ministry for the Environment, and required that farmers undertake a number of measures to reduce their impacts on freshwater. The agreement at first appeared impressive but closer investigation revealed many failings. These failings include that the accord lacks any ability to enforce requirements, and the stream fencing requirements ignore the smaller streams where actions could be most effective. A further crucial flaw is that all the monitoring requirements are for assessing whether the accord requirements are being implemented rather than any assessment of whether they are in fact improving water quality.

The result has been that while the accord progressed stream fencing, it did not include riparian buffer zones and mostly only occurred on larger waterways. What it did do, however, was to focus publicity on the continuing problems of dairy effluent management; and it resulted in the uptake of farm nutrient budgeting. The down side, however, was that it gave regional councils a pretext to continue to defer introducing rules to address the impacts of farm intensification and diffuse pollution. So the result was that, while the accord was a great public relations tool for the industry to suppress criticism, there is no evidence that it has done anything to halt the decline of water quality. The updates to the accord that have occurred since its inception have not addressed any of the issues raised above and in 2013 the phrase 'Clean Streams' was removed and it is now called the Water Accord.

Future solutions

The precedent and example for reducing farming intensity, and thus impacts on freshwater, have been set with cap and trade limits on nutrient loads to Lake Taupo. While this is just one of a range of options, it does give a model for the sort of approach that could be adopted nationally. The other potentially positive change is the agreements made to protect and improve the health of the Waikato River resulting from a claim over the river taken to the Waitangi Tribunal by Tainui-Raupatu. Under this co-management agreement (Waikato-Tainui 2010), Tainui-Raupatu iwi have had their vision and strategy for cleaning up the Waikato River legislated. The vision statement is aspirational and is summarised in this statement from the report: 'Our vision is for a future where a healthy Waikato River sustains abundant life and prosperous communities who, in turn, are all responsible for restoring and protecting the health and wellbeing of the Waikato River, and all it embraces, for generations to come'. As an example of just how far reaching this vision is, one of the objectives is: (objective k) 'the restoration of water quality within the Waikato River so that it is safe for people to swim in and take food from over its entire length'. To achieve these aspirational objectives however, substantial changes would be required to land-use in the Waikato River catchment. However, at the time of writing, three years after the enactment of this legislation, there is little sign of any changes to the rules necessary to achieve the vision and strategy. Nevertheless this vision and strategy may still lead the way for the changes in land-use required to ultimately improve water quality in New Zealand.

On farm, the only solution for protecting the natural capital of New Zealand while at the same time producing large quantities of low value milk powder or any other agricultural product is simply to 'close the loop' and ensure that nutrients and soils stay on farms and are cycled within the system, and that fossil fuel use for fertiliser or energy is reduced (Nelson 1996). Examples of this truly sustainable style of farming are occurring in North America and Europe and these farms can be used to show the way in New Zealand.

The future prospects for freshwater health in New Zealand are bleak, there is no prospect of any polluter pays legislation and the lag times for nutrients entering waterways are often decades. Thus, even if moves to cap and reduce nutrient loads were immediate and applied nationally, water quality will continue to decline for some time. If the polluter-pays principle had been applied in New Zealand some decades ago as promised at the Rio Summit in 1992 then the massive intensification of dairy farming would likely not have occurred and increases in profit would instead have come through adding value. Thus, the hands-off approach over the last two decades has led to a huge overshoot of the carrying capacity of soils and water and the withdrawal from this situation will be difficult and expensive. Even worse than the failures to limit intensification, councils are now involved in funding irrigation schemes that will inevitably increase nutrient loadings on freshwater systems. The regional councils have a crucial legislative frontline role in protecting the environment but several have entered into a conflict of interest when they have become investors in schemes that will result in further freshwater degradation. This development has seen moves by these councils to massively increase nutrient limits in waterways. The justification being used is that by controlling one of the two nutrients (nitrogen and phosphorus) required for algal proliferation they can allow excessive levels of another without impacts occurring. This limiting nutrient scenario only happens in rare cases and allowing build-up of one nutrient will set up the potential for a major algal bloom as it is simply not possible to stop nutrient loss from the landscape.

Summary

The deterioration in freshwater health in New Zealand developed through the twentieth century but accelerated over time, especially in the last few decades. At the same time the USA and many European countries have implemented regulatory changes and halted declines, resulting in improvements in water quality in many cases. New Zealand has ignored this and continued with unconstrained intensification of farming in association with exponential increases in fertiliser use and importation of stock feed. The relationship between land cover (a surrogate for land-use) and fish communities reveals the obvious causes of declines (Joy 2009). In general, deterioration in the health of fresh waters is related to agricultural impacts: excess sediment, phosphorus and nitrogen, as well as faecal pathogens (NIWA 2010). The major driver of this deterioration is the expansion and intensification of agriculture, particularly dairy farming (Wright 2007). The decline in fish biodiversity is also related to the loss of habitat, a result of barriers to migration such as hydroelectric dams and weirs and the draining of more than 90% of wetlands, mainly for agriculture (Joy 2012).

In 1991 the RMA came into effect. It encompassed the lofty ideals of a generation of New Zealanders committed to a healthy and environmentally sustainable future. Sadly the work of the authors of the RMA proved futile because over the following two decades the RMA was systematically diluted by a lack of enforcement and then later weakened through the Resource Management Simplifying and Streamlining Act 2009, with further proposals now being considered to further weaken the protection intended by the RMA. This legislation put more emphasis on speeding up the consent process and less emphasis on the quality of decisions. This weakening of the law combined with a failure to address the most pervasive impact on water quality – the intensification and industrialisation of dairy farming – has in part resulted in New Zealand's slide to the lowest levels of environmental performance globally (Bradshaw *et al.* 2010). This study based on a suite of measures including fertiliser use, biodiversity loss, marine captures, water quality and more, ranked New Zealand around 130 of 180 countries.

The only indication of a future move to improve water quality in New Zealand is the involvement of Māori in freshwater management (the Waikato co-management example) and the economic value of tourism leading to moves to protect Lake Taupo by reducing dairy farming intensity. However, while this co-management has been mandated, there is little evidence of changes in regional plans to meet the aspirations.

The conflicting needs of agricultural intensification, biodiversity conservation, sport fisheries management, and urban spread, have created many pressures on water resources. These show no sign of abating – in fact, all are increasing. Despite the many unequivocal measured impacts on fresh water from intensification of farming, the government is backing further intensification, mainly of dairy farming, through irrigation in drier areas. Consequently, impacts on freshwater biodiversity will inevitably accelerate. Irrigation has already increased; for example, from 1999 to 2006 water allocation grew by fifty per cent mostly for irrigation, and this is likely to increase substantially. Undoubtedly the combination of climate change, agricultural intensification, and further urban spread will have very serious consequences for freshwater biodiversity in New Zealand (Ling 2010).

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