

INFORMING DECISION-MAKING WITH INDIGENOUS AND LOCAL KNOWLEDGE AND SCIENCE

Perspective

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Centring Indigenous knowledge systems to re-imagine conservation translocations

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Abstract

1. Conservation translocations—particularly those that weave diverse ways of knowing and seeing the world—promise to enhance species recovery and build ecosystem resilience. Yet, few studies to date have been led or co-led by Indigenous peoples; or consider how centring Indigenous knowledge systems can lead to better conservation translocation outcomes.
2. In this Perspective, as Indigenous and non-Indigenous researchers and practitioners working in partnership in Aotearoa New Zealand, we present a novel framework for co-designing conservation translocations that centre Indigenous peoples and knowledge systems through Two-Eyed Seeing.
3. We apply this framework to Aotearoa New Zealand's threatened and under-prioritized freshwater biodiversity. In particular, we highlight the co-development of conservation translocations with Te Kōhaka o Tūhaitara and Te Nohoaka o Tukiaau that are weaving emerging genomic approaches into mātauraka Māori (Māori knowledge systems), including customary practices, processes and language.
4. We envision the Two-Eyed Seeing framework presented here will provide a critical point of reference for the co-development of conservation translocations led or co-led by Indigenous peoples elsewhere in the world to build more resilient biocultural heritage.

For this Perspective, we have used the Kāi Tahu dialect 'k' in place of the northern 'ng' (underlined in text). This reflects local pronunciation and does not necessarily change the meaning of the word (i.e. where underlined, ng and k are interchangeable).

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Auheke

1. Torutoru noa iho kā nekeneke o kā momo tata korehāhā kua puta mai i te mahi tahi a kā iwi taketake me kā kairakahau. Tēnā pea mā te mātauraka o kā iwi taketake, ka whakahaumako i te whāomoomo o te pūnaha hauropi.
2. Kua hakaia he pou tarāwaho e mātou hei whakakaupapa i kā mahere neke momo tata korehāhā. Ko te kako o tēnei pou tarāwaho ko te arotahika ki kā mātauraka o kā iwi taketake kia āwhina i ēnei mahi.
3. Mai i te whakakotahitaka o kā rarauka huika ira me kā momo mātauraka Māori—mai i kā mahika kai, tae ana ki te reo—ka whakatinana mātou i tēnei pou tarāwaho ki kā momo tata korehāhā i kā wai o Te Kōhaka o Tūhaitara me Te Nohoaka o Tukiaua.
4. Ko te tūmanako ka whakatinana tēnei pou tarāwaho e kā iwi taketake me kā kairakahau o te ao whānui ki te hāpai i te whāomoomo o kā koiora mai i ō rātou whenua.

KEYWORDS

biocultural, conservation genomics, ecosystem resilience, freshwater biodiversity, Indigenous knowledge, mātauranga Māori, species recovery, Two-Eyed Seeing

1 | INTRODUCTION

Researchers, practitioners and communities around the world are exploring creative strategies to enhance resilience in threatened species (Suding et al., 2015). The fate of our biological diversity is closely tied to cultural and linguistic diversity, and many are looking beyond Western science to bring together diverse ways of knowing and seeing the world (e.g. McAllister et al., 2019; Mercier, 2018; Wehi, Beggs, & McAllister, 2019). Mi'kmaq Elder Dr Albert Marshall describes the Mi'kmaq principle of *Etuaqtmumk* or 'Two-Eyed Seeing' as 'learning to see from one eye with the strengths of Indigenous knowledge and ways of knowing, and from the other eye with the strengths of Western knowledge and ways of knowing ... and learning to use both these eyes together, for the benefit of all' (Bartlett, Marshall, & Marshall, 2012; Kutz & Tomaselli, 2019; Marshall, 2004). Indigenous communities sustain a vast portion of the world's remaining biodiversity through knowledge systems (knowledge–practice–belief complexes) that are carefully and iteratively adapted to local landscapes over generations, and often millennia (Gadgil, Berkes, & Folke, 1993; Garnett et al., 2018; Ginsberg, Chieza, Frank, Rands, & Vilutis, 2019; Reed, Brunet, Longboat, & Natcher, 2020). Yet, despite promising dialogue, Indigenous knowledge, processes and practices are often side-lined from conservation decision-making (Box 1; IUCN, 2016; Mistry & Berardi, 2016; Reed et al., 2020).

Conservation translocations—that is, the movement of organisms from one location to another for conservation benefit—promise to build resilience across threatened populations, species and ecosystems (Seddon, 2010). While translocations to enhance biodiversity are not novel, nor unique, to Western science (e.g. Ross et al., 2018; Silcock, 2018), few publications reflect on how

Indigenous-led approaches could inform conservation translocations (Leiper et al., 2018). In this Perspective, as Indigenous and non-Indigenous scientists and practitioners working in partnership under Aotearoa New Zealand's Tiriti o Waitangi (the Māori version of the Treaty of Waitangi, 1840)—a critical founding document that frames the relationship between Māori (Indigenous peoples of Aotearoa New Zealand) and the Crown—we consider Two-Eyed Seeing in a conservation translocation context. In particular, we reflect on how conservation translocations can be enhanced by decentring Western perspectives to co-develop approaches that centre Indigenous people, knowledge, process and practices.

2 | WHY TRANSLOCATE?

Threatened species often exist as small, fragmented populations leading to increased inbreeding and reduced genetic diversity (Frankham, 2005). Over time, this can limit their ability to respond—or adapt—to a changing environment (de Villemereuil et al., 2019). Thus, conservation strategies generally seek to build resilience such that populations can respond to future change; in part by promoting large, genetically diverse metapopulations (Frankham et al., 2017; Galla et al., 2019). Evidence-based conservation translocations can build resilience by increasing genetic, biological and functional diversity (Malone et al., 2018; Parker, 2008; Polak & Saltz, 2011; Seddon, Griffiths, Soorae, & Armstrong, 2014).

The International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) classifies conservation

BOX 1 Conservation treaties and agreements reflect a shift towards biocultural approaches

Conservation biology is entangled with the marginalization of Indigenous communities from ancestral lands and natural resources (Wehi & Lord, 2017). Increasingly, Western conservation policy, research and practice recognize the inclusion of Indigenous rights and knowledge is central to realizing biodiversity aspirations (Artelle et al., 2019; Bridgewater, Rotherham, & Rozzi, 2019; Gavin et al., 2018; Moola & Roth, 2019). The United Nations Convention on Biological Diversity calls on signatories to preserve biological diversity, including for sustainable use, and to maintain equitable sharing and use of genetic resources (IUCN, 2016; United Nations, 1992, 2015a, 2015b); although the extent to which global treaties such as the above Convention have realized meaningful legislative change is debatable (Koutouki, 2011). A number of countries—Aotearoa New Zealand, the United States of America and Canada included—have yet to sign the Nagoya Protocol, which is arguably the most pertinent to recognizing Indigenous sovereignty over biodiversity. Nonetheless, treaties and agreements such as these can provide platforms for conservation policy, research and practice to realize Indigenous needs and aspirations.

Te Tiriti o Waitangi (the Māori version of the Treaty of Waitangi, 1840) is a critical founding document of Aotearoa New Zealand. The original document affirms and protects the tino *rakaitirataka* (self-determination, sovereignty) of iwi Māori, and further upholds the rights of both Māori as *tākata* whenua (people of the land) and non-Māori as *tākata* Tiriti (people of the Treaty). Breaches of Te Tiriti o Waitangi over the past 250 years have significantly eroded *mātauraka* Māori (Māori knowledge systems) and sought to separate Māori from the natural environment (e.g. Ngāi Tahu Settlement Claims Act, 1998; Ruru, O'Lyver, Scott, & Edmunds, 2017; Wehi & Lord, 2017). In particular, Ko Aotearoa Tēnei (This is New Zealand)—the Waitangi Tribunal report into the WAI 262 claim—found that Māori, and Māori cultural values, have been side-lined 'from decisions of vital importance' to te Ao Māori (the Māori world; Waitangi Tribunal, 2011). Although the Crown has yet to respond to Ko Aotearoa Tēnei, many Māori and non-Māori have moved towards 'an era of growth and partnership' since the Waitangi Act (1975) and the establishment of the Waitangi Tribunal (Collier-Robinson, Rayne, Rupene, Thoms, & Steeves, 2019; Walker, 1990). For example, the Ngāi Tahu Claims Settlement Act (1998)—a product of negotiations between Te Rūnanga o Ngāi Tahu (the Kāi Tahu tribal council) and the Crown—has paved the way for partnerships between Kāi Tahu and non-Māori (e.g. Whakaora Te Waihora, Te Kōhaka o Tūhaitara Trust, Te Nohoaka o Tukiauau, Whakamana te Waituna, Whakaora Healthy Harbour).

translocations according to their primary objective. For example, *population reinforcement* can increase resilience of existing populations by decreasing inbreeding and increasing genetic diversity. Translocations may also seek to re-establish species where they have been lost from an ecosystem entirely (*population restoration*). These may be particularly important in fragmented landscapes where habitat rehabilitation does not guarantee that biodiversity will return naturally (e.g. the 'build it, and they will come' Field of Dreams hypothesis; Bond & Lake, 2003; Palmer, Ambrose, & Poff, 1997; Sudduth, Hassett, Cada, & Bernhardt, 2011). *Conservation introductions* may also be performed outside of natural ranges, either to prevent focal species extinction (*assisted colonization*) or to replace ecological function (*ecological replacement*). Out-of-range translocations such as these are increasingly considered in the context of climate change; for instance, where a species' present range is predicted to become unsuitable (Bay et al., 2018; Chauvenet, Ewen, Armstrong, & Pettolelli, 2013). *Mitigation translocations* further seek to move populations to new habitat—either within or outside the species' current range—in response to impending local extirpation (e.g. due to urban development or habitat loss).

To increase the likelihood of success, best-practice guidelines such as those developed by the IUCN/SSC Conservation Translocation Specialist Group (CTSG) provide a comprehensive overview of considerations relating to conservation translocations

(IUCN/ SSC CTSG Guidelines for Reintroductions and Other Conservation Translocations; herein, 'the CTSG guidelines'). These evidence-based considerations include comprehensive risk assessment, multidisciplinary teams, existing baseline knowledge, multigenerational population monitoring, iterative management and documentation (IUCN/SSC, 2013; Moehrenschrager, Shier, Moorhouse, & Stanley Price, 2013; Weeks et al., 2011).

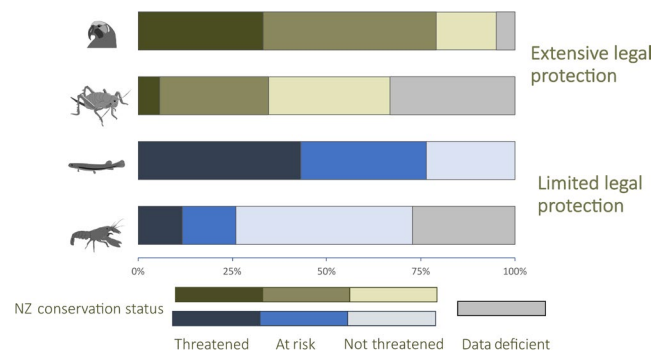
3 | EVIDENCE-BASED CONSERVATION TRANSLOCATIONS ARE CHALLENGING FOR MANY UNDER-STUDIED SPECIES

Case-by-case evaluations of the benefits and risks of conservation translocations are routine for many terrestrial species (e.g. Lloyd, Hostetter, Jackson, Converse, & Moehrenschrager, 2019; Parker et al., 2015; Seddon, Armstrong, & Maloney, 2007), plants (e.g. Godefroid et al., 2011) and some recreationally or commercially valued species (Anderson et al., 2014; Dunham, Gallo, Shively, Allen, & Goehring, 2011). However, comprehensive evaluations—and as a result, evidence-based protocols—are more challenging for many invertebrates, marine and freshwater fish (Box 2; Fischer & Lindenmayer, 2000; Seddon, Soorae, & Launay, 2005). The discrepancy across taxonomic groups is reflected in the CTSG database of annually published case studies

BOX 2 Freshwater conservation translocations: Underwater and out of mind?

Freshwater ecosystem restoration often proves challenging due to dynamic and degraded habitat (Reid et al., 2019). Many freshwater conservation translocations are further complicated by limited biological or ecological data, and social challenges—for example, reconciling conservation outcomes for threatened species with commercial or recreational harvest of protected introduced predators (e.g. trout *Salmo trutta*; McIntosh et al., 2010). Further, measuring freshwater conservation translocation success is difficult; partially due to challenges in monitoring translocated individuals, but also due to a general lack of post-translocation monitoring (Lintermans, Lyon, Hammer, Ellis, & Ebner, 2015). As a result, estimated success rates of freshwater conservation translocations are low, both globally (Palmer, Hondula, & Koch, 2014) and locally in Aotearoa New Zealand (Aldridge, 2008; O'Brien & Dunn, 2007; Pham, West, & Closs, 2013). Although mitigation translocations are increasingly common, these are generally performed by contracted commercial companies and rarely observe best-practice guidelines. Instead, most published empirical evidence relating to freshwater translocations is restricted to North America, or to commercially or recreationally valued species. While these studies can inform freshwater conservation translocations elsewhere, the extensive heterogeneity of freshwater systems limits the degree to which lessons learned can be extended to other species or catchments (Olden, Kennard, Lawler, & Poff, 2011).

For the reasons described above, freshwater species tend to have fewer comprehensive evaluations, protocols and empirical evidence to inform conservation translocations compared to terrestrial vertebrates. In Aotearoa New Zealand, challenges related to freshwater conservation translocations are further exacerbated by non-responsive legislation (Box 2 Figure): while the National Threat Classification System considers 76% of freshwater fish and 26% of freshwater invertebrates to be Threatened with or At Risk of extinction, the only legally protected indigenous freshwater species is the long extinct upokororo (grayling *Prototroctes oxyrhynchus*; Dunn et al., 2018; Grainger et al., 2018). With a significant proportion further listed as Data Deficient under national and international (IUCN) threat classification systems, the decline of many freshwater species likely remains undocumented or poorly addressed (Betts et al., 2020; Nelson et al., 2019).



BOX 2 FIGURE Aotearoa New Zealand's freshwater fish (represented by kōwaro) and invertebrates (represented by kēkēwai) share a similar percent of threatened species with terrestrial biota (vertebrates represented by kākā; and invertebrates by wētāpunga) according to the National Threat Classification System; but this is not reflected by their legal protection (data from Ministry for the Environment; <https://data.mfe.govt.nz/tables/>)

('Global Re-introduction Perspectives'; <http://publications.iucn-ctsg.org/ead>). Despite commendable efforts to incorporate a diverse taxonomic breadth, charismatic terrestrial vertebrates remain highly overrepresented: at the time of writing, 168 of the 351 global case studies focus on birds or mammals, compared to 34 fish and 29 invertebrate case studies across marine and freshwater systems combined. Indeed, while Aotearoa New Zealand is globally renowned for evidenced-based bird translocations to offshore predator-free islands, only two of its 22 conservation translocations listed in the CTSg database relate to freshwater species (Armstrong, Moro, Hayward, & Seddon, 2015).

Whether these taxonomic trends—which are conservative estimates, at best—reflect lower rates of reporting or fewer translocations overall is unclear. Regardless, we anticipate these trends can partially be attributed to the complex and varied motivations that underlie translocations (Brichieri-Colombi & Moehrenschrager, 2016). For example, terrestrial conservation translocations generally centre around enhancing conservation outcomes for specific focal species (e.g. Braidwood, Taggart, Smith, & Andersen, 2018), whereas marine conservation translocations tend to be ecosystem-driven (Swan, McPherson, Seddon, & Moehrenschrager, 2016). Excluding Cochran-Biederman, Wyman, French, and Loppnow (2015)—who

reviewed correlates of success relating to native freshwater fish reintroductions—to our knowledge, a comprehensive review for all freshwater conservation translocations is lacking; but examples in this Perspective and elsewhere suggest that ecological, rather than species, considerations tend to be prioritized (Germano et al., 2015). Indeed, there is ample scope to bridge the gap between ecosystem restoration and threatened species recovery for conservation translocations in general (Franklin, 1993; Hughes, Grabowski, Leslie, Scyphers, & Williams, 2018; Hughes, Inouye, Johnson, Underwood, & Vellend, 2008; Lindenmayer et al., 2007; Tilman, Isbell, & Cowles, 2014).

4 | INDIGENOUS-LED APPROACHES BUILD MORE RESILIENT BIOCULTURAL HERITAGE

Whereas Western science has often prioritized an ‘either-or’ approach to ecosystem restoration and threatened species recovery, Indigenous-led approaches are more likely to integrate both (Hudson et al., 2016; Kutz & Tomaselli, 2019; Long, Tecle, & Burnette, 2003). For example, in Kakadu Country, Australia, traditional wetland burning forms an integral part of contemporary land management to maintain and enhance local resources, including habitat heterogeneity and culturally significant species such as almagyi (long-necked turtle *Chelodina rugosa*; McGregor et al., 2010). In Hawai‘i, the Nā Kilo ‘Āina Program (NKA) seeks to build resilient socio-ecological systems through Indigenous-based frameworks to improve the ‘well-being of ‘āina, Hawai‘i’s biocultural landscapes and seascapes’ (Morishige et al., 2018; Sterling et al., 2017). These frameworks incorporate biocultural monitoring, customary management and social mechanisms that are informed by native Hawaiian knowledge systems (e.g. Huli ‘Ia, a platform for recording ‘place-based cycles of productivity’ as they relate to seasonal indicators and lunar cycles; Winter et al., 2018). Further, ample evidence demonstrates that Indigenous knowledge systems are highly sensitive and adaptable to novel challenges such as climate change (Berkes, 2009; Ginsberg et al., 2019). For instance, Skolt Sámi in Finland have taken adaptive measures to preserve Atlantic salmon *Salmo salar* numbers in response to rising water temperatures and reduced catch rates, including by increasing harvest of pike to reduce predation pressure (Mustonen & Feodoroff, 2018; Nakashima, McLean, Thulstrup, Castillo, & Rubis, 2012; Pecl et al., 2017).

The significance of Indigenous-led approaches extends to species that are often underrepresented in Western science and conservation management (Noble et al., 2016; Sato, Price, & Vaughan, 2018). For example, Gunditjmara communities of the Budj Bim landscapes in southeast Australia have managed the declining, culturally significant kooyang (short-fin eel *Anguilla australis*) for millennia, including through complex aquaculture systems (Gunditjmara People & Wettenhall, 2010; McNiven, Crouch, Richards, Dolby, & Jacobsen, 2012). Gunditjmara communities have led restoration of wetland habitat and stream connectivity to re-establish kooyang

migratory pathways (e.g. Framlingham Aboriginal Trust & Winda Mara Aboriginal Corporation, 2004; Noble et al., 2016). In the Khong province of southern Laos, local communities along the Mekong River have developed freshwater fisheries management systems that have improved freshwater stocks compared to areas managed entirely by national government (Baird, 2007). These include measures—such as size-selective harvest, establishment of Fish Conservation Zones and restrictions on catching methods—that are grounded in local knowledge, including comprehensive taxonomic systems and understanding of foraging or migratory behaviour (Baird, 2007). In Aotearoa New Zealand, Māori are revitalizing traditional harvesting methods for kōura (freshwater crayfish *Paranephrops* spp.) as a monitoring tool and for customary management (Kusabs, Hicks, Quinn, & Hamilton, 2015; Whaanga, Wehi, Cox, Roa, & Kusabs, 2018).

The inclusion of Indigenous knowledge in Western science and conservation management enables more nuanced insights (Wehi, Whaanga, & Roa, 2009). For instance, Seri Indian knowledge holds that the diversification of spiny-tailed iguana *Ctenosaura hemilopha* spp. in the Sea of Cortez pre-dated human migration—in contrast to prevailing Western thought that species diversification was human-mediated—and this knowledge has since been observed in a recent phylogeographic study (Davy, Méndez de la Cruz, Lathrop, & Murphy, 2011). Examples such as this represent a promising start towards Two-Eyed Seeing in a conservation translocation context; and there is ample scope to build on the inclusion of Indigenous knowledge by centring this knowledge alongside Indigenous peoples, processes and practices. For example, in Aotearoa New Zealand, mātauraka Māori (Māori knowledge systems) describe historical translocations of culturally significant species—including kōura, tuna (eel *Anguilla* spp.), kākahi (freshwater mussel *Echyridella* spp.), pūpū whakarongotaua (kauri snail *Placostylus ambagiosus*) and toheroa (clam *Paphies ventricosa*)—that have informed phylogeographic studies and increasingly, contemporary conservation translocations (Daly, Trewick, Dowle, Crampton, & Morgan-Richards, 2020; McDowall, 2011; McEwan, Dobson-Waitere, & Shima, 2020; Michel, Dobson-Waitere, Hohaia, McEwan, & Shanahan, 2019; Ross et al., 2018).

5 | CENTRING INDIGENOUS KNOWLEDGE SYSTEMS IN CONSERVATION TRANSLOCATIONS THROUGH TWO-EYED SEEING

Indigenous and non-Indigenous researchers and practitioners are increasingly working at the interface of Indigenous knowledge systems and Western science to build more resilient biocultural heritage (e.g. Bond, Anderson, Henare, & Wehi, 2019; Clapcott et al., 2018; Delevaux et al., 2018; Dobbs et al., 2016; Long et al., 2003; Lyver et al., 2018). However, published and grey literature indicates that contemporary conservation translocations are rarely Indigenous led or co-led (e.g. <http://publications.iucn-ctsg.org/ead>; Leiper et al., 2018). Given the broad scope of conservation translocations (i.e. translocations where the primary objective

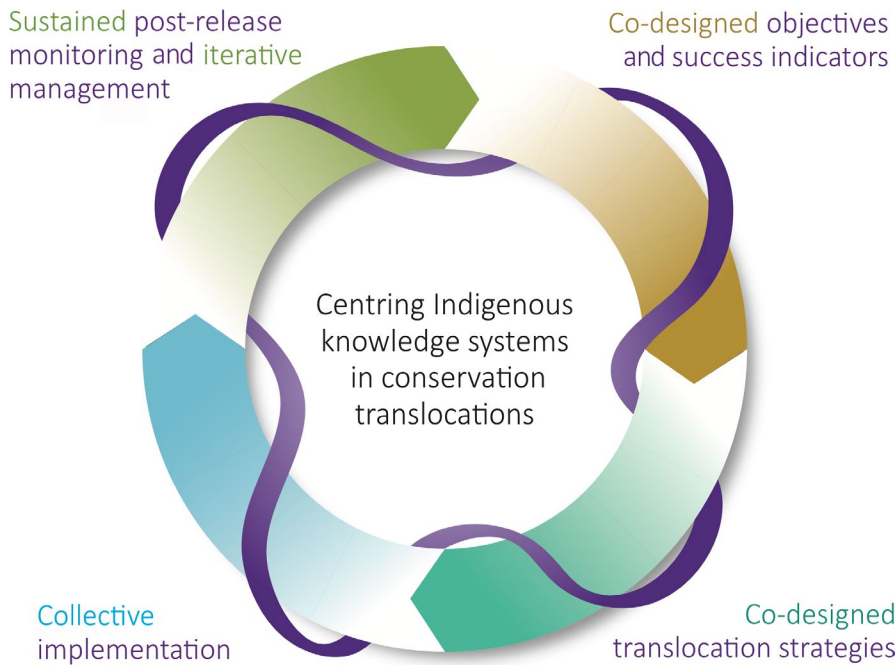


FIGURE 1 A novel framework for re-imagining conservation translocations through Two-Eyed Seeing. The main circle—comprised of key conservation translocation steps (purple text) based on IUCN/SSC guidelines—represents the centring of Indigenous knowledge systems, while the purple weave around it represents Western science. The coloured (non-purple) text reflects ways in which Indigenous-led approaches can enhance each key step. At the centre lies genuine partnership where relationships built on mutual trust and respect and collective decision-making are embedded throughout. For an example of how this framework can be reflected locally, see Figure 2

is a 'measurable conservation benefit at a population, species or ecosystem level'; IUCN/SSC, 2013), we see a clear opportunity to extend existing frameworks such as the CTSG guidelines through Two-Eyed Seeing.

As more conservation translocations are Indigenous led or co-led, we envision this will be reflected in both the defined objectives and indicators of success. Where success indicators in CTSG case studies tend to focus on the conservation status of target species (e.g. an improvement in a species' national threat ranking), we anticipate co-designed success indicators will capture a wider breadth of biocultural outcomes (Mooney & Cullen, 2019; Sterling et al., 2017). Further, conservation translocations that are intended to enable or enhance sustainable customary practices are well-placed to incorporate long-term monitoring and iterative management (Herse et al., 2020). In Aotearoa New Zealand, frameworks that are grounded in mātauraka Māori such as the Cultural Health Index (CHI) are recognized as robust measures of waterway health (Harmsworth, Young, Walker, Clapcott, & James, 2011). The CHI generally assesses three key components: site status (e.g. significance to tāketa whenua; people of the land); values associated with food and other natural resources (e.g. presence of culturally significant species, changes in biodiversity and whether people would return to harvest at the site); and cultural stream health, including riparian vegetation, catchment land-use and water quality (Tipa & Teirney, 2006). Measures such as these could be readily adapted to assess conservation translocation success. For example, we are actively co-developing translocations of the culturally significant species kēkēwai (freshwater crayfish *Paranephrops zealandicus*) for customary harvest at Tūhaitara Coastal Park. For kēkēwai, a key objective is to establish self-sustaining populations that are resilient to future change; and one success indicator is sustainable customary harvest. However, beyond this species-specific target,

additional indicators of success are signalled in a 200-year vision for the wetland, including the revitalization of mātauraka Māori, tikaka (customary processes and practices) and te reo Māori (Māori language).

As outlined in national and international treaties and agreements (e.g. Box 1), it is critical that Indigenous communities with local authority are at the decision-making table when co-developing conservation translocations; particularly when translocating culturally significant species. That is, the first—and ongoing—step towards any conservation translocation should be building trusted relationships between relevant Indigenous and non-Indigenous researchers, practitioners and communities. We capture these ideas in a novel framework (Figure 1) that can be readily extended to suit local contexts (e.g. see Figure 2). Our intent is for this framework to inspire a wealth of local conservation translocation strategies that are responsive to diverse ways of knowing.

6 | CAN WE RE-IMAGINE FRESHWATER CONSERVATION TRANSLOCATIONS? AOTEAROA NEW ZEALAND AS A CASE STUDY

There is growing recognition by Western-trained researchers and practitioners that conservation translocations may be critical for enhancing resilience in freshwater biodiversity (Blanton, Cashner, Thomas, Brandt, & Floyd, 2019; Eikaas & McIntosh, 2006; Pavlova et al., 2017). For example, in the Murray-Darling Basin of Australia, post-European habitat fragmentation has impeded population connectivity for the southern pygmy perch *Nannoperca australis*, contributing to its recent and rapid decline (Brauer & Beheregaray, 2020). If these patterns are widespread—as indicated

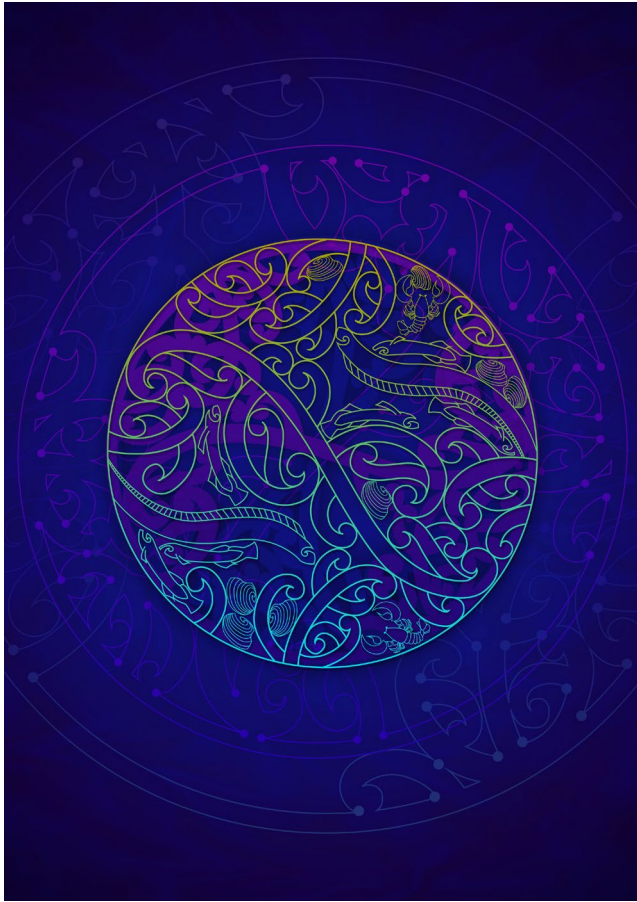


FIGURE 2 Freshwater conservation translocations under a Kāi Tahu lens. In this illustration, produced by Kaaterina Kerekere (KEdesign), line art refers to whakapapa (genealogy) and the terminology of whakapapa, while kōwhaiwhai (patterns) symbolize the development, movement and pathways of mātauraka Māori (Māori knowledge systems). The main design sits within a sphere, reflecting Te Pō, Te Ao Mārama and Te Ao Hurihuri (three layers of the Māori world). In the layers of line work beneath the main illustration, the bold circles represent genetic markers, referring to Western knowledge systems. Combined with the kōwhaiwhai (patterns), these repetitive layered designs depict the weaving together of mātauraka Māori and Western knowledge. Within the sphere are tuna (eel), kōwaro (Canterbury mudfish), kēkēwai (freshwater crayfish) and kākahi (freshwater mussel), representing Aotearoa New Zealand's freshwater biodiversity. The colours make reference to the relationships between light, water and land—reflection and refraction, the blending and movement of light and water. Reproduced with permission

by a comprehensive review in Lindenmayer and Fischer (2007)—actions to restore population connectivity and prevent further species declines are urgently needed (Cowx & Portocarrero Aya, 2011; Pavlova et al., 2017). As per the examples described above, Indigenous-led or co-led approaches can be readily extended to freshwater conservation translocations. For instance, United States Native American Tribes and Canadian First Nations have co-led freshwater reintroductions and restoration of fish passage in the Columbia River Basin (US Columbia Basin Tribes & Canadian First Nations, 2014).

In Aotearoa New Zealand, freshwater conservation translocations are also being explored through Indigenous-led or co-led approaches. Māori maintain a profound understanding of local landscapes and humankind's place through mātauraka Māori, at the centre of which lies whakapapa (genealogy, but see below; Black, 2014; Mead, 2003). Embedded within these relationships is a paradigm of responsibility and reciprocity that is integral to kaitiakitaka (trusteeship). Kaitiakitaka is a way of managing the environment through traditional Māori worldviews (Marsden, 2003; Walker, Wehi, Nelson, Beggs, & Whaanga, 2019). It is also a guiding principle of mahika kai (literally 'working the food'). Mahika kai is itself an expression of te Ao Māori (the Māori world) and steeped in a rich body of language, knowledge and practice (Phillips, Jackson, & Hakopa, 2016). By its very nature, mahika kai acts to maintain the health of the entire ecosystem through strategies including cultural health monitoring; selective harvest of specific size classes; translocations to establish new populations and augment existing ones; rāhui (restrictions on access or harvest); and customary fishing reserves such as mātaimai or taiāpure (Awatere et al., 2017; Hudson et al., 2016; Tipa, 2013). Practices such as these ensure natural resources are maintained and enhanced to sustain future generations. For example, mahika kai species are generally translocated according to specific objectives related to cultural vitality (Williams, 2012). Evidence of how mahika kai-centred approaches can restore and enhance biodiversity is beginning to enter the conservation literature, such as customary management of tītī (sooty shearwater *Puffinus griseus*; Moller, 2009), transdisciplinary research projects on īnaka (whitebait *Galaxias maculatus*) management in the Waikōuaiti River catchment (Carter, 2019) and Māori co-led translocations of kākahi (freshwater mussel; McEwan et al., 2020; Michel et al., 2019).

In the face of new challenges (e.g. climate change) and emerging technologies (e.g. genomic data), we are increasingly asking whether—and if so, how—different populations should be mixed (Allendorf, Hohenlohe, & Luikart, 2010; Harrison, Pavlova, Telonis-Scott, & Sunnucks, 2014; Weeks et al., 2011). For example, the potential to characterize adaptive variation has reignited debate over the benefits and risks of mixing disparate populations (e.g. Borzee et al., 2019; Burrige, 2019; Kolodny et al., 2019; Ralls et al., 2018). We anticipate that bringing together Indigenous and Western knowledge systems through Two-Eyed Seeing will enable more nuanced decisions for questions such as these. For instance, in Aotearoa New Zealand, conservation policy around moving individuals between catchments has generally followed precautionary principle—that is, in the absence of evidence, cross-catchment translocations are actively discouraged to avoid mixing populations that may be locally adapted. However, for species such as kēkēwai (freshwater crayfish), mātauraka Māori directly challenges this line of thought. Evidence of historical translocations to establish or supplement kēkēwai along Kāi Tahu travel routes (McDowall, 2011; Monk, 2017) is also observed in preliminary genomic data (A. Rayne, R. Moraga, M. Rupene, & T.E. Steeves, unpubl. data). We are combining mātauraka Māori relating to historical translocations with genomic approaches to characterize adaptive variation to inform contemporary conservation translocation decisions. These

decisions are further informed by primary industry, including the KEEWAI freshwater crayfish farming manual—the product of a partnership between Te Rūnanga o Ngāi Tahu, forestry company Ernslaw One and aquaculture company KEEWAI (Hollows, 2016). With expertise ranging across kēkēwai physiology, ecology, management and biosecurity, the manual represents a wealth of knowledge intended for use by iwi Māori and the wider public. Thus—even for under-studied species such as kēkēwai—there is ample evidence that could inform translocation policy in Aotearoa New Zealand's freshwater ecosystems, provided that Western-trained researchers and practitioners are open to multiple ways of knowing.

7 | IN AN AOTEAROA NEW ZEALAND CONTEXT, WHAKAPAPA IS CENTRAL TO REALIZING BIODIVERSITY OUTCOMES

In Aotearoa New Zealand, a complex system of genealogical relationships exists in the form of whakapapa (Collier-Robinson et al., 2019). Although whakapapa is generally defined as genealogy, it encompasses much more than that; whakapapa acts as a knowledge system that describes and contextualizes the origins and order of all things in the Māori world in relation to the individual (Tau, 2001). It explains the relationships between whānau, iwi and hapū (families, tribes and sub-tribes), and therefore which landscapes and natural resources they have intergenerational connections to (Te Rito, 2007). In doing so, whakapapa binds tākata whenua (people of the land) to the mountains, rivers, coasts and other landscapes—linking the health of the people with that of the environment. For example, Kāi Tahu are connected to the landscapes of Te Waipounamu (South Island of Aotearoa New Zealand) through whakapapa.

Like humans, species have whakapapa that connects them to their natural environment and to other species (Ataria et al., 2018; Collier-Robinson et al., 2019). Just as it has guided how mahika kai and taoka (treasured) species were managed in the past, whakapapa can—and should—inform contemporary translocation strategies. When considering out-of-range translocations, the knowledge

embedded within whakapapa can aid in identifying ecologically and culturally suitable sites. For example, whakapapa describes the ecological needs of kākahi (freshwater mussel), including interconnections with the sand, rocks, gravel and aquatic vegetation (Best, 1982, 1986; Rainforth, 2008). If whakapapa is understood thoroughly, we can build the right environment to protect and enhance every living thing. Therefore, when co-developing conservation translocations in an Aotearoa New Zealand context, whakapapa should be central to all decision-making (Figure 2).

8 | EXAMPLES FOR CO-DEVELOPING CONSERVATION TRANSLOCATIONS THROUGH MĀTAURAKA MĀORI AND WESTERN SCIENCE: TE NOHOAKA O TUKIAUAU AND TŪHAITARA COASTAL PARK

As an example of how our framework can be applied to enhance conservation translocations, we focus on two Māori-led and co-led restoration projects in the tribal region of Kāi Tahu in Aotearoa New Zealand. At Tūhaitara Coastal Park and Te Nohoaka o Tukiauaui, we are exploring how weaving genomic data into mātauraka Māori and revival of customary practice could inform translocation policy to enhance resilience in kēkēwai (freshwater crayfish) and kōwaro (Canterbury mudfish *Neochanna burrowsius*) populations.

Along the eastern coast of Te Waipounamu (the South Island) stretches nearly 600 ha of indigenous coastal, freshwater and terrestrial habitat (Figure 3a). The site—known as Tūhaitara Coastal Park—was gifted to the people of Aotearoa New Zealand as an outcome of a Waitangi Tribunal settlement between Kāi Tahu and the Crown. A charitable organization, Te Kōhaka o Tūhaitara Trust, was established in 1998 to oversee the management and rehabilitation of the Tūhaitara Coastal Park. The Trust is run by six trustees, three of whom are appointed by TroNT. Tūhaitara Coastal Park includes the culturally significant Tūtaepatu Lagoon, once connected to the ocean and rich with mahika kai. Near the lagoon lies the burial site



FIGURE 3 Since being returned to Kāi Tahu through the Ngāi Tahu Claims Settlement Act (1998), Tūhaitara Coastal Park (a) and Te Nohoaka o Tukiauaui (b) have undergone extensive ecosystem rehabilitation to revive biocultural diversity. Photo 3a: David Baird (David Baird Photography). Photo 3b: Glen Riley (Coordinator, Te Nohoaka o Tukiauaui)

of the founder of the nearby settlement: Turakautahi. For the past two decades, Te Kōhaka o Tūhaitara Trust has led the restoration of indigenous biodiversity and the co-development of recreational, cultural and community opportunities towards a 200-year vision for the future.

Further south on the Taieri Plains, Te Nohoaka o Tukiauau (the Sinclair Wetlands) Trust seeks to protect and enhance the Te Nohoaka o Tukiauau wetlands (Figure 3b) by reconnecting people back to the land via education and hands-on experience. At Te Nohoaka o Tukiauau (the dwelling place of Tukiauau), in the early 18th century, a Kāti Māmoe chief—Tukiauau—and his people took temporary refuge on Whakaraupuka (Ram Island) to establish their nohoaka (dwelling place). The name of Tukiauau remains attached to the wetlands; and the swamp complex an important food basket and precious taoka (treasure) for later peoples. The Taieri Plains wetlands were drained during European Pākehā settlement—including the culturally and ecologically significant Tatawai Lake—leaving just two of the original lakes (Waihola and Waipori) and their adjacent swamps. The water from these wetlands was diverted through the nearby settlement, displacing tākata whenua (people of the land) from their land and natural resources. This led to an intergenerational loss of knowledge, customary process and practices that is still being recovered today. In 1998, the

property was returned to Kāi Tahu as part of the Ngāi Tahu Claims Settlement Act (1998). Since 2011, the wetlands have been managed by Te Nohoaka o Tukiauau Trust comprising up to eight volunteer Trustees, including representatives of Te Rūnaka o Ōtākou, and Tatawai Whenua Tapu Trust.

Tūhaitara and Te Nohoaka o Tukiauau wetlands provide valuable habitat for numerous species, including freshwater fish and invertebrates. At Te Nohoaka o Tukiauau, in addition to supporting wildlife, the wetlands provide plant materials for food, weaving and clothing. At both sites, initial efforts have included restoration of indigenous habitat to support species above and in the water. For example, at Tūhaitara Coastal Park, a network of small ponds ('biota nodes') has been created near Tūtaepatu Lagoon. Ultimately, the biota nodes will be connected towards a 200-year vision of continuous habitat that supports metapopulations of taoka (treasured) and mahika kai species. Until then, the nodes will enable early translocations of freshwater species such as kōwaro, kēkewai and kākahi (freshwater mussel). These species once lived in the silty channels of the wetlands where they provided food for humans and freshwater predators, filtered sediment and processed waste (Noble et al., 2016; Phillips, 2007; Thoms, 2016; Vaughn, 2018). However, as of recent decades, they exist outside Te Nohoaka o Tukiauau and Tūhaitara in increasingly small and isolated populations (Thoms, 2016).



FIGURE 4 Tuna (eel) monitoring with rakatahi (youth) at Te Nohoaka o Tukiauau. All identifiable individuals have consented to the use of this image. Photo: Paulette Tamati-Elliffe



FIGURE 5 LCR collecting DNA samples for kōwaro (Canterbury mudfish) with tamariki (children) at Tūhaitara Coastal Park. All identifiable individuals have consented to the use of this image. Photo: Ashley Overbeek

As part of strategies to revitalize mahika kai at both wetlands, we are co-developing evidence-based conservation translocations to reintroduce or augment threatened freshwater species. For example, conservation translocations have previously been attempted to enhance recovery of the critically endangered kōwaro. However, little regard has been given to the potential for translocations to disrupt locally adapted populations. Although conservation genomic approaches to characterize adaptive variation can help to identify appropriate source populations for translocation, these generally require relevant ecological data. Where relevant ecological data are lacking in Western science, other knowledge systems may provide even more holistic ecological data. Kāi Tahu hold extensive records from the 19th century with mātauraka Māori—including traditional ecological knowledge—that has been passed down from tūpuna (ancestors). To inform conservation translocations of kōwaro into Tūhaitara Coastal Park, we are weaving this mātauraka Māori into a genotype–environment association study that includes present-day ecological data and whole genome resequences for kōwaro populations across their contemporary range (Collier-Robinson et al., 2019). As described above, similar approaches are being applied to conservation translocations of kēkewai; and eventually other species such as kākahi. For each conservation translocation, source populations will ultimately be identified and selected by mana whenua (those

with local authority) using the best available evidence in the form of both mātauraka Māori and Western science.

To assess the long-term effects of conservation translocations on genomic diversity and fitness (i.e. survival and reproductive success), we are co-developing monitoring strategies that combine genomic and non-genomic data. Crucially, these monitoring strategies centre around transferring knowledge—both mātauraka Māori and Western science—across generations. For example, at Te Nohoaka o Tukiaua, rakatahi (youth) are working with cultural experts from Te Rūnaka o Ōtākou, He Waka Kōtuia and freshwater ecologists to monitor local tuna (eel) populations (Figure 4; Ka Hao te Rakatahi, 2019). Part of this research seeks to compare the efficacy of hīnaki (traditional eel nets) and Western fyke nets, while learning the wetland ecology, tuna life cycle and the practices and language associated with mahika kai. At Tūhaitara Coastal Park, local schools, university groups and organizations are responsible for managing and monitoring their allocated biota nodes. For example, tamariki (children) have been involved from early riparian planting; invertebrate monitoring; through to translocations of freshwater species such as kōwaro (Figure 5). By engaging local people—young and old—as stewards of the knowledge, language and practices associated with these places, Te Kōhaka o Tūhaitara and Te Nohoaka o Tukiaua Trusts intend to maintain these ecosystems and their biocultural diversity long into the future.

9 | CONCLUSION

The biodiversity crisis calls on all of us—including Indigenous and non-Indigenous researchers, practitioners and communities—to work together at the interface of Indigenous knowledge systems and Western science (Artelle et al., 2019; Diaz et al., 2019). Here, we have focused on Aotearoa New Zealand's freshwater biodiversity as a case study for re-imagining conservation translocations through Two-Eyed Seeing. For example, at Te Nohoaka o Tukiaau and Tūhaitara Coastal Park, the revival and intergenerational transfer of knowledge, customary practices and language represents a powerful approach that will lead to diverse ecosystems renowned for sustainable practice, community involvement and as important *Kāi Tahu mahika kai*. By layering genomic data into *mātauraka Māori*, we can co-design more nuanced conservation translocation decisions for culturally significant freshwater fish and invertebrates. We anticipate approaches that centre Indigenous knowledge, people, processes and practices through Indigenous governance, or genuine co-governance, can be extended to enhance conservation translocation outcomes elsewhere; particularly for our most threatened and least prioritized species.

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CONFLICT OF INTEREST

The authors state no conflict of interests.

AUTHORS' CONTRIBUTIONS

All authors conceived and substantially developed the idea, including Western science perspectives provided by Rayne, Collier-Robinson, Hollows, McIntosh, Thoms and Steeves, and te Ao Māori perspectives provided by Collier-Robinson, Ramsden,

Rupene, Tamati-Elliffe and Thoms. Byrnes, Hollows and Tamati-Elliffe contributed knowledge and text associated with each of the two case studies. Rayne led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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This manuscript does not include any data.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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