Department of Conservation
Te Papa Atawhai

Toitū Te Whenua
Land Information New Zealand

Long-term Insights Briefing

How can we help biodiversity thrive through the innovative use of information and emerging technologies?

Te Kāwanatanga o Aotearoa
New Zealand Government

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Department of Conservation and Toitū Te Whenua Land Information New Zealand. March 2023. *Long-term Insights Briefing: How can we help biodiversity thrive through the innovative use of information and emerging technologies?*

Chief Executives' foreword

Gaye Searancke, Tumu Whakarae mō Toitū Te Whenua, Secretary for Land Information and Chief Executive.

Penny Nelson, Director-General of the Department of Conservation.

Welcome to our Long-term Insights Briefing (LTIB) that explores how information and emerging technologies can play a role in looking after the biodiversity in Aotearoa New Zealand.

Biodiversity plays an essential role in the natural processes that support all life on Earth. Here in Aotearoa New Zealand, our rich and unique biodiversity sets us apart internationally and as people. We have a duty of care to ensure the unique species found here are healthy and thriving, and that we use natural resources sustainably.

Sadly, our biodiversity is in crisis, and this is mostly due to our own actions. We need to fix this, because when nature is in trouble, so are we. Transformational change is possible but only if we understand the issues we face and act now. We must respond at all levels from local to global, and we must use all the means at our disposal, including exploring the opportunities offered by emerging information and technology tools.

Together, Te Papa Atawhai Department of Conservation (DOC) and Toitū Te Whenua Land Information New Zealand (Toitū Te Whenua) manage around 40 percent of Aotearoa New Zealand's land on behalf of all New Zealanders. This includes some of our most iconic and biodiversity-rich alpine environments, wetlands and marine reserves.

Both agencies work to protect biodiversity but many of the tools we currently use are resource intensive, expensive, and do not cover enough of our land and sea. The Parliamentary Commissioner for the Environment has identified other barriers including data deficiencies, fragmented environmental reporting and a lack of clarity in how we measure outcomes.

There are technologies on the horizon that could make a difference to Aotearoa New Zealand's biodiversity and the work we do to protect it. In this LTIB, we discuss three areas that stand out as having particular promise:

- remote sensing
- artificial intelligence and data-driven technologies
- genetic technologies.

Understandably, we can't use every new technology that is invented. To be a valuable addition to our tool kit, the tools we do use must be safe, affordable and scalable, and the resulting data must be accurate, accessible and, where possible, reusable. It must also support iwi in their role as kaitiaki and those carrying out conservation work at all levels.

The LTIB process is about imagining a preferred future and opening discussions on how we might get there. We have received generous and insightful feedback from submitters throughout this LTIB process. These contributions have broadened our perspective on the use of information and technology in biodiversity protection, and have made us pause, think, shape and reshape this document as a result. We look forward to continuing the conversation with you.

Penny Nelson

Director-General
Department of Conservation

Gaye Searancke

Gaye Searancke

Tumu Whakarae mō Toitū Te Whenua
Secretary for Land Information
and Chief Executive

Contents

Imagining our biodiversity response in 2033

To set the scene for this LTIB, let's imagine how emerging technology and data could help us detect and solve a problem in the future in one of our lakes.

Lake Pukaki, Canterbury Region. Sourced from LINZ Data Service under Creative Commons Attribution 4.0 captured for Environment Canterbury.

It is 8 March 2033…

Drone footage and detailed satellite images, analysed by artificial intelligence (AI), have identified a biosecurity risk in one of Aotearoa's lakes. This lake is important to local iwi as a traditional source of mahinga kai. It contains threatened taonga species, such as tuna (freshwater eel), kōura (freshwater crayfish), and kākahi (freshwater mussels). It is also a popular site for swimming and recreation. Precision predator control of mustelids and rodents has been undertaken in the surrounding farmland and native forest in preparation to release kiwi in 2035.

The satellite and aerial footage indicate that chlorophyll-A levels are rising in the southern half of the lake, suggesting nutrification and unwanted algae growth. We suspect that a recreational boat may have inadvertently introduced this unwanted pest.

A local community group and iwi respond by surveying the lake and taking water samples. They are looking for environmental DNA (eDNA), or the genetic 'breadcrumbs' left behind by animals. The eDNA can quickly provide a list of the species present. When the results come back, we can see changes to the lake's ecosystem compared with previous years. The most concerning is the detection of koi carp (a pest fish) and hornwort (an aquatic weed). These highly invasive species were not found in previous eDNA surveys, so we think they are recent introductions. We know we need to respond rapidly.

Working together with local councils, iwi and neighbouring landowners, an action plan is put in place. The lake is temporarily closed to recreational use. New rules are developed to manage biosecurity risks, and signage is installed. Preventative education is key. An app is made available to explain the steps boat owners must take if they wish to use the lake when it is reopened for recreational use. A communication plan is in full swing, supported by ranger monitoring and enforcement.

Our intervention team is deployed. They set up a temporary barrier to prevent spread of koi and hornwort into the neighbouring waterways and focus their efforts on the sites where DNA samples from koi and hornwort were detected last week.

Camera-equipped underwater bait stations are set up to dispense pellets containing a toxin that local fish find unpalatable. Aquatic drones will be deployed on regular 'smart' search patterns, with data sent in real time to AI software trained to detect images of koi and hornwort.

The AI is 98.5 percent accurate, giving us confidence in our eradication mission. High resolution GPS helps direct staff and volunteers to where interventions are most needed. It's a 35-hectare shallow lake, so figuring out where to focus the elimination effort is vital.

Raking up hornwort from the lakebed is still the most effective way of removing this invasive plant. Two aquatic herbicides are available as a last resort if physical removal isn't effective. Research is progressing well on a 'next generation' herbicide that uses RNA technology to target genes only found in hornwort. If this goes well it will be a game-changer for controlling this weed across Aotearoa New Zealand, and around the world.

We hope we have caught the outbreak in this lake soon enough. The lake is reopened for recreational use and now joins 30 others on a priority watchlist. This means it will have remote sensing buoys temporarily installed to provide accurate, real-time data on nutrients, the soundscape, and images of biota, all monitored by AI, which can quickly and efficiently analyse complex layers of data.

A new generation of buoys also collects water samples for eDNA analysis. eDNA lets us see the food-webs that underpin a healthy lake. From this we can assess the levels of connectivity of biota in the lake. Is it a healthy ecosystem? Can it support the reintroduction of species that used to live there, including kākihi (limpet) and kanakana (lamprey)? Has work to enable fish passage in the lower catchment been successful?

Toitū Te Whenua has launched a new web service that monitors lakes on the watchlist. Data is stored in New Zealand-based servers and is shared with other agencies and groups in accordance with a data governance charter centred around the wellbeing of te taiao. The website also hosts a virtual reality tour of lakes and is a hit with our tamariki who love exploring and learning about restoration work in aquatic environments.

We are working with iwi and hapū to monitor the mauri of the ecosystem. Methods that look at the interconnectedness of the whole environment are now widely recognised as the best way to monitor the health of our lakes.

We aim to remove the lake from our watchlist before the summer of 2034. Using satellites, drones, remote-sensing buoys and the ongoing eDNA testing we can watch and analyse the lake from afar. If we need to go back, we can, but for now our resources can be prioritised elsewhere.

The early detection and timely response imagined here is not possible today. It relies on us making some of the technology choices discussed in this LTIB.

1. About this Long-term Insights Briefing

Agency responsibilities

Te Papa Atawhai Department of Conservation (DOC) and Toitū Te Whenua Land Information New Zealand (Toitū Te Whenua) have produced a joint Long-term Insights Briefing (LTIB). It examines how innovation in the way we use information and emerging technologies can help biodiversity thrive.

Both agencies have roles and responsibilities for protecting Aotearoa New Zealand's biodiversity on behalf of, and for the benefit of, present and future New Zealanders. DOC is responsible for conserving the natural and historic heritage of Aotearoa New Zealand while Toitū Te Whenua manages Crown lands including many of our most iconic lakes and rivers, and significant parts of the South Island's high country pastoral land.

Together, DOC and Toitū Te Whenua manage about 40 percent of Aotearoa New Zealand's land, including areas of high biodiversity such as the South Island's high country and our marine reserves. Innovative ways of managing biodiversity on this Crown administered land can be rolled out to private land.

Te Ika-a-Māui/North Island land administered by DOC and Toitū Te Whenua. Areas marked with a blue border and blue tint are Crown land managed by Toitū Te Whenua. A teal border and green tint indicate pastoral lease land. Brown borders with yellow highlights designate national parks, with brown borders with orange highlights are conservation land.

Te Waipounamu/South Island, land administered by DOC and Toitū Te Whenua.

Areas marked with a blue border and blue tint are Crown land managed by Toitū Te Whenua. A teal border and green tint indicate pastoral lease land. Brown borders with yellow highlights designate national parks, with brown borders with orange highlights are conservation land.

Identifying the topic and first consultation

LTIBs are intended to stimulate debate while exploring the medium- and long-term trends, risks and opportunities facing Aotearoa New Zealand, and potential options for responding to them.

DOC and Toitū Te Whenua originally proposed the topic of this briefing due to the opportunity new technologies present to scale up conservation efforts over the longer term. The key areas of interest identified as critical to supporting efforts to protect biodiversity included:

- biotechnologies, with gene editing as a subsection of this group
- data, including satellites and remote sensing technologies as valuable tools for collecting data, with artificial intelligence (AI) as a powerful way to analyse this data.

This LTIB isn't a comprehensive plan for saving biodiversity. Its purpose is to start a conversation about how to improve and scale up biodiversity restoration efforts in new ways, and with tools that are starting to show their potential.

Feedback from first consultation

Public consultation on this proposed topic was undertaken in November 2021, with responses showing strong support for the topic. Submitters also noted:

- the importance of understanding risks associated with emerging technology (particularly genetic technologies) and the need for the use of emerging technology to be transparent, participatory, use robust science and information, and be responsive to areas of concern
- a preference by some to explore nature-based solutions before considering gene editing
- the need for a thorough consideration of how data is collected, managed and used, with mention of the value of technologies such as satellites, LiDAR and drones for data collection
- the importance of finding ways to build understanding and expertise in using data and technology, and how to identify and manage opportunities and risks (AI was noted as a data-driven technology that can support biodiversity protection and restoration through faster and more efficient analysis of large amounts of data)
- the value of data and the importance of having proper oversight, transparency and coordination to ensure it was used safely and ethically
- the importance of Māori data sovereignty, including the rights and interests that Māori have in the collection, ownership and use of digital information and knowledge that is about them, their culture, language and environment.

The consultation also included futures-thinking workshops that were held in March 2022. The most common insight from these workshops was that the systems supporting the use of technology and information have a significant influence on its success or failure.

Refining the topic and second consultation

Throughout the research and first consultation process, three areas of transformation stood out as having particular promise for biodiversity conservation:

- remote sensing including satellite imagery (for much greater environmental monitoring and surveillance)
- AI and data-driven technologies (for collecting and analysing vast quantities of data)
- genetic technologies (for new realms of environmental monitoring and management).

These areas are covered in depth in chapter 3, where we examine their current state, future opportunities, benefits and limitations. Submissions included many additional technologies or subsets of the areas that we looked at.

As outlined in chapter 4, which sets out options for making the most of developments in new technology, the submissions highlighted the wealth of knowledge in our communities and the importance of working together to halt and reverse our biodiversity losses.

The Capital Kiwi Project team returning kiwi to the wild in the hills west of Wellington. Source: Capital Kiwi.

Feedback from second consultation

We consulted on the areas of transformation and the topic 'How can we help biodiversity thrive through the innovative use of information and emerging technologies?' from 28 November 2022 to 16 January 2023.

The main themes to come through in submissions were the importance of:

- working with interested groups to leverage their knowledge, experience and skills
- partnership, honouring Te Tiriti o Waitangi and collaborative incorporation of indigenous knowledge (mātauranga Māori)
- relationship building, of listening to different viewpoints and being open to different ways of doing things
- having the right foundations in place, such as regulation, data and digital infrastructure, and ethical frameworks
- education and training in digital technology at all levels to build capacity and capability to use these tools to protect biosecurity
- the government's role in providing strategic leadership, clear goals and the pathway and resources to achieve those goals.

2. Our starting point

Lamenting our losses

Biodiversity is the variability among living organisms from all sources, including land, marine and freshwater ecosystems, and the ecological complexes they are part of.[1]

The biodiversity crisis is global and Aotearoa New Zealand is not immune. Since human settlement in Aotearoa, at least 81 plant and animal species, including 62 birds, have become extinct. Measuring extinctions in groups such as invertebrates or fungi is much more difficult. Many species continue to decline or are just hanging on, with around 4,000 currently threatened or at risk of extinction. In 2021, 94 percent of reptiles were threatened with extinction or at risk of becoming threatened.[2]

Many New Zealanders are trying to change this situation. More people than ever are doing conservation work, setting traps, recording bird numbers, planting trees next to rivers or in reserves, and monitoring biota in their local rivers or lakes. However, biodiversity continues to decline.

Healthy ecosystems rely on a network of species to function. Accordingly, we must strive towards a te ao Māori view of mauri (lifeforce) and interconnectedness to achieve a healthy te taiao for future generations. While it might be convenient to count and focus on single species, it is widely accepted that this is not a good proxy for the healthy functioning of ecosystems.

The Marlborough green gecko (*Naultinus manukanus*) is endemic to New Zealand and classed as 'declining'. Credit: Paddy Ryan, Crown copyright.

[1] United Nations Convention on Biological Diversity. 1992. https://www.cbd.int/doc/legal/cbd-en.pdf

[2] Environment Aotearoa 2022. https://environment.govt.nz/assets/publications/environment-aotearoa-2022.pdf

Rob McGowan is a rongoā Māori (traditional healing) practitioner. He describes the changes he's seen first-hand over a lifetime spent carefully observing the natural world.

Rob McGowan, also known as Pa Ropata, is Amo Aratu for Ngā Whenua Rāhui.

'As I travel around, I see that more and more areas are depleted and there is less and less biodiversity. A forest might seem nice and green but if you look for specific things that you need for rongoā and they're missing, you realise it's not in good shape.

'What is happening now is far in excess of what has happened in the past. It's really troubling. In some areas the land is incapable of being healthy. Possums have stripped the trees, and goats and deer have eaten out the undergrowth. Not only are the critically endangered plants gone – the ordinary plants are disappearing.

'Many people who are close to the land have an overwhelming sense of sadness, as if the land is physically crying out for us to notice and to help. I've seen people sobbing their hearts out because of the powerlessness they feel. It's like when you see someone in tremendous pain and you can't do anything to help – it's a rotten feeling.

'For biodiversity to thrive, all its different components need to thrive. The mauri (life force) of the whenua (land) is found within the connections between them. So when all the connections are in place the mauri thrives, but when they become fractured, the mauri starts to recede.

'If we are to be well, our whole landscape needs to be well. All the species, the connections and the whole support network needs to be put back so the land can heal itself.'

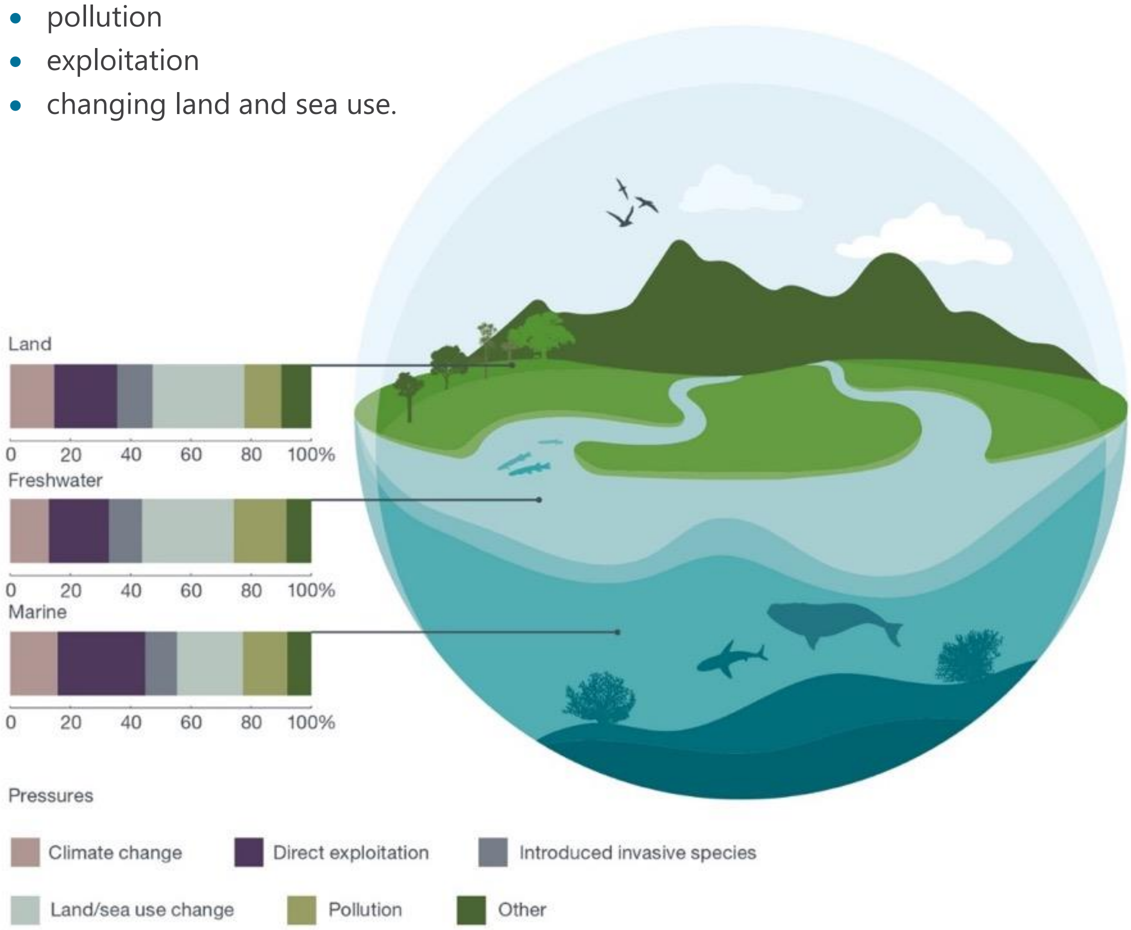
A vision for thriving biodiversity

Te Mana o te Taiao Aotearoa New Zealand's Biodiversity Strategy 2020 sets out a vision for biodiversity: te mauri hikahika o te taiao – the mauri of nature is vibrant and vigorous. It describes three pou (pillars) to guide nationwide actions at all levels to achieve the vision:

- **Tūāpapa** – getting the system right: having the right systems in place to tackle the biodiversity crisis.
- **Whakahau** – empowering action: getting all New Zealanders involved to help protect and restore our biodiversity.
- **Tiaki me te whakahaumanu** – protecting and restoring: addressing the direct pressures causing a decline in biodiversity, ensuring the sustainable use of biodiversity, and restoring biodiversity in areas where it has been lost.

While there are opportunities for new technologies to support all three pou, our LTIB is primarily focused on how emerging technologies can address the five main drivers of biodiversity loss:

- invasive species
- climate change
- pollution
- exploitation
- changing land and sea use.



Pressures on biodiversity, Aotearoa New Zealand Biodiversity Strategy (ANZBS).

Actions that directly address the drivers of biodiversity loss and enable preventative intervention are likely to make the biggest difference.

Lack of reliable data is a major barrier to action in these areas. Many of our taonga (treasured) species have a threatened species classification of 'data deficient', meaning there is not enough information to assess their risk of extinction. We don't have enough information on:

- more than a third of land invertebrates
- around one quarter of our freshwater invertebrates

Information for marine species is particularly sparse. Mapping and monitoring oceans can be difficult and expensive, but without it we cannot know where protection and restoration would be most effective.

Data status of different species, Aotearoa New Zealand biodiversity strategy (ANZBS).

Placing Treaty partnerships at the centre of work for biodiversity

Te Mana o te Taiao recognises that Māori exercising rangatiratanga (authority) and kaitiakitanga (guardianship) is essential to halting and reversing biodiversity loss.

Issues of importance to Māori need to be at the centre of any conversations about the potential use of new information and technologies for biodiversity in the future. Submitters on the LTIB stressed the importance of supporting iwi and hapū to use their knowledge of biodiversity to develop solutions to local issues. We acknowledge submissions that told us that mātauranga belongs to, and cannot be separated from, tangata whenua. Biodiversity strategies that seek to incorporate mātauranga held by local iwi, hapū and whānau need to be developed collaboratively.

Māori, as tangata whenua and kaitiaki, have knowledge and aspirations related to biodiversity. Many of these are laid out in the Waitangi Tribunal flora and fauna claim (Wai 262). Taking steps to realise the aspirations of Wai 262, and our responsibilities to give effect to the Treaty principles of partnership and active protection, will affect how decisions about indigenous flora and fauna are made, and how mātauranga and Māori aspirations are protected. This will have implications for the potential use of new and improved information and biotechnologies. Importantly, many Māori and non-Māori are aligned in that we see a future that prioritises the wellbeing and mauri of te taiao.

3. Technologies and data that can transform how we monitor and protect biodiversity

To demonstrate how innovation, information and emerging technologies present opportunities for biodiversity, this LTIB explores three areas of technological innovation that could be explored or scaled-up to improve biodiversity outcomes:

1. Remote sensing, including the use of satellites and drones, can efficiently collect more – and more accurate – environmental data. These could enable large-scale monitoring and access to places that are currently very difficult to reach.

2. Data-driven technologies, including AI, machine learning and modelling, can process and analyse vast quantities of data quickly and accurately, including remote sensing and genetic data. AI can also be used to analyse multiple types of data for nowcasting and forecasting.

3. Genetic technologies allow for new ways to collect environmental data and provide innovative tools for addressing pressures on biodiversity. Genetic technologies expand what is possible for biodiversity monitoring, protection and decision-making, and are becoming increasingly affordable.

While many of these technologies are already in use internationally, none have a large footprint here in Aotearoa. Accordingly, there is opportunity to co-develop the toolkit to suit Aotearoa New Zealand conditions. Submitters rightly point out that there are additional technologies that could be added to this list. These may be where we look in our next LTIB, or in other workstreams. The primary aim of this LTIB is to discuss the opportunities and considerations of this subset of technologies and approaches to support a national conversation to improve biodiversity outcomes.

Our aim is to create an environment where technology and data can work with other real-world tools and actions to support the aims of *Te Mana o Te Taiao*. Chapter 3 of this document showcases how technology and information are already working together and provide some examples of how they could work together more seamlessly in the future.

One of the most exciting aspects of data from technologies such as satellite imagery and environmental DNA (eDNA) is the use and re-use of data from multiple stakeholders. Satellite images collected for the monitoring of lakes could also be used to map carbon uptake of forests, or to monitor whether buildings have appropriate permits. Likewise, eDNA data collected to monitor native fish could be used to assess the suitability of water for swimming and drinking. We can imagine a future where data is commissioned and analysed more holistically to benefit many applications.

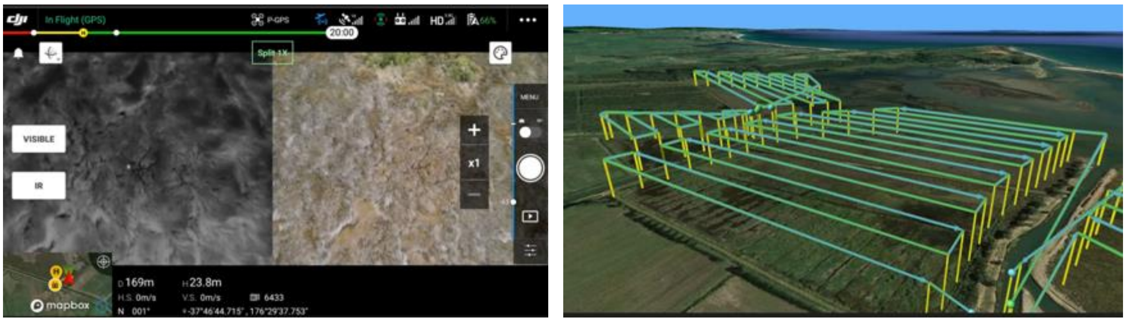
Central to the collection, use and reuse of data from the technologies discussed below is careful attention to the CARE[3] and FAIR principles.[4] These guidelines are articulated in the United Nations Educational, Scientific and Cultural Organization 'Recommendation on Open Science'.[5] Such considerations should feature heavily as we seek to integrate new technologies, and the data they generate, into our workplans.

Finally, we must recognise that a shift into technologies such as drones, AI and eDNA also needs to keep people engaged with the 'why'. There is a risk that, without education and making the information accessible, people may feel disconnected from the data as opposed to empowered by it.

Remote sensing including the use of satellite and drone imagery

Remote sensing technology has helped us to better understand our environment. We use a wide range of satellites and other remote sensing technologies such as drones and remote cameras to collect data, monitor the state of our environment and protect habitats and species.

Remote sensing is the science of obtaining information about objects or areas from a distance, typically from satellites, aircraft or drones.



Thermal (left) and visual (right) images from a drone being used to monitor bittern, a threatened bird species, at Waihi Estuary wetlands. Customised search patterns are mapped and the drone then follows that pattern but can investigate other areas as required. This image was followed up by an investigation on foot, and a bittern nest was discovered in the rush land. Metadata at the bottom of the image includes the drone's distance from the pilot, height and bearings. Credit: Henry Caley.

[3] Collective benefit, authority to control, responsibility and ethics, and their respective sub-principles, with regard to how data is treated with respect to indigenous governance.

[4] Findable, accessible, interoperable and reusable, and their respective sub-principles.

[5] https://unesdoc.unesco.org/ark:/48223/pf0000379949.locale=en

Status and current uses

The first satellite, Sputnik 1, was launched in 1957 and sent a radio signal to Earth for three weeks before its batteries died. Satellites are now orders of magnitude smaller and cheaper. They carry a wide range of instruments and are used for data collection, telecommunications, safety, weather forecasts, navigation, defence and environmental monitoring. Satellite numbers have steadily increased, with a record 1,400 launched in 2021.

Historical satellite data has been used by NIWA to track the amount of sediment reaching the coast in the past 20 years. The images show where the most sediment is coming from, so work to reduce erosion can be targeted to particular river catchments. Future images may show how restoration activities are making a difference.[6]

Plumes of damaging sediment are clearly visible along the South Island's east coast.

Other current uses for satellite imagery include protected area management[7], species reintroductions[8] and population monitoring[9].

LiDAR (light detection and ranging) is the use of lasers to produce high definition, three-dimensional images of a landscape including the vegetation. Toitū Te Whenua is partnering with councils to map 80 percent of the country by 2025. The information is publicly available and is being used to accurately map environmental changes over time.

Drone use has grown rapidly in the past decade as these have become cheaper, and can easily be equipped with a variety of sensors. Current uses include control of pest insects[10], monitoring habitat and managing wildlife.[11]

Drones have been used in Marlborough to search for chalk cress, a tiny native plant with a conservation status of Nationally Critical.[12] Much of the plant's habitat is too dangerous for humans to survey, but the data can be collected by drones.

[6] Monitoring suspended sediment in Aotearoa New Zealand coastal waters. https://www.doc.govt.nz/nature/habitats/marine/threats-facing-our-oceans/sediment-and-our-coasts/monitoring-suspended-sediment/

[7] Digital Observatory for Protected Areas. http://dopa.jrc.ec.europa.eu/

[8] Earth observation: overlooked potential to support species reintroduction programmes. https://onlinelibrary.wiley.com/doi/abs/10.1111/aje.12060

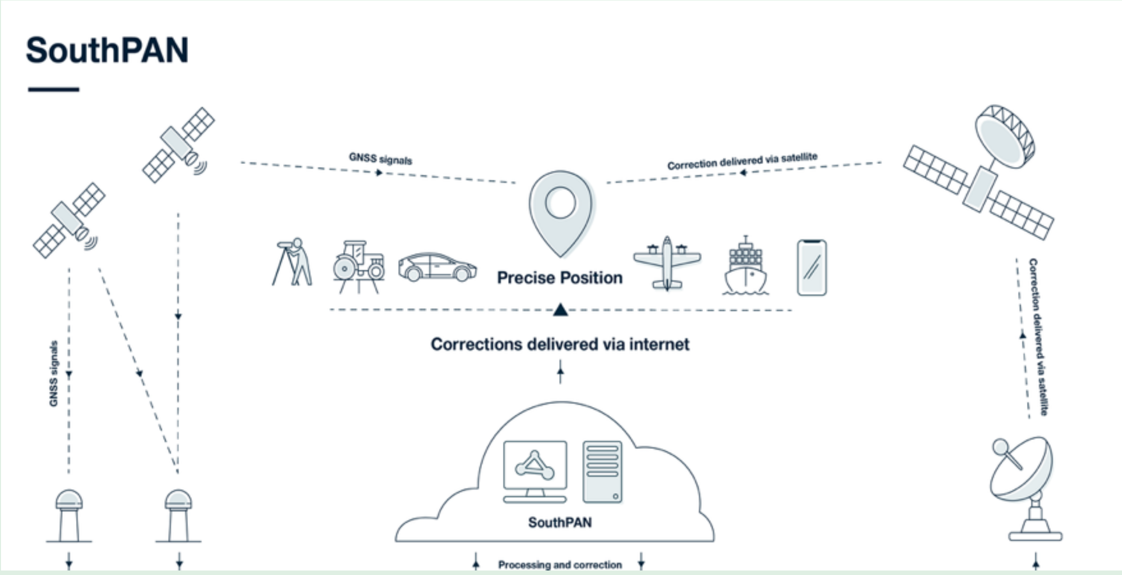
[9] For example, counting penguins from space. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0033751

[10] The processionary of the pine. https://www.fitostinger.com/en/pest-control-with-drone-technology/pine-processionary/

[11] Drone technology for monitoring protected areas in remote and fragile environments. https://www.mdpi.com/2504-446X/6/2/42/htm

[12] How drones are helping our threatened plants. https://blog.doc.govt.nz/2021/09/30/how-drones-are-helping-our-threatened-plants/

More accurate GPS information for Australasia



SouthPAN satellite-based augmentation system. Source: https://www.linz.govt.nz/products-services/geodetic/southpan

Many conservation and land management tasks depend on knowing the location of an object, like a riverbank, a trap, a wetland, a tree or where a pest fish was found. Current GPS systems are accurate to within 10 metres, but the new SouthPAN (Southern Positioning Augmentation Network) system will improve the precision of positioning to within 10 centimetres.

SouthPAN is a partnership between Toitū Te Whenua and Geoscience Australia.

During the planning phase, agencies and organisations involved in conservation were asked how the new system would benefit their work.

Responses included:

- Greater precision would make it easier to monitor biodiversity in a plot of land
- More accurate farm planning and animal management could reduce environmental impacts
- Accurate location data for people and machinery could improve safety
- Pollution sources could be pinpointed and dealt with more easily
- The exact location of nesting birds or seed fall from specific trees could be mapped
- Trapping and use of pesticides could be more accurate and efficient

Compliance monitoring could be supported and environmental standards enforced.

SouthPAN could help us identify changes to habitats and species, improving decision-making around conservation. In the long term, more precise global positioning could lead to new innovations and benefits we haven't even thought of yet.

While SouthPAN has already started operating, its capability will be progressively enhanced over the next five years as ground stations are established and new satellites come online.

Oblique imagery – a new angle on ecology

Because oblique imagery is captured at an angle, it provides more detail than a standard orthorectified aerial photograph.

Dr Paul Dutton, Waikato Regional Council scientist, says oblique imagery has been useful for identifying and managing forest fragments along the Waikato River. 'No council has enough money to visit every site, and access is always an issue – if you're lucky, you could visit one site per day. But with oblique imagery, one person can review the pictures and classify dozens of forest types and locations in a day. It's very efficient.'

The information we now have because of the oblique imagery and the analysis and classification done can be used to inform decisions around restoration projects.

'In one project, we're trying to join up the tiny fragments of kahikatea forest that were found using oblique imagery, and fence and buffer what's left. It's an ecosystem type with only 1 percent of its original cover left in the region, so it's a priority to protect it.'

This data also provides a historical reference which can be continually compared over time to observe change.

The work was commissioned by Toitū Te Whenua, with 30,000 photos taken from an aeroplane along the length of the river. The data is publicly available and could also be used for farm plans and other monitoring and restoration work.

Future trends

More accurate GPS could protect biodiversity by fitting collars to cattle to create a virtual fence. CQ University Australia. Source: https://frontiersi.com.au/wp-content/uploads/2018/08/SBAS-Test-bed-Overview-Report.pdf

Technological innovation means the tools we use to study the natural environment will continue to become cheaper, smaller, durable, more precise and accessible.

As GPS receivers and harmonic radar transmitters[13] shrink, they could be used to monitor smaller species, including insects, and learn more about their movements.

Increased precision would help in monitoring the growth or shrinking of wetlands, for example. This could allow the more accurate application of pesticides, weedkillers and fertiliser, reducing the amount used while increasing their effectiveness.

The area of Aotearoa New Zealand that has been mapped by radar and LiDAR is steadily increasing, which will enable us to map changes over time, such as the effects of climate change and land management.

Measuring sensors are becoming cheaper and are in the hands of more people. For example, many phones have LiDAR capability built into them[14], giving millions of people the opportunity to report data and contribute to community conservation projects.

Improvements to the hardware used in satellites has significantly increased the resolution of satellite imagery. Huge amounts of this imagery are widely available online.

[13] Harmonic radar is used for tracking tagged species over different terrain.

[14] LiDAR is one of the iPhone and iPad Pro's coolest tricks: Here's what else it can do. https://www.cnet.com/tech/mobile/lidar-is-one-of-the-iphone-ipad-coolest-tricks-its-only-getting-better/

Aerial drones also have the potential to improve and automate data collection for biodiversity monitoring, particularly in areas where traditional survey techniques are expensive or impractical.

As part of the Biological Heritage National Science Challenge, the Eco-Index team is seeking to take satellite and aerial imagery and overlay investment data. The aim of the tool is to better visualise and track progress in activities such as environmental restoration. Once operational, dashboards (underpinned by models) are proposed to assist decision-makers in a more co-ordinated manner. Initiatives such as Eco-Index directly address the Parliamentary Commissioner for the Environment's 2022 concern that 'it is well-nigh impossible to provide any meaningful sense of the actual outcomes we are securing for all that spending'.[15]

Long-tailed bat classed as 'nationally critical' wearing wing band. Credit: Sabine Bernert.

[15] Parliamentary Commissioner for the Environment. 18 October 2022. *"Environmental reporting, research and Investment: Do we know if we are making a difference?"* https://pce.parliament.nz/publications/environmental-reporting-research-and-investment/

The future of drones

Drone being piloted with a hand-held controller. The drone carries thermal and visual light cameras, weighs around 900g, and can reach 72km/h. Credit: Craig McKenzie.

Drones and autonomous aerial vehicles have become far more common over the past decade and are used in a variety of areas, such as wildlife management, habitat monitoring and weed control. They can carry a variety of sensors, making them a versatile tool for collecting information. Drones have also become cheaper and can be great for citizen science[16] and other cost-sensitive programmes. Advances in battery life will also benefit the useability of drones by extending flight times.

One area where progress has occurred is the use of drones in fighting pests. For example, drones can inject pesticides into the nests of pine processionary, a moth that damages coniferous forests.[17] In Aotearoa New Zealand, drones are starting to be used for distributing bait as they can be more cost-effective, safer and easier than helicopter or hand-baiting.

Drones provide many possibilities for biodiversity protection. Autonomous drones may soon be able to independently and accurately recognise a pest or weed species, such as a stoat or golden dodder,[18] and eliminate them. If this proved viable it could be faster and more efficient than manual eradication, as well as much cheaper.

Drones could also be used for observation, protection and policing. For example, drones could monitor illegal fishing in the Kahurangi Marine Reserve. They would be able to cover larger areas than an enforcement officer in a vehicle or boat, making them very cost-efficient. Because of their size and speed, they would be harder for offenders to spot, making detection of illicit activities easier for the regulators.

[16] 'Citizen science' refers to public participation in science projects. https://www.pnas.org/doi/10.1073/pnas.1903393116

[17] The processionary of the pine. https://www.fitostinger.com/en/pest-control-with-drone-technology/pine-processionary/

[18] Golden dodder is a type of parasitic plant. https://www.doc.govt.nz/nature/pests-and-threats/weeds/common-weeds/golden-dodder/

Considerations

Viewing live drone footage of a target wetland. Heat signatures can be investigated if they appear to be related to the target species, such as bittern or harrier. The towel and blanket help reduce glare on the screen. Credit: Henry Caley.

Remote sensing technology that provides satellite and aerial imagery can be used across large areas and diverse environments. This has the potential to yield fast, accurate results without being invasive or destructive, providing an excellent complement to field observations. Data from remote sensing can also be set up for re-use and exploring changes over time.

Despite advances in technology, some limitations to their use may continue. For example, if a satellite is not flying overhead we may be unable to capture the data at the moment we need. There is also potential for weather limitations.

Cost may also be an issue. Most satellites are privately owned and operated. Receiving data from them can be expensive due to the cutting-edge technology, uncompetitive nature of the market and other operational limitations, such as orbit and the location of the satellite and its suitability to capture data.

When SouthPAN becomes fully operational in a few years, it could trigger a wider discussion about whether Aotearoa New Zealand needs its own fleet of observation satellites or drones specifically designed and operated for our needs. Alternatively, our commercial aircraft could be further enlisted to enable spatial coverage across Aotearoa.

Combining data from different sensors helps ensure full coverage of an area, such as using satellite imagery as well as LiDAR to map a forest. Using remote sensors and imagery with other technologies also provides better and more accurate analysis. For example, by mapping the extent of a forest and using GPS tracking to ensure it is large enough that an endangered species is not forced to leave the area in search of food.

Artificial intelligence and data-driven technologies

AI is the theory and development of computer systems that can perform tasks which normally require human intelligence.

Artificial intelligence (AI) could achieve positive environmental outcomes and results for biodiversity protection. Having access to relevant and timely data is critical for making decisions about protecting and restoring biodiversity. AI can analyse fragmented or large quantities of data quickly and effectively, allowing insights to be gained much faster than if this analysis were conducted by people.

The value of AI tools for good biodiversity outcomes has been well documented in many reports, including a detailed 2022 report from the AI Forum of New Zealand.[19] Our own earlier consultation for this draft LTIB highlighted AI as one of the technologies with the most promise for supporting efforts that protect biodiversity. Commenters mentioned the value of data, and the importance of having proper oversight, transparency and coordination of AI and data use and reuse. The FAIR and CARE principles (outlined above) discuss these topics.

Status and current use

Work in other countries provides a range of examples for how AI tools can be used to support biodiversity outcomes:

Māui dolphins. Credit: University of Auckland and Department of Conservation.

- In California, ProjectSharkEye is using machine-learning models to detect individual sharks and help with conservation efforts.[20]
- In Australia, koalas are being identified, counted and protected with data being collected by drones and analysed by AI.[21]
- Satellite data and AI analysis is being used in Brazil to understand the scale of climate change and water loss in waterways and wetlands.[22]
- In Australia, the Great Barrier Reef Marine Park Authority uses AI-enabled drones to identify damage caused by climate change, and the presence of any pollution that is threatening the reef.[23]

[19] AI Forum New Zealand, AI for the Environment in New Zealand. https://aiforum.org.nz/reports/ai-for-the-environment-in-aotearoa-new-zealand/

[20] Project SharkEye. https://sharkeye.org/

[21] Cutting-edge technologies to amplify insights drawn from digital surveys of the landscape. https://conservationai.net/

[22] Map Biomass Brazil. https://mapbiomas.org/en

[23] Drones, AI, and e-DNA keeping tabs on Great Barrier Reef and animal health. https://www.barrierreef.org/news/news/drones-ai-and-edna-keeping-tabs-on-great-barrier-reef-and-animal-health

In Aotearoa New Zealand, current applications include the following:

- The development of machine learning, a type of AI, to analyse video footage from fishing vessels and identify possible seabird captures.[24]
- The MAUI63 project involves flying a drone over the sea and using AI to locate Māui and Hector's dolphins.[25] Data on the habitat, size, location and behaviour of the dolphins is collected, and can then be used to protect the species.
- The TAIAO data science programme[26], where environmental data is analysed using state-of-the-art machine learning methods for time series and data in real time. One of the focal points is the dynamic analysis of data as it is collected to enable more agile decision-making.
- As part of the kiwi monitoring programme, DOC and Qrious recorded 2,000 hours of audio. These recordings were converted into a spectrogram that shows the sound as a graph. AI image classification technology and machine learning were used to identify kiwi calls in the files, and can now identify calls faster and more accurately than people can.[27]
- Niwa researchers have developed new ways to detect and identify weeds in our lakes and rivers, using artificial intelligence. The new technology allows agencies to survey far larger areas more efficiently and will lead to faster response to incursions.[28]

New advances in data collection, processing and management are making it possible to increase the amount of monitoring we do, as well as scale and speed up our efforts in protecting and restoring native species and ecosystems. Data can come from a multitude of places, including from the public. This array and spread of data helps to train AI systems, provides feedback loops to improve models, and gives us exciting and effective ways to protect and manage our biodiversity. Simulating the impact of different interventions through the use of digital twins also provides a means to visualise the impact of different strategies.

NIWA freshwater ecologist Dr Daniel Clements tests a submerged invasive weed detector in a test flume in Hamilton. The new technology uses artificial intelligence to survey larger areas more efficiently, potentially resulting in a faster response to incursions. Credit: Louis Skovsholt/NIWA.

[24] Catching birds on film. https://www.dragonfly.co.nz/news/2022-06-29-fishing-video-analysis.html

[25] Saving the world's rarest dolphin with technology. https://www.maui63.org/

[26] TAIAO is short for 'Time evolving data science and artificial intelligence for advanced open environmental science'. It is led by the University of Waikato and funded by MBIE. https://taiao.ai

[27] https://www.qrious.co.nz/our-work/department-of-conservation

[28] AI developed for lake weed | Otago Daily Times Online News (odt.co.nz)

Everyone is a scientist

Harnessing the power of people enables more data to be collected, including data that wouldn't otherwise be gathered. Citizen science data quality has proven to be just as good as data that professionals collect.

Many citizen science projects are focused on observations of the natural world. In Aotearoa New Zealand you can share an observation of a lizard, a moth or patch of old man's beard, report a predator kill, count cockles, contribute a bird sighting and much more. Citizens can also help with co-designing studies and processing data.

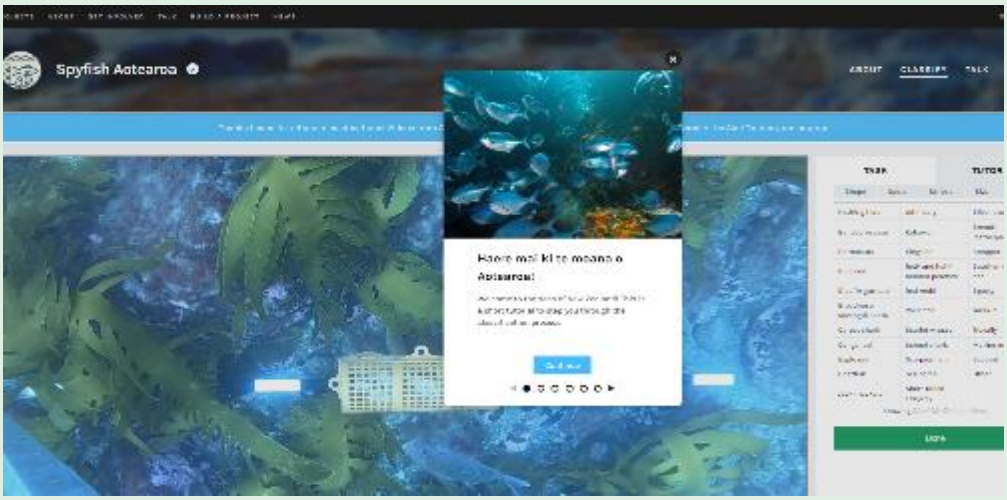
Dr Monica Peters, co-chair of the Citizen Science Association of Aotearoa New Zealand, believes enabling community members to go out and get a better understanding of their environment is critical. 'With the right support and enough resourcing, citizen science can be an amazingly powerful way for communities to collect much-needed data.

'What's missing, though, is support, funding and having a plan in place to support the field as it grows. It's critical to ensure funding for citizen science is included in policy.'

A well-informed and connected approach is also required. 'There's an exciting future ahead with scientists, communities and policy makers working together to manage, monitor and protect our ecosystems. But we need to connect up so we don't duplicate effort.'

A DOC project, Spyfish Aoteoroa, uses volunteers to identify and count fish recorded on video to help monitor marine reserves. About 2,500 people have used it in just over a year. The goal is to be able to share the online platform with regional councils and iwi, hapū and whānau, so they can monitor their local marine environment and make decisions about limiting catches if necessary.

SpyFish takes the data generated by the volunteers and feeds it into AI models, helping train them on what fish look like. The more data the AI tool has, the more effective it is at recognising common species, and the more sophisticated its analysis will be.



Spyfish Aotearoa.

Future trends

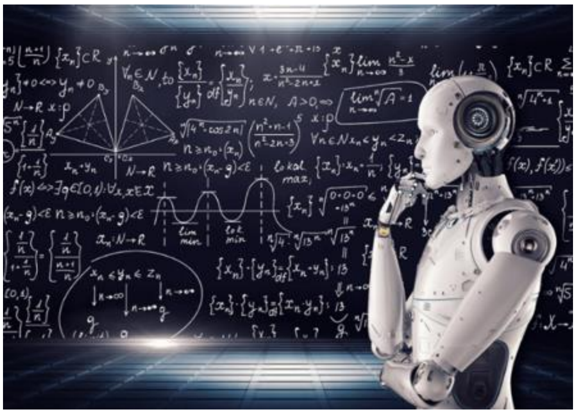
In the future we can expect to see:

- AI being applied to environmental problems that were previously difficult to solve, for example disentangling underwater acoustic 'soundscapes' (such as DeepSqueak)[29]
- simultaneous analysis of data from many different sources, including historical data, to discern patterns and develop solutions
- AI being used to build more accurate models of the environment than was possible with previous data analysis methods
- the ability to analyse data more rapidly and be more responsive with interventions
- growth in citizen science projects involving collecting or analysing data.

Exciting progress is being made overseas, where databases are combining data from a variety of different sources to protect biodiversity. The Biodiversity Digital Twin (BioDT) project, funded by the European Union,[30] uses modelling, simulation and prediction to model interactions between species and their environment. It brings together technology and interoperable data from relevant research infrastructures and the resulting information guides decisions about the optimal actions to take.

One path for Aotearoa New Zealand could see a large database being developed that brings together several data sources that would feed AI and other technologies. An example is a database that could tap into satellite data, eDNA, species distribution models and investment. This would combine information we already have and use data from a wide array of sensors and inputs across the motu. The connected datasets would use the same standards, giving an understanding of what is happening in the biodiversity realm in one portal, and presented in a way that shows a compelling story about our biodiversity.

AI can help in smaller ways, where running algorithms over different datasets can improve decision-making. Researchers from Sweden, Switzerland and the United Kingdom developed software to analyse biodiversity and climate change data, together with information on the funding available for wildlife protection projects. The software can identify places where creating protected areas would have the most benefit.[31]



Artificial Intelligence & AI & Machine Learning by mikemacmarketing, licensed under CC BY 2.0. https://creativecommons.org/licenses/by/2.0/?ref=openverse

[29] DeepSqueak is a software tool developed by University of Washington which identifies, processes and sorts rat and mouse squeaks. https://www.nature.com/articles/s41386-018-0303-6#Sec1

[30] A Digital Twin prototype to help protect and restore biodiversity. https://biodt.eu/

[31] AI can help preserve biodiversity. https://www.gu.se/en/news/ai-can-help-preserve-biodiversity

Considerations

AI can play a significant role in supporting biodiversity, helping provide real-time and accurate information. To be fully successful, several factors must be considered:

- Gaining the trust and agreement of the public. There are a range of ethical and legal considerations with the use of data-driven technologies. Work is underway globally and domestically in this area, with the Government Chief Data Steward (Stats NZ) leading work within government on data ethics. Aotearoa New Zealand is also a part of several global organisations that have designed worldwide standards and principles (for example, OECD and Global Partnership on AI).
- The inherent rights and interests that people have in their data. This is particularly important when looking at Māori data expectations and Māori data sovereignty, where Māori have existing systems and protocols around the protection and sharing of collective knowledge. They may wish to adapt this tikanga to digitised data about their people, language, culture, resources or environments.
- AI is only as good as the data fed into it. Incomplete or biased data can lead to conclusions that may not have been intended. Human oversight is necessary if AI is used as the basis for decisions that have significant implications.
- Collection, storage, and use of data, how data is kept safe, the way it can be made interoperable, and ownership of the data.
- Data silos and fragmentation, the accuracy of data and access to high-quality data are also issues that will need to be addressed to realise the full potential of AI and other data-driven technologies.
- Fit-for-purpose, reliable and resilient digital infrastructure is needed to realise the full potential of new technologies. Satellite systems such as Starlink[32] along with pseudo-satellites such as high-altitude platform systems[33] are helping to address connectivity issues and broadband deployment in rural and remote areas.
- Building understanding and capabilities in data and AI use, strengthening relationships and increasing collaboration.

Interoperability is about making sure that data generated by – or held in – different formats can be used together. The government digital standards catalogue contains digital standards and guidance that should be used by Aotearoa New Zealand government organisations to support interoperability and transformation. However, data comes from a number of places, not just government, and is currently governed by a wide range of different standards. A key issue in the use of data-driven technologies is how we standardise all these different sources of data so it can easily flow across multiple systems.

[32] Starlink is a large satellite constellation which uses a low-Earth orbit to deliver broadband internet. https://www.starlink.com/technology .

[33] High-altitude platform systems can be placed in Earth's stratosphere (between 20 and 50 kilometres above the ground) to improve wireless broadband deployment in remote areas.

Genetic technologies

Genetic technologies are anything to do with understanding, making or adapting genetic material.

Amy Gault sampling eDNA from the Hutt River. A low-cost and easy-to-use syringe type filter, developed by Wilderlab, has made eDNA more accessible. Credit: Wilderlab.

There have been rapid advances in how genetic information, primarily in the form of DNA sequence data, is collected and used. In addition to obvious benefits in the fields of medicine and forensics, there has also been significant development of genetic tools to protect and restore biodiversity. Some of these DNA-based tools are already here, but many more are expected in the future. During the consultation we heard that exploring how genetic technologies can improve Aotearoa New Zealand's biodiversity toolkit is vital, but there are some areas where caution, education and additional kōrero is needed.

Status and current uses

Genetic technologies are a branch of biotechnology. They focus on characterising genetic material (such as DNA), which is the material found in cells that carries information about an organism's characteristics and functions. Genetic technologies allow us to examine and alter the genetic material of plants, animals, bacteria and ourselves. In recent years this blueprint provides clues on how we might edit genes to promote health and combat disease.

The project to map the first human genome (the full set of genetic instructions found inside a person's cell) was started in the 1990s. It cost billions and took a decade to complete but today the same data can be generated overnight for a few hundred dollars. In 2012, the CRISPR-Cas-9[34] system enabled precise changes to the genes of living cells, and a decade later this enables precision medicine that saves lives. Today, the opportunities presented by genetic technologies, including for conservation, are being actively researched worldwide and span many applications.[35,36,37,38]

It is important to recognise that DNA technologies is a 'catch all' phrase, but as others have advocated,[39] it is time to discuss specific applications of the technology rather than develop a stance on the 'DNA technology' per se. For example there is a large gap between surveying the biota in a river using eDNA (see example below) compared to editing the genes of a pest species to achieve predator-free status by 2050. The latter is a scenario discussed in the 2019 Te Apārangi (the Royal Society of New Zealand) report on gene editing. Aotearoa New Zealand has a turbulent past when discussing genetic technologies but, in a post-pandemic world where genetic technology in the form of RNA vaccines saved the lives of thousands of New Zealanders, there is a need to restart this kōrero, arguably more so in the face of the biodiversity and climate crises.

In Aotearoa New Zealand the genomes of ship rats[40] and stoats[41] were mapped in 2020. This knowledge will contribute to research into controlling these predators. Brent Beaven from DOC describes the project, 'We have the book, now we just have to learn how to read it and what the words mean. When we do, it will open a whole raft of opportunities to explore and look for, and take advantage of, weaknesses.'

[34] A gene editing technology we can harness to modify, delete or correct precise regions of DNA.

[35] New powers granted to research gene editing in plants. https://www.gov.uk/government/news/new-powers-granted-to-research-gene-editing-in-plants

[36] New genomic techniques: European Commission study and first reactions. https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/698760/EPRS_BRI(2021)698760_EN.pdf

[37] Australians open to using genetic technology to manage feral cats. https://www.csiro.au/en/news/news-releases/2022/australians-open-to-using-genetic-technology-to-manage-feral-cats

[38] GMOs and the American Chestnut Tree. https://gmo.uconn.edu/gmos-and-the-american-chestnut-tree/#

[39] Royal Society Te Apārangi, 'Gene Editing'. August 2019. https://www.royalsociety.org.nz/assets/Uploads/Gene-Editing-FINAL-COMPILATION-compressed.pdf

[40] Significant milestone in Aotearoa New Zealand's Predator Free 2050 research reached. *Rattus rattus* genome sequenced. https://pf2050.co.nz/news/significant-milestone-in-new-zealands-predator-free-2050-research-reached-rattus-rattus-genome-sequenced/

[41] Aotearoa New Zealand's most devastating predators' genomes sequenced. DNA codes broken for stoat and ship rat. https://oldwww.landcareresearch.co.nz/about/news/media-releases/new-zealands-most-devastating-predators-genomes-sequenced-dna-codes-broken-for-stoat-and-ship-rat

The Kākāpō125+ project mapped the genomes of almost all living kākāpō in 2018.[42] This information will guide breeding programmes so genetic diversity and desired traits are passed on to future generations.

Critically endangered Kākāpō. Crown copyright.

Genetic technologies are also being researched to help combat kauri dieback[43] and to control wasps.[44] Methods to use CRISPR-Cas9 for malaria control[45] and coral conservation[46,47] are being studied overseas.

A very different technology is environmental DNA (eDNA) analysis, a powerful tool for identifying which species are in an area using the genetic material they leave behind when they move through an environment. The game-changer with eDNA is that it can survey the whole 'tree of life', from microbes to mammals.

'Such holistic approaches are enabling the concept of ecosystem-based monitoring to be realised,' says DOC's Chief Science Advisor Professor Mike Bunce, an international expert in eDNA. 'For a few hundred dollars per sample, we can get a genetic snapshot of all the biota. It's powerful stuff.'

eDNA technologies are already being used to develop new scales to measure the impact of aquaculture[48] and the health of our lakes[49] and rivers.[50] As DNA references are populated onto databases, the ability to identify species will only improve.

[42] Kākāpō125+ gene sequencing. https://www.doc.govt.nz/our-work/kakapo-recovery/what-we-do/research-for-the-future/kakapo125-gene-sequencing/

[43] Fighting back with science. https://www.scionresearch.com/about-us/about-scion/corporate-publications/scion-connections/past-issues-list/issue-21,-september-2016/fighting-back-with-science

[44] The potential for a CRISPR gene drive to eradicate or suppress globally invasive social wasps. https://doi.org/10.1038/s41598-020-69259-6

[45] Self-destructing mosquitoes and sterilized rodents: the promise of gene drives. https://www.nature.com/articles/d41586-019-02087-5#ref-CR1

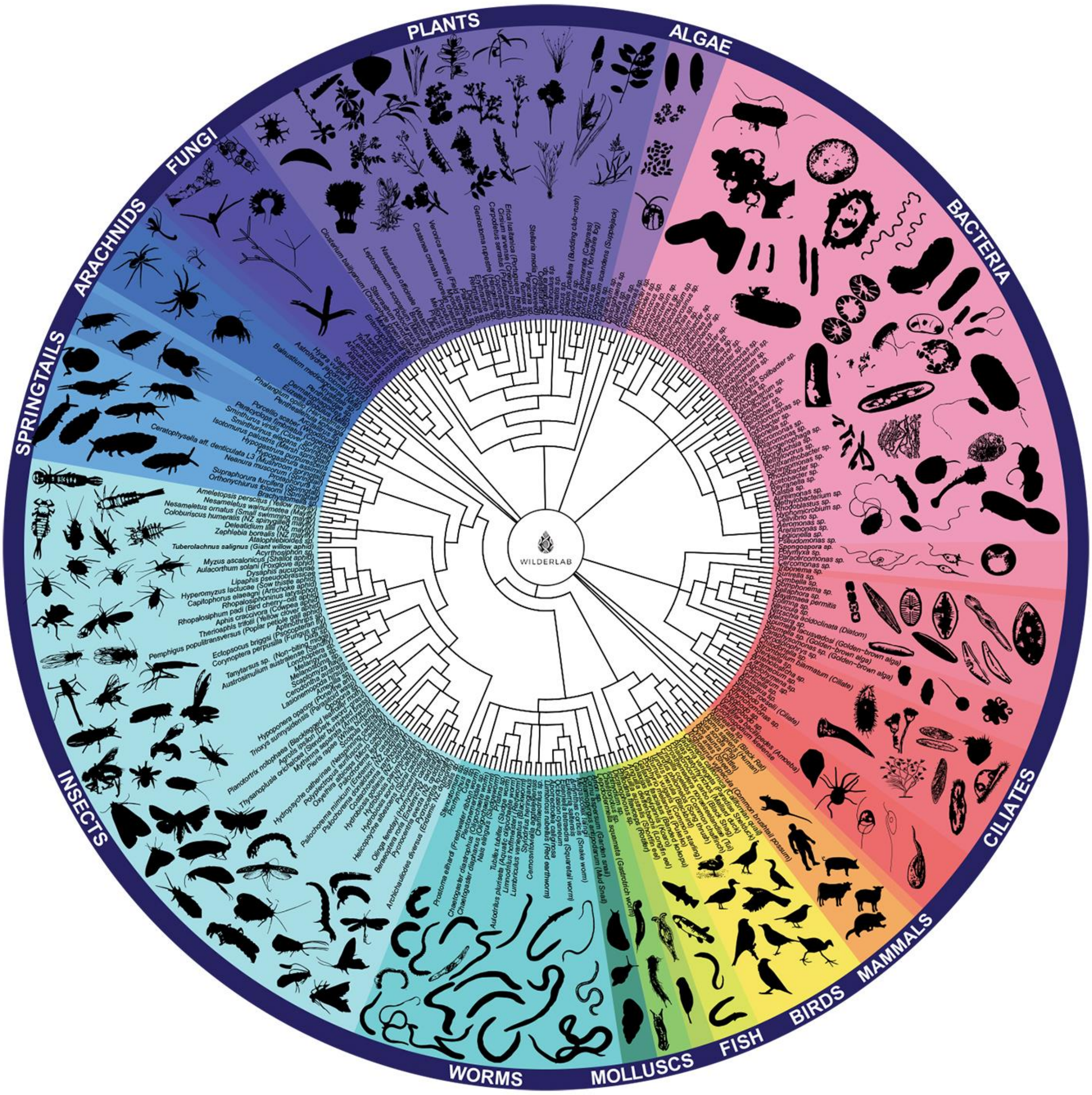
[46] CRISPR/Cas9-mediated genome editing in a reef-building coral. https://www.pnas.org/doi/full/10.1073/pnas.1722151115

[47] Gene editing is revealing how corals respond to warming waters. It could transform how we manage our reefs. https://theconversation.com/gene-editing-is-revealing-how-corals-respond-to-warming-waters-it-could-transform-how-we-manage-our-reefs-143444

[48] Xavier Pochon, Javier Atalah, Olivier Laroche, Anastasija Zaiko, Nigel Keeley. 2020. A validated protocol for benthic monitoring of Aotearoa New Zealand's salmon farms using environmental DNA. https://www.researchgate.net/publication/368029395_A_validated_protocol_for_fish_farm_monitoring_using_environmental_DNA

[49] https://lakes380.com/

[50] https://www.wilderlab.co.nz/tici



This eDNA 'tree of life' shows the biodiversity present in 6 litres of water taken from the Pauatahanui stream in Wellington by the Mountains to Sea Wellington community group (samples taken on 15 April 2022 at the coordinates -41.098943, 174.990792). Source: Wilderlab.

The genetics of stream water

Dr Shaun Wilkinson with an easy to use eDNA testing kit.

The method is simple. Take a litre of water, squirt it through a syringe equipped with a filter, add a splash of preservative, and send the filter to a lab. A week or so later the result is spectacular – the identification of thousands of species that have been in contact with the water, including birds, fish, plants, mammals, insects, worms, algae and bacteria.

The technology relies on DNA sequencing machines and reference databases to identify the trace amounts of genetic material in a sample. Recent research has shown that similar samples can be collected from the air (it turns out dust is a rich source of DNA). Collectively, these methods are transforming environmental monitoring, biosecurity and how we manage threatened species.

Dr Shaun Wilkinson is the founder of Wilderlab, a Wellington-based company that provides environmental DNA (eDNA) analysis. 'It's a very powerful biodiversity tool that doesn't involve catching or handling of animals. Because of the sensitivity, it's really well suited to picking up things that are hard to survey visually.'

Many of Wilderlab's samples are for biosecurity, with clients looking for pest species like rodents, stoats, fish, plants and invasive algae such as didymo.

'You can detect tiny traces of DNA left by a single invasive predator in an otherwise clear area. That's a real frontier for eDNA, and we're working with researchers from the University of Otago and ZIP (Zero Invasive Predators) to confirm the limits of detection for their landscape predator control work. It's not just about detecting pest species, it's also about tracking the recovery of biodiversity.'

While uses for the technology are diverse and growing, Shaun believes that we've just scratched the surface of what's possible.

'It's such an easy method to use that you don't have to be a seasoned monitoring professional to go and take samples. We're seeing more and more conservation groups sampling their local waterways. The Environmental Protection Authority's "wai tuwhera o te taiao" that we collaborate on has led the way on this. It's a new lens for people of all ages to engage with their environment and is much more accessible than you might first think.'

The Wilderlab website[51] enables people to share eDNA data if they wish, via a map with thousands of sample points. You can find eels, sandflies, possums, moths, frogs, snails, a capybara from a local zoo and countless other species.

[51] https://www.wilderlab.co.nz/explore

'There's lots to explore. People are using it to study the spread of invasive fish, map the distribution of lizards, discover where disease is present – and probably lots more.'

After sample analysis, the DNA and the data are archived for perpetuity. 'By freezing the DNA, there's always an opportunity to go back and use another assay to detect different things. Same with the data. As more and more reference data comes online we can retroactively assign old datasets and update the webpage. The reports become more powerful as time goes on.'

A new population of Clutha flathead galaxias (Nationally Critical) was discovered in a DOC eDNA survey of a stream in Otago in 2022. The population was surveyed (as pictured), and measures to protect the fish from trout predation were put in place. Project team is from DOC, Otago Regional Council, Fish & Game, Wai Wānaka and the University of Canterbury.

Clutha Flathead Galaxias. Crown copyright. Credit Rod Morris.

Future trends


Kauri dieback dead branches. Crown copyright.

By developing a better understanding of genomes and surveying biodiversity using eDNA, we can create a more detailed picture than ever before. Genome mapping and eDNA analytics are examples of how genomic data can inform biodiversity management decisions. In the case of eDNA, a sample taken for fish monitoring can also be used to monitor for pest species, or the swimability (or drinkability) of a river. Alternatively, it might be used to track the impacts of chemicals on river health. To extract the most out of eDNA data, there will have to be some joined up thinking on the commissioning, analysis and storage of environmental samples (known as biobanking) and the resulting data.

One recent innovation is the ability to use the thousands of segments of DNA detected from eDNA to construct a DNA-based 'barometer' of river health across the motu. This Taxon-independent community index is a way to condense a large amount of DNA sequence information into a single metric for better understanding stream condition. While still in development, this has been benchmarked against existing measures of waterway health and performed well in 53 rivers across Aotearoa New Zealand.

Genomic data can also fuel innovation and the development of new tools and ground-breaking opportunities to reduce a range of pressures on biodiversity. For example, scientists are working to better understand the genetics of disease resistance in kauri trees, with the goal of using genetic technologies to help protect them from kauri dieback disease.[52] Likewise, a new generation of RNA-therapeutics (called RNAi) is being developed in Australia as a precise way to combat myrtle rust.[53] Myrtle rust is a relatively recent airborne arrival into Aotearoa New Zealand, and is a cause for concern as it can infect iconic trees including mānuka, pōhutukawa, rātā and kānuka.

The recent DOC report 'Current applications and future promise of genetic/genomic data for conservation in an Aotearoa New Zealand context' explores in greater depth the use

[52] Fighting back with science. https://www.scionresearch.com/about-us/about-scion/corporate-publications/scion-connections/past-issues-list/issue-21,-september-2016/fighting-back-with-science

[53] Exogenous double-stranded RNA inhibits the infection physiology of rust fungi to reduce symptoms in planta. https://bsppjournals.onlinelibrary.wiley.com/doi/10.1111/mpp.13286

of genetic and genomic data to improve biodiversity outcomes.[54] Among the topics covered is the need to plan for the future. Cryopreservation or 'biobanking' involves preservation of DNA, gametes, embryos, somatic cells, blood or tissue samples for later use in assisted reproduction.

Cryopreserved samples in liquid nitrogen dry shipper. Credit: Diane Ormsby (Te Herenga Waka | Victoria University of Wellington).

Tāpui Aotearoa[55] is a local project that aims to discuss the establishment of a biobank for endemic fauna in Aotearoa New Zealand. Such projects are a safety net that may be needed in the future, especially in species that have undergone a severe reduction in population size and/or genetic diversity.

Mapping of genomes is enabling developments in gene editing technologies. Gene editing tools like CRISPR-Cas9 can be used to change a particular gene and introduce a specific trait. CRISPR-Cas9 could change genes to build resilience to the effects of climate change or switch off genes that make a species more susceptible to infection or disease. CRISPR-Cas9 has not yet been used for conservation, but its potential has been studied overseas for malaria control[56] and coral conservation[57,58] and, in Aotearoa New Zealand, to control wasps.[59]

CRISPR gene editing can also be used to induce 'gene drives', a technique that forces an altered (self-replicating) gene into a targeted population[60]. For example, a gene called 'doublesex' has been used as a gene drive to produce sterile female mosquitoes that can't bite or spread malaria.[61]

Gene drives could offer a humane way of managing invasive populations and protecting the species they endanger. For example, introducing genes that supress fertility into the

[54] Current applications and future promise of genetic/genomic data for conservation in the Aotearoa New Zealand context. https://www.doc.govt.nz/globalassets/documents/science-and-technical/sfc337entire.pdf

[55] https://www.nextfoundation.org.nz/investment/tapui-aotearoa/

[56] Self-destructing mosquitoes and sterilized rodents: the promise of gene drives. Scudellari M. Self-destructing mosquitoes and sterilized rodents: the promise of gene drives. Nature. 2019 Jul;571(7764):160-162. doi: 10.1038/d41586-019-02087-5. PMID: 31289403. https://www.nature.com/articles/d41586-019-02087-5#ref-CR1

[57] CRISPR/Cas9-mediated genome editing in a reef-building coral.

https://www.pnas.org/doi/full/10.1073/pnas.1722151115

[58] Gene editing is revealing how corals respond to warming waters. It could transform how we manage our reefs. https://theconversation.com/gene-editing-is-revealing-how-corals-respond-to-warming-waters-it-could-transform-how-we-manage-our-reefs-143444

[59] The potential for a CRISPR gene drive to eradicate or suppress globally invasive social wasps. https://www.nature.com/articles/s41598-020-69259-6

[60] The use of gene editing to create gene drives for pest control in Aotearoa New Zealand. https://royalsociety.org.nz/assets/Uploads/Gene-editing-in-pest-control-technical-paper.pdf

[61] Kyrou, K., Hammond, A., Galizi, R. *et al.* 2018. A CRISPR–Cas9 gene drive targeting *doublesex* causes complete population suppression in caged *Anopheles gambiae* mosquitoes. *Nat Biotechnol* 36, 1062–1066. https://www.nature.com/articles/nbt.4245

DNA of an invasive species could be a powerful, cost-effective way to reduce or eradicate that species in Aotearoa New Zealand.

The Genetic Biocontrol of Invasive Rodents programme[62] is an international collaboration that is researching the use of gene drives to manage rodent populations. This could be a breakthrough opportunity for biodiversity in Aotearoa New Zealand because rodents kill an estimated 26.6 million native bird chicks and eggs each year.[63]

Considerations

A key consideration in the collection of genetic genomic data is how data and insights are collected, analysed and stored. Many eDNA samples, for example, are collected without a clear understanding of how they relate to indigenous knowledge, but this could also be said of more traditional forms of biodiversity data collection. Regardless, there is opportunity to integrate different knowledge systems to guide our approach to collection and management of genetic data, noting that an eDNA profile is not the same as a genome, which captures the entire genetic code. New Zealand eScience Infrastructure and Genomics Aotearoa are investigating how a data repository for genomic data generated from taonga species could support Māori interests.[64] Recent international agreements (such as the Convention on Biological Diversity) are actively exploring the fair and equitable sharing of benefits from the use of DNA data.

In contrast to eDNA approaches, the use of gene editing technologies remains a contentious issue for Aotearoa New Zealand, despite the breakthrough potential for predator control. Deciding if, how or when they might be used will require cross-disciplinary kōrero, regulatory approvals and global collaboration. There is a set of complex ecological, social and cultural issues to consider and debate. This was highlighted throughout our consultations, with a preference expressed by some contributors to explore the potential of nature-based solutions before considering gene editing, and concerns about unintended consequences arising from the use of gene editing. Other submissions advocated that these technologies should be explored to protect the biodiversity of Aotearoa New Zealand. This LTIB contributes to the ongoing discussion in Aotearoa New Zealand about the use of gene editing technologies.

Outlined below are some key considerations posed by gene editing technologies.

[62] The Genetic Biocontrol of Invasive Rodents program. https://www.geneticbiocontrol.org/

[63] Predator-Free New Zealand: Conservation Country. https://academic.oup.com/bioscience/article/65/5/520/323246

[64] Building a treaty-compliant data archive for Aotearoa New Zealand's taonga species. https://www.nesi.org.nz/news/2021/09/building-treaty-compliant-data-archive-new-zealands-taonga-species

Ecological considerations

There is uncertainty about how organisms that have been genetically altered will affect ecosystems both in Aotearoa and overseas. Fulfilling our obligation of kaitiakitanga (guardianship) of the natural world requires careful consideration of the risks that we are willing to take to protect biodiversity. Conversely, are we prepared to deal with a decline (or extinction) of biodiversity if we choose not to deploy genetic tools that could prove effective?

Summer view of Lake Wakatipu and the road from Queenstown to Glenorchy. Credit: nzgmw2017/ iStockphoto.

[65] Towards a bioeconomic vision for New Zealand – Unlocking barriers to enable new pathways and trajectories. https://www.sciencedirect.com/science/article/pii/S1871678420301783?via%3Dihub

[66] Aotearoa New Zealand boosted by Biotech: Innovating for a sustainable future. https://biotechnz.org.nz/wp-content/uploads/sites/16/2020/11/Biotech-Report-2020_online.pdf

[67] The burden of proof within the scope of the precautionary principle: International and European perspectives. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2101613

[68] Kathlene, L., Munshi, D., Kurian, P. *et al*. 2022. Cultures in the laboratory: mapping similarities and differences between Māori and non-Māori in engaging with gene-editing technologies in Aotearoa, New Zealand. *Humanit Soc Sci Commun* 9, 100. https://www.nature.com/articles/s41599-022-01104-9

Tikanga, mātauranga and partnerships with Māori

Māori, as tangata whenua and kaitiaki, have a wide range of knowledge, information and aspirations related to biodiversity. Understanding how specific technologies can align with mātauranga and tikanga Māori to support the principles of partnership and active protection under the Treaty of Waitangi. For example, we need to work with Māori to consider how gene editing technologies affect species whakapapa. Gene editing that does not transfer genes between species could maintain and enhance the whakapapa of species.[69]

Ruru, Willowbank. Credit: Sabine Bernert.

Technical and regulatory considerations

Legislation and the regulatory framework would likely need to be updated to support the deployment of some genetic technologies.[70] The current laws around genetic technologies are outdated and restrict Aotearoa New Zealand's ability to effectively respond to the risks and opportunities the technologies provide.

[69] Indigenous Perspectives and Gene Editing in Aotearoa New Zealand. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6470265/

[70] Gene editing in Aotearoa: Legal considerations for policy makers. https://ojs.victoria.ac.nz/vuwlr/article/view/5990

Tame Malcolm: gene technology


Tame Malcolm. Credit: Lance Lawson.

Tame Malcolm, Te Arawa, is Deputy Director-General of Treaty relationships at DOC. Despite years of research, interviewing people and in wānanga, he has not found any evidence that gene editing contradicts tikanga (tradition).

‘We often talk about features of the landscape that define us. They can be maunga, lakes and rivers, but for some of us it was the trees that gave us life. For us in Ngāti Tarāwhai, we wouldn’t be here without the rātā – it’s part of our whakapapa.

‘I loved learning about different trees when I was young – I couldn’t get enough of it! As I grew up, I realised we had to control pests to protect the trees.

‘When CRISPR-Cas9 gene editing technology came up, I thought it was interesting and potentially very useful. Some people were saying it wasn’t compatible with te ao Māori, and that manipulating genes compromises or undermines whakapapa.

‘But in my view, tikanga often impacts whakapapa, including through marriage. And te ao Māori is not inconsistent with new technology. You can see this in our oral histories – for example, according to Māori, kererū were once plain white but when Māui saw his mum wearing a nice dress, he liked the colour so much he gave it to all kererū, just like a gene drive could push a trait through the population.

‘Still, I can understand some Māori being hesitant over editing the genes of our taonga species, but introduced species like possums don’t belong to us and are different. We should be talking to indigenous people in their home and seeing what they think about these ideas.

‘The conversation about gene tech for taonga species needs to be led with Māori and include lots of genuine engagement.

‘Within 200 years of arriving in Aotearoa, our tūpuna saw the demise of moa and other species. They lamented this loss, and its learnings were stitched into our culture. If we lose more species, we lose more of our culture and our sense of identity. Our opportunity is not just to save what we have, but to put systems in place so there’s an abundance of species that are scarce today.

‘A whakataukī from our iwi sums it up for me: Ko te whenua te kura, kia kura te whenua – learn from the whenua and there will be so many rātā that the land is red from their flowers. If rātā are flowering then everything else is flourishing as well.’

4. Pathways to implementation

The technological innovations described in this LTIB all hold potential to enhance our ability to protect biodiversity. More concerted actions to adopt these tools would be a step-change from more conventional approaches that have, through necessity, involved time-intensive counting of animals, sometimes using invasive or destructive approaches.

The adoption of new technologies and data analysis methods is not simply a matter of getting the science and data systems in place – there are other dimensions that need to be considered when transitioning such as social, regulatory, fiscal, legal, ethical and cultural factors. While a technology might work well in a research capacity, is it possible to train (or retrain) others to provide the capacity and capability needed to implement new technologies? In this chapter we briefly discuss some of the considerations that are needed to walk these new pathways.

The need to integrate approaches

The arrival of these new tools does not mean discarding the traditional ways of doing things. Instead, it requires dovetailing of approaches to use the right tool at the right time. We will always need people 'on the ground'. The more nuanced question is how best to integrate new technologies to improve biodiversity outcomes.

However transformative these tools might be, there are risks, and if they are not carefully integrated they will not realise their full potential. Part of this integration process involves upskilling scientists, rangers, decision-makers, Māori, iwi and communities on the strengths and weaknesses of each approach.

Implementing new methods often requires training, re-training, new infrastructure, vision, agility and funding. Knowledge, self-awareness, preparedness and patience are all required for new technologies to be effective.

The adoption of tools such as eDNA, AI and aerial imagery described in this LTIB could drive a better understanding of biodiversity outcomes, a goal clearly articulated by the Parliamentary Commissioner for the Environment,[71] and they could be used for multiple types of reporting.

Recent data[72] suggests that additional tools are needed to realise a predator free status by 2050. Accordingly, there is a need to explore, test and discuss emerging technologies.

By contributing to a nationwide conversation now, we can all understand and think about the best ways to use these new tools and make well-informed decisions that benefit te taiao in the long term.

[71] Parliamentary Commissioner for the Environment. 2022. *Environmental reporting, research and investment: Do we know if we're making a difference?*

[72] Murphy, E. C., et al. 2019. Conserving New Zealand's native fauna: a review of tools being developed for the Predator Free 2050 programme. *Journal of Ornithology*, *160*(3), 883–892. https://link.springer.com/article/10.1007/s10336-019-01643-0

Build an understanding of new tools and approaches

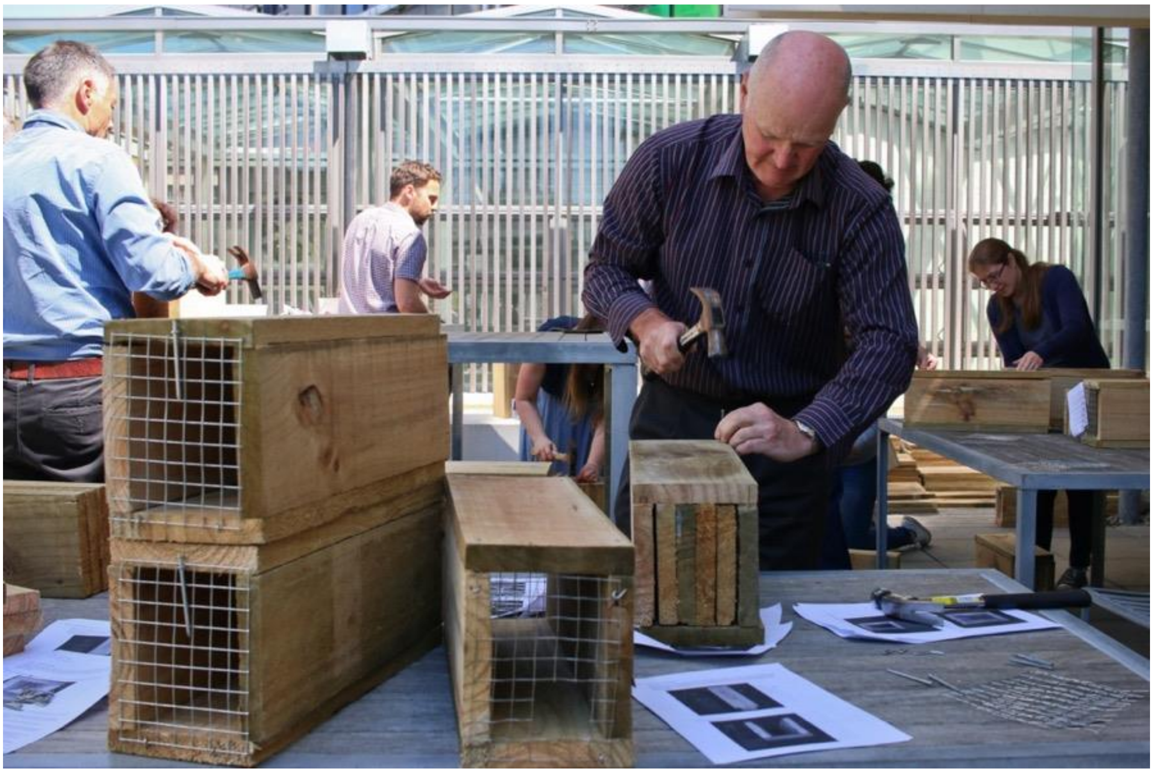
To make the most of the opportunities that information and emerging technologies offer, we need to build trust and create social and cultural licence for their use. This emerged as a theme in the consultation, particularly around gene editing.

It is interesting to note that better ways of ensuring citizen engagement with government is the theme of two other LTIBs. Te Tari Taiwhenua Department of Internal Affairs has prepared an LTIB focused on how digital technology can connect communities and promote engagement in participatory processes. Te Kawa Mataaho Public Service Commission's LTIB is on public participation in government.

This work, alongside other work done by the Aotearoa New Zealand government on public engagement, provides useful tools for future engagement.[73] The social dimension sitting behind these new and often exciting technological innovations cannot be ignored, and neither can considerations of Māori data sovereignty. More kōrero is needed on who 'owns' environmental data and what it should (and should not) be used for.

Empowering community participation

Technologies can help raise awareness of key issues and problems, as well as help people engage in data collection and initiatives to protect biodiversity (for example, citizen science).



Trap making at DOC's National Office in Wellington. Crown copyright.

[73] WEF / NZ Government, AI National Conversations Playbook. https://digitaltechitp.nz/2021/07/21/ai-playbook/; DPMC Policy Project, Community Engagement https://dpmc.govt.nz/our-programmes/policy-project/policy-methods-toolbox/community-engagement

Submitters told us that iwi, hapū and communities need to be engaged and that this might require education, training, direction and resourcing. Many submitters felt that approaches needed to be place-based. Iwi that responded to the consultation were clear that they needed to be meaningfully involved, and approaches needed to be developed using local knowledge.

Submissions to this LTIB also noted the important role that private landholders play in conservation work across the motu. Native and pest species don't recognise a distinction between private and conservation land, so our approaches should also seek to work across boundaries.

New forms of data and models can be very complex. Historically, this may have led to inequity in who had access to a new technology. It has been said that if eDNA remains a tool for geneticists then it will only realise a small fraction of its potential.[74] Design principles of accessibility and education can, and should, be wrapped into any roll-out of new technologies such as those described in this LTIB.

Apply rules and oversight

The innovative use of data and emerging technologies needs rules and oversight to guide and monitor their use. During the first consultation, submitters noted that a decision-making model for biotechnologies should be transparent, participatory in nature, use robust science and information, and be responsive to areas of concern.

Responses were similar during the second consultation. Several submitters emphasised the relevance of the Crown's responsibilities under Te Tiriti o Waitangi. Some submitters also told us that decision-making, particularly in relation to biotechnology, should be based on the precautionary principle. In contrast, other submitters advocated for more agility in the uptake of some biotechnologies. Finding the right balance here will not be straightforward.

Strengthen funding and investment

A recent review of environmental research funding in Aotearoa New Zealand identified the need for defined research priorities, informed by regular monitoring, the right research approaches to deliver on these priorities, and adequate investment in environmental research that secures critical research capability – both human and technical.[75]

[74] Berry, O, Jarman, S, Bissett, A, et al. 2021. Making environmental DNA (eDNA) biodiversity records globally accessible. *Environmental DNA*. 3: 699–705. https://onlinelibrary.wiley.com/doi/10.1002/edn3.173

[75] A review of the funding and prioritisation of environmental research in New Zealand. https://pce.parliament.nz/publications/environmental-research-funding-review

Submitters had different ideas about where funding should be targeted. Everyone agreed that the need is urgent, and investment needs to be effective. The development of a multi-tiered priority-setting process (within Te Ara Paerangi research, science and innovation reforms[76]) may provide a mechanism to focus, refocus and prioritise funding.

Further investment to support the opportunities outlined in this briefing will need to be considered in light of strategic research priorities, including the developing Environment and Climate Research Strategy.[77]

5. Next steps and concluding remarks

Biodiversity is declining globally at an alarming rate. To stop this decline, and ideally reverse it, good decision making is vital. It is difficult (if not impossible) to make good decisions or prioritise when data is missing, poor or deficient. In managing biodiversity and its threats, Aotearoa New Zealand is grappling with all of these issues.

These issues are international, so we are not alone. While Aotearoa New Zealand will forge its own path, it is important to remember that we must stay connected to the international community that is working through similar issues.

The aim of this LTIB is to start conversations and imagine preferred futures. Between DOC, Toitū Te Whenua and the submitters, these conversations have begun. We will continue them.

A unifying theme across all of the tools discussed in this LTIB is the pressing need for cost-effective and landscape-wide approaches that can address the biodiversity data deficiencies that exist across the country. However, there remain a few risks that we must consider as we walk this path.

First, there is a risk that we are simply developing ever more intricate ways of measuring nature, but to what effect? Measurements are a means, not an end. There must be a reason for collecting the information in the first instance.

Second, there is a risk that we wait for the 'next innovation' that shows promise, and in doing so take our eye off actions that could make a tangible difference today.

Finally, there is risk of not involving people. Many New Zealanders have close connections to Papatūānuku and remain engaged in projects to protect, revive and restore biodiversity. The benefits and outputs of technological advances needs to remain grounded in values that iwi, hapū and communities value.

[76] Te Ara Paerangi is a long-term programme which aims to build a modern, future focused research system in Aotearoa New Zealand. https://www.mbie.govt.nz/science-and-technology/science-and-innovation/agencies-policies-and-budget-initiatives/te-ara-paerangi-future-pathways/te-ara-paerangi-future-pathways-white-paper/

[77] Environment and Climate Research Strategy. https://environment.govt.nz/facts-and-science/science-and-data/environment-and-climate-research-strategy/

The monitoring of complex biological systems is difficult. It is even more difficult to do well. The vison and goals laid out in Predator Free 2050, *Te Mana o te Taiao*, our national policy statements and in international agreements (such as the Kunming Declaration[78]) are ambitious – but to settle for anything less is to accept that a gradual decline in biodiversity and ecosystem health is inevitable.

As we seek to halt, and preferably reverse, declines we need all the help we can get – including the capability offered by the technologies discussed in this LTIB. We hope you explore these possible futures with us and feel empowered and optimistic about the possibility of integrating new technologies into our work as the guardians and kaitiaki of te taiao.

[78] The 15th Conference of Parties to the UN Convention on Biological Diversity (COP15) in December 2022 included the 30x30 initiative, which called on the world's governments to designate 30 percent of Earth's land, waters and ocean as protected areas by 2030.