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3

4 **Embedding indigenous principles in genomic research of culturally significant species: a**
5 **conservation genomics case study**

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11

12 **Abstract**

13 Indigenous peoples around the world are leading discussion regarding genomic research of humans,
14 and more recently, species of cultural significance, to ensure the ethical and equitable use of DNA.
15 Within a Māori (indigenous people of Aotearoa New Zealand) worldview, genomic data obtained from
16 taonga (culturally significant) species has whakapapa – generally defined as genealogy, whakapapa
17 layers the contemporary, historical and mythological aspects of bioheritage – thus genomic data
18 obtained from taonga species are taonga in their own right and are best studied using Māori
19 principles. We contend it is the responsibility of researchers working with genomic data from taonga
20 species to move beyond one-off Māori consultation toward building meaningful relationships with
21 relevant Māori communities. Here, we reflect on our experience embedding Māori principles in
22 genomics research as leaders of a BioHeritage National Science Challenge project entitled
23 “Characterising adaptive variation in Aotearoa New Zealand’s terrestrial and freshwater biota”. We are
24 co-developing a culturally-responsive evidence-based position statement regarding the benefits and
25 risks of prioritising adaptive potential to build resilience in threatened taonga species, including
26 species destined for customary or commercial harvest. To achieve this, we co-developed a research

27 programme with the local subtribe, Ngāi Tūāhuriri, that integrates Māori knowledge with emerging
28 genomic technologies and extensive ecological data for two taonga species, kōwaro (Canterbury
29 mudfish; *Neochanna burrowsius*) and kēkēwai (freshwater crayfish; *Paranephrops zealandicus*). The
30 foundation of our research programme is an iterative decision-making framework that includes tissue
31 sampling as well as data generation, storage and access. Beyond upholding the promises made in
32 The Treaty of Waitangi, we contend the integration of Māori principles in genomics research will
33 enhance the recovery of taonga species and enable the realisation of Māori values.

34

35 **Tuhinga whakarāpopoto**

36 He taonga ngā raraunga huinga ira mai i ngā koiora o Aotearoa na te mea he whakaahuatanga ēnei
37 raraunga o te whakapapa o Aotearoa. Nā konā, he tapu ēnei raraunga huinga ira, ā, he tika kia Māori
38 te rangahau o te mātai iranga. Ko te haepapa o ngā kairangahau e mahi ana ki ngā raraunga huinga
39 ira ki te whakawhanaunga atu ki ngā mana whenua o te takiwā kia kaha ake ngā mahi rangahau. Nā
40 konei, ka whaiwhakaaro mātou e pā ana ki tō mātou whakakotahitanga o ngā āhuatanga o te
41 kaupapa Māori me ngā mahi rangahau mātai iranga ki roto i tētahi kaupapa matua mai i Ngā Wero
42 Pūtaiao o Ngā Koiora Tuku Iho o Aotearoa, ā, ko te ingoa o tō mātou take ko “Characterising adaptive
43 variation in Aotearoa New Zealand’s terrestrial and freshwater biota”. Kei te whakawhanake a tahi
44 mātou ko ngā kaitiaki o Ngāi Tūāhuriri i tētahi kōrero e pā ana ki ngā piki me ngā heke o te
45 whakaarotautanga o ngā urutaunga ira ki te awahi i ngā momo tata korehāhā, ngā momo mahinga kai
46 hoki. Kia tutuki i ēnei wawata, i hangaia tētahi kaupapa e mātou. Ko te take o tēnei kaupapa ko te
47 whakakotahitanga o te mātauranga Māori, ngā hangarau hou o te mātai iranga, me ngā āhuatanga o
48 ngā pūnaha hauropi hoki, o te kōwaro (*Neochanna burrowsius*) rāua ko te kēkēwai (*Paranephrops
49 zealandicus*). Ko te paparahi o tēnei kaupapa ko tētahi pou tarāwaho mō ngā tikanga o te kohinga
50 pūtautau, te waihanga raraunga huinga ira, me te rāhuitanga o ngā raraunga. Ko te tumanako ka
51 tūtaki i ngā wawata o Te Tiriti o Waitangi, atu i tērā, mai i te whakakotahitanga o te kaupapa Māori me
52 te mātai iranga, ka pai ake te atawhai ki ngā koiora o Aotearoa, ā, ka whakamana hoki i ngā
53 whanonga o ngā iwi Māori.

54

55 **Keywords:** Mātauranga Māori, rangatiratanga, kaitiakitanga, mahinga kai, taonga species, kaupapa
56 Māori

57

58 **Lay summary:** To provide an example of an effective approach for building meaningful relationships
59 with relevant indigenous communities for mutual benefit, we reflect on our experience and show that
60 using a bicultural approach enriches genomic research on culturally significant species. Embedding
61 indigenous principles leads to more contextualised research thereby maintaining both cultural and
62 biological integrity.

63

64 Indigenous peoples around the world are leading discussions regarding genomic research to ensure
65 the ethical and equitable use of DNA (e.g. Hudson et al. 2016a, 2016b; Hudson et al. 2019; Jacobs et
66 al. 2010; Reardon and Tallbear 2012). While these discussions have primarily focused on humans
67 (e.g. Hudson et al. 2016a, 2016b), there is a growing dialogue regarding genomic research of species
68 that have cultural significance to local indigenous people. In Aotearoa New Zealand, there are many
69 native and endemic species that are **taonga** to **Māori** (herein see Glossary for words in bold). Taonga
70 species can be generally defined as culturally significant species that shape **Mātauranga Māori** and
71 **whakapapa**, but ultimately, local **iwi** and **hapū** have the authority to define their own taonga
72 (<http://www.waitangitribunal.govt.nz/>; Ngāi Tahu Claims Settlement Act 1998). Many of these taonga
73 species are also of significant interest to both national and international researchers. Here, we
74 discuss the cultural significance of taonga species and show how Māori approaches can be better
75 integrated in the genomic research of taonga species in Aotearoa New Zealand.

76

77 **Te Tiriti o Waitangi** / The Treaty of Waitangi (1840) is a crucial founding document that frames the
78 relationship between Māori and the British Crown in Aotearoa New Zealand. Thus, Te Tiriti o Waitangi
79 should be at the forefront of all interactions between Māori and **Pākehā**. Article Two of Te Tiriti o
80 Waitangi guarantees to Māori the **rangatiratanga** over their taonga and ensures that the rights of
81 both Māori as **tangata whenua** and Pākehā are preserved. Historically there have been numerous
82 actions from the Crown that breached these promises of Te Tiriti o Waitangi (Walker 1990). Iwi Māori
83 fought for generations to settle these historical grievances which led to the Treaty of Waitangi Act
84 1975 and the establishment of the Waitangi Tribunal (Walker 1990). Now, many iwi are moving
85 beyond settling their historical grievances into an era of growth and partnership. For example, in his
86 address at the Ngāi Tahu Treaty Commemoration Hui at Ōnuku Marae (2019), Tā Tipene O'Regan
87 stated:

88

89 "...we have now reached a point where we must see ourselves no longer as the damaged and
90 dispossessed victims of the New Zealand Project but as part of, and contributors to, the development
91 of what this nation might yet become."

92

93 As a living document in Aotearoa New Zealand, Te Tiriti o Waitangi has led to government policies
94 and Waitangi Tribunal Reports that provide a clear mandate for research partnership. Of particular
95 relevance, Vision Mātauranga (Ministry of Research, Science and Technology 2007) seeks to ‘unlock
96 the science and innovation potential of Māori knowledge, people and resources’ and Ko Aotearoa
97 Tēnei/This is New Zealand, a report into the WAI 262 claim conventionally known as WAI 262
98 (<http://www.waitangitribunal.govt.nz/>), extends the scope of Te Tiriti o Waitangi to claim the rights of
99 Māori to ngā taonga katoa (reviewed in Ataria et al. 2018). In Te Ao Māori, ngā taonga katoa refers to
100 all things that are treasured by Māori, including indigenous culture, knowledge, flora and fauna. Thus,
101 Te Tiriti o Waitangi is an important consideration for all research conducted in Aotearoa New Zealand,
102 especially research involving taonga species.

103

104 As researchers based at The University of Canterbury, we fall within the territory of Ngāi Tahu who
105 are **mana whenua** for most of Te Waipounamu / the South Island. Ngāi Tūāhuriri is the hapū that are
106 mana whenua from Hurunui to Hakatere and inland to the Main Divide. Te Rūnanga o Ngāi Tahu
107 negotiated Treaty settlements with the Crown earlier than most iwi and since then, have experienced
108 significant growth and development. However, not all tribal groups have had the same experiences,
109 and each iwi and hapū are at a unique stage of development. These factors can affect the capacity for
110 mana whenua to be involved in taonga species research, but it does not influence the relevance of
111 the research to them. Furthermore, for researchers, developing a deeper understanding of the needs,
112 aspirations and circumstances of relevant iwi or hapū enables them to better apply their skills to
113 research questions that are of interest to mana whenua.

114

115 The following quote from Kemps Deed, the largest Ngāi Tahu land purchase by the Crown (Evison
116 2006) details the importance of **mahinga kai** to Ngāi Tahu:

117

118 *“Ko ō mātou kāinga nohoanga, ko ā mātou mahinga kai, me waiho mārie mō ā mātou tamariki, mō
119 muri iho i a mātou.”*

120 *“Our places of residence, cultivations and food gathering places must still be left to us, for ourselves
121 and our children after us”.*

122

123 As a reminder of past breaches of Te Tiriti o Waitangi and a forecast of the future direction for the iwi,
124 it led to the following quote which now acts as the guiding **whakataukī** for Ngāi Tahu:

125

126 *“Mō tatou, ā, mō kā uri ā muri ake nei”*

127 *“For us, and our descendants after us”*

128

129 **Kaupapa Māori** research is based on several key principles and philosophies that are applicable to
130 all research conducted in Aotearoa New Zealand. It is an approach that has arisen from Te Tiriti o
131 Waitangi that enables researchers to consider ethical, methodological and cultural issues from
132 another perspective throughout the research process (Pihama et al. 2002; Smith 1997; Smith 2013;
133 Walker et al. 2006). Kaupapa Māori research originated within an education context (Smith 1997) and
134 has since been expanded by several Māori theorists to encompass research in a more general sense
135 (Pihama 2012; Pihama et al. 2002; Smith 2013). Although there are many interconnected kaupapa
136 Māori research principles, some may be more relevant than others within any given context.

137

138 Ngāi Tahu and Ngāi Tūāhuriri place a strong emphasis on embodying the following core values:
139 whakapapa, **whanaungatanga**, **manaakitanga**, **tikanga**, **tohungatanga**, rangatiratanga and
140 **kaitiakitanga**. All of these are either kaupapa Māori principles themselves or encompassed by them.
141 Below, we frame these core values and highlight four key aspects of kaupapa Māori research
142 applicable to genomic research involving taonga species with a particular focus on Ngāi Tahu
143 interests.

144

145 **Ngā taonga katoa**

146

147 This context provided by Article Two of Te Tiriti o Waitangi is about acknowledging the validity and
148 relevance of Māori ways of knowing and understanding the world (Pihama et al. 2002). Below we
149 discuss several interconnected concepts in Te Ao Māori that we advocate researchers use when
150 working with taonga species that may lead to opportunities to integrate Mātauranga Māori and
151 western science.

152

153 **Te Reo Māori** is an excellent starting point. Te Ao Māori is entrenched in the language, including
154 Māori place names, whakataukī, and associated stories (Wehi et al. 2009; Whaanga et al. 2018). In
155 contrast to the analytical nature of the English language, Te Reo Māori is filled with symbolism and
156 emotional embellishment that allows Māori to intuitively grasp complex concepts. Embracing the
157 strengths of both languages can lead to co-development of research frameworks relevant to both
158 Māori and non-Māori (Mercier 2018; Walker et al. 2006). For example, **mauri** is the life force found in
159 all things: it is the essential quality and vitality of an entity, whether that is a physical object, an
160 individual or an ecosystem (Hikuroa et al. 2011). The integration of Mātauranga Māori and western
161 science can enable frameworks that seek to maintain and enhance mauri and other Māori values
162 (Harmsworth and Tipa 2006; Hikuroa et al. 2011; Hudson et al. 2016c; Rainforth and Harmsworth
163 2019).

164

165 **Tikanga Māori** is about the appropriate way to operate within a Māori context; including customary
166 practices, protocols and ethics (Mead 2003). While the details of tikanga vary across iwi, tikanga still
167 apply to all facets of Māori life. It dictates how Māori interact with each other, and with their
168 environment and taonga. Tapu and noa are multifaceted Māori concepts that fundamentally shape
169 tikanga Māori. Tapu refers to that which is sacred, special, forbidden or restricted; whereas noa is the
170 inverse of tapu and refers to the common and unrestricted (Mead 2003). All taonga are inherently
171 tapu, and tikanga therefore determine how people interact with our taonga.

172

173 Mātauranga Māori is traditionally passed down orally through **pūrākau, waiata, pepeha** and
174 whakataukī, or visually through **mahi toi** (Hikuroa 2017). These ancestral stories are then
175 contextualised using whakapapa (Tau 2001). Although many pūrākau are myths and heavily symbolic
176 in nature, they still serve the practical function of passing on Māori culture and the knowledge of the
177 natural world through a Māori world view (Hikuroa 2017). They also explain the relationship that
178 **tangata whenua** share with the world around them by associating their ancestors with specific
179 aspects of the environment. For researchers with a genuine interest in embedding Mātauranga Māori
180 in their research, developing a general understanding of Te Ao Māori is invaluable. Moreover, we

181 argue it is imperative for researchers to be mindful of local context, particularly when working with the
182 whakapapa of taonga species.

183

184 Whakapapa is generally defined as genealogy, but in Te Ao Māori, it encompasses much more than
185 that (Te Rito 2007). It layers the contemporary, historical, spiritual and mythological aspects of
186 heritage (Tau 2001). Whakapapa is critical in shaping how Māori view the world, and from a traditional
187 Māori perspective, all life on Earth can be traced back through whakapapa (Tau 2001; Te Rito 2007).
188 Although the most common application of whakapapa in a modern context is to describe family
189 pedigrees, whakapapa is not limited to people. The whakapapa of people, animals and plants;
190 mountains, rivers and winds are all interconnected and explain these complex relationships through a
191 Māori lens (Tau 2001). There are a multitude of similarities between whakapapa and a range of
192 western science disciplines, the most literal being DNA-based research.

193

194 DNA is a physical expression of whakapapa. Like DNA, whakapapa is unique to any one hierarchical
195 group. This uniqueness inherently renders whakapapa - and by extension, DNA - as a taonga and
196 something that is tapu (Beaton et al. 2017; Hudson et al. 2016a, 2016b, 2016c). Therefore, tikanga
197 should influence the way that genetic and genomic data are generated and used. However, not all
198 traditional tikanga practices apply to something so novel. Indeed, as modern western science
199 continues to develop new methods, the tikanga surrounding it will also change. Thus, there is a need
200 for Māori communities to be involved with emerging DNA technologies so actions appropriate for
201 Aotearoa New Zealand can be co-developed by researchers and tangata whenua.

202

203 The whakapapa of Māori deities can be viewed as a hierarchical classification of the origin of both the
204 abiotic and biotic aspects of the environment. There are similarities in these ancient creation stories
205 across iwi, but subtle differences between them reflect the need for Māori to describe novel
206 landscapes in new ways. Whakapapa in these settings is used as a tool to enrich Mātauranga Māori
207 within local contexts. For example, the story of Ranginui, Papatūānuku and their children is a very
208 common Māori creation narrative (Reed 2004). However, Pokoharuatepō, the first wife of Ranginui
209 and the mother of Aoraki has special significance to Ngāi Tahu. In this narrative, the creation of what
210 is now known as Te Waipounamu is attributed to the wreckage of Te Waka o Aoraki when Aoraki and

211 his brothers journeyed to meet their new step-mother Papatūānuku. Aoraki and his brothers
212 eventually turned to stone on top of their overturned canoe where they now form the principal peaks
213 of the Southern Alps. This perspective of the landscape in Te Waipounamu is unique to Ngāi Tahu
214 and this whakapapa illustrates the importance of Aoraki / Mt Cook to the people of Ngāi Tahu. By
215 extension, researchers working in the Ngāi Tahu takiwā need to be mindful of the local narrative, for
216 example, by developing an understanding of the significance of place names and the stories behind
217 them (e.g., publicly available resources such as the cultural mapping project, Kā Huru Manu,
218 <http://www.kahurumanu.co.nz/>).

219

220 **Key kaupapa Māori principles for genomic research on taonga species**

221

222 A major focus of kaupapa Māori research is enabling rangatiratanga by providing tangata whenua
223 with the autonomy and authority to practice and share their own culture, knowledge and other taonga
224 in their own way (Pihama et al. 2002; Smith 1997). Within a research context, it enables Māori to
225 shape how their taonga are researched.

226

227 *“He aha te mea nui o te Ao? He tāngata, he tāngata, he tāngata.”*

228 *“What is the most important thing in the world? It is the people, it is the people, it is the people.”*

229

230 **Whanaungatanga** represents our relationships with one another and enables kaupapa Māori
231 research through the process of building and maintaining meaningful partnerships with tangata
232 whenua that are necessary for collaborative projects and an expression of rangatiratanga (Smith
233 2013; Walker et al. 2006). It lies at the core of Māori culture and society, therefore,
234 **whakawhanaungatanga** is the most important step for researchers looking to engage with Māori in a
235 meaningful way. Although there are frameworks available to assist researchers (e.g. Wilcox et al.
236 2008; Hudson and Russell 2009; Smith 2013), building significant relationships with Māori cannot be
237 reduced to simple step-by-step procedures. However, these frameworks can help researchers to
238 recognise and acknowledge the unique culture and tikanga of each iwi, hapū and **whānau** that are
239 involved in the research.

240

241 **Kaitiakitanga** is often translated as guardianship or stewardship. It is a term that has become widely
242 used in mainstream New Zealand regarding species conservation and ecosystem restoration.
243 However, it encompasses more than just conserving species or restoring ecosystems: kaitiakitanga
244 includes everything that is taonga to tangata whenua, including knowledge, culture and language
245 (Lyver and Tylianakis 2017, Wehi and Lord 2017, Wehi et al. 2018, Lyver et al. 2019). Research
246 focused on recovering taonga species, particularly mahinga kai species, has the potential to enhance
247 these interconnected elements. Kaitiakitanga of mahinga kai includes the environment, language,
248 culture and knowledge associated with harvesting practices. Thus, research that aims to enhance
249 species recovery can facilitate more interactions with these species, allowing for the revitalisation of
250 the associated language and practices (Wehi and Lord 2017, Wehi et al. 2018).

251

252 Tohunga were traditionally expert practitioners in a given field that gave direction to others and helped
253 to develop others. Therefore, **tohungatanga** encourages whānau to develop capability and capacity
254 while supporting the development of others. The very nature of science collaboration with mana
255 whenua achieves tohungatanga, as it builds expertise within iwi and hapū to pursue knowledge and
256 ideas that will enable them to strengthen and grow. Furthermore, whanaungatanga is realised through
257 genuine co-development of research ideas and active engagement throughout research process. In
258 doing so, rangatiratanga and kaitiakitanga are also realised because the authority and sovereignty
259 that mana whenua have over their own taonga are recognised.

260

261 As researchers with pre-existing relationships with Ngāi Tahu and Ngāi Tūāhuriri, we were given the
262 opportunity to incorporate these key kaupapa Māori principles in a new scope of work involving
263 genomic research of threatened taonga species, and together with mana whenua frame a narrative
264 that speaks to the subtleties of Te Ao Māori often overlooked by typical western science practice.
265 Here, we share this narrative, not as a template to be followed or as a series of boxes to be ticked,
266 but as an example of one way to better enhance the recovery of taonga species.

267

268 **Genomic research**

269

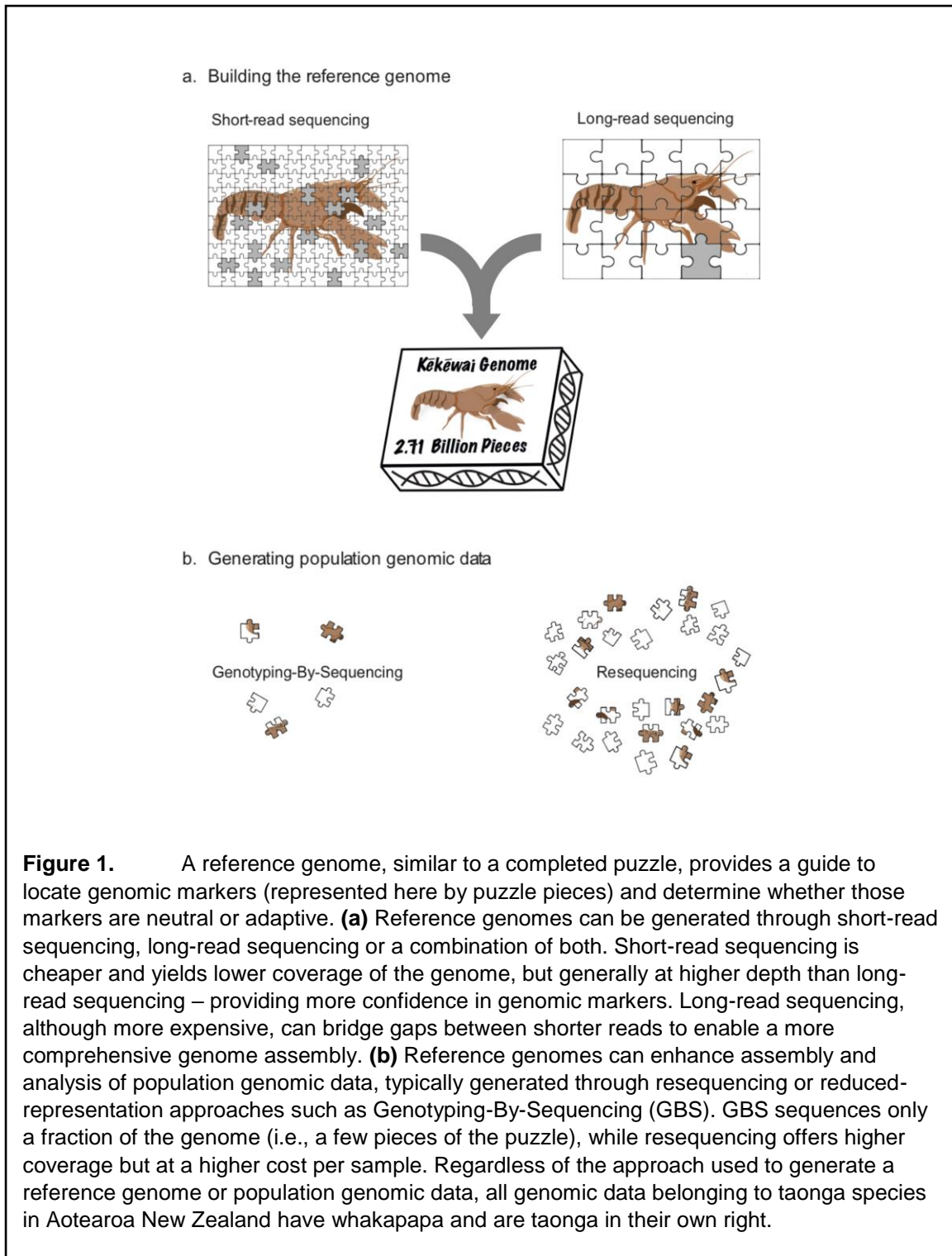
270 Genetics and genomics approaches for studying DNA have become invaluable tools for many
271 biological disciplines, including the conservation of threatened species (reviewed in Galla et al. 2016).
272 New technologies are rapidly expanding our ability to extract, generate and understand DNA. As
273 these technologies become more efficient, they become more affordable and accessible too. Here,
274 we provide a brief description of conservation genetics and genomics, and outline several necessary
275 considerations when generating these data from taonga species.

276

277 Traditionally, conservation genetic studies use a small set of genetic markers scattered throughout
278 the genome to estimate genetic diversity within and between populations in an effort to inform
279 conservation management (Frankham et al. 2010). These strategies are generally implemented in a
280 way that seeks to reduce adverse effects associated with small, isolated populations by minimising
281 inbreeding and the loss of genetic diversity (Frankham et al. 2017). However, there are limitations to
282 using only a small number of genetic markers within a genome that has millions, if not billions, of DNA
283 base pairs, including variation at a small number of selectively neutral markers unlikely being
284 representative of genome-wide variation and, at best, only being able to be used as a proxy for the
285 ability of a species to adapt to changing environments (Allendorf et al. 2010; Ouborg et al. 2010; Funk
286 et al. 2012; Defaveri et al. 2013).

287

288 High-throughput DNA sequencing is rapidly changing the way that we address conservation genetic
289 questions. These new technologies are enabling the generation of reference genomes, as well as the
290 characterisation of many thousands of single nucleotide polymorphisms (SNPs), for non-model
291 species (e.g., Galla et al. 2019). The ability to generate a large number of genome-wide markers
292 within and among natural populations is enabling researchers to address old questions at higher
293 resolution (e.g., estimating relatedness; Lemopoulos et al. 2019) and to tackle entirely new ones (e.g.,
294 characterising adaptive potential; Chen 2019; de Villemerueil et al. 2019).



295

296

297 Regardless of whether researchers generate handfuls of microsatellites versus thousands of SNPs, or

298 single reference genomes versus numerous re-sequenced genomes, the status of these data as

299 taonga remains the same (Figure 1). However, researchers working with genetic and genomic data

300 from taonga species have often failed to acknowledge this in a meaningful way. As a result, data

301 security and management of genetic and genomic data from taonga species has become paramount
302 and considered discussions from a Māori perspective are underway across Aotearoa New Zealand
303 (e.g., SING Aotearoa – Summer internship for Indigenous peoples in Genomics,
304 <https://www.singaotearoa.nz/>). These include discussions that will lead to the development of
305 guidelines for genomic research of taonga species led by Genomics Aotearoa (Te Nohonga Kaitiaki,
306 <https://www.genomics-aotearoa.org.nz/projects/te-nohonga-kaitiaki>). In the meantime, there are
307 growing initiatives in Aotearoa New Zealand that seek to manage access and storage of genomic
308 data from taonga species with appropriate kaitiakitanga (Catanach et al. 2019, Galla et al. 2019,
309 Wellenreuther et al. 2019; for example, password protected genomic data at: [https://www.genomics-](https://www.genomics-aotearoa.org.nz/data)
310 [aotearoa.org.nz/data](https://www.genomics-aotearoa.org.nz/data) and <http://www.uconsert.org/data>).

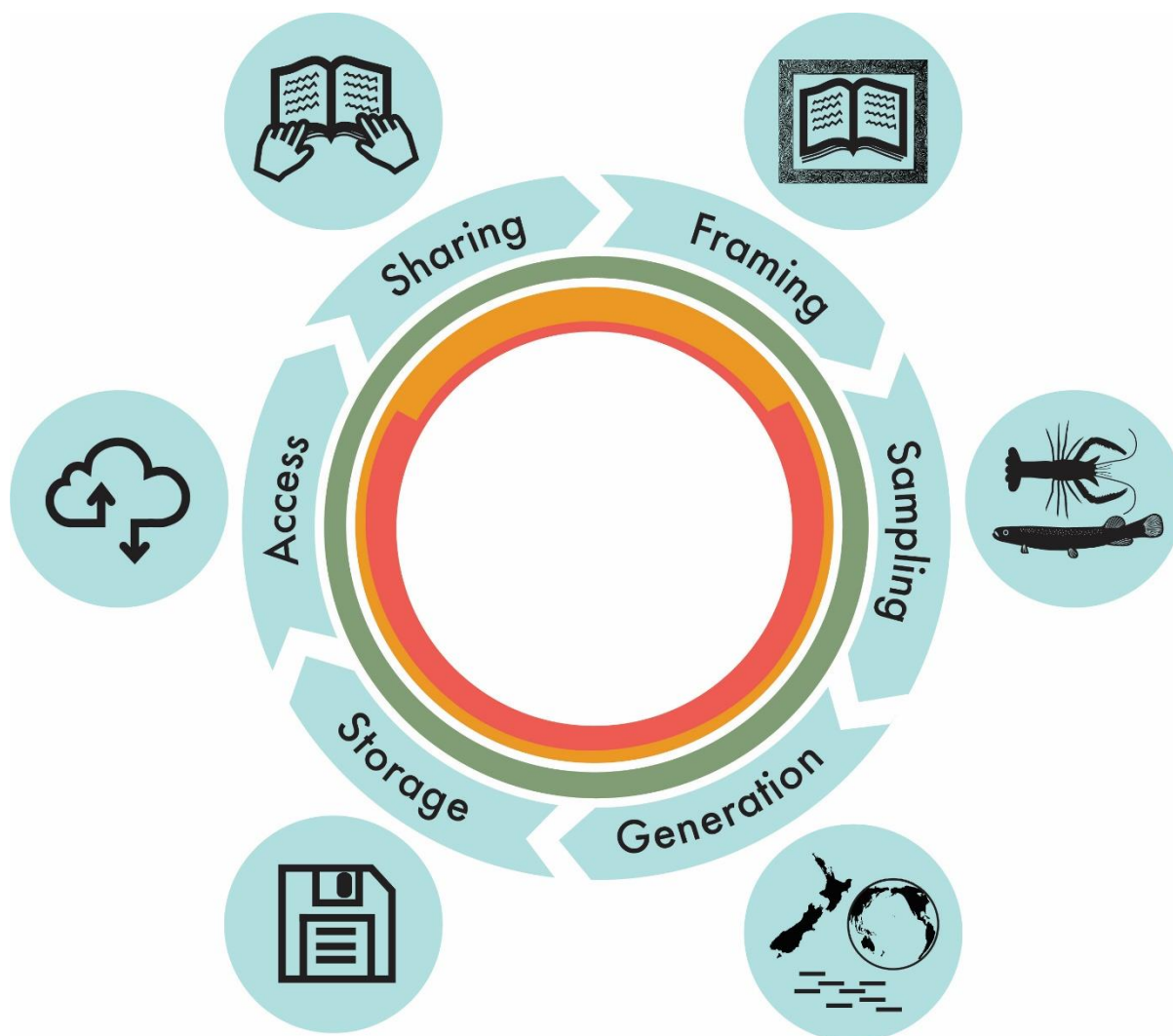
311

312 **Case study**

313

314 As leaders of a Biological Heritage National Science Challenge project entitled “Characterising
315 adaptive variation in Aotearoa New Zealand’s terrestrial and freshwater biota”, we co-developed a
316 research programme with mana whenua that is integrating Mātauranga Māori with emerging genomic
317 technologies and extensive ecological data to characterise adaptive potential - or the ability to adapt
318 to environmental change - in two taonga species, kōwaro (*Neochanna burrowsius*) and kēkēwai
319 (*Paranephrops zealandicus*). We are combining these data with three additional focal species to co-
320 develop a culturally-responsive, evidence-based position statement regarding the benefits and risks of
321 prioritising adaptive potential to build resilience in threatened taonga species, including mahinga kai
322 species destined for customary or commercial harvest. The foundation of our research programme is
323 an iterative decision-making framework that embeds kaupapa Māori relevant principles. It begins by
324 framing the research narrative in partnership with mana whenua followed by active engagement to
325 make decisions regarding tissue sampling as well as data generation, storage and access, and ends
326 by sharing the research narrative in partnership with mana whenua (Figure 2). Below, we show how
327 we applied the iterative decision-making framework to our conservation genomic research on kōwaro
328 and kēkēwai. We also demonstrate how this framework is broadly applicable to all genomic research
329 on taonga species.

330



331

332 Figure 2. An iterative decision-making framework co-developed with Ngāi Tūāhuriri indicating relevant
 333 kaupapa Māori principles and focal areas for active engagement with mana whenua regarding
 334 genomic research on two threatened taonga species, kōwaro (*Neochanna burrowsius*) and kēkēwai
 335 (*Paranephrops zealandicus*). Colours denote the following: Rangatiratanga (blue) – realising the
 336 authority that tangata whenua have to practice and share their culture in their own way.
 337 Tohungatanga (green) – enabling the development of capability, capacity and expertise of tangata
 338 whenua. Whanaungatanga (light orange) – building and maintaining meaningful relationships with
 339 tangata whenua. Kaitiakitanga (dark orange) – enabling the guardianship of all taonga by tangata
 340 whenua – including environment, knowledge and culture. While all four of these kaupapa Māori
 341 principles feature in the entirety of our genomic research on kōwaro and kēkēwai, whanaungatanga is
 342 particularly relevant when co-developing and co-sharing research, whereas enabling kaitiakitanga is
 343 particularly critical when making decisions about tissue sampling, data generation, data storage and
 344 data access. See text for details.

345

346

347 The first taonga species that we co-identified with Ngāi Tūāhuriri is kōwaro (Canterbury mudfish;
348 *Neochanna burrowsius*), one of the most endangered endemic freshwater fish species in Aotearoa
349 New Zealand, currently classified as “Nationally Critical” by the Department of Conservation (Dunn et
350 al. 2018). Kōwaro are restricted to the Canterbury plains, and they have a fragmented distribution
351 between the Rakahuri (Ashley) and Waitaki river catchments (Cadwallader 1975; O'Brien and Dunn
352 2007). Range restriction and severe loss of habitat due to land use intensification in Canterbury are
353 key factors contributing to its current conservation status (Barrier 2003; Dunn et al. 2018; O'Brien and
354 Dunn 2007). The continued threat of local extirpation across its range has led to a call for urgent
355 conservation action (Dunn et al. 2018).

356

357 One such conservation action is a translocation project based at Tūhaitara Coastal Park. The park
358 was established by Te Kōhaka o Tūhaitara Trust following the Ngāi Tahu settlement with the crown
359 and it encompasses Te Tiriti o Waitangi; a collaborative effort between the people of the treaty. The
360 area is rich in Ngāi Tūāhuriri history and mahinga kai, and kōwaro are an integral part of this
361 ecosystem. Kōwaro was co-selected for our project because a conservation genomics approach is
362 likely to enhance conservation outcomes to help preserve kōwaro as part of the unique biodiversity of
363 Tūhaitara Coastal Park.

364

365 Endemic to Aotearoa New Zealand, kēkēwai (freshwater crayfish / kōura; *Paranephrops zealandicus*)
366 are a declining taonga species found in lakes, streams and ponds in the east and south side of Te
367 Waipounamu / South Island as well as Rakiura / Stewart Island (Grainger et al. 2018). The
368 *Paranephrops* genus has been a traditional food source for Māori across Aotearoa New Zealand for
369 centuries and has more recently been the focus of aquaculture initiatives for customary and
370 commercial harvest (Parkyn and Kusabs 2007; Monk 2017).

371

372 Although kēkēwai as a species is not at immediate risk of extinction, land use intensification in
373 Canterbury is fragmenting kēkēwai populations and driving local decline (Thoms 2016). Most

374 remaining populations within the Ngāi Tūāhuriri takiwā now face extirpation. In addition to informing
375 the recovery of declining wild populations, kēkēwai was co-selected for our project because a
376 conservation genomics approach can enhance customary and commercial harvest, making these
377 practices more sustainable so that they can continue for generations to come (Kristensen et al. 2015;
378 Galla et al. 2016).

379

380 After framing the research narrative for each species, we discussed sampling design with Ngāi
381 Tūāhuriri, including tissue sampling at sites of cultural significance traditionally used for mahinga kai.
382 Doing so is especially important when generating reference genomes because these invaluable
383 resources are a physical representation of Ngāi Tūāhuriri whakapapa. For the kōwaro reference
384 genome, the obvious choice of location was within Tūhaitara Coastal Park. However, due to the
385 uncertain status of this small, fragmented and isolated population, we collectively decided to lethally
386 sample a single individual from a larger, healthier population elsewhere in the Ngāi Tūāhuriri takiwā.
387 For kēkēwai, we lethally sampled two individuals approximately one year apart from a small stream
388 near Tuahiwi at the heart of the Ngāi Tūāhuriri takiwā.

389

390 Sampling animals has its own tikanga and practices within western science, typically regulated by
391 animal ethics committees. Māori have their own tikanga and Mātauranga for taonga species and have
392 harvesting practices that are excellent for sampling (Kusabs and Quinn 2009). As a mahinga kai
393 species, kēkēwai allowed us to integrate Mātauranga Māori into a modern context to sample
394 effectively and ethically. We used bundled bracken ferns to create tau kōura as a traditional method of
395 harvest to efficiently capture kēkēwai (Parkyn and Kusabs 2007; Kusabs and Quinn 2009; Thoms
396 2016) and the maramataka (Māori lunar calendar) to determine favourable days for collection.

397

398 In addition to the lethal sampling conducted for the reference genomes, we also used non-lethal
399 methods for sampling populations across both species' range (i.e. fin-clips for kōwaro, pleopod-clips
400 for kēkēwai). This was also an opportunity to include Ngāi Tūāhuriri children from Te Kura o Tuahiwi
401 (Tuahiwi School) in the population sampling of kōwaro at the nearby Tūhaitara Coastal Park, which
402 helped whakawhanungatanga with the wider hapū by following their tikanga. All tissue sampled from
403 kōwaro and kēkēwai has value in the information it contains, therefore the tissue itself is taonga

404 (Hudson et al. 2016c). Ngāi Tūāhuriri have the rangatiratanga to determine the tikanga for generating
405 the reference genomes for these species. As researchers with the relevant expertise, it was our
406 responsibility to clearly communicate the benefits and risks of any given approach (Figure 1). Thus
407 far, we have focused on whether to generate the reference genomes here in Aotearoa New Zealand
408 or overseas. After considering data quantity, data quality, data security, turnaround time and cost, we
409 made the collective decision to send DNA for both kōwaro and kēkēwai to a trusted provider overseas
410 with extensive experience handling culturally sensitive material. By including mana whenua in this
411 way, we promote rangatiratanga while building tohungatanga around the research. In addition to
412 generating genomic data, we are characterising the ecological characteristics of kōwaro and kēkēwai
413 habitats. It is important to note that like tissue and DNA, ecological data from taonga species each
414 have their own mauri, all of which add another layer to the whakapapa and should therefore be
415 treated with the same manaakitanga (e.g., Bond et al. 2019).

416

417 During our research we have encountered existing or new transcriptome data that can be used to
418 supplement the reference genomes for both kōwaro and kēkēwai (Wallis and Wallis 2014, P. Dearden
419 unpublished data). Despite the fact that they are readily available, we are actively engaging with
420 relevant mana whenua prior to the inclusion of these data in our own research. Related to this, we are
421 also expanding our research to elsewhere across the wider Ngāi Tahu takiwā. As anticipated,
422 whakawhanaungatanga is a unique experience with each hapū and papatipu rūnanga but the intent to
423 be responsive to the needs and aspirations of each different group remains..

424

425 Te Tiriti o Waitangi promises that tangata whenua retain the rangatiratanga over their own taonga
426 which includes the whakapapa of taonga species. Genetic data have traditionally been shared openly
427 on globally accessible databases. Rapid advancements in the field of genomics has led to data that
428 are more complex and valuable. Therefore, rangatiratanga has become increasingly important in how
429 knowledge and data from taonga species are shared. The challenge of upholding Te Tiriti o Waitangi
430 is a national one, but it is tangata whenua who ultimately have the right to determine how their own
431 whakapapa is shared. As people of Te Tiriti o Waitangi, researchers and tangata whenua can
432 collectively make decisions regarding how whakapapa as genomic data is stored and accessed in a
433 mutually beneficial way (e.g. password protection of genomic data). For example, as one of few

434 available decapod genomes, the kēkēwai reference genome is likely to be of interest to domestic and
435 international researchers to address both fundamental and applied questions. Thus, we will continue
436 to engage with relevant mana whenua regarding the ongoing security and management of these data.

437

438 **Concluding Remarks** - We have shown that using a bicultural approach enriches research: In
439 addition to upholding the promises of Te Tiriti o Waitangi, embedding kaupapa Māori principles leads
440 to more contextualised genomic research on taonga species thereby maintaining both the cultural and
441 biological integrity of Aotearoa New Zealand.

442

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444

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458

459 **Glossary:**

460 Hapū – subtribe

461 Iwi – tribe

462 Kaitiakitanga – guardianship, stewardship (see main text for extended definition)

- 463 Kaupapa – topic, agenda
- 464 Mahinga kai – refers to all aspects of traditional food gathering and the places where those resources
465 are obtained
- 466 Mahi toi – art
- 467 Manaakitanga – respect
- 468 Mana whenua – authority over the land
- 469 Māori – Indigenous people of New Zealand
- 470 Mātauranga Māori – Māori knowledge
- 471 Mauri – life-force
- 472 Pākehā – New Zealander of European descent
- 473 Papatipu rūnanga – regional tribal council
- 474 Pepeha – tribal saying
- 475 Pūrākau – myth, legend, story
- 476 Rangatiratanga – Chieftainship, sovereignty, autonomy, authority (see main text for extended
477 definition)
- 478 Rūnanga – tribal council
- 479 Takiwā – territory, area, district
- 480 Tangata whenua – people of the land
- 481 Taonga – treasure, culturally significant
- 482 Te Ao Māori – The Māori world
- 483 Te Reo Māori – The Māori language
- 484 Te Tiriti o Waitangi – The Māori version of The Treaty of Waitangi
- 485 Tikanga Māori – Māori customs, etiquette, protocol
- 486 Tohungatanga – expertise
- 487 Waiata – song(s)
- 488 Whakapapa – genealogy (see main text for extended definition)
- 489 Whakataukī – proverbs
- 490 Whānau – family, extended family
- 491 Whakawhanaungatanga – building relationships
- 492 Whanaungatanga – relationship, sense of family connection (see main text for extended definition)

493

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