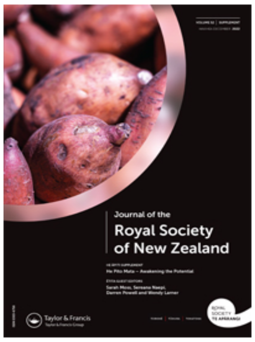

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VIEWPOINT

The future of molecular ecology in Aotearoa New Zealand: an early career perspective

Libby Liggins [a], Vanessa Arranz[a], Heather E. Braid[b], David Carmelet-Rescan[c], Joane Elleouet [d], Ekaterina Egorova [e], Michael R. Gemmell [f], Simon F. K. Hills [g,h], Lyndsey P. Holland[i], Emily M. Koot[j], Alexandra Lischka[b], Kimberley H. Maxwell[g,k,l], Laura J. McCartney[i], Hang T. T. Nguyen[m], Cory Noble[a], Pamela Olmedo Rojas[n], Elahe Parvizi[o], William S. Pearman[a], Jenny Ann N. Sweatman [a], Te Rangitākuku Kaihoro[p], Kerry Walton[q], J. David Aguirre [a] and Lucy C. Stewart[r]

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ABSTRACT

The skills, insights, and genetic data gathered by molecular ecologists are pivotal to addressing many contemporary biodiversity, environmental, cultural, and societal challenges. Concurrently, the field of molecular ecology is being revolutionised by rapid technological development and diversification in the scope of its applications. Hence, it is timely to review the future opportunities of molecular ecological research in Aotearoa New Zealand, and to reconcile them with philosophies of open science and the implications for Indigenous data sovereignty and benefit sharing. Future molecular ecologists need to be interdisciplinary, equipped to embrace innovation, and informed about the broader societal relevance of their research, as well as advocates of best practice. Here, we present an ideal future for molecular ecology in Aotearoa, based on the perspectives of 23 early career researchers from tertiary institutions, Crown Research Institutes, research consultancies, and government agencies. Our article provides: a guide for molecular ecologists embarking on genetic research in Aotearoa,

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

and a primer for individuals in a position to support early career molecular ecologists in Aotearoa. We outline our goals and highlight specific considerations – for molecular ecology and the scientific community in Aotearoa – based on our own experience and aspirations, and invite other researchers to join this dialogue.

Introduction

Genomic approaches are becoming more diversely applied across disciplines, reaching a wider scientific community and the general public. The interface of genetics and genomics (hereafter collectively referred to as 'genetics') with ecology and environmental sciences is 'molecular ecology' (Rowe et al. 2017). Molecular ecology draws on related disciplines of ecology and evolution, often providing a unique approach to answering long-standing theoretical questions, while also providing a toolbox for applications in fields such as conservation (e.g. Dussex et al. 2021; Forsdick et al. 2021), environmental monitoring (e.g. Bourlat et al. 2013), and biosecurity (e.g. Dearden et al. 2018; Zaiko et al. 2018). These diverse applications require molecular ecologists to be broadly skilled and adept at moving between different biological systems and disciplinary contexts. It is quite typical for a molecular ecologist to be trained in molecular genetics and population genetics, and, as a consequence, knowledgeable about population demography, metapopulation theory, and broader evolutionary biology. Molecular ecologists are often avid natural historians, with knowledge of biodiversity and biogeography, including community ecology. They may also be skilled in field and laboratory techniques, statistics and bioinformatics, as well as mathematical modelling. Recent advances in high-throughput sequencing technologies (Jain et al. 2016; Levy and Myers 2016) and associated molecular genetic and bioinformatics approaches to harness these technologies (e.g. Danecek et al. 2011; Elshire et al. 2011; Lee et al. 2014) are reducing the cost of data generation and further extending the capabilities of modern molecular ecologists. As such, the future for molecular ecologists will be diverse and exciting, but also challenging, necessitating working within interdisciplinary teams with complementary expertise.

Many of the national and global challenges we now face would benefit from the skills and data resources that molecular ecologists bring. Genetic data are increasingly being embraced to respond to the biodiversity crisis (Hunter et al. 2018), inform public health (van Dorp et al. 2021), monitor ecosystem health (e.g. Clark et al. 2020), address issues of food security (Esquinas-Alcázar 2005), to inform wild stock determination (Koot et al. 2021) and breeding of domesticated species (Hayes et al. 2013), and are considered in international policy, such as the United Nation's Sustainable Development Goals (SDGs) and the Convention on Biological Diversity (CBD). In Aotearoa New Zealand, the Department of Conservation (DOC) has recently revised the national biodiversity strategy, 'Te Mana o te Taiao', citing that over the next three decades we need to ensure species' populations are genetically diverse and buffered from impacts arising from a loss of genetic diversity (DOC 2020). This strategy will underpin the reporting of Aotearoa against the post-2020 Global Biodiversity Strategy currently being finalised (Secretariat of the CBD 2021) and for which there have been calls for a greater focus on the use of genetic data and derived measures as indicators (Laikre et al. 2020; Hoban et al. 2020, 2021). Furthermore, the 2018 Australasian Taxonomy

Strategy acknowledged the power of molecular ecology to describe ecological 'dark matter' – species we do not even yet know exist (Taxonomy Decadal Plan Working Group 2018). Even the current COVID-19 pandemic is being tackled with molecular ecological approaches, such as sequencing viral RNA in wastewater to spatially track the pandemic's spread (Wurtzer et al. 2020), further demonstrating the diverse application of molecular ecology skills and techniques.

Just as the influence and contributions of molecular ecology expands, practice within the field is responding to changing philosophies. Although the expectation that science should be reproducible is not new, the 'open science' movement proposes that all field and laboratory methods are disclosed and transparent (Hampton et al. 2015; Powers and Hampton 2019), with the additional requirement for molecular ecologists that all raw DNA sequence data be provided (Whitlock et al. 2010; supporting the FAIR [Findable, Accessible, Interoperable, and Re-usable] Guiding Principles; Wilkinson et al. 2016), and any bioinformatic workflows used to derive the analysed dataset and results be fully described. As a consequence of the Joint Data Archiving Policy (JDAP; FAIRsharing.org 2011) initiated by leading ecology and evolution journals in 2011, molecular ecologists have routinely made their raw genetic data publicly accessible via the International Nucleotide Sequence Database Collaboration (INSDC; Cochrane et al. 2016), or in other open data repositories (such as DataDryad; Vines et al. 2013). However, to further ensure reproducibility and allow potential interoperability and re-use of data, molecular ecologists are now encouraged to additionally deposit the metadata corresponding to individual organisms sampled for genetic analysis (Pope et al. 2015; Sibbett et al. 2020), and the programmatic code they used to manipulate and analyse these data. Consequently, the future molecular ecologist needs to be savvy with the standard vocabularies for metadata, their deposition and linking to genetic data, and how to share and comprehensively annotate all analytical steps and relevant code.

Although open access to genetic resources may seem fair from the research community perspective (but see Mills et al. 2015), there has been a call for a re-calibration of this philosophy to include the CARE (Collective benefit, Authority to control, Responsibility, Ethics) Principles of Indigenous Data Governance (Carroll et al. 2020; Hudson et al. 2020; McCartney et al. 2022). The 'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization' (United Nations 2011) specifies that realising fairness and equity extends beyond the research community to consider Indigenous Peoples. The 'First Draft Post-2020 Global Biodiversity Framework' further articulates that fair and equitable sharing of monetary and non-monetary benefits includes the conservation and sustainable use of biodiversity (Secretariat of the CBD 2021). In Aotearoa, the Wai 262 Claim (https://www.tpk.govt.nz/en/a-matou-kaupapa/te-ao-maori/wai-262-te-pae-tawhiti; Waitangi Tribunal 2011) identifies breaches of Te Tiriti o Waitangi (the Treaty of Waitangi) concerning Māori cultural heritage, intellectual property, and flora and fauna including genetic resources, stipulating the expectation of Māori that these resources should support their aspirations. Enacting the principles of CARE alongside the open principles of FAIR will provide Indigenous Peoples with stewardship roles, mutually beneficial access, and use of data resources (Carroll et al. 2021). There is urgency in developing this capability to support Māori and other Indigenous Peoples, and to help molecular ecologists conduct their research in both scientifically ethical and socially responsible ways.

Although Aotearoa has not ratified the Nagoya Protocol, many countries have, so to ensure continuity of our research globally (Marden 2018), we must demonstrate our commitment to recognising Indigenous rights as a research community. Thus, we are entering a pivotal time in the field of molecular ecology regarding the use and stewardship of genetic resources in Aotearoa and globally, that coincides with the professional development of our early career molecular ecologists.

Current and future molecular ecologists of Aotearoa will have to navigate this defining period and embrace opportunities to collaborate across disciplines to tackle some of the major issues we face. A step-change will require individual action (or 'buy-in') by molecular ecologists, and top-down support from mentors, institutions, and agencies. Several interest groups have recognised this need and are very active toward these goals (Tables 1 and 2, see statement I.). Nonetheless, for an Early Career Researcher (ECR) navigating technological advances in the field, the principles of FAIR and CARE, as well as the heightened relevance and interest in the application of genetic data to the challenges we face, is a confronting experience. For that reason, a workshop was run over five days in May 2019, comprising 24 ECRs of Aotearoa, and supported by 8 mentors active in progressing and extending the field of molecular ecology, or supporting best practice of molecular ecologists (see Box 1). Here, we present the perspectives of 23 participating ECRs, to serve as: a statement of commitment to best practice from these ECRs; to highlight important considerations for any ECR embarking on genetic research in Aotearoa; and an introduction to the pertinent issues (from an ECR perspective) for those in a position to support ECRs.

Box 1. The Ira Moana Project Early Career Workshop

This workshop brought together ECRs interested in an open discussion and collaborative learning environment to take stock of genetic research in Aotearoa, the practice of molecular ecologists in Aotearoa, and most importantly, to define the priorities that need to be addressed for the future of molecular ecology in Aotearoa. The career stage of participants varied from Masters and PhD level, through to postdoctoral fellows, early lectureship, and professional scientific appointments within regional and national government departments and CRIs (representing 11 institutions). The group included ECRs who varied in gender, ethnicity, immigration status, and regional location within Aotearoa. The workshop was co-facilitated and supported by several mentors, both domestic and international, with expertise in Te Ao Māori, Indigenous data sovereignty, ethics, genomics, bioinformatics, spatial ecology, and conservation.

The intention was to invite the ECRs to think outside their current research or professional activity and think forward and laterally about the opportunities for the field of molecular ecology, with a specific focus on an Aotearoa context. Through optionally anonymous feedback, the ECRs expressed that they enjoyed learning about Te Ao Māori, the importance of recognising cultural values within their research practice, and mindfulness. The ECRs enjoyed the opportunity for extended discussion, the guided and collaborative tutorials in spatialising genetic data, and the potential application of those genetic data and their skills as molecular ecologists to other fields, such as conservation. The workshop enabled the ECRs to hear about the research of others, to meet ECRs from other research institutions, and to propose future collaborations.

There were several avenues left open for further exploration and discussion following the workshop. The participants wanted to stay in touch and to contribute to research outputs as a result of discussions and knowledge acquired. Recognising that together the ECR participants represent a considerable proportion of research institutions in Aotearoa and interests in genetic data and research, the group acknowledged their role as potential change-makers in the future research scene of Aotearoa. This ECR perspective on the future of molecular ecology in Aotearoa is one such contribution.

Our future aspirations for molecular ecology

Here, we state goals and aspirations for the field of molecular ecology in Aotearoa from an ECR perspective. Below each statement, we elaborate on our view and highlight

Table 1. Considerations relevant to genetic research in Aotearoa New Zealand, and resources and infrastructures available to support molecular ecologists.

Considerations	Available Resources/Infrastructure
(1) Should/could this research be (co-)led by Māori?	Refer to relevant policies, guidelines and reports including Vision Mātauranga, Te Nohonga Kaitiaki, Te Mata Ira, He Tangata Kei Tua, Te Ara Tika, Te Pūtahitanga, Rauika Māngai, the Kaupapa Māori and Rangahau website, Collier-Robinson et al. (2019) and other references cited in text, and communicate with relevant iwi, hapū, and whānau and other Māori entities.
(2) Animal ethics and value of the study organism/environment	Listen and refer to advice on Te Ao Māori and tāonga species in (1). Refer to the DOC Threat Status of species, Fisheries NZ commercial and recreational fisheries species, Biosecurity NZ list of pest species and disease threats, and advice of institution ethics committees.
(3) Government legislation and permissions	Consult DOC, MBIE, MPI (including Fisheries NZ and Biosecurity NZ), EPA regulations.
(4) Māori iwi, hapū, whānau and other Māori entity permissions	Listen, and refer to advice on Te Ao Māori, engagement and research practice in (1) and (6). Check whether TK and BC Labels are applied in the Local Contexts Hub, or relevant metadata in INSDC or GEOME.
(5) Local community permissions	Seek advice from government agencies (3) and Māori entities (4) and refer to society/community/government publications to find relevant local community bodies.
(6) Collaboration/communication with Māori, government, and local community	See (1), (3), (4) and (5) above. This should happen at all stages of the research.
(7) Communication/collaboration with relevant science experts	Consult/contact the molecular ecology research community via email, Twitter, Slack, e.g. GFANZ, Genomics Aotearoa, NZMolEcol, MapNet. Consult relevant taxonomic specialists.
(8) Existing tissue or DNA collections that could be used	Check museum/national collections, query GEOME, and consult molecular ecology research community in (7).
(9) Existing genomic data that could be used	Query INSDC, GEOME, AGDR and consult molecular ecology research community in (7).
(10) Study design	Consult the appropriate literature and molecular ecology research community in (7) to guide the design of the research, including appropriate use of molecular markers, adequate sample sizes and sampling design, datamining and analysis decisions. Also see (12) and (13).
(11) Sample data, genomic data, and metadata recording and management	Refer to metadata standards of TDWG and GSC (including MIxS), and downloadable metadata templates in GEOME.
(12) Best-practice laboratory and field protocols	Search for existing protocols (e.g. Protocols.io), and consult molecular ecology research community in (7).
(13) Reproducible bioinformatic and analysis workflows	Search for existing workflows (e.g. GitHub/GitLab) and consult molecular ecology research community in (7), and repositories of GFANZ and Genomics Aotearoa.
(14) Genomic data and metadata accessibility	Consider using INSDC, AGDR, and/or GEOME.
(15) Māori data sovereignty	Refer to (1) for advice on Māori interests in genetic resources and data sovereignty, and accommodate the preferences of collaborating Māori entities, iwi, hapū, and whānau in (4). Consider using an access controlled genetic data repository (e.g. AGDR), applying TK and BC Notices using the Local Contexts Hub, and using GEOME to maintain relevant metadata.
(16) Research dissemination to end-users, Treaty Partners, and interested parties	Refer to advice in (1) for engagement and research practice with Māori, and follow guidance of collaborating Māori entities, iwi, hapū, and whānau in (4). Consult Science Media Hub resources, and any institutional communication/media support. Communicate results directly to taxonomic specialists, and to relevant government directorates and teams. This should happen at all stages of the research.

Note: These considerations are relevant to many stages of research, and should be revisited frequently. Further explanation of resources and infrastructures can be found in Table 2.

Table 2. Explanation of resources and infrastructure referred to in the main text and Table 1 (in alphabetical order).

Resource/Infrastructure	Description
Aotearoa Genomic Data Repository, AGDR	An online repository jointly developed by Genomics Aotearoa and NeSI to provide a secure place to store and share genomic data within a Māori values context, following the principles of Māori Data Sovereignty. Researchers can deposit, browse, and request access to datasets via the data repository. https://repo.data.nesi.org.nz/
CARE Principles for Indigenous Data Governance	Designed to complement the FAIR Principles, these people – and purpose-oriented principles and supporting concepts (Collective benefit, Authority to control, Responsibility, Ethics) reflect the crucial role of data in advancing innovation, governance, and self-determination among Indigenous Peoples (Carroll et al. 2020). https://www.gida-global.org/care
Convention on Biological Diversity, CBD	Initiated at the Rio Earth Summit in 1992 with three objectives: (1) The conservation of biological diversity, (2) The sustainable use of the components of biological diversity, (3) The fair and equitable sharing of the benefits arising out of the utilisation of genetic resources. https://www.cbd.int/
Darwin Core, TDWG	A glossary of terms (i.e. properties, fields, columns, attributes) intended to facilitate the sharing of information/metadata about biodiversity by providing identifiers, labels, and definitions. Darwin Core is primarily based on taxa, their occurrence in nature as documented by observations, specimens, samples, and related information (Wieczorek et al. 2012). https://dwc.tdwg.org/
Department of Conservation | Te Papa Atawhai, DOC	A public service department of Aotearoa charged with the conservation of natural and historical heritage. https://www.doc.govt.nz/
Environmental Protection Authority | Te Mana Rauhī Taiao, EPA	A government agency of Aotearoa responsible for regulating activities that affect environment. https://www.epa.govt.nz/
FAIR Guiding Principles	Guidelines for scientific data management and stewardship intended to improve the Findability, Accessibility, Interoperability, and Reuse of digital assets (Wilkinson et al. 2016). https://www.go-fair.org/fair-principles/
Genomic Observatories Metadatabase, GEOME	A web-based database that helps capture and curate the metadata associated with biological samples and associated genetic sequences according to global data standards and best practices (Deck et al. 2017; Riginos et al. 2020). https://geome-db.org/
Genomics Aotearoa	A Strategic Science Investment Funded Platform established to ensure that Aotearoa can continue to lead and participate in genomic and bioinformatic research internationally. Genomics Aotearoa distributes a newsletter, funds positions and projects, and hosts seminars, and workshops, to facilitate Aotearoa-wide genomic research activities. https://www.genomics-aotearoa.org.nz/
Genomics for Aotearoa New Zealand (NZ), GFANZ	A charitable society that has been building genomic research capacity through networking events, workshops, and tool and infrastructure development. https://genomics.nz/
Genomics Standards Consortium, GSC	An international open-membership working body that aims to enable genomic data integration, discovery, and comparison through international community-driven standards. https://press3.mcs.anl.gov/gensc/
GitHub	A provider of internet hosting, sharing, and version control for code, bioinformatics workflows, and software development. Several molecular ecology researchers and organisations of Aotearoa have GitHub repositories. https://github.com/
He Tangata Kei Tua	A framework for addressing Māori ethical issues within the context of biobanks, which are collections of biospecimens used for health research. Most relevant to molecular ecologists working with collections and data derived from humans, but outlines mātauranga and tikanga of relevance to other collections and data (Hudson et al. 2016a).
Institution (CI) Notices	These Notices (including 'Attribution Incomplete' and 'Open to Collaborate') and are for use by collecting institutions, data repositories, and organisations who engage in collaborative curation

(*Continued*)

Table 2. Continued.

Resource/Infrastructure	Description
	with Indigenous Peoples to support the recognition of Indigenous interests in collections and data. https://localcontexts.org/notices/cultural-institution-notices/
International Nucleotide Sequence Database Collaboration, INSDC	Several online genetic data repositories that share data on a daily basis, including the DNA DataBank of Japan (DDBJ), the European Nucleotide Archive (ENA), and the National Center for Biotechnology Information (NCBI, including GenBank; Cochrane et al. 2016). https://www.insdc.org/
Ira Moana – Genes of the Sea – Project	An MBIE funded project to establish a searchable metadatabase using GEOME for genetic and genomic data to help researchers follow international best-practice and contribute to a national genetic data resource for Aotearoa (Liggins and Noble 2021b). https://sites.massey.ac.nz/iramoana/
Joint Data Archiving Policy, JDAP	Describes a requirement that data supporting publications be publicly available. This policy was adopted in a joint and coordinated fashion by many leading journals in the fields of ecology and evolution in 2011. https://datadryad.org/docs/JointDataArchivingPolicy.pdf
Kaupapa Māori and Rangahau website	Provides guidance on research practice within a kaupapa Māori-framework, relevant to all stages of the research process. The website is developed to support Māori, but is also informative to non-Māori. http://www.rangahau.co.nz/
Local Contexts Hub	A web portal that allows Indigenous Peoples to customise the TK and BC Labels, apply them, and share them nationally and internationally. The Hub also allows researchers and institutions to generate Notices, and to connect with Indigenous Peoples about adding Labels. https://localcontexts.org/tk-label-hub/
MapNet	An annual conference for Aotearoa-based scientists involved in genomics related research
Ministry for Business, Innovation, and Employment | Hīkina Whakatutuki, MBIE	The public service department of Aotearoa responsible for delivering policy, services, advice, and regulation contributing to economic productivity and business growth. https://www.mbie.govt.nz/
Ministry for Primary Industries | Manatū Ahu Matua, MPI	The public service department of Aotearoa responsible for overseeing, managing and regulating the farming, fishing, food, animal welfare, biosecurity, and forestry sectors of primary industries. https://www.mpi.govt.nz/
MIxS	The minimum information standards (i.e. metadata checklists) for any (x) sequence devised by the GSC (Field et al. 2008; Yilmaz et al. 2011). https://press3.mcs.anl.gov/gensc/mixs/
Nagoya Protocol	The 'Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization' is a supplementary agreement to the CBD that specifies that realising fairness and equity extends beyond the research community to include Indigenous Peoples (United Nations 2011). https://www.cbd.int/abs/
NZ eScience Infrastructure, NeSI	A national infrastructure and service provider that helps build infrastructure and provide support for computational research projects for improved science outcomes and downstream benefits to the society of Aotearoa. https://www.nesi.org.nz/
NZ Molecular Ecology Group, NZMolEcol	A group facilitating interaction among molecular ecologists of Aotearoa, including an annual ECR-oriented conference. https://www.nzmolecol.org
Protocols.io	A collaborative platform that provides a DOI for protocols of relevance to field sampling protocols, laboratory procedures, and computational workflows aimed to facilitate collaboration, reproducibility, and refinement of best practices. https://www.protocols.io/
Rauika Māngai	A 'A guide to Vision Mātauranga: lessons from Māori voices in the New Zealand science sector' presents perspectives and recommendations gathered at the VM Leadership Hui in 2019. For Māori researchers, it provides guidance for active leadership; for non-Māori researchers, it explains fundamental concepts underpinning VM, and introduces terminology and tools that may be helpful; specific recommendations

(*Continued*)

Table 2. Continued.

Resource/Infrastructure	Description
	for government agencies are also provided (Rauika Māngai 2020). http://www.rauikamangai.co.nz/
Science Media Centre, SMC	A trusted, independent source of information for the media of Aotearoa on all issues related to science. SMC helps researchers promote their research, and provides resources and training to help them interact with media. https://www.sciencemediacentre.co.nz/
Summer Internship for INdigenous Genomics, SING	SING Aotearoa is a week-long internship programme providing knowledge and experience in genomic research for Māori (of diverse expertise including law, ethics, business, science, and leadership) wanting to better understand the opportunities and challenges associated with genomic research as well as the technical, cultural, and ethical issues. https://www.singaotearoa.nz/ (part of https://www.singconsortium.org/)
Te Ara Tika	'Guidelines for Māori Research Ethics' outlines a framework for addressing Māori ethical issues for researchers and ethics committee members. The framework draws on tikanga Māori (Māori protocols and practices) to provide recommended best practices aligned with expectations of behaviour within Te Ao Māori. It considers humans and related data, but is also relevant to research focused on taonga species (Hudson et al. 2010)
Te Mana Raraunga	The Māori Data Sovereignty Network aims to advance Māori aspirations for collective and individual wellbeing by: asserting Māori rights and interests in relation to data, and the safeguarding and protecting these data by Māori. The webpage provides resources outlining principles, guidelines, and policy relevant to Māori and Indigenous Data Sovereignty. https://www.temanararaunga.maori.nz/
Te Mata Ira	'Guidelines for genomic research with Māori' outlines a framework for addressing Māori ethical issues within the context of genetic or genomic research. It draws on a foundation of mātauranga and tikanga Māori to help guide researchers, ethics committee members, and those who engage in consultation or advice about genomic research (Hudson et al. 2016b).
Te Nohonga Kaitiaki	'Guidelines for Genomic Research with Taonga Species' describes the role of kaitiaki and mana whenua (Māori with authority over land or territory) in managing Māori interests in biological samples or genetic resources, including derived data. For molecular ecologists working on any organisms (including taonga [tangible and intangible treasures]), it provides background on relevant principles and issues, and checklists to guide practice at different stages of research (Hudson et al. 2021)
Te Pūtahitanga	'A Tiriti – led science-policy approach for Aotearoa New Zealand' examines the interface between science and policymaking and provides recommendations for strengthening our research, science, and innovation sector, guided by Te Tiriti o Waitangi and mātauranga Māori (Kukutai et al. 2021)
Te Tiriti o Waitangi	The Treaty of Waitangi. An agreement drawn up between representatives of the British Crown and representatives of Māori iwi and hapū and has played a major role in framing the political relations between New Zealand's government and Māori. Named after the place in the Bay of Islands where it was first signed on 6 February 1840
Traditional Knowledge (TK) and Biocultural (BC) Labels	These Labels are customised by Indigenous Peoples to express local and specific conditions for sharing and engaging in future research and relationships in ways that are consistent with already existing community rules, governance, and protocols for using, sharing, and circulating knowledge and data (Anderson and Christen 2019; Anderson and Hudson 2020). https://localcontexts.org/labels/traditional-knowledge-labels/, https://localcontexts.org/labels/biocultural-labels/
Traditional Knowledge (TK) and Biocultural (BC) Notices	These Notices are specific tools for institutions and researchers which support the recognition of Indigenous interests in collections and data. The Notices can function as place-holders on collections, data, or

(*Continued*)

Table 2. Continued.

Resource/Infrastructure	Description
	metadata until a TK or a BC Label is added by an Indigenous community (Anderson and Christen 2019; Liggins et al. 2021a). https://localcontexts.org/notices/aboutnotices/
Vision Mātauranga, VM	'Unlocking the Innovation Potential of Māori Knowledge, Resources and People' is the guiding policy for MBIE aimed to: help recognise Māori as important partners in science and innovation; build the capability of Māori; maximise the quality of the relationship between Māori and the Crown through science and innovation and through te Tiriti (Ministry of Research, Science, and Technology 2007).
Wai 262 Claim	A claim lodged to the Waitangi Tribunal in 1991 that asserted Indigenous ownership over the natural and cultural world of Aotearoa, stating that the Crown had breached its Te Tiriti o Waitangi guarantee to enable Māori to exercise tino rangatiratanga (self-determination, independence, autonomy) over our mātauranga Māori and taonga. https://www.tpk.govt.nz/en/a-matou-kaupapa/te-ao-maori/wai-262-te-pae-tawhiti

particular issues or existing resources and capabilities that may help progress practices in a favourable direction. Considerations relevant to genetic research, and resources and infrastructures available to support molecular ecologists are in Table 1 and further explained in Table 2.

A. We will learn about Te Ao Māori (Māori worldviews) with respect to genetic research and collaborate with, and support, Māori.

There is unanimous positivity regarding the importance and value of engaging Māori perspectives and communities to inform molecular ecological research and ensure our research is relevant. To align with national strategies such as Vision Mātauranga (VM, Ministry of Research Science and Technology 2007; and several institutions have their own related strategies and policies), ECRs need resources and infrastructure to support their engagement with Māori, and to operationalise these relationships. Indigenous and Māori perspectives on modern genetics, and exchanges with researchers, have been fostered through programmes such as the Summer internship for INdigenous peoples in Genomics (SING). These opportunities provide Māori communities and ECRs (Māori and non-Māori) with valuable knowledge. However, many molecular ecology ECRs have little experience with Te Ao Māori and mātauranga Māori (Māori knowledge) and little understanding of Te Tiriti. To initiate a better understanding in this area, we have compiled some resources around the relevant cultural context of Aotearoa and Māori interests in genetic research (Tables 1 and 2).

Researchers are eager to collaborate and engage with Māori communities without compromising the sincerity/integrity of the process. Communications with iwi (tribes) and hapū (subtribes) are often via DOC, the Māori engagement offices of research institutions, or iwi boards. Liaison facilitated by such groups has the advantages of streamlining the process and relieving the burden on all parties. However, a mediated relationship can fail to create and maintain mutual trust and understanding between researchers and iwi, hapū or other Māori entities (e.g. fisheries forums and kaitiaki rōpū [custodian groups]), and does not invite a pre-research design discussion regarding the shared interests and needs of Māori that would enable co-led and co-developed research (Wilcox et al. 2008; Collier-Robinson et al. 2019). Furthermore, differing perspectives and values exist within and among iwi and hapū, which cannot be adequately represented by a single mediating party. Several initiatives are underway to facilitate better relationship building among researchers and iwi or hapū. While VM normalises the consideration and promotes inclusion of Te Ao Māori and mātauranga Māori in all research, ECRs need to be included in 'bottom-up' approaches such as SING, and some of the co-developed research activities within Government-funded National Science Challenges and Endeavour Fund Research Programmes that offer valuable learning experiences. Outside of these high profile initiatives, transitioning to new ways of working will take time, but as a sign of support and commitment, institutions and research groups can use 'Institution Notices' developed by Local Contexts (https://localcontexts.org/; see Tables 1 and 2) to signal that they are 'Open to Collaborate' with Indigenous Peoples.

Māori molecular ecologists are often burdened as cultural trainers for their non-Māori colleagues, owing to limited capacity within many research institutions (Haar and Martin 2021). Māori ECRs need opportunities to lead research at the interface of mātauranga Māori and molecular ecology. For instance, the Māori worldview of te orokohanga (creation), te ira tangata (the human element), and whakapapa (genealogy, lineage, descent) resonates with the concept of 'genealogy', core to molecular ecology. This rich knowledge base shared through whare wānanga (places of knowledge exchange), the toi (Māori arts), and pūrākau (oral narrations) can be interwoven with molecular ecological research (e.g. Rayne et al. 2020; Rayne et al. 2022 and references therein). One of the leading journals in molecular ecology has dedicated an upcoming special issue ('Indigenous Contributions to Molecular Ecology', https://onlinelibrary.wiley.com/page/journal/17550998/homepage/call_for_submissions_indigenouscontributions) to highlight and promote the work of Indigenous scientists, spotlight Indigenous role models, and 'place explicit value on Indigenous research methodologies and traditional knowledge as important to Indigenous communities and scientists in the research process'. It is anticipated this special issue will showcase the research of Māori ECRs, providing a platform upon which they can connect with diverse researchers and international networks, affirming Indigenous-led research as world-leading. Similarly, in Aotearoa, the 2020 and 2022 MapNet conferences were themed 'Mātauranga and Te Ao Māori to guide better genetics research: better outcomes for people and for science', featuring only Indigenous speakers. It is hoped that such celebration of Indigenous scholarship and its importance to our collective scientific and societal gains opens pathways for our Māori early career molecular ecologists to excel, without them needing to forge their own.

B. We will acknowledge Māori and Indigenous contexts, rights, and interests in our research.

Indigenous rights and contexts can be acknowledged using existing research infrastructures. For instance, within journal articles researchers can often include te reo (Māori language) abstracts, use Māori names (including individual organism names; Carroll et al. 2020), and provide context regarding the cultural value of the study organisms, locations, and associated mātauranga Māori in the main text of publications (e.g. Short and Trnski 2021; Rayne et al. 2022). Co-authorship and acknowledgement of individuals, hapū, and iwi, including specific contributions in the authorship and acknowledgement sections, are quite typical. The taxonomic naming of some species has also included iwi as a naming authority (e.g. Heesch et al. 2021). However, we could additionally make use of the 'Data accessibility' section of publications to disclose how benefits have been shared with Indigenous Peoples (as suggested by Marden et al. 2021), and to provide text that acknowledges the role of Māori as kaitiaki (stewards) of biodiversity and related data resources (e.g. Hauser et al. 2022), including the implications this may have for future data re-use (Liggins et al. 2021a, and further described in statement C.; e.g. using the Local Contexts Hub, Wu et al. 2022; and using controlled access repositories as described in statement C., Dussex et al. 2021; McCartney et al. 2021).

As the provisioning of metadata alongside genetic data becomes common practice (described in statements C. and D.), there is the opportunity to routinely represent Te Ao Māori and provide information pertaining to the interests and aspirations of Māori involved with the research. For instance, using the infrastructure provided by the Genomic Observatories MetaDatabase (GEOME, Deck et al. 2017; Riginos et al. 2020; see statement E.), the Ira Moana Project (Liggins and Noble 2021b) has developed a custom metadata template for genetic studies of marine biodiversity in Aotearoa that provides several fields that could be used for this purpose. In collaboration with Local Contexts and GEOME, the Ira Moana Project has implemented a metadata field called the 'Traditional Knowledge (TK) Notice' (Anderson and Christen 2019). This TK Notice is applied by researchers, and signals that there are accompanying cultural rights and responsibilities that need further attention for any future sharing and use of the associated genetic data. The TK Notice may indicate that other more specific 'TK Labels' or 'Biocultural (BC) Labels' (Anderson and Hudson 2020) are in development by an Indigenous community. In lieu of specific Labels or Notices attached to individual items, collection holders may alternatively use the Institution Notice, 'Attribution Incomplete', to identify those collections which have incomplete, inaccurate, or missing attributions with regard to the local Indigenous Peoples and origin/s of the collection/s.

C. We will make genetic resources findable, accessible, and interoperable, but responsive to Māori data sovereignty.

Increasingly, institutional natural history collection holdings are becoming publicly available online, including details of tissue collections and genetic resources. Ongoing digitisation efforts will help reduce duplication of sampling effort, the associated costs, and impacts of collecting on biodiversity and those involved in permitting processes. Such resources would also help motivate research that may otherwise be deemed unfeasible or impossible. Several institutions of Aotearoa have publicly searchable holdings; however, making collections visible may take some time, largely because of resourcing issues (see Nelson et al. 2015) and the required consideration of Māori data sovereignty over collections and associated data (Wehi et al. 2020; Forsdick et al. 2021). Even so, we are not aware of a nationwide commitment to open online availability of our biological specimens or related genetic resources.

There are cross-institutional models for facilitating the sharing of tissues and genetic resources (e.g. INSDC for genetic data; GEOME for biological samples pertaining to genetic data; and Otlet for tissues, https://otlet.io/). However, in Aotearoa, Indigenous rights recognition including rangatiratanga (governance) over data accessibility is essential (Hudson et al. 2020; Carroll et al. 2021). These rights extend to archived material, such as museum specimens, tissue collections (Forsdick et al. 2021), and all derived genetic data (Hudson et al. 2020; Liggins et al. 2021a) and metadata. In cases where genetic data already exist in open access databases (e.g. INSDC), the Local Contexts Hub and metadatabases for genetic resources, such as GEOME, can help mediate controlled access through the use of additional metadata fields that maintain the interests of the relevant Indigenous Peoples regarding access, re-use, and attribution (e.g. via TK and BC Labels; see statement B.). Alternatively, some institution-specific repositories and the Aotearoa Genomic Data Repository (AGDR) provide the opportunity to store genetic data within Aotearoa, where access is controlled by the appropriate kaitiaki (e.g. kākāpo, Dussex et al. 2021; mānuka, Koot et al. 2022). In cases of controlled-access, provision of open metadata enables genetic resources to be findable and interoperable with data coming from other data sources, should access to the data be granted.

D. We will provide metadata associated with genetic data to ensure study reproducibility and data reusability.

While there has been a culture of providing open access to all genetic data produced toward a given study objective (owing to the JDAP), this has not necessarily ensured study reproducibility, or that the data are in a reusable form (Pope et al. 2015; Toczydlowski et al. 2021). Information about the genetic data, such as the location and year of collection, are often essential to reproduce the original study, and to enable any future re-use of the genetic data.

Internationally, groups such as the Biodiversity Information Standards Organization (TDWG, administering the Darwin Core Standard, Wieczorek et al. 2012) and the Genomic Standards Consortium (GSC, Wooley et al. 2009) have defined appropriate vocabularies and metadata standards for genetic biodiversity studies (e.g. Field et al. 2008; Yilmaz et al. 2011 defining the 'Minimum Information about any (x) Sequence', MIxS standard). The retention and stewardship of these metadata have now been operationalised by GEOME, and some repositories of the INSDC. Provisioning these metadata for genetic data can help make sure our molecular ecological research is reproducible, future-proofed, and useful to the next generation of our nation (see statements G., H., J., K.). Taking precedent over such openness, however, is consideration of Māori data sovereignty. When collected for taonga (treasured) species, some metadata may also be considered taonga (Collier-Robinson et al. 2019), meaning that collaborating iwi and hapū may prefer to protect or redact certain metadata fields from the public domain. In Aotearoa, GEOME's infrastructure has been used by the Ira Moana Project to provide Aotearoa's molecular ecologists with a template to guide collation, upload, and on-going storage of metadata relevant to the nation's interests, including a TDWG field 'informationWithheld' that can name metadata that exist, but are not shared, for reasons of sensitivity.

E. We are committed to generating interoperable and reproducible bioinformatic and analysis workflows.

With the commitment to open science, there is a growing need for transparent and reproducible bioinformatic workflows to derive and analyse genetic data from raw sequence reads. Making these workflows available through public repositories such as GitHub or GitLab not only ensures that genetic datasets and analyses are reproducible, it also helps promote interoperability with other existing and future tools. Additionally, although many of these workflows are tailored to tackle unique problems in the discipline, others are easily generalised for use across datasets. By increasing the availability of bioinformatic and analysis workflows, the need for individuals to re-develop their own approaches is reduced, and there is the opportunity to learn from, build on, and peer-review each other's approaches.

Several researchers and organisations of Aotearoa are leaders in developing bioinformatic and analysis routines and share these in open-access repositories. For instance, Genomics Aotearoa has a Github repository used to guide and support workshops, and to develop best-practice workflows, providing opportunities to collaborate and raise the standard of analyses (https://github.com/GenomicsAotearoa). In addition, Genomics for Aotearoa New Zealand (GFANZ) has created an infrastructure to generate docker containers for workflows that contain all the software, dependencies, and descriptive metadata required, alleviating the initial hurdle of software installation, working across various software and coding languages (https://gitlab.com/gfanz/genomics-tools).

F. We are committed to progressing equity in access to infrastructure, software, computing and storage.

The large amounts of genetic data generated by modern sequencing technologies require significant computing power to analyse, handle, and store. Researchers employed by universities, Crown Research Institutes (CRIs), and other government agencies, and those associated with Genomics Aotearoa, may have access to New Zealand eScience Infrastructure (NeSI), or internal computing resources, but independent researchers may not. Without options to use private or national computing resources, public cloud computing resources provide an alternative to ECRs, albeit at (sometimes considerable) cost and providing less opportunity to maintain Māori data sovereignty. Additionally, ECRs who are moving between institutions or employed on a rolling contractual basis rarely have continuous access to computing services or data storage. To help serve these ECRs, GFANZ is developing an automated, reproducible, bioinformatics analysis cloud computing system (https://gitlab.com/gfanz/argo-workflow-development). This resource will be an open access, cost-effective, transparent, and version-controlled bioinformatics platform, for which GFANZ will provide training.

G. We will consolidate genetic data resources for the biodiversity of Aotearoa.

While new genomic approaches deliver a great abundance of data that can be safeguarded by uptake of best practices (see statements C. – E.), the genetic data that have been generated in the past are still of value and in some cases irreplaceable. Decades of molecular genetic research on the biodiversity of Aotearoa has created a substantial genetic data resource that can be used to monitor the genetic integrity of threatened native species (Hoban et al. 2021), the spread of invasive species (e.g. Goldstien et al. 2013), the potentially changing genetic composition of range extending and climate-adapting species (e.g. Jump and Penuelas 2005), or those translocated or affected by re-stocking efforts (e.g. pāua, Roberts et al. 2007; see also Rayne et al. 2020, 2022). Furthermore, these data could now be used to inform multispecies genetic diversity indices and biogeographic patterns at the genetic level across our land – and sea-scapes (Leigh et al. 2021; e.g. Arranz et al. 2022), informing spatial conservation and management planning (e.g. Beger et al. 2014; Nielsen et al. 2017). A quantitative synthesis, however, would require these data to be available in a standard, searchable, and easily accessible infrastructure.

Efforts are underway to upload metadata for existing genetic studies for marine biodiversity of Aotearoa into the Ira Moana Project in GEOME (similar to existing efforts elsewhere, e.g. Diversity of the Indo-Pacific Network, Crandall et al. 2019, www.diversityindopacific.net; and MacroPopGen, Lawrence et al. 2019). This resource will provide a baseline overview of available data that may be used to identify research gaps (taxonomically and spatially) and inform new research directions. Similar efforts for other biomes (e.g. forest, wetland, estuarine, alpine) could be undertaken using the infrastructure and approaches developed in the Ira Moana Project.

H. We will make genetic data for biodiversity of Aotearoa available alongside other biodiversity and environmental information.

We acknowledge that the format of genetic data may be more challenging to engage with, and measures derived from genetic data may be more difficult to comprehend, than in other biodiversity and environmental sciences (also see statement K.). Nonetheless, measures such as genetic diversity are globally acknowledged as important in conserving biodiversity (included in the CBD) and in sustainable development (e.g. SDG 2.5 stipulates ‘maintain genetic diversity’). There are cases where genetic data can provide unique insights that may influence our perception of biodiversity valuations based on species diversity and ecosystem features. For instance, changes in the genetic composition of populations are expected to precede species extinctions (Leroy et al. 2018) and ultimately, the genetic diversity of populations determines their potential to withstand and adapt to environmental changes (e.g. Jump et al. 2009). There is also the potential for environmental DNA (eDNA) approaches to enable more standardised, streamlined and automated monitoring of biodiversity and ecosystem health (Ruppert et al. 2019).

It is the responsibility of molecular ecologists to present genetic information in a format that is easily understood alongside other forms of biodiversity and environmental data. Globally, in response to the biodiversity crisis and 2020 re-drafting of the CBD targets, several groups are working to ensure genetic data and genetic diversity information are considered alongside other biodiversity measures (e.g. Hoban et al. 2021). For instance, the Essential Biodiversity Variables (EBVs, Pereira et al. 2013) concept has been proposed as a means to help collate, summarise, and interpret complex biodiversity data, including genetic data (Hoban et al. 2022), to make them more relevant to end-users (Navarro et al. 2017). Following the lead of other proactive nations (e.g. Hollingsworth et al. 2020; Posledovich et al. 2021), and if our genetic data resources for biodiversity are consolidated (see statement G.), Aotearoa may be well placed to implement the rapid use of these indices within existing initiatives such as the Eco-Index (Rout et al. 2021) or DOC's New Zealand Threat Classification System.

I. We will use resources and infrastructure to enhance communication and collaboration among molecular ecologists.

Many molecular ecologists in Aotearoa work in small teams, or are the sole molecular ecologist in their institution, and, increasingly, molecular ecologists are employed within private research and consulting agencies outside universities and CRIs. Conducting research in isolation makes it more difficult to keep up with important innovations and to deliver the best research outcomes. Nonetheless, the molecular ecology and genetics communities within Aotearoa have a long legacy of cross-institutional collaboration (Table 1), which is important at various stages of the research process. For 13 years (until 2015), the Allan Wilson Centre (a Centre of Research Excellence) brought together molecular ecologists of Aotearoa, including ECRs. The collaborative sentiment built during this time persists. Currently, there are several inclusive organisations which support the molecular ecology research community, including: the New Zealand (NZ) Molecular Ecology Group, which has run ECR-oriented conferences over the past 20 years; GFANZ, a charitable society that has been building genomic research capacity; the annual MapNet meetings, which foster exchange between university, human health, and primary industry scientists; and Genomics Aotearoa, which is a Strategic Science Investment Funded Platform established to ensure that Aotearoa can continue to lead and participate in genomic and bioinformatic research internationally (Table 2). These organisations and their initiatives to bring scientists, industries, and applications of molecular ecology together are crucial to ensure ECRs of Aotearoa remain amongst the world's best molecular ecologists. Increasingly, online workshops, webinars, and communication platforms (e.g. newsletters, blogs, and slack channels) enable greater ECR participation without the barriers of institutional affiliation, travel, and cost.

J. We will provide our molecular ecology skills, knowledge, and genetic data for use in cross-disciplinary collaboration.

We want to encourage broad uptake and use of genetic data in applied disciplines, including conservation and decision science (see statements H. and K.), epidemiology (e.g. Dellicour et al. 2020), and others we are yet to imagine. In these collaborations, we pledge to take an active role in representing and communicating the integrity (and limitations) of the data and approaches. Furthermore, we will seek the appropriate, complementary expertise and advice where necessary. For instance, although molecular ecological research outputs often suggest where taxonomic revision may be necessary within an organismal group, taxonomy is a specialist field. 'Integrative taxonomy' reduces erroneous taxonomic assignments and can expedite the resolution of diverse and/or poorly understood groups, but requires molecular, ecological, behavioural, and/or morphological lines of evidence. Moreover, place-based knowledge and mātauranga can further guide the characterisation of relationships among natural populations (e.g. Rayne et al. 2022). For these reasons, molecular ecologists are encouraged to actively collaborate with iwi and hapū, to undertake early consultation with taxonomic experts, and to retain viable tissue samples and voucher specimens to accession into a national natural history collection, where appropriate (i.e. according to the needs and aspirations of mana whenua [iwi and hapū with territorial rights over a given area]), to ensure reproducibility.

In parallel, as we gain greater volumes of data from modern sequencing technologies, we encourage further cross-disciplinary collaboration in fields such as data science (including spatial data science), machine-learning, and artificial intelligence, to foster new ways of understanding, visualising, and communicating about genetic data (relevant to statements G., H. and K.).

K. We are committed to ensuring that research is accessible and comprehensible to Treaty partners, end-users, and interested parties.

We acknowledge that improvements are needed to ensure that our research outputs have maximum impact and are valued and usable beyond the scientific community, be that government policy makers, resource managers, iwi and hapū, conservation practitioners, or other interested parties. For instance, molecular ecological research outputs are directly applicable to current and developing national government policies, and to long-term strategic research and management planning. Explicit references to genetic data, measures derived from genetic data, and genetic technologies are referred to in the aforementioned Te Mana o te Taiao (reviewed in Forsdick et al. 2021), the Primary Sector Science Roadmap Te Ao Tūroa (Ministry for Primary Industries 2017), and multiple review and strategy documents, for example regarding fisheries management (Mace et al. 2020), and marine conservation (e.g. the Conservation Services Programme Medium Term Research Plans for marine mammals, protected fishes, and corals, DOC 2021/2022). In addition, recent reports (2020–2021) from the Office of the Prime Minister's Chief Science Advisor, Kaitohutohu Mātanga Pūtaiao Matua ki te Pirimia, frequently reference genetic information, including reports reviewing commercial fishing, antimicrobial resistance, and multiple urgent COVID-19 papers (https://www.pmcsa.ac.nz/what-we-do/publications/). However, despite being mutually beneficial for researchers and policy makers, the translation and integration of genetic data and research outputs into government policy development and decision-making is rare. This disconnect stems from molecular ecological research outputs largely being inaccessible to those outside research institutions, and their findings being incomprehensible for those without genetic or even scientific expertise (Taylor et al. 2017).

As a molecular ecology research community, we must commit to: disseminating our research outputs beyond our institutions and scientific journals; translating technical information for end-users (Forsdick et al. 2021); and understanding the broader environmental and societal (including cultural and political) context of our research, to hone our approach and the specific contributions we make (e.g. Inwood et al. 2020; see Table 2). To aid decision-makers and molecular ecologists (and ECR molecular ecologists especially), more processes and platforms need to be initiated where information about relevant government work programmes and strategic directions and data applicability can be mutually exchanged (Garner et al. 2016). Furthermore, to increase science literacy and societal trust in science, we commit to engaging in citizen science (e.g. Martin-

Sanchez et al. 2021), science communication and public education, in order to promote interactions between citizens, scientists, and policy makers (Fritz et al. 2019). Finally, to increase the impact of our research outputs, more trained molecular ecologists are required in data curation and translation roles (Huang et al. 2015), and in advisory roles in policy-making, legislation, Māori entities, and public education (also advocated by Forsdick et al. 2021), which ultimately will expand research and career pathways for future molecular ecologists.

Conclusion

Here, as 23 ECRs, we provide goals based on our own experience and aspirations for the field of molecular ecology in Aotearoa. Our motivation for outlining these goals is not to criticise past or present practices, but to embrace the opportunities that have arisen via recent technological innovations, new applications of genetic data, new international standards, and the philosophies of FAIR and CARE. We want to be in a position to support our governing bodies to make well-resourced, transparent, and informed decisions with regard to biodiversity conservation, management of biological resources, and future research priorities, based on what has been done before. We want to address the national priorities of Aotearoa, such as Wai 262, by developing our practice as molecular ecologists, and to support commitments to international conventions such as the CBD, so that Aotearoa might be in a position to also ratify the Nagoya Protocol. As tangata tiriti ('people of the treaty', all non-Māori citizens) and tangata whenua (Indigenous Peoples), we want to pursue equity with regard to developing, managing, and accessing biological and genetic resources. We want to ensure that Aotearoa continues to be a hub of molecular ecology globally, and that future molecular ecologists are well placed to contribute and collaborate with the world's top researchers to address important challenges. Toward these goals, we have identified simple steps that each molecular ecologist can take, regardless of career stage, to create a step-change in the practice of molecular ecologists in Aotearoa.

We hope to offer a fresh perspective on where to expect future change in molecular ecology research and the community. Some of our goals are ambitious, whereas others are near being met, and new practices operationalised. Articulating these goals is our way of updating the wider research community, informing researchers new to the field, establishing and reinforcing 'new norms', and celebrating the proactivity and positive steps our community is already making. We will take responsibility for our part in enacting progress toward these goals and continuing to find avenues to reach them, but we invite others to also help enable progress toward them. Here, we focus on the national setting of Aotearoa; however, several (if not all) of the goals equally relate to the global research scene and challenges that research communities are facing elsewhere.

The future of many ECRs in Aotearoa and thus outcomes for molecular ecology practice in Aotearoa – is contingent on employment security. The precarity of employment at this career stage has been exacerbated by the global COVID-19 pandemic (Early Career Researcher Forum of Royal Society Te Apārangi 2020; Simpson et al. 2022), which has disproportionately affected minority groups (Ministry for Business, Innovation, and Employment 2020; and references therein). At this time, the molecular ecology early career workforce has been bolstered by postdoctoral and PhD opportunities created by

Genomics Aotearoa, the Whitinga fellowships provided by the Royal Society Te Apārangi, and a call to increase the stipend of PhD candidates in Aotearoa to the living wage (Soar et al. 2021) which, when enacted, will help retain the appeal of a higher education, and potentially a future career in molecular ecology. However, given the appetite for molecular ecological research, these incentives and employment opportunities are too few to retain the number of postdoctoral researchers required to deliver future impact. It is important to note that, although genetic research has historically been (at least perceived as) expensive relative to other forms of biological research, these costs are decreasing as technology advances; the field includes more computational biologists and the re-use of existing data requiring little space, specialist resources, and research funding. Thus, the real investment in molecular ecological outcomes for Aotearoa requires investment in people and viable career pathways.

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