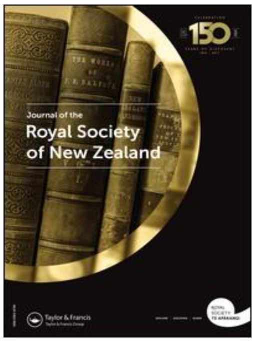

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REVIEW ARTICLE

Intractable: species in New Zealand that continue to decline despite conservation efforts

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ABSTRACT

Global biodiversity loss is accelerating at an alarming rate. While considerable effort and resources have gone into conservation management for many threatened species in New Zealand (NZ), some species are still 'losing the battle' despite much effort, and others have been ignored altogether. Here, we present seven case studies to illustrate the breadth of complex, often ambiguous, threats faced by taxa in NZ. These threats originate from the effects of agriculture and harvesting, irreversible habitat modification and loss, impediments to connectivity, disruption of parasite–host relationships, introduced species and susceptibility to disease, and are further exacerbated by complexities of political and legal inertia, low prioritisation and limited conservation funding. We outline the conservation challenges and identify advances needed to meet NZ's long-term conservation goals. The next 30 years of conservation require new tools in order to protect especially those 'intractable' species that have thus far defied efforts to ensure their survival.

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Introduction

The sixth mass extinction may be the defining feature of the Anthropocene. Globally, habitat loss, invasive species, over-exploitation, pollution, disruption to connectivity, bureaucratic inefficiencies, climate change, as well as myriad interactions among these factors have led to catastrophic declines in abundance and range of numerous species (e.g. vertebrates; Ceballos et al. 2017). This massive loss of biodiversity caused by human activities is likely affecting the essentials of human life (food, clean water, safe housing), through the inability of ecosystems to continue to provide necessary services (Ceballos et al. 2017). Ideally, humans need to balance their detrimental effects on species and ecosystem process with the services biodiversity provides (Lawton 1997). This need for balance is recognised in New Zealand (NZ) through various Acts (e.g.

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Conservation Act, 1987) as well as the NZ Biodiversity Strategy, which emphasises that New Zealanders have a moral (generational) obligation to be kaitiaki (guardians of nature) and to reverse the decline of biodiversity (Anon 2000). In addition, NZ has committed to international agreements (e.g. Convention on Biological Diversity) and has further responsibilities enshrined in Article 2 of Te Tiriti o Waitangi/The Treaty of Waitangi signed in 1840. Te Tiriti o Waitangi guarantees Māori people 'undisturbed possession of their Lands and Estates, Forests, Fisheries and other properties'. Modern interpretation (WAI 262 2011) concludes that the Treaty obliges government agencies to facilitate kaitiakitanga (guardianship) by Māori of natural taonga (treasures).

The NZ Department of Conservation (DOC; formed 01 April 1987) is the government agency required to meet the obligations regarding natural resources as identified in the Treaty by ensuring that ecosystems have the highest possible ecological integrity (*sensu* Lee et al. 2005), while providing recreational opportunities and conserving historical artefacts – factors that are often in conflict (Conservation Act 1987). Regional and local authorities also have responsibilities as outlined in the Environment Act (1986). Although approximately one-third of the country is public land administered by DOC, NZ may face one of the highest rates of terrestrial biodiversity and ecosystem loss in the world (see Anon [2000] for review). This loss of species does not include the limited understanding of threats facing the marine environment in NZ's Exclusive Economic Zone, which is approximately 15 times the size of NZ's land area. Managing conservation threats presents financial and logistical challenges, and in an attempt to understand the extent of the biodiversity crisis in NZ, DOC developed the NZ Threat Classification System (NZTCS). The NZTCS, in use since 2011 and assessed over a 5-year cycle, complements the IUCN Red-list (IUCN 2017), but provides greater sensitivity to circumstances unique to NZ (e.g. historically isolated populations; Townsend et al. 2008), and has been used to set priorities for funding from the NZ government to conservation agencies. However, despite substantial conservation effort (e.g. time, resources and funding), many species continue to decline. For example, Te Waipounamu/South Island (SI) populations of hoiho/yellow-eyed penguins (*Megadyptes antipodes*) have been managed intensively (management costs NZ$68,600 per nest; Busch and Cullen 2009) yet the species is still declining with predicted functional extinction on the historic stronghold of Otago Peninsula by 2060 (Mattern et al. 2017).

Quantification of species recovery and whether conservation efforts are succeeding are topics of debate (see Akçakaya et al. 2018 for review), with success or failure often a matter of perception (Nelson et al. 2018). Here we ask whether commonalities exist among NZ taxa that could be termed conservation 'losers', either because they have been largely ignored by managers or because they have been resistant to management efforts – collectively, intractable species. Our approach is similar to that of Nelson et al. (2018), which used a series of case studies to assess the outcomes of conservation actions over the past 30 years with DOC as the responsible government agency. Each of the following seven case studies was provided by an expert (now, co-author) to provide an example of a taxon that seemingly has not benefitted from conservation action along with possible explanations for that failure. Each case study asks the same set of questions outlined by Nelson et al. (2018): Why was the focal species chosen? What conservation actions have taken place to date and what was the outcome? Are these taxa dependent on ongoing conservation action and what are their prospects for the next 30 years? In choosing our case studies, we aimed for a breadth of scenarios, rather than representative species from every taxon and habitat type. Our studies come from marine, aquatic and terrestrial ecosystems (and are ordered in that manner) covering a variety of conservation issues and complex, and perhaps unsolvable, problems (Table 1).

MĀUI dolphin

Māui dolphins (*Cephalorhynchus hectori maui*) are endemic to NZ and restricted to the west coast of Te Ika-a-Māui/North Island (NI), where they are the only resident coastal dolphin. Taxonomically, they are a small, remnant population of *Cephalorhyncus*, genetically distinct from Hector's dolphins (*C. h. hectori*) of the SI, taxonomically differentiated at the subspecific level, and managed as a separate conservation unit (Baker et al. 2002). As a top predator, they likely once played an important role in the coastal ecosystem. They are the rarest marine dolphin in the world, with only 63 (95% CI 57–75) individuals over 1 year of age (Baker et al. 2016a), and are ranked as 'Critically Endangered' by the IUCN Red-list (IUCN 2017) and 'Nationally Critical' using the NZTCS (Baker et al. 2016b).

During the late 1980s and 1990s, declines of *Cephalorhynchus* dolphins were attributed to the unsustainable rates of gillnet bycatch, with urgent calls for action to save the Māui subspecies after its genetic identification (Martien et al. 1999; Slooten 2013). However, years of legal action and delays in implementing protection resulted in continued decline during the 1990s and 2000s, with the population estimated to have been reduced to as few as 55 individuals at one point (95% CI 48–69; Hamner et al. 2014a). In 2008, a sanctuary encompassing the core range was established and further extended in 2013 (Anon 2018a). This sanctuary banned gillnets and limited trawl fisheries, but is unable to mitigate threats from toxoplasmosis (Roe et al. 2013) and natural predation from sharks (Currey et al. 2012).

No global precedent exists for the successful recovery of a cetacean once the population reaches such low numbers. However, future conservation actions include active mitigation against anthropogenic risk and monitoring for possible genetic hybridisation via recent dispersal of Hector's dolphins (Hamner et al. 2014b; Baker et al. 2016a). Innovative survey methods are being developed to enable year-round monitoring, but despite improvements in monitoring, numbers remain critically low, and stakeholders still struggle to coordinate conservation actions. Māui dolphins have an uncertain future.

Toanui/flesh-footed shearwater

Toanui (*Ardenna carneipes*: Procellariidae) are medium-sized (~700 g), wide-ranging, apex predators that forage mainly on fish and squid in the Indian and Pacific Oceans, and migrate to Japanese waters during the Austral winter. Due to declining numbers for over 40% of global populations (total population ~74,000 pairs; Lavers 2014), toanui are listed as 'Near Threatened' by the IUCN Red-list (IUCN 2017) and 'Nationally Vulnerable' under NZTCS (Robertson et al. 2017). They face threats on land (e.g. invasive predators, habitat loss, harvesting) and at sea (e.g. fisheries bycatch, pollution, climate change). Despite conservation actions across jurisdictions, they are still declining (Sharp et al. 2013; Bond and Lavers 2014; Lavers et al. 2014).

Table 1. Summary table of actions, outcomes and prospects for the New Zealand taxa used in case studies of conservation issues in this paper.

Case study	Primary conservation issues	Conservation actions	Conservation outcomes	Conservation prospects in next 30 years	Potential positive factors
Māui dolphin (*Cephalorhynchus hectori maui*)	• Economic conflict (fisheries) • Stakeholder conflict • Low genetic diversity • Disease	• Habitat protection	• Marine mammal sanctuary in core range	• Likely extinction	• Novel technologies may help • Highly charismatic
Toanui (*Ardenna carneipes)*	• Economic conflict (fisheries) • Multiple jurisdictions • Ecosystem change • Pollution	• Halt cultural harvest • Predator control	• Some breeding populations rebound	• Continued serious decline	• Cultural importance • International conservation agreements
Pīngao (*Ficinia spiralis*, Cyperaceae)	• Extreme change to ecosystem • Economic conflict (agriculture/ urbanisation) • Private land • Climate change	• Coast care groups restore and protect small populations • Development of propagation techniques and restoration methods	• Scattered small populations • Few large populations (larger populations are more resilient to disturbance)	• Continued serious decline	• Cultural importance • Dedicated restoration groups
Kākahi (*Echyridella* species)	• Non-charismatic and inconspicuous • Complex life cycle	• Laboratory propagation methods under development for *E. menziesii*	• Incidental protection through catchment protection, riparian and water quality management, and fish barrier remediation	• Stable in some places for *E. menziesii* • Low for *E. aucklandica* in northern streams • Unknown for *E. onekaka*	• Long-lived • Fish passage guidelines[a] may lead to improvements in fish host populations
Forest ringlet butterfly (*Dodonidia helmsii*)	• Limited knowledge on range and biology • Demes	• Surveys of some populations	• Decline in most surveyed populations and reduced distribution	• Localised extinctions likely without conservation action	• Some new populations found

Hihi (*Notiomystis cincta)*	• Ecosystem change/ Habitat loss • Conservation dependence • Low genetic diversity/ inbreeding • Disease	• Predator control & exclusion • Monitoring • Supplementary feeding • Translocation	• Five reintroduced populations; all require nest boxes and supplementary feeding	• Additional populations may increase numbers	• Charismatic
Grand and Otago skinks (*Oligosoma grande* and *O. otaganse*)	• Conservation dependence • Economic conflict (agriculture/ mining) • Limited resources • Demes	• Captive management • Community/Māori involvement • Land purchase/habitat protection • Monitoring • Predator control & exclusion • Translocations	• Managed eastern populations are stable (but small) • Western populations in decline	• Managed eastern populations remain stable; others go extinct • Western populations extinct in wild, unknown outcome for managed areas	• The past 30+ years of effort has stopped extinction, developed methods for mainland lizard conservation and benefited five other lizard species

Taxa are ordered in the same manner as in the text, from marine to onshore to subalpine. See main text and Table 2 for more details. Note: All species have cultural importance, but we indicate those with particular importance as a source of cultural harvest.

[a]https://www.niwa.co.nz/static/web/freshwater-and-estuaries/NZ-FishPassageGuidelines-upto4m-NIWA-DOC-NZFPAG.pdf.

NZ populations (16% of the global population) breed at ~15 sites from northern NZ to Cook Strait, but are declining. At least four colonies have disappeared since surveys began in the 1930s (Waugh et al. 2013). The main drivers of the decline in NZ were initially assumed to be invasive mammalian predators and over-harvesting of chicks from burrows. However, the population on Tītī Island, Cook Strait, continues to decline despite cessation of legal cultural harvest and eradication of Norway rats (*Rattus norvegicus*) in the 1970s (Gaze 2000). Elsewhere, breeding populations of toanui have benefitted from invasive predator eradications (e.g. *R. exulans*; Waugh et al. 2013).

Fisheries remain a consistent threat to toanui which are classified as being at 'high risk' of being caught by recreational and commercial fishing activities in NZ (Richard et al. 2017); significant levels of mortality are also reported in Australian fisheries (Sharp et al. 2013; Lavers 2014). Both NZ and Australian fisheries likely contribute to regional population declines. Furthermore, stable isotope analyses suggest either spatial shifts or reduced availability of prey of toanui (Bond and Lavers 2014). Finally, plastic ingestion is associated with population declines through reduced reproductive fitness and mortality of adults and chicks (Lavers et al. 2014). Plastics have been found in digestive tracts and burrows of toanui on Ohinau Island, Hauraki Gulf (Buxton et al. 2013) and in 90% of chicks on Lord Howe Island (Lavers 2014).

Despite the use of fisheries bycatch mitigation methods in Australian fisheries and eradications of invasive predators on breeding islands in NZ, toanui are predicted to continue to decline by as much as 50% (to ~37,000 pairs) by 2050 (Waugh et al. 2013; Lavers et al. 2014; Baker and Wise 2005). Effective conservation action may be achieved by expanding global co-operation on fisheries bycatch mitigation, reducing marine plastic pollution and eradicating invasive terrestrial predators from breeding sites in other parts of the world (i.e. Australia and the Indian Ocean). These conservation actions are consistent with the commitments outlined in the Agreement on Conservation of Albatrosses and Petrels (ACAP) and the Convention on the Conservation of Migratory Species (CMS). In NZ, toanui have historically been relatively low priority for conservation funding (Joseph et al. 2008), and this may need to change.

Pīngao/golden sand sedge

Like many endemic NZ plant species, pīngao (pīkao; *Ficinia spiralis;* Cyperaceae) are declining through habitat loss, weed invasion and habitat degradation (e.g. Dixon et al. 2004). Pīngao grows in coastal ecosystems nation-wide and are a treasured source of fibre for weaving and art (Bergin and Herbert 1998; Figure 1A). Pīngao thrive on foredunes where new sand is regularly deposited (Courtney 1983; Figure 1B,C). As a foundation species, pīngao create the dune ecosystem by binding sand with leaves and rhizomes, thus creating habitat for native animals (e.g. NZ dotterel, *Charadrius obscurus*; katipō, *Latrodecus katipo*). Despite its wide distribution, pīngao have been classified in the NZTCS for the past 15 years as being in 'Gradual Decline' (2004) or 'At Risk – Relict' (2009) or 'At Risk – Declining' (2012) (de Lange et al. 2018). They are not listed under the IUCN Red-list.

Natural coastal ecosystems were once extensive in NZ, but now comprise a very small percentage of their former extent (Johnson 1992; Partridge 1992). The ecosystems that pīngao create have been reduced and degraded by past anthropogenic factors, including

Figure 1. Pīngao (Pīkao; *F. spiralis*) are of cultural and ecological significance, and are morphologically variable across different parts of New Zealand. **A,** Woven tukutuku panel – the yellow fibre is pīngao and the white fibre is kiekie (*Freycinetia banksia*). **B,** Pīngao in many Te Ika-a-Māui/North Island locations have long spreading rhizomes, such as those pictured from Matakana Island, Bay of Plenty. **C,** Pīngao from many Te Waipounamu/South Island populations have short rhizomes, such as those pictured from Kaitorete Spit, Canterbury. (Photos: Stacey Bryan©).

fire, land clearance and development for human habitation, agriculture and forestry. Throughout the twentieth century, much government money and many person-hours were devoted to stabilisation of coastal areas by planting dunes with invasive plant species, such as marram grass (*Ammophila arenaria*), tree lupin (*Lupinus arboreus*) and pine trees (*Pinus radiata*), all of which are now significant competitors of pīngao (e.g. Dixon et al. 2004). In addition, pīngao are negatively impacted by human disturbance (i.e. vehicles, foot traffic) and introduced mammalian herbivores. Pīngao are slow growing (Courtney 1983) and given the high levels of physical disturbance (both natural and anthropogenic) combined with the diminishing habitat of most remnant and restored populations, the path to recovery is challenging. Predicted sea level rise and increased frequency and severity of storms in the future (www.stats.govt.nz) will likely cause continued reduction in suitable habitat.

For several decades, pīngao have been successfully propagated using locally sourced seed and planted in dozens of sand dune restoration initiatives by DOC, local government and coastal care groups throughout NZ (Bergin and Herbert 1998; Bergin and Kimberley 1999; Jenks 2018). However, the success of these plantings is unclear and will depend on determining the interactions of native vegetation, climatic change and geomorphological processes. Despite considerable public attention and value as a taonga, pīngao continue to decline. Without major changes in coastal land-use, coupled with restoration and weed control to recreate and rehabilitate sand dune systems, pīngao may not be able to recover.

Kākahi/freshwater mussels

New Zealand has three recognised extant species of kākahi which are considered 'Threatened' or 'At Risk' in the NZTCS (Grainger et al. 2014), and 'Data Deficient' or 'Least Concern' by the IUCN Red-List (IUCN 2017; see also Marshall et al. 2014). The most widespread species, *Echyridella menziesii*, is found in lakes and waterways throughout the country and is declining (e.g. Whanganui River, Rainforth 2008). *Echyridella onekaka*, a poorly known species difficult to distinguish from *E. menziesii*, is thought to be restricted to the north-west of the SI, and *E. aucklandica* (formerly *Cucumerunio websteri*) is considered under most threat (see below), inhabiting upper NI with outlier populations in Lake Wairarapa near Wellington and Lake Hauroko in Fiordland (Marshall et al. 2014). All three species are long-lived; estimates for *E. menziesii* are up to 50 years (Grimmond 1968) and longevity may be greater for the larger *E. aucklandica*.

Size structure of *E. aucklandica* populations is skewed towards old individuals with little evidence of recruitment in northern streams. Like all unionids, *E. aucklandica* has a larval glochidial stage that parasitises fish (probably native diadromous fish) before transforming into juveniles that detach and sink into the benthos. Barriers to upstream passage contribute to the decline of native diadromous fish in NZ (Leathwick et al. 2008), which then negatively impacts mussel populations which need an annual influx of naïve fish hosts. In addition, *E. aucklandica* appears to have a more specialised reproductive strategy than the more common *E. menziesii*, involving the production of conglutinates (M. Melchior, The University of Waikato, personal communication, 1 April 2018), supporting the idea that reproductive constraints may be a key factor contributing to the high number of senile populations with high extinction debt (see Kuussaari et al. 2009). Other negative factors include invasive non-native macrophytes that clog water channels and alter habitat conditions at the sediment–water interface (e.g. through de-oxygenation), and the spread of non-native fish which are unsuitable larval hosts, at least for *E. menziesii* (T. Moore, The University of Waikato, unpublished data, 1 April 2018).

In NZ, freshwater ecosystems are a key focus of management and restoration initiatives, often with the assumption that enhancing water quality will have flow-on benefits for aquatic biodiversity. However, for long-lived, sessile species with complex life cycles like kākahi, the answer is not that simple. The largest known population of *E. aucklandica* in the Waikato Region is in a small, low gradient coastal stream with headwaters in native forest, suggesting the need for high quality water, suitable benthic conditions and access for diadromous fish to aid population success. Accordingly, conservation of kākahi must consider whole of catchment environmental management, i.e. upstream (water quality, sediment) and downstream (host fish passage) requirements. To date, conservation actions have not enhanced recruitment of *E. aucklandica* populations in northern NZ, and more targeted measures are needed to reinstate regional recruitment processes and prevent local extinction (Table 1). A recent conservation initiative is the translocation of 200 kākahi from lakes in the Wairarapa to ZEALANDIA ecosanctuary's upper dam in Wellington (Ballance 2018).

Forest ringlet butterfly

The forest ringlet butterfly (*Dodonidia helmsii*) was once widespread as far south as Greymouth and Lewis Pass in the SI, but has become increasingly rare over the past 50 years. It is ranked as 'At Risk – Relict' in the NZTCS (Hoare et al. 2017), but not listed on the IUCN Red-List. The cause of the decline in abundance and distribution is unknown, but habitat loss, over collection, parasitism, predation by introduced birds and rodents, as well as impacts of feral pigs (*Sus scrofa*) on host plant (*Gahnia* and *Chionochloa* species) abundance have all been suggested as contributing factors (Wheatley 2017). In addition, introduced *Vespula* wasps may reduce forest ringlet populations (Watts et al. 2012). For example, once wasp populations on Te Hauturu-o-Toi/Little Barrier Island began to decline in abundance (from c. 2004; R. Veitch. pers. comm.) a resident population of butterflies was found for the first time (2017; Griffiths et al. in press).

To avoid localised extinctions of this butterfly, the causes of the decline (and the yet to be explained increase on Te Hauturu-o-Toi/Little Barrier Island) need to be determined. Despite obvious risk of continuing decline in butterfly numbers, only surveys to monitor numbers have been undertaken to date. Better understanding of factors controlling population numbers is needed to identify optimal management options. Possible interventions recommended by Wheatley (2017) include captive rearing, further understanding of biology, standardising data collection on its distribution and population densities, and understanding of habitat requirements as ways to actively work to reverse the decline.

Hihi/stitchbird

Hihi (*Notiomystis cincta*) are medium-sized (30–40 g) nectar-feeding forest-dwelling passerines. The species is the sole member of an endemic family of birds (Notiomystidae) once widespread on the NI and adjacent larger offshore islands. From the 1870s, hihi underwent a rapid decline in range and numbers; by the late 1880s they were restricted to a single remnant population (~600–6000 birds) on the 3083 ha isolated offshore island Te Hauturu-o-Toi/Little Barrier Island (Taylor et al. 2005). Hihi build their nests in tree cavities, a behavioural trait considered to predispose them to the negative impacts of forest clearance and introduced mammalian predators (Perrott and Armstrong 2011). For example, their decline in numbers coincided with extensive forest clearance and the arrival of ship rats (*R. rattus*), and quickly turned to extinction on the mainland with the release of mustelids in the 1880s (DOC 2005). Hihi are regarded as 'Nationally Vulnerable' in the NZTCS because existing populations are at least stable, but conservation dependent (Robertson et al. 2017) and are ranked as 'Vulnerable' in the IUCN red-list (IUCN 2017).

Beginning in the 1980s, an ongoing national recovery program aimed to increase the range and numbers of hihi using reintroduction. Initially a captive population was established to provide founders for reintroduction, but later harvesting from wild populations has provided most birds for reintroduction. To date, there have been 21 translocations to eight different locations (Castro 2013). Although mammalian predators had been eliminated on islands or heavily suppressed in sanctuaries where hihi were introduced, no population has become self-sustaining (Taylor et al. 2005). In addition, all surviving populations outside of Te Hauturu-o-Toi are maintained by supplementary feeding, suggesting deficiencies in available nectar sources in young growth forests (Perrott and Armstrong 2000). Further, hihi are highly vulnerable to respiratory infections (aspergillosis) from the fungus *Aspergillus fumigatus* (Alley et al. 1999) which is common in young growth forest habitats and spread through contaminated soil (Perrott and Armstrong 2011).

Habitat requirements for hihi are difficult to identify. Successful establishment at sites with populations of aggressively competing species such as bellbird (*Anthornis melanura*) and tūī (*Prosthemadera novaeseelandiae*) remains the acid test for restoration of hihi. However, despite considerable effort by multi-agency hihi recovery groups since the mid-1990s (e.g. Taylor et al. 2005), the species has little prospect of increasing in numbers until large tracts of mature forest are cleared of introduced predators on the mainland and suitable regenerating forests mature on offshore islands (Ewen et al. 2013).

Grand and Otago skinks

Grand (*Oligosoma grande*) and Otago skinks (*O. otagense*), collectively known as GAOS, inhabit middle-altitude fractured schist in shrub and tussock grasslands of Central Otago in SI (Reardon et al. 2012). Their ranges are <10% of historic estimates, and both species now occur within two widely spaced and genetically diverse groups in the east and west (Whitaker and Loh 1995; Chapple et al. 2012); the genetic diversity is such that the eastern and western populations are managed as separate units. The NZTCS ranking for both GAOS improved from 'Nationally Critical' to 'Nationally Endangered' in 2015 (Hitchmough et al. 2016; Towns et al. 2016), with *O. otagense* ranked as 'Endangered', and *O. grande* as 'Vulnerable', in the IUCN Red-list (IUCN 2017). However, persistence of the western populations is uncertain, and all remaining populations are dependent on ongoing conservation action.

Like the other 100+ endemic lizard species, GAOS are at risk from a combination of habitat destruction, predation/competition with invasive species and wildlife trafficking (Towns et al. 2016; Table 2). The GAOS are large-bodied with late sexual maturity and low reproductive output, but unlike other large lizard species in NZ, they lack mammal-free island strongholds (Towns et al. 2016; Cree and Hare 2016). Conservation management began in the early 1980s and has included a multi-faceted formal recovery plan with a long list of actions (Table 1; Whitaker and Loh 1995; Towns et al. 2016 and references within).

The eastern populations were identified in the late 1990s as more economically feasible than western populations for large-scale mammal-control operations. Intensive management of the scattered western populations was less feasible, due to populations being confined to rugged terrain and private farmland. Indeed, the first GAOS recovery plan noted that ' … it is not physically or financially possible to protect all the remaining populations of [GAOS] and […], no matter how successful the conservation programme is, many will die out' (Whitaker and Loh 1995). To date, most research and conservation knowledge is based on the eastern populations (Towns et al. 2016; Reardon et al. 2012), which are also easier to keep successfully in captivity than individuals from western

Table 2. Summary of stressors and threats affecting seven case study taxa from New Zealand described in this paper.

		Case study taxon						
Threats	Description	MD	Toanui	Pīngao	Kākahi	FRB	Hihi	GAOS
Ecosystem change	Change or complete loss of ecosystem structure, function integrity or composition		●	●	●	◌	●	●
Pollution*	Mortality, developmental or reproductive impacts (e.g. nutrient and sediment loads, toxins, light)		●		●			
Invasive species*	Mortality, developmental or reproductive impacts (e.g. consumption, competition, hybridisation)		●	●	●	◌	●	●
Exploitation and harassment	Mortality or decreased fitness (e.g. harvesting, hunting, bycatch, road kills, persecution, disease)	●	●	●		◌	●	●
Accelerated climate change*	Further ecosystem change (e.g. change in weather, extreme weather, temperature change)		●	◌	◌			◌
Natural causes	Stochastic events (e.g. geologic events, wildfire, natural irruptions)	●	◌	●	◌	◌	◌	◌
Fragmentation/ connectivity	Isolation of small habitats and/or loss of migratory pathways				●	●		●
Limited data on habitat or biology	Insufficient information to adequately classify or provide conservation action				●	●		
Other threats*	Conservation dependent; perceived value; clash with economic or developmental priorities	●	●	●	●	●	●	●
Lack of direction	No obvious solution, causing debate and indecision	●				●		

Threats are based on Wong (2011), with additional information from Anon (2000). Taxa discussed include: **MD** (Māui dolphin; *C. hectori maui*); **toanui** (flesh-footed shearwater, *Ardenna carneipes*); **pīngao** (pīkao, golden sand sedge, *F. spiralis*); **kākahi** (three species within genus *Echyridella*); **FRB** (forest ringlet butterfly; *D. helmsii*); **hihi** (stichbird; *N. cincta*); **GAOS** (grand [*O. grande*] and Otago [*O. otagense*] skinks). ● = known factors; ◌ = possible factors. *May also modify ecosystems.

populations. Indeed, the eastern GAOS populations are excellent examples of what can happen with dedicated conservation action underpinned by strong scientific evidence (e.g. Reardon et al. 2012).

Sustainable harvest of western juveniles for genetic security was done (2009–2013), and long-term monitoring of remaining natural populations indicated a probable steady decline susceptible to stochastic events. In 2014, an emergency salvage of 85 GAOS from all known western populations was carried out. Forty-five juveniles (a mix of wild and captive-raised) were immediately released to a community-led 0.3 ha fenced sanctuary, but most vanished (COET 2016). The captured adults were paired for captive breeding, with a 5-year plan to release to a new 14-ha predator-exclusion area (completed 2015; Collen et al. 2009); unfortunately, survival and breeding success were low in both the translocated population (juveniles) and captivity (adults; COET 2016). In December 2018, 67 of the surviving captive-held GOAS were released early from captivity into the 14-ha sanctuary (Anon 2019).

In the next 30 years, wild GAOS in the western and non-protected eastern areas seem on a trajectory for extinction. With ongoing predator control and habitat protection, eastern managed populations could persist at present levels (Reardon et al. 2012). However, remaining eastern populations are vulnerable to stochastic events, reduction in conservation management and further habitat loss (particularly for populations on private land). Reproductive and physiological biology of GAOS has had minimal attention and intensive research and management programmes along the lines of the successful programme for tuatara (Nelson et al. 2018) could be a useful pathway for reversing population declines of GAOS. Coupled with the new predator-free sanctuaries developed by community-led projects and extensive control of predators in other areas, survival of western GAOS may be improved in the future.

Discussion

Innovative methodologies for conservation management have built NZ's reputation as a world leader in this arena, as evidenced by many conservation 'winners' (Nelson et al. 2018). However, an unknown, but likely large number, of 'intractable' species continue to decline. Our case studies describe a multitude of complex and interacting issues that hamper recovery of intractable species, including but not limited to: economic conflict, limited knowledge, complex life cycles, habitat management issues, limited resources for conservation management and conflicts with stakeholders (see Tables 1 and 2). In undertaking our review, we built on the suite of conservation threats identified by Wong (2011) and included additional information from the New Zealand Biodiversity Strategy 2000–2020 (Anon 2000). We identified 10 types of threats/stressors that adversely affect the recovery of species in NZ (outlined in Table 2). Between four and six different threats/stressors affected our case study species. The most common threats experienced (five of seven case studies) were 'ecosystem change', 'invasive species' and 'exploitation and harassment' (Table 2). However, all seven taxa were impacted by 'Other Threats' (e.g. dependence on continuing management, perceived value, economic conflict). Conflict with economic initiatives affected both our marine examples and is also implicated in declines of other high-profile endemic species such as hoiho and pīngao. Toanui confront the most unusual conservation issues because they cross multiple jurisdictions and are affected by non-point source pollution. Collectively, our seven case studies provide examples of the known stressors and threats to ongoing persistence of NZ species (Table 2).

The scale of the conservation challenge is enormous

The biodiversity challenge facing NZ is massive and includes one of the highest numbers of threatened species in the world (Anon 2000). The Department of Conservation (DOC) manages about 30% of NZ's land area (8 million ha), all Marine Protected Areas, as well as all its biodiversity on both land and in water, which is estimated at ~80,000 species (Anon 2000). Only c. 38% of all NZ native species are described, with nearly 1000 taxa listed as threatened, and many more as 'Data Deficient' (Anon 2000). The total annual DOC budget allocated for 2018–2022 cannot support active management of all these species ($407 to $453 million; www.doc.govt.nz; Towns et al. this issue). Additionally, growing understanding of the risks of climate change and demands from increased human populations on habitat and resources compound these issues (e.g. Table 2). Clearly, the task of reducing decline in biodiversity is too large for a single conservation agency.

The DOC has explicitly acknowledged the need to increase its limited resources for addressing the biodiversity crisis by developing a partnerships model (Towns et al. this issue). The partnerships model integrates conservation management across government, organisations and the community. In military terms, partnerships are a 'force multiplier' that, by engaging other parties in conservation, increase resources available for conservation actions (e.g. Million Dollar Mouse project to eradicate mice from the Anitipodes Islands; www.milliondollarmouse.org.nz). The recent translocation of kākahi to ZEALANDIA Ecosanctuary is one example of partnership actions that aim to improve the prospects of intractable species. However, while the partnerships model provides DOC with a mechanism to increase its effectiveness, a challenging outcome is where partners pressure DOC to provide charismatic species for reintroduction to newly developed conservation areas (A. Styche, Department of Conservation, 17 May 2018). Thus as DOC has an obligation to continue to protect and halt the decline of biodiversity, it needs robust information to maintain a pragmatic, cost-effective and timely approach to conservation management as well as increased tools for management.

Building our knowledge: the role of research

Many of the outcomes for the 'winners' outlined in Nelson et al. (2018) were made possible through research, including technological advances in pest eradication methods, habitat restoration and translocation techniques, as well as knowledge of the species' biology. However, for numerous NZ taxa little is known about their biology (e.g. forest ringlet butterfly), many have yet to be described (e.g. c. 45% of native lizard species are undescribed; Chapple 2016), and little is known about their requirements for persistence or whether remnant populations are in optimal habitat. It is even unclear whether our case studies of intractable species (Table 1) represent a large or small fraction of NZ threatened taxa.

The scientific community has a role to increase investigation of the basic biology of species, providing species descriptions, collecting natural history data, and determining optimal habitat and resource requirements. In addition, a clear line of communication between DOC and the scientific community is required if these data are to be used effectively for conservation management. For example, the fringe-gilled mayfly (*Isothraulus abditus*) was listed as 'At Risk' in the NZTCS due to its narrow distribution (Towns and Peters 1996; Grainger et al. 2014), but an in-depth study detected the species at 54 locations from Northland to Whanganui (Pohe et al. 2018) determining that it is 'Not Threatened'. This new knowledge was sufficient to confirm the change in status of the fringe-gilled mayfly. However, given the scale of the conservation challenge (outlined above) conservation action will be required for most species and this will require massive levels of support. Such large-scale conservation action will require unprecedented social mobilisation for community conservation (e.g. Jarvis et al. this issue), and strong support from institutions and conservation agencies.

The relationship between people, landscapes and biodiversity is at the centre of all conservation efforts, and is exemplified in the strategy of the NZ Biological Heritage and Sustainable Seas National Science Challenges, which include quality research that aims for support from NZ coupled with strong blending with Mātauranga Māori (Māori knowledge; e.g. Anon 2018b). Without such provision for adequate social engagement, social and economic complexities can be difficult to overcome and may stall conservation action to the point that nothing happens. These difficulties are especially prevalent where species inhabit areas subjected to economically important endeavours, such as freshwater, fisheries, urban and agricultural development, and mining (e.g. 6/7 of our case study species; Tables 1 and 2). For example, attempts to resolve bycatch issues for Māui dolphin were hampered by the added complexities of early conflict among stakeholders, limited coordination among agencies and lengthy legal procedures (Table 1). Urgent action is now needed to avoid Māui dolphins following the path of extinction seen in other dolphins with small populations (e.g. the baiji (*Lipotes vexillifer*) was considered extinct in 2006; Turvey et al. 2007). Therefore, new tools and knowledge on effective social engagement will contribute to strong conservation initiatives and outcomes. The DOC will continue to have a leading role in providing conservation guidance, facilitation among partners and developing methods for social engagement, through both strategy and policy.

The NZ Biodiversity Strategy (NZBS) is currently under revision and due for release at the end of 2019 (www.doc.govt.nz). The revision of the NZBS provides a timely opportunity to include priorities for investigation of new techniques and technologies, including those for social engagement, in order to mitigate complex conservation issues, and ultimately reverse the decline of intractable species. The NZBS review also provides an opportunity to clearly outline processes and guidance around setting priorities for conservation of less charismatic species that require a concerted effort to protect. In addition, decisions around management units/demes of a species (e.g. GAOS and forest ringlet butterflies; Table 1) are challenging and consistent guidance to stakeholders is needed. Furthermore, DOC's credibility in these roles will need scientific evidence as support for effective decisions. These data will also enable DOC to provide clear oversight and guidance to both the government and its partners under NZ's national and international agreements. Indeed, in the case of toanui, whose range spans multiple jurisdictions, support from other countries is required, and the commitments of the Agreement on Conservation of Albatrosses and Petrels (ACAP), and the Convention on the Conservation of Migratory Species (CMS) are pivotal. Such international agreements can work, as seen through the global cessation of hunting successfully implemented for humpback whales (*Megaptera novaeangliae*) (Nelson et al. 2018).

Hope for the intractable species

The extermination of rodents from islands was once thought impossible, but now more than 100 islands in NZ are mammal free, and NZ leads the world in effective eradication methods (Towns and Broome 2003 and references within). Currently NZ is embarking on another ambitious conservation initiative – Predator Free 2050, which aims to eradicate from the NZ archipelago a suite of invasive predatory mammals by 2050 (Russell et al. 2015). The initiative has been endorsed and seed-funded by the NZ government, and will require unprecedented new technical, social and economic initiatives (Russell et al. 2015). Strong local support has already been developed with recently announced community-based programmes (e.g. Predator-free Taranaki, Predator-free Waiheke Island; Jarvis et al. this issue). However, we have shown that removing predatory mammals as the sole management approach will not be enough for intractable species, which are impacted by a suite of complex and interacting threats and stressors (Table 2). Instead, restoration of entire ecosystems or landscapes may be the only viable solution to these complex problems.

Soulé (1987, p. 181) offered clear guidance for what appeared to be intractable problems: 'There are no hopeless cases, just expensive cases and people without hope'. Fortunately, no recent extinctions are known from NZ, and DOC has had a pivotal role in maintaining species in the face of imminent extinction (Towns et al. this issue). However, major problems remain to be resolved for numerous species, and these require mobilisation of the scientific community, ongoing engagement with the NZ public and strong leadership. A growing commitment from people, including increased funding, can give the people of NZ some hope for the future of the intractable species.

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References

Akçakaya HR, Bennett EL, Brooks TM, Grace MK, Heath A, Hedges S, Hilton-Taylor C, Hoffmann M, Keith DA, Long B, et al. 2018. Quantifying species recovery and conservation success to develop an IUCN Green List of Species. Conservation Biology. 32:1128–1138.

Alley MR, Castro I, Hunter JEB. 1999. Aspergillosis in hihi (*Notiomystis cincta*) on Mokoia Island. New Zealand Veterinary Journal 47:88–91.

Anon. 2000. New Zealand Biodiversity Strategy 2000-2020. New Zealand Department of Conservation. ISBN O-478-21919-9.

Anon. 2018a. Protection measured for Māui dolphin. New Zealand Department of Conservation. [accessed 2018 April 22]. http://www.doc.govt.nz/nature/native-animals/marine-mammals/dolphins/maui-dolphin/current-protection-measures/.

Anon. 2018b. New Zealand's Biological Heritage National Science Challenge, Ngā Koiora Tuku Iho. Strategy 2019–2024. [downloaded 2019 January 17]. http://www.biologicalheritage.nz/__data/assets/pdf_file/0006/172842/STRATEGY-FINAL-JULY092018.pdf.

Anon. 2019. Manaaki Whenua Landcare Research – Bringing home the lizards. [downloaded 2019 February 04]. https://www.youtube.com/watch?v = 6Ihj43y9zHI.

Baker GB, Wise BS. 2005. The impact of pelagic longline fishing on the flesh-footed shearwater *Puffinus carneipes* in Eastern Australia. Biological Conservation. 126:306–316.

Baker AN, Smith ANH, Pichler FB. 2002. Geographical variation in Hector's dolphin: recognition of a new subspecies of *Cephalorhynchus hectori*. Journal of the Royal Society of New Zealand. 32:713–727.

Baker CS, Steel D, Hamner RM, Hickman G, Boren L, Arlidge W, Constantine R. 2016a. Estimating the abundance and effective population size of Māui dolphins using microsatellite genotypes in 2015–16, with retrospective matching to 2001–16. Wellington, New Zealand: Department of Conservation. 70p.

Baker CS, Chilvers BL, Childerhouse S, Constantine R, Currey R, Mattlin R, van Helden A, Hitchmough R, Rolfe J. 2016b. Conservation status of New Zealand marine mammals, 2013. New Zealand Threat Classification Series 14. Wellington, New Zealand: New Zealand Department of Conservation. 18p.

Ballance A. 2018. Mussels on the move. Radio New Zealand 2 August 2018. [downloaded 2018 December 24]. https://www.radionz.co.nz/national/programmes/ourchangingworld/audio/2018656022/mussels-on-the-move.

Bergin DO, Herbert JW. 1998. Pīngao on coastal sand dunes. Guidelines for seed collection, propagation and establishment. CDVN Technical Bulletin No 1. New Zealand Forest Research Institute.

Bergin DO, Kimberley MO. 1999. Rehabilitation of coastal foredunes in New Zealand using indigenous sand-binding species. Science for Conservation 122.

Bond AL, Lavers JL. 2014. Climate change alters the trophic niche of a declining apex marine predator. Global Change Biology. 20:2100–2107.

Busch J, Cullen R. 2009. Effectiveness and cost-effectiveness of yellow-eyed penguin recovery. Ecological Economics. 68:762–776.

Buxton RT, Currey CA, Lyver POB, Jones CJ. 2013. Incidence of plastic fragments among burrow-nesting seabird colonies on offshore islands in northern New Zealand. Marine Pollution Bulletin. 74:420–424.

Castro I. 2013 [updated 2016]. Stitchbird. In: Miskelly CM, editor. New Zealand Birds Online [accessed 2018 May 15]. www.nzbirdsonline.org.nz.

Ceballos G, Ehrlich PR, Dirzo R. 2017. Biological annihilation via the ongoing sixth mass extinction signaled by vertebrate population losses and declines. PNAS 30: E6089-E6096. https://doi.org/10.1073/pnas.1704949114.

Chapple DG. 2016. Synthesising our current knowledge of New Zealand lizards. In: Chapple DG, editor. New Zealand lizards. Switzerland: Springer; p. 1–11.

Chapple DG, Birkett A, Miller KA, Daugherty CH, Gleeson DM. 2012. Phylogeography of the endangered Otago skink, *Oligosoma otagense*: population structure, hybridisation and genetic diversity in captive populations. PLoS ONE. 7:e34599. doi:10.1371/journal.pone.0034599.

Collen R, Reardon J, Tocher M. 2009. Grand skink (*Oligosoma grande*) and Otago Skink (*Oligosoma otagense*) Captive Management Plan 2007–2014. New Zealand Department of Conservation. docdm-127594.

COET. 2016. Mokomoko Newsletter, Number 14. 16 September 2016. Central Otago Ecological Trust. 4 p. [accessed 2018 May15]. http://www.coet.org.nz/documents/COETnewsletterNo14Sep16.pdf.

Courtney SP. 1983. Aspects of the ecology of Desmoschoenus spiralis (A. Rich.) Hook. F. Unpublished MSc thesis, University of Canterbury, New Zealand.

Cree A, Hare KM. 2016. Reproduction and life history of New Zealand lizards. In: Chapple DG, editor. New Zealand lizards. Switzerland: Springer; p. 169–206.

Currey RJC, Boren LJ, Sharp BR, Peterson D. 2012. A risk assessment of threats to Maui's dolphins. Wellington, New Zealand: Ministry for Primary Industries and Department of Conservation. 51p.

de Lange PJ, Rolfe JR, Barkla JW, Courtney SP, Champion PD, Perrie LR, Beadel SM, Ford KA, Breitwieser I, Schönberger I, et al. 2018. Conservation status of New Zealand indigenous vascular plants, 2017. Wellington: New Zealand Threat Classification Series 22. New Zealand Department of Conservation. 82 p.

Dixon P, Hilton M, Bannister P. 2004. *Desmoschoenus spiralis* displacement by *Ammophila arenaria*: the role of drought. New Zealand Journal of Ecology. 28:207–214.

DOC. 2005. Department of conservation 2005. Hihi/Stitchbird (*Notiomystis cicta*) recovery plan 2004–09. Wellington, New Zealand: New Zealand Department of Conservation.

Ewen JG, Renwick R, Adams L, Armstrong DP, Parker KA. 2013. 1980–2012: 32 years of re-introduction efforts of the hihi (stitchbird) in New Zealand. In: Soorae PS, editor. Global Re-introduction Perspectives: 2013. Further case studies from around the globe. Gland, Switzerland: IUCN/SSC Re-introduction Specialist Group and Abu Dhabi, UAE: Environment Agency-Abu Dhabi; p. 68–74.

Gaze P. 2000. The response of a colony of sooty shearwater (*Puffinus griseus*) and flesh-footed shearwater (*P. carneipes*) to the cessation of harvesting and the eradication of Norway rats (*Rattus norvegicus*). New Zealand Journal of Zoology. 27:375–379.

Grainger N, Collier KJ, Hitchmough R, Harding JS, Smith BJ, Sutherland DL. 2014. Conservation status of New Zealand freshwater invertebrates, 2013. Wellington, New Zealand: New Zealand Threat Classification System, New Zealand Department of Conservation.

Griffiths R, Bell E, Campbell J, Cassey P, Ewen JG, Green C, Joyce L, Rayner M, Toy R, Towns D, Wade L, Walle R, Veitch CR. in press. Costs and benefits for biodiversity following rat and cat eradication on Te Hauturu-o-Toi/Little Barrier Island. Proceedings of Island Invasive Species Conference, Dundee, Scotland.

Grimmond NM. 1968. Observations on growth and age in Hyridella menziesii Mollusca: Bivalvia) in a freshwater tidal lake. Unpublished MSc thesis, University of Otago, Dunedin, New Zealand.

Hamner RM, Wade P, Oremus M, Stanley M, Brown P, Constantine R, Baker CS. 2014a. Critically low abundance and limits to human-related mortality for the Maui's dolphin. Endangered Species Research. 26:87–92.

Hamner RM, Constantine R, Oremus M, Stanley M, Brown P, Baker CS. 2014b. Long-range movement by Hector's dolphins provides potential genetic enhancement for critically endangered Maui's dolphin. Marine Mammal Science. 30:139–153.

Hitchmough R, Barr B, Lettink M, Monks J, Reardon J, Tocher MD, van Winkel D, Rolfe J. 2016. Conservation status of New Zealand Reptiles, 2015. Wellington, New Zealand: New Zealand Department of Conservation.

Hoare R, Dugdale J, Edwards E, Gibbs G, Patrick B, Hitchmough R, Rolfe J. 2017. Conservation status of New Zealand butterflies and moths (Lepidoptera). New Zealand Threat Status Classification Series 20. Wellington, New Zealand: Department of Conservation.

IUCN. 2017. IUCN Red List of Threatened SpeciesTM. International Union for Conservation of Nature and Natural Resources. http://www.iucnredlist.org/.

Jarvis RM, Galbraith M, Ough Dealy H, Perrott J, Towns DR. this issue. The past, present, and future of community-led conservation in New Zealand. Journal of the Royal Society of New Zealand.

Jenks GK. 2018. Restoring the natural functional capacity of coastal dune ecosystems: Utilising research records for New Zealand littoral refurbishment as a proxy for analogous global responses. Journal of Coastal Conservation. 22:623–665.

Johnson PN. 1992. The Sand Dune and Beach Vegetation Inventory of New Zealand: II South Island and Stewart Island. Christchurch: Land Resources Scientific Report No. 16, Department of Scientific and Industrial Research. 278 p.

Joseph LN, Maloney RF, O'Connor SM, Cromarty P, Jansen P, Stephens T, Possingham HP. 2008. Improving methods for allocating resources among threatened species: the case for a new national approach in New Zealand. Pacific Conservation Biology. 14:154–158.

Kuussaari M, Bommarco R, Heikkinen R, Helm AR, Krauss J, Lindborg R, Ockinger E, Pärtel M, Pino J, Rodà F, et al. 2009. Extinction debt: a challenge for biodiversity conservation. Trends in Ecology & Evolution. 24:564–571.

Lawton JH. 1997. The science and non-science of conservation biology. Oikos. 79:3–5.

Lavers JL. 2014. Population status and threats to flesh-footed Shearwaters (*Puffinus carneipes*) in South and Western Australia. ICES Journal of Marine Science. 72:316–327.

Lavers JL, Bond AL, Hutton I. 2014. Plastic ingestion by flesh-footed shearwaters (*Puffinus carneipes*): Implications for fledgling body condition and the accumulation of plastic-derived chemicals. Environmental Pollution. 187:124–129.

Leathwick JR, Elith J, Chadderton WL, Rowe D, Hastie T. 2008. Dispersal, disturbance and the contrasting biogeographies of New Zealand's diadromous and non-diadromous fish species. Freshwater Biology. 35:1481–1497.

Lee W, McGlone M, Wright E. 2005. Biodiversity inventory and monitoring: a review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation. Landcare Research Contract Report LC0405/122.

Marshall BA, Fenwick MC, Ritchie PA. 2014. New Zealand recent Hyriidae (Mollusca: Bivalvia: Unionida). Molluscan Research. 34:181–200.

Martien KK, Taylor BL, Slooten E, Dawson S. 1999. A sensitivity analysis to guide research and management for Hector's dolphin. Biological Conservation. 90:183–191.

Mattern T, Meyer S, Ellenberg U, Houston DM, Darby JT, Young M, van Heezik Y, Seddon PJ. 2017. Quantifying climate change impacts emphasises the importance of managing regional threats in the endangered yellow-eyed penguin. PeerJ. 5:e.3272.

Nelson NJ, Briskie JV, Constantine R, Monks J, Wallis GP, Watts C, Wotton DM. 2018. The winners: species that have benefited from 30 years of conservation action. Journal of the Royal Society of New Zealand. doi:10.1080/03036758.2018.1518249.

Partridge T. 1992. The Sand Dune and Beach Vegetation Inventory of New Zealand: I North Island. Christchurch: Land Resources Scientific Report No. 16. Department of Scientific and Industrial Research. 253 p.

Perrott JK, Armstrong DP. 2000. Vegetation composition and phenology of Mokoia Is, and implications for the reintroduced hihi population. New Zealand Journal of Ecology. 24:19–29.

Perrott JK, Armstrong DP. 2011. *Aspergillus fumigatus* densities in relation to forest succession and edge effects: implications for wildlife health in modified environments. EcoHealth. 8:290–300.

Pohe SR, Winterbourn MJ, Goldstien SJ, Ball OJ-P, Harding JS. 2018. Distribution, nymphal habitat, genetic structure and conservation of the New Zealand mayfly *Isothraulus abditus* (Insecta: Ephemeroptera) and a description of its subimago. New Zealand Journal of Zoology. doi:10.1080/03014223.2018.1464034.

Rainforth HJ. 2008. Tiakina kia ora – protecting our freshwater mussels. Unpublished Master of Restoration Ecology Thesis, Victoria University of Wellington, Wellington, New Zealand.

Richard Y, Abraham ER, Filippi D. 2017. Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2012–13. Wellington, New Zealand: Ministry for Primary Industries, Manatū Ahu Matua.

Reardon JT, Whitmore N, Holmes KM, Judd LM, Hutcheon AD, Norbury G, Mackenzie DI. 2012. Predator control allows critically endangered lizards to recover on mainland New Zealand. New Zealand Journal of Ecology. 36:141–150.

Robertson HA, Baird K, Dowding JE, Elliott GP, Hitchmough RA, Miskelly CM, McArthur N, O'Donnell CFJ, Sagar PM, Scofield RPP, Taylor GA. 2017. Conservation status of New Zealand birds, 2016. Wellington, New Zealand: New Zealand Department of Conservation.

Roe WD, Howe L, Baker EJ, BurrowsL HS. 2013. An atypical genotype of *Toxoplasma gondii* as a cause of mortality in Hector's dolphins (*Cephalorhynchus hectori*). Veterinary Parasitology. 192:67–74.

Russell JC, Innes JG, Brown PH, Byrom AE. 2015. Predator-free New Zealand: conservation country. BioScience. 65:520–525.

Sharp B, Cryer M, Richard Y, Abraham E. 2013. New Zealand's approach to assessment of risk to seabirds associated with fishing-related mortality. In: Fifth meeting of the Seabird Bycatch Working Group, La Rochelle, France, 1–3 May 2013. ACAP, La Rochelle, France. p 11.

Slooten E. 2013. Effectiveness of area-based management in reducing bycatch of the New Zealand dolphin. Endangered Species Research. 20:121–130.

Soulé ME. 1987. Where do we go from here? In: M. E. Soule, editor. Viable populations for conservation. Cambridge, England: Cambridge University Press; p. 175–183.

Taylor S, Castro I, Griffiths R. 2005. Hihi/stitchbird (*Notiomystis cincta*) recovery plan 2004–2009. Threatened species recovery plan 54. New Zealand Department of Conservation, Wellington, New Zealand.

Towns DR, Broome KG. 2003. From small Maria to massive Campbell: forty years of rat eradications from New Zealand islands. New Zealand Journal of Zoology. 30:377–398.

Towns DR, Peters WL. 1996. Leptophlebiidae (Insecta: Ephemeroptera). Fauna of New Zealand number 36. Lincoln, New Zealand: Manaaki Whenua Press.

Towns DR, Hitchmough RA, Perrott J. 2016. Conservation of New Zealand lizards: A fauna not forgotten but undervalued? Chapter 11. In: Chapple DG, editor. New Zealand lizards. Switzerland: Springer; p. 292–320.

Towns DR, Broome K, Timmins S, Daugherty CH. this issue. The thirty-year conservation revolution in New Zealand: an introduction. Journal of the Royal Society of New Zealand.

Townsend AJ, de Lange PJ, Duffy CAJ, Miskelly CM, Molloy J, Norton DA. 2008. New Zealand Threat Classification System manual. Wellington, New Zealand: New Zealand Department of Conservation.

Turvey ST, Pitman RL, Taylor BL, Barlow J. 2007. First human-caused extinction of a cetacean species? Biology Letters. 3:537–540.

WAI 262. 2011. Waitangi Tribunal Ko Aotearoa Tēnei: A report into claims concerning New Zealand law and policy affecting Māori culture and identity (Wai 262, 2011). Vol. 2 at 500.

Watts CH, Stringer I, Gibbs G. 2012. Insect conservation in New Zealand: An historical perspective. In: New T, editor. Insect conservation: past. Present and prospect. Netherlands: Springer; p. 213–243.

Waugh SM, Tennyson AJ, Taylor GA, Wilson K-J. 2013. Population sizes of shearwaters (*Puffinus* spp.) breeding in New Zealand, with recommendations for monitoring. Tuhinga. 24:159–204.

Wheatley SR. 2017. *Dodonidia helmsii* – Forest Ringlet Butterfly: Review of the literature, analysis of current data and proposal of future conservation. Moths and Butterflies of New Zealand Trust unpublished report. 29 p.

Whitaker AH, Loh G. 1995. Otago skink and grand skink recovery plan (*Leiolopisma otagense* and *L. grande*). Wellington, New Zealand: Department of Conservation.

Wong C. 2011. Guidance for the preparation of ESTR products – classifying threats to biodiversity. Canadian Biodiversity: Ecosystem Status and Trends 2010. Technical Thematic Report No. 2. Canadian Councils of Resource Ministers, Ottawa, ON. iii + 30 p. http://www.biodivcanada.ca/default.asp?lang = En&n = 137E1147-1.