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Asking the right questions about Predator Free New Zealand

Carolyn King[1]*

[1]Environmental Research Institute- Te Pūtahi Rangahau Taiao, School of Science, University of Waikato, Hamilton, New Zealand

*Author for correspondence (Email: carolyn.king@waikato.ac.nz)

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Abstract: The official Predator Free New Zealand programme launched in 2016 is based on a hugely inspiring, aspirational ambition to eradicate all invasive rodents (rats *Rattus norvegicus* and *R. rattus* but not mice *Mus musculus*), mustelids (stoat *Mustela erminea*, ferret *M. furo* and weasel *M. nivalis*) and possums (*Trichosurus vulpecula*) from throughout New Zealand by 2050. Others had already been doing predator control for years, but this campaign has caught the public imagination as no previous operation ever has. It is achieving some impressive results at local scales, to well-deserved acclaim. But its underlying philosophical world view is less often discussed, which, I argue, poses a risk to its prospects of long-term, national-scale public support. World views matter much more than we usually recognise because they determine the questions we ask and the answers we consider reasonable. The history of environmental management in New Zealand offers some thought-provoking examples of programme managers unconsciously committed to unhelpful world views. Some overlook hidden assumptions, e.g. that top-down methods of imposing artificial mortality can exceed the high natural mortality of resilient pest species such as rats, stoats, rabbits (*Oryctolagus cuniculus*), or deer (*Cervus elaphus*). Some ask the wrong questions, such as how to find better ways to kill pests rather than how to reduce the numbers to be killed, which is usually controlled by food supplies from the bottom up. Some favour the wrong conclusion, such as when an observed change in pest numbers or distribution is attributed to suppression by artificial means even when the natural means are unknown. The philosophy of reasoning suggests that the PF2050 programme could best be considered as a game of two halves. First, short-term prevention of damage to native values by existing top-down suppression that cannot eradicate pest populations but can at least protect the most vulnerable native fauna until we can think of better means to save them. Second, long-term removal of pest populations by supplementing suppression with unknown future methods of minimising pest fertility and immigration.

Keywords: history; pest management; philosophy of reasoning

Introduction

New Zealand conservation biologists share a deep-seated grief over the historic and ongoing loss of our native biodiversity, plus an accelerating worry for its future. Consider the following observations. In Nelson Lakes National Park, standard five-minute bird counts were run along identical transects through unmanaged forest intermittently over 30 years. The long-term counts varied considerably, but in general the counts for all species declined, over time and by elevation, throughout the study (Elliott et al. 2010). If we do nothing to prevent these trends from continuing, many birds that are now still common will continue to decline.

Another analysis (Innes et al. 2010) sharply illustrated the urgency of preventing predation damage to the surviving native bird species of mainland forest. It plotted the numbers of species listed in the six major threat categories defined by the Department of Conservation (hereafter DOC) against the numbers of the latest Bird Atlas squares those species still occupy. These categories rise in urgency from "restricted range" to "critically endangered". Preventing predation damage was considered necessary to save at least the 18 species in the various degrees of threat, but (at that time) only seven were getting it. There were four in the next category down ("Atlas decrease"). Only 11 other species were, at the time of the analysis, deemed to have large, secure populations. If nothing is done, the Atlas decrease species will be reclassified as range restricted, and more common species are likely to move into higher threat categories over time. Predictions of the long-term consequences are clear and alarming.

These losses are usually if not solely attributed to the arrival of introduced mammalian predators. So, one of our dominant world views, widely shared among the public generally, is that much of what we have left could be restored by intensive suppression of predators.

Predator management is only one component of a robust national strategy for conservation of native biodiversity in New Zealand (Russell & Stanley 2018), but unfortunately,

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it is the most obvious. Why unfortunately? Because the sight of eggs, chicks and adult birds killed by predators is a simple and much more obvious source of loss—and of public outrage—than the more complex problems of loss of ecosystem structure, year-round food resources and secure, productive nesting habitat. These are much less visible but also much more significant factors damaging national biodiversity values in the long run.

Predator-free islands have long been proven to protect nesting birds, enhance their breeding success and restore their biodiversity. Successes in removing predators from uninhabited offshore islands that can be defended from reinvasion have stimulated a strong public desire to restore birdlife on the inhabited mainland (Towns 2023). But on the main islands, habitat protection had to come first. Predator control would not have been necessary to protect the last few North Island kōkako (*Callaeas wilsoni*), had not logging of their only habitat in the west Taupō forests already been stopped in 1978, only just in time. Even Shakespeare knew that, when he put into Shylock's mouth the words "you take my life when you take the means whereby I live".

Therefore, much of the 1970s and 1980s concentrated on the fight for habitat protection, especially in old-growth native forests threatened by logging. But even after the conservation victories that saved Manapouri, Pureora, Whirinaki, and the South Island's west coast beech forests, birds continued to disappear from forests that still stood. Decades of strict protection of the Murchison Mountains was not preventing the continuing decline of the South Island takahē *Porphyrio hochstetteri*.

In the mid 1990s, several key papers documented the effects of predation by stoats on threatened bird species, especially kiwi *Apteryx* sp (McLennan et al. 1996) and hole-nesting passerines such as mohua *Mohoua ochrocephala* (Elliott 1996). These and similar revelations created strong public pressure for a vastly expanded effort to kill more predators over larger and larger areas, especially stoats.

The origins of the Predator Free New Zealand campaign (PF2050)

In 1999 the New Zealand Government accepted the argument that only an extensive, nationally funded campaign could protect endangered ground and hole-nesting birds from stoats. It therefore granted DOC NZ$6.6 million to instigate a five-year program to find more cost-effective and sustainable approaches to managing stoats, including fertility control. The funding stimulated an explosion of new research, as summarised in the annual reports of the Stoat Technical Advisory Group and published by the Department of Conservation (Murphy & Fechney 2003).

For a short period, far more money was being spent on stoat research in New Zealand than in any other country in the world: for example, NZ$1 352 000 in 2000/01 (Parkes & Murphy 2003). By the time the funding ran out, DOC had a new humane kill trap (the DOC 200 and 250 series, still the standard design used throughout the country), which is a great advance on the inhumane leghold and Fenn traps. But the effort to develop some form of fertility control could only confirm that stoat reproductive processes are far more difficult to disrupt than expected.

Meanwhile, DOC began a programme of establishing "mainland islands", where patches of forest habitat were managed as refuges for native species. Starting in 1990, by 1995 the programme had expanded to six sites, listed by Towns (2023; Table 14.1). Almost all were larger than any offshore islands from which pests had been eradicated, and none met that goal, but they pioneered the need to document the results at ecosystem level, and to engage local communities in the work. That in turn fired up wider ambitions for more public investment in predator control operations, greatly encouraged by Sir Paul Callaghan's 2012 vision of an "Apollo programme" for a New Zealand free of all introduced predators.

Over the next few years, increasing documentation of the damage to native biota due to rampant numbers of rats and possums broadened concern from stoats to invasive mammals in general. Rob Fenwick and Gareth Morgan, both close friends of Sir Paul, set up the Predator Free NZ Trust, an independent charitable organisation aiming to encourage, support and connect New Zealanders in getting involved in the predator free movement. A 2015 review of the economic costs and benefits of local eradications suggested that co-ordination of "a 50-year strategy for a predator-free New Zealand …to be ecologically obtainable, socially desirable, and economically viable" (Russell et al. 2015).

In 2016 the Government launched the PF2050 mission with a televised announcement by the then Prime Minister John Key. It offered NZ$7 million a year to seed-fund a new, visionary programme aiming to eradicate rats, mustelids, and possums from throughout the main islands by 2050. The idea has blossomed into a national movement now deploying NZ$300 million, distributed among more than 30 organisations working together in a broad collaboration of iwi and hapū, NGOs, businesses, government, and community groups. They are united in a common cause and monitored by a DOC team under Programme Manager Brent Beaven. It also includes a new Crown entity, Predator Free 2050 Ltd, a company set up to invest in large landscape scale projects and breakthrough research. The first five-year report on PF2050 summarises some impressive results (Department of Conservation 2021). Better still, wide publicity and more funding have encouraged strong public participation in many other new and existing programmes not directly affiliated with the official PF2050 movement.

Early successes are very encouraging and help to promise more of the same. Only in hindsight may it appear that even a carefully planned project could not produce the right answer to a problem in the long run, because it was either asking the wrong question, or asking the right question but choosing the wrong answer. That happens easily when the wrong one seems the most obviously right one at the time.

For recovery of New Zealand's biodiversity, the right questions are not only about how to kill more pests, but, more urgently, also about how prevent rapid reinvasion of cleared areas, and how to develop an outcome-based monitoring system. Counting dead pests does not measure outcomes, but is easy and necessary to maintain enthusiasm among field staff and volunteers. Management policies of the past that could not prove they were asking the right question are common (Caughley & Gunn 1996). Some of these, that were not noticed or corrected in time, have committed massive effort at national scale for little benefit to New Zealand's native ecosystems. A recent review raises the possibility that PF2050 might become one of them (Leathwick & Byrom 2023).

How world views determine management questions

Even though it has long been known that all the species targeted by PF2050 are actually controlled from the bottom up (Norbury 2017), the campaign as announced in 2016 was and is based on the assumption that they can be controlled from the top down, by attempting to exceed the already high mortality of adult mustelids and rats despite their huge reproductive rate. The original announcement prompted immediate and explicit warnings, from a large group of experienced pest managers (Parkes et al. 2017), that top-down methods alone cannot control highly productive pest populations even in principle, unless the cleared areas can be isolated from immigrants.

History has long ago demonstrated that problem when official mass killing campaigns didn't work for deer (1930s) or rabbits (1947–71). The well-known conditions for eradication of a pest—every individual must be at risk, reinvasion prevented, and funding unlimited—were emphasised by Parkes and Murphy (2003) and have been confirmed many times since (Leathwick & Byrom 2023). These conditions can be met for island populations of rats or mustelids, but on the mainland only in fenced sanctuaries. It could be argued that PF2050's millions now allocated to impossible national eradication schemes would be better spent on building more fenced sanctuaries.

The world views of managers charged with removing deer, rabbits, and predators are pivotal to the design of their programmes because they determine what those managers see as the most important facts to gather, what questions to ask, and what would count as acceptable answers. The PF2050 programme and its participants are collectively committed to the particular world view that fewer possums, rats, and mustelids will inevitably allow more wildlife, even while the many other ecosystem processes that damage the native fauna are (at the moment) outside its remit. All such usually unconscious defaults depend more than we usually recognise on our view of how the world works. The philosopher Mary Midgley states simply that "Facts are not gathered in a vacuum, but to fill gaps in a world-picture that already exists" (Midgley 1985).

We scientists pride ourselves on being able to see the world objectively, without reference to personal opinions. In practice, that is nearly impossible. All scientists perceive their work through a particular world view, shared with the colleagues they work with. Our world views are fundamental to our thinking because they determine how we judge what questions are worth asking, and what answers are, or are not, potentially acceptable. The problem is that our world views are seldom scrutinised because they "peep out only briefly, like very early mammals, from a protective thicket of assumptions" (Midgley 1992).

Most of us are unaware of the extent to which our unrecognised world views determine, not only the way we think, but also the extent to which we manage our work to make it acceptable to the people we respect. Few researchers or graduate students working in a prestigious zoology department question their common and deeply shared world view based on the currently accepted version of Darwinian evolution. Likewise, few editors of high-profile mainstream journals (other than those specialising in philosophy) would publish a manuscript overtly contradicting the world view of most of their readers, except as a provocative comment. The few authors that try, tend to find a sceptical audience (Steer 2015; Doherty & Ritchie 2016).

In the 1970s, the official aim to exterminate stoats from all national parks was taken for granted as necessary and feasible. My own first attempt to explain why that aim would be impossible, but that temporary protection of birds in selected places and times might be feasible (King 1981), only angered those who had expected me to show them how to eradicate stoats from all the national parks. Fortunately, official world views can be modified by experience over the long term and by robust discussions acknowledging the challenges presented by those who disagree with their assumptions. So the dismal discussions and conclusions of a 1976 conference on the impossibility of controlling rodents in New Zealand nature reserves, expertly summarised by William Stolzenburg (2011), were overturned by the discovery of brodifacoum.

In our work, as in life generally, our world view admits new ideas or facts only if we can relate them to what we already know. We each have a set of mental pigeonholes classifying categories of acceptable knowledge. To process a new idea or fact, we need to put it into an understandable context, so as to make sense of the unknown in terms of the known. Most of us judge the truth of a statement by whether it is consistent with what else we know about that subject. If there is no relevant pre-existing context, unfamiliar facts can be ignored, or even become quite invisible.

For example, the world view of nineteenth-century pastoralists, convinced that rabbit numbers are controlled by their natural enemies, could see only the need to introduce rabbit predators to kill more rabbits. They were warned that introduced predators would kill native fauna as well as rabbits (Buller 1877), but they dismissed that idea as irrelevant because their world view saw native fauna as inferior, and less valuable than sheep anyway. In 1876, one runholder, a Captain Fraser, informed Parliament that he "was very fond of birds; but if it came to a question whether he would have birds or sheep, he would certainly vote in favour of the sheep". This story and many other examples explaining the whole sorry saga is summarised by King (2017, 2020). Contemporary research on rabbit ecology asks quite different questions and collects quite different sets of facts (Norbury & Jones 2015).

In 1930, botanist Leonard Cockayne believed that over-browsing by deer was damaging mountain vegetation and vastly accelerating soil erosion. His world view led to his prediction, quoted with relish by Graeme Caughley (1983), that, if the numbers of deer were not controlled, "vast areas of mountain-side will be turned into moving debris". Ten years of intense official effort by teams of ground hunters and a lot of money spent to eradicate deer from the high country proved that the high erosion rate in mountain land could not be prevented by removing deer browsing. Yet, even after the official programme stopped, the vested interests of deer hunters ensured that Cockayne's view remained widely acceptable for decades.

A better answer, related to the vulnerability of New Zealand's fragile, young landscape to heavy rainfall, did not appear until the 1980s. Every past period of warm, wet high-energy atmospheric conditions caused massive storms and episodes of heavy soil erosion, accumulating thick layers of gravel downstream. Hydrologist Pat Grant showed that these layers are dateable to long before the arrival of deer in the high country (Grant 1985). Bruce McFadgen (2007) documented the effects of mass erosion episodes on pre-European Māori communities. The risk of massive erosion and landslides caused by such storms have seldom been more clearly demonstrated than by Cyclone Gabrielle that hit New Zealand in February 2023.

These examples starkly demonstrate how the perceived problem is usually only the most obvious symptom of a deeper issue, not the actual cause of the trouble, unknown to those afflicted by it. The wool barons could not know, or even imagine, that rabbit density more often controls the numbers and distribution of their natural enemies than vice versa (Norbury et al. 2002). Cockayne's world view "evolved into a treasured axiom rather than into a testable hypothesis" (Caughley 1983). So, the process of identifying the right question depends on profound knowledge of the hidden landscape underlying the visible problem.

Hence, even if two or more people holding radically different world views are looking at the same real-world scenario, they can extract different sets of facts from it, and draw opposite conclusions from them. The technology and social licence of managing invasive species are at risk of becoming increasingly controversial, so have huge potential for conflict generated by colliding world views (Simberloff et al. 2013). An equivalent truism is very obvious on the public stage of recent American politics.

Thinking about these examples of how researchers were seduced by the wrong questions in the past leads to speculation about what possible examples of the same mistakes might arise in the future. We are not immune to asking the same sort of wrong questions that our predecessors did, so we should be especially alert to spot them before we commit money on management policies that cannot solve a current problem because they are not asking the right question about it. Like our predecessors, we are vulnerable to tunnel vision: concentrating on one question (or one aspect of a wider question) to the exclusion of all others. But the emotional associations of the PF2050 campaign vastly strengthen the incentive to think that way.

The fundamental dilemma of PF2050

In 1984, Graeme Caughley published a seminal paper outlining his view of the two most important paradigms of conservation biology (Caughley 1984). His second paradigm, concerning the rescue of a declining population, asserted that if the cause of the decline could be identified and defeated, the decline could be reversed. The PF2050 campaign accepts this statement at face value and therefore reasons that if the distressing national biodiversity decline is caused mainly by introduced predators, past losses of national biodiversity could be reversed by removing predators at national scale. The unstated assumptions behind that view are expertly dissected by Leathwick and Byrom (2023).

The fundamental dilemma of PF2050 is that it is a particular world view based on two back-to-front ideas. PF2050 generally assumes that (1) pest numbers can be reduced by imposing massive top-down surplus mortality on pest populations, and (2) that success in reducing pest numbers will automatically benefit native biota even if not measured. PF2050 operates standard and emerging predator control methods which are based on human attempts to exceed the natural losses of resilient pest populations.

This approach is achieving good progress against possums, but rats and mustelids are supreme opportunists, with wide tastes in food and enormous reproductive capabilities. Their numbers are controlled from the bottom up by their food supplies. Their life history strategy is one of "breed early, live fast, die young" in which individuals are short-lived, with high fertility and high natural mortality. Top-down pest management against rats and mustelids risks being seldom intense enough even to match the level of sustainable harvesting.

Pest numbers are easily predicted by regular resource monitoring, even when the pests themselves are elusive. Any period of abundant food, such as during a masting event in beech forest or alpine tussock, produces predictable, massive increases in juvenile survival of mice, rats, and stoats, leading to brief but unpreventable peaks in predator numbers dominated by short-lived young of the year (Innes et al. 2001; Wittmer et al. 2007; King & Powell 2011). Monitoring seedfall and temperature cues in forests dominated by southern beeches (Nothfagaceae) can reliably predict the next irruption of mice and stoats, giving conservation authorities 6–12 months to prepare a co-ordinated response (O'Donnell & Phillipson 1996; Kelly et al. 2013).

The same applies to podocarp-broadleaf forests. For example, at Okarito Kiwi Sanctuary, good fruiting seasons for rimu *Dacrydium cupressinum* in 2002, and for kahikatea *Dacrycarpus dacrydioides* in 2003, were followed by huge irruptions of ship rats and stoats (Murphy et al. 2008). Rats and mustelids can usually replace themselves faster than they can be removed, except in really bad breeding seasons. For example, the summer of 2000/01 was a crash year for mice in Fiordland, and no juvenile stoats survived to independence at all; the peak population of stoats comprised one-year-olds born during the previous irruption (Purdey et al. 2004). Likewise, an especially good breeding season for rabbits benefits ferrets, with equally drastic consequences for lizards, adult kiwi and other ground-nesting birds (Norbury 2001; Robertson & de Monchy 2012).

The irruptive capabilities of rats and mustelids have enabled them to resist the population-level effects of every kind of lethal device people have thrown at them for many, many generations. Stoats and weasels have been targeted since the mid nineteenth century by gamekeepers in Britain. Collections of gamekeepers' carcases and kill records have proved to be valuable resources for understanding why British stoats and weasels are so hard to control even over landscapes much more accessible than most of New Zealand (McDonald & Harris 1999, 2002).

In New Zealand, the imported stoats, weasels, and ferrets were at first protected as "enemies of the rabbit", but this privilege was increasingly challenged in rabbit-free forested areas until 1936 when it became legal to kill mustelids anywhere (Wells 2009). Likewise, Norway and ship rats have been subject to traps, poisons, dogs, ferrets, and any other lethal device people could think of since their ancestors arrived in Europe centuries ago, with only local and temporary effects on their numbers, if any. Their descendants that reached New Zealand as stowaways on European ships could not have been prevented from landing. They are still abundant despite decades of attempts to get rid of them (Innes et al. 2023).

Of course, predation is not the only factor determining the numbers of prey animals. But it is prominent because it is easier to understand than the much bigger and far more important question of true ecological restoration (Towns 2023). So the most uncritical advocates of extending PF2050 to national scale constantly maintain their view even though (1) it cannot meet the known conditions for national eradication of pests and does not target other significant pest species, the feral cats (*Felis catus*), mice, and hedgehogs (*Erinaceus europaeus*) widespread in all habitats (Breedt & King 2021); (2) it invites mesopredator release (Sweetapple & Nugent 2007;

Whitau et al. 2023); (3) as a strategy intended to apply across the inhabited main islands, it is rejected by experienced pest managers, and has so far proved impossible even at smaller scale, e.g. on Waiheke Island; (4) and counting numbers of pests killed is the wrong measure of success (Innes et al. 2023; Leathwick & Byrom 2023). Critics point out that the focus on predator suppression supplies little new information on ecosystem dynamics compared with the operational funds spent and distracts attention and funding from other, potentially more achievable aims (Linklater & Steer 2018). Such persistence in upholding a questionable ambition against cogent objections risks later exposure that could discourage its most enthusiastic supporters (Palmer & McLauchlan 2023). Mary Midgeley points out that "'campaigning activists are usually defending a commitment to a particular view of the world, and only secondarily if at all to the prospects of achieving it" (Midgley 1992).

To be fair, only those deeply involved in the background management of PF2050 know that its work also has extensive links with other biodiversity programmes and is always aware of the broader suite of research and development required to make progress. DOC has a National Eradication Team to develop new tools for predator removal and outcome monitoring, and a proactive islands programme. All of that is important, necessary, and welcome, but is not the same thing as enabling the eventual success of PF2050 on the mainland at national scale. The critical issue there is not achieving an eradication but preventing reinvasion, for which only pest-proof fencing is a proven tool.

Kiwi, the critical test case

Kiwi are our national icon and the focus of much anxiety as their numbers continue to decline. The formulation of the First Kiwi Recovery Plan in 1991 led to important advances in kiwi conservation work. Many active programmes have been preventing the loss of some critically endangered kiwi populations since long before the launch of the PF2050 programme. But the promised relief for kiwi, as for native biodiversity generally, is not a simple on-off switch; rather, there is a sliding scale of suppression benefits linked to the extent and efficacy of protection.

DOC's Fourth Kiwi Recovery Plan 2018–2028 (Department of Conservartion 2018) sets a national target of at least 2% annual population increase to 100 000 kiwi by 2030. Figure six of that plan shows that five of nine named kiwi populations are achieving that growth rate and, in all five, 50% or more of the birds are under existing management. Four others with 20% protection or none are still declining. So, the gains made by the protected populations are being offset by the losses in others, especially to stoats in the South Island. The present overall growth rate of 1% a year is much too slow to reach the 2% threshold.

At one of four Northland sites with a high adult mortality of 7.3%, unprotected chick survival was 0.111 and population growth rate was minus 2.54. At a second site, trapping over 200 ha conveyed scarcely any benefit (survival 0.147, growth rate minus 1.710). A third site using toxins permitted a marked increase in chick survival and growth rate (to 0.326, 3.330). At the fourth site, Operation Nest Egg had the same effect as an eradication, but by removing kiwi eggs rather than predators from the field. Under captive incubation, chick survival reached 0.869, but other species got no benefit (Robertson et al. 2011). For PF2050, the third and fourth options are much better than doing nothing or trapping alone, but both are problematic at landscape scales.

In any small area undefended from reinvasion, the protection offered by trapping is poor, but in very large kiwi sanctuaries protecting thousands of hectares by long term trapping, adult mortality rates of 1%, chick survival rates of > 60%, and population growth rates of 6% are routine. But even there, trapping efficiency declines as the proportion of trap-shy stoats increases. The progressive reduction in trapping effectiveness is well illustrated at Whangārei Kiwi Sanctuary, from 67% in 2003 to 24% in 2008, and at Moehau, from 95% in 2002 to 38% in 2007 (Robertson & de Monchy 2012). Large and important offshore islands cannot be cleared of stoats, at least not by trapping.

The view that stoats kill many native birds, especially kiwi chicks < 6 months old, is a standard hypothesis that has been tested many times and confirmed to be true in kiwi sanctuaries. At Okarito between April 2001 and July 2004, more than 10 000 rats and 1950 stoats were removed from the sanctuary, yet this intensive trapping could not prevent the loss of all 14 radio-tagged kiwi chicks of the 2002 season of which 13 were killed by stoats (Murphy et al. 2008). This example warns that mass removal of stoats and rats does not necessarily provide the benefit expected.

The implication, that "the persistence of kiwi on mainland New Zealand is now largely dependent on the development of new techniques for controlling stoats" (Basse et al. 1999) was one of the driving forces behind PF2050, and in much of the South Island is still true. At the moment, suppression of stoats by regular trapping on any large area is possible, but total eradication is not, even on uninhabited Fiordland islands, because adult stoats are so quick to develop trap evasion (Veale et al. 2013).

Predation on adult kiwi by dogs (not included in PF2050) is a different matter, now being addressed by various programmes such as kiwi avoidance training. Where dogs are absent or effectively managed, the next main threat comes from ferrets. The series of landscape-scale 1080 drops in the Tongariro Forest Kiwi Sanctuary show that kiwi populations increased for two straight years after each of the regular 1080 aerial control operations (Robertson et al. 2019), but then the gains were reversed as ferrets returned.

So in the North Island, the long-cherished vision of PF2050 restoring kiwi populations by eradication of stoats has been overtaken by later observations showing that the restoration of kiwi populations does not depend only on protection of chicks from stoats. In some areas, kiwi declines are driven by a combination of losses, of adults killed by ferrets and dogs, and of juveniles killed by stoats. In these places, the critical factor affecting kiwi population growth is unnaturally high mortality of adults (Robertson et al. 2011), which can reduce the life expectancy of the normally long-lived breeding stock by two thirds. How far can PF2050 make a difference over the long term?

Try seeing PF2050 as a game of two halves

The Roman god Janus stood at the turn of the year, watching the transition from the old year to the new (hence the first month of the year is named January, after him). The PF2050 campaign today also stands on a significant threshold. It is suspended between past assumptions that often proved wrong and future aspirations that cannot yet be achieved. Present top-down, short term strategies can provide welcome and necessary temporary relief, while the future bottom-up strategies that are needed for the long term are currently impossible and the immediate benefit to whole native ecosystems is seldom measured.

This dilemma is likely to continue for as long as those who make decisions avoid paying attention to the main strategic problem, identified by Leathwick and Byrom (2023) as the "current disconnect between Aotearoa's predominantly predation-focused management and the fact that predation is just one of a complex set of pressures driving the decline of Aotearoa's indigenous biodiversity". Worse, not nearly enough attention is being paid to meeting the ironclad rules of statistically valid, post-management outcome monitoring, as required to confirm eradication success (Barron et al. 2023) and the expected benefits for biodiversity (Allen et al. 2023). Surely, both failures are simple consequences of the way that pest-focussed PF2050 operations dominate the funding of management and research on restoring New Zealand's biodiversity. Projects necessarily go where the money is. But that situation could change.

PF2050 now: short-term, temporary top-down predator suppression

Before PF2050, eradication best practice was developed to operate on offshore islands and in fenced sanctuaries and is widely successful in removing all pest species together (except mice), enabling wonderful recovery of protected bird communities (Innes et al. 2019). The greatest beneficiaries are the rare species, for example, the nine endemics that have recorded increased numbers in sanctuaries (Bombaci et al. 2018). PF2050 as it is being implemented now, aiming to expand the protected area, is disregarding eradication best practice and consequently achieving predator suppression rather than eradication (Innes et al. 2023).

Mainland islands cannot gain an equivalent general effect, but they can cover larger areas and help to minimise further damage to the native species we still have, until we can think of more permanent ways to protect them. It is essential to keep using available top-down methods to achieve the critically important local predator suppression needed to hold off further and imminent catastrophes. Caughley called such an approach "frontal assault". Local PF2050 groups have mass public support and their work is absolutely critical to minimising or preventing further damage to native biota at local scale (local areas keep getting bigger, but few are big enough to escape reinvasion). PF2050 Ltd is working hard on improving tools for conventional lethal control and wider and wider scales.

Five years on, the first report on the progress of PF2050's work outlines many successful and inspiring local programmes. The report calmly repeats PF2050's original basic assumption that it will lead to "a land abundant with wildlife, where people's connection to nature and each other is enhanced" (Department of Conservation 2021). It sounds wonderful, and at some times and places it is, but it ignores many significant snags, plus some never-anticipated counter-intuitive dilemmas.

First, top-down methods used consistently have limitations. Trapping selects for trap-shy stoats so effectively that some individuals, especially older females, become essentially untrappable (Veale et al. 2013). The same applies to bait-shy rats. Even large-scale 1080 operations can achieve only temporary suppression of rats, which recover very quickly (Sweetapple & Nugent 2007). Occasionally supplementing traps with a short burst of 1080, or bringing in trained predator dogs, or some other alternative methods where possible, can clear out the resistant individuals and reset a trapping programme (Robertson et al. 2016), but the problem remains where 1080 cannot be used or is resisted (Hansford 2016).

Second, the assumption that blanket predator suppression should benefit native biodiversity in general does not consider the influence of evolutionary history. Two large meta-analyses (Fea et al. 2020; Binny et al. 2021) surveyed the responses of multiple bird species to different mammal control operations. Both found many cases of positive responses by deep endemic species, long adapted to life in mammal-free New Zealand, while shallow endemics benefitted less.

One unexpected finding is that some species can actually tolerate invasive mammals to the extent of being disadvantaged if removal of predators no longer suppresses their competitors. For example, a survey of 21 small Fiordland islands (most < 10 ha) compared bush bird count data from both before and after they had been cleared of predators. South Island robins/toutouwai (*Petroica australis*) and kākā (*Nestor meridionalis)* nesting in tree holes have significantly increased in numbers and spread to other islands. But six other species were encountered on significantly fewer islands; kererū (*Hemiphagus novaeseelandiae*), tomtits/miromiro (*Petroica macrocephala*), grey warblers/riroriro (*Gerygone igata*), and silvereyes/tauhou (*Zosterops lateralis*), plus the introduced dunnock (*Prunella modularis*) and chaffinch (*Fringilla coelebs*). Direct aggression by toutouwai is the most likely reason why these smaller bird species have declined on (or are excluded from) small islands when toutouwai become abundant (Miskelly et al. 2021).

Third, the essential literature review vital to preparing for any expensive operation is now often limited to recent sources only. Hence, the experience and thoughtful advice available in the older literature is overlooked, and forgotten past lessons have to be learned again. For example, in the days when the primary pest management problem was the use of natural enemies to control rabbits, Richard Henry pointed out that "The real natural enemy of any animal is that which removes its food: - the rabbit of the sheep; the ferret of the cat; and the weasel of the stoat." (Henry 1887). Henry's insight on the intraguild relationships among predators has been confirmed by the work of Patrick Garvey (Garvey et al. 2015; Garvey et al. 2022).

In the 1990s, research on ferrets was funded by agencies concerned to limit the spread of bovine tuberculosis (Moller et al. 1996), but the results are very relevant to contemporary efforts to protect adult kiwi from ferrets. Removal of stoats is increasingly benefitting weasels, and removal of ferrets surely has implications for PF2050 operations that cannot yet include cats.

PF2050 in future: long-term eradication from the bottom up

By contrast, the PF2050 vision of the future needs a quite different and longer-term approach. Without denying the critical value of top-down methods for immediate damage control, a permanent result needs to find a way to supplement top-down logic with new tools that work from the bottom up. For success at the national level, PF2050 must of course continue to develop new lethal tools, but ultimately these still feel like bailing out a bucket with a teaspoon. In the long run we need smaller buckets, not more teaspoons.

To make that transition, we need to move from asking questions about how to maximise efficient killing of pests to asking different questions about how to minimise the number of pests out there to be killed. This is a wicked problem (Woodford et al. 2016), dogged by deep disagreements among stakeholders holding different world views defining acceptable technologies. Standard evidence-based approaches may fail to resolve them, if they are deeply influenced by layers of social inequity and history, says David Towns (2023).

Geneticists might think about various potential forms of heritable anti-fertility agents, but gaining a practical formulation and permission to use it may be challenging in a country hitherto reluctant to authorise release of genetically engineered animals. That view could change, but any such newly permissible technology will take time to develop. Historians would certainly be nervous that any future release of a successful self-perpetuating control agent would become a 21st century equivalent of the original importations of mustelids. Understandably, the substantial investment needed to revitalise previously unsuccessful research on fertility control of stoats is not officially mentioned (Murphy et al. 2019), and progress on new ideas is confidential.

Meanwhile, we already know that stoat and ferret numbers are controlled primarily by juvenile survival, which depends on food supplies from August to January, especially on the abundance of mice, rats, and rabbits. For less than the cost of new anti-fertility methods aimed at disrupting the productivity of the adults, we could perhaps accelerate existing methods of removing whole cohorts of the young before they learn to evade traps. Well-timed landscape-scale 1080 drops that clear out all mammalian predators and prey together do that job very well, although not for long. We do urgently need a better way of doing the same thing more permanently, by asking the right questions about traditional assumptions and outcomes.

Conclusions

Graeme Caughley used to say "If your management action does not produce the result you expected, you haven't understood the problem". That is why functional, effective management programmes for protected fauna can make progress only by first formulating clear objectives testable on real documented cases (Caughley & Gunn 1996). By comparing the expected and actual answers to each test, researchers can be led to ask the right questions about how to protect our biodiversity at steadily increasing scales.

The paradigm example is the eight-year experiment run by Innes et al. (1999). It listed the possible causes of the decline of the North Island kōkako and predicted the results from management actions targeted at each cause and no other. The net result was that the right questions to ask turned out to concern the removal of rats and possums, but not stoats, plus extended legal protection of their primary habitat, old-growth podocarp forests. Implementing these conclusions over 30 years has not only arrested what once seemed an inevitable decline, but reversed it so strongly that DOC could report by March 2021 that the national population of kōkako exceeded 2000 pairs.

The failed historic battles against deer and rabbits did not conduct any such experiments. Even the kōkako example was too narrowly focused on a single species to be an example for PF2050 generally, and other programmes with no such preparation all too easily end up by asking the wrong question. So why would PF2050's aspirations be any different?

It could be argued that PF2050 and its broad-scale, co-operative organisations really have found a different approach. The deer and rabbit programmes were operated by employees paid to work in remote country according to fixed employment rules. Some of them did also personally aspire to see the mountain forests protected from too many deer, or to see "the last rabbit" removed from sheep pastures, but most worked largely for the pay. The world views of the Government departments providing the funding, and of their programme managers, were driven by and limited to serving the commercial interests of city planners, soil and water authorities, farmers, and pastoralists.

By contrast, PF2050 has become a mass movement inspired and driven by community action. The people who faithfully tramp around their trap networks in all weathers share a common, unlimited vision of future restoration of threatened national identity, most untroubled by scientific doubts. They cannot catch all the rats and mustelids that are present, and that those they do catch will be quickly replaced. But they hold on to the hope that they are helping to at least "hold the fort", and they do it for love: a much more powerful incentive than money.

Indeed, PF2050's world view, based on determined faith in national pest suppression by top-down methods, does work locally and over the short term, with welcome and encouraging results especially where biodiversity monitoring proves a benefit and reinvasions can be prevented. But as applied to the whole country over the long term, it is as vulnerable to failure as any past programme. PF2050's confidence, in itself derived from local successes, needs to take notice of calls for much more than casual observation as evidential support that predator control alone is actually beneficial for all native biota in general.

For example, long-term (1998–2009) intensive control of stoats and rats plus pulsed 1080 drops in beech forest of the Landsborough Valley removed hundreds of pests, but later analyses concluded that the benefits for the two focal threatened taxa (mohua and kākā) did not much help other bird species (O'Donnell & Hoare 2012). Targeted removal of rats may even be counterproductive, because it favours mice, which are significant predators of skinks (Monks et al. 2023). A wider survey of 155 published field-based studies assessed claims of biodiversity benefits and found frequent violations of the statistical rules required to test the evidence (Allen et al. 2023).

Without minimising the value of their many local successes, PF2050's hope of extending their results to the entire inhabited mainland, with minimal linkage between action and ecological benefit, or including scientists in policy development, remains a concern. The assumption that eradication of only mustelids, possums, and rats will be enough to benefit native communities generally has not been proven.

Exclusive concentration on predator suppression makes it the wrong—or at least, incomplete—long-term answer to the question of restoring national biodiversity. The right question asks about the critical role of functioning ecosystem dynamics in supplying the food and shelter needed by the surviving threatened species. Some 40% of New Zealand's pastoral landscape comprises exotic grassland where forest-adapted native species cannot find enough food to live; so how would removal of passing predators benefit them? We've had this problem before. Why do we not learn from history? Because we think that things are different now, forgetting that, as Mary Midgley points out, “Past errors differ from present ones only by being easier to see” (Midgley 1992).

We forget that nature is on the side of the pests. Natural selection favours all traits providing a reproductive advantage to any individual able to escape or refuse engagement with our technology. Surely, we ought to be able to learn from our own history of failed previous pest control programmes. But the accelerating public demand for increased predator control technology is entirely understandable and has stimulated very welcome community participation in PF2050 projects, a simple one-issue campaign that speaks to the heart. The idea of PF2050 is also easily captured by passionate and well organised lobby groups, in part because, in some cases at least, it is able to offer financial rewards to those who agree with its underlying assumptions.

A future shift in focus will require re-examining our world views so as to better see what are the right questions to ask and what facts our research programmes should gather. Arthur C. Clarke’s third law of prediction pointed out that any sufficiently advanced technology is indistinguishable from magic (Clarke 1973). The future success of PF2050 will certainly require a magical combination of known and unknown ways to tackle pest numbers from bottom and top together. And more attention to Caughley’s advice on how to identify the right questions to ask.

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