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Threatened species research gaps and priorities for the Department of Conservation Te Papa Atawhai

Tara J. Murray, Kerry M. Borkin, Anni Brumby, and Colin F.J. O'Donnell

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Threatened species research gaps and priorities for the Department of Conservation Te Papa Atawhai

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Abstract

Despite efforts across Aotearoa New Zealand to recover threatened species populations, only 430 (10%) of the 4118 taxa currently categorised as Threatened or At Risk are managed in at least one site, and < 2% are fully managed, meaning current actions are comprehensive enough to ensure their long-term persistence. One reason for this is that implementing sufficient species protection is limited by considerable knowledge gaps in how to manage them. Therefore, a research gap analysis was completed in 2020–2021 for 1068 of the most threatened taxa across 12 groups. An expert elicitation process to determine what research would be required to develop or improve management for each taxon showed that 964 (90%) of the taxa assessed required research under at least one of four broad categories: understanding causes of decline (34% of all taxa), developing new management plans (54%), improving existing management plans (35%), and developing detection and monitoring methods (38%). Most taxa with high research needs were terrestrial or freshwater invertebrates, reflecting their numerical dominance and a lack of past investment. The research gaps identified were organised into 10 research programmes, investment in all of which will be required to cover the full suite of knowledge gaps that need to be filled to prevent further extinctions. The research gap analysis should not be seen as providing a list of taxa to work on in rank order, but rather provides a strategic tool for identifying and prioritising research to maximise benefits for the conservation of threatened species.

Keywords: knowledge gaps, research priorities, Threatened species, Data Deficient species, improving management plans

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1. Introduction

1.1 The state of biodiversity in Aotearoa New Zealand

Papatūānuku (Mother Earth) and the indigenous biodiversity of Aotearoa New Zealand are in crisis (DOC 2020b, 2020e). There have been numerous extinctions and significant declines in the abundances and distributions of species in this country since the arrival of humans because of the clearance and modification of vast areas of terrestrial and aquatic habitats, and the introduction of exotic predators, competitors, and browsers (McGlone 1989; Innes et al. 2010; MacDiarmid et al. 2012; O'Donnell et al. 2015; Dunn et al. 2018). The New Zealand Threat Classification System (NZTCS) was developed as a tool to assess a species' risk of extinction in Aotearoa. In 2020, when the research gap analysis (RGA) presented in this report was conceived, 9108 taxa had been categorised as Threatened[1] ($n = 1004$), At Risk[2] ($n = 3114$), or Data Deficient ($n = 4990$) under the NZTCS (DOC 2020a). A total of 798 of these taxa (across all threat categories) still needed their taxonomy to be resolved. Only 55 (<1%) of the 9108 taxa were categorised as At Risk – Recovering as a result of investment in their conservation (DOC 2020a, p. 37, Fig. 5).

Taxa that are listed as Threatened, particularly those that are categorised as Nationally Critical, face the most immediate risk of extinction. These include numerous taonga (treasured) and iconic taxa that are highly valued by New Zealanders. A large proportion of taxa in the Data Deficient category are also likely to be threatened, but there is currently insufficient information about their distributions, population sizes, population trends, or taxonomic positions to assess their status (Townsend et al. 2008). Although there are widespread efforts across Aotearoa to recover threatened species populations, only 430 (10%) of the 4118 Threatened and At Risk taxa are managed by the Department of Conservation Te Papa Atawhai (DOC) in at least one site (DOC 2020a). Furthermore, only 78 taxa (<2%) are fully managed to a level considered sufficient to ensure their long-term persistence[3] (DOC 2020d), with the remainder requiring more conservation effort than is currently being applied to ensure that they do not go extinct. For many threatened taxa, there is not yet sufficient knowledge to understand how to halt their decline.

Te Mana o te Taiao – the Aotearoa New Zealand Biodiversity Strategy 2020 (DOC 2020e) calls for there to be no further known human-driven extinctions of indigenous species by 2025 (goal 10.7.1) and for populations of all indigenous species that are known to be at risk of extinction to be managed to ensure their future stability or an improving state by 2030 (goal 10.7.2). In addition, goals 10.1.1 and 10.1.2 of the strategy call for prioritised research to lead improvements in the knowledge of species, their distributions, and causes of decline so that their management can be improved.

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1 At the time of writing, the NZTCS umbrella category 'Threatened' includes three categories: Nationally Critical, Nationally Endangered, and Nationally Vulnerable. 'Threatened' in this report refers to these collectively, unless otherwise specified. See the NZTCS website for details of the classification system.

2 At the time of writing, the NZTCS umbrella category 'At Risk' includes four categories: Declining, Naturally Uncommon, Relict, and Recovering. This report mainly discusses species with the status At Risk – Declining, unless otherwise specified. See the NZTCS website for details of the classification system.

3 The Department of Conservation Te Papa Atawhai defines 'long-term persistence' as 'a 95% probability of a species surviving for the next 50 years or three generations (whichever is longer) if all human-induced threats that are likely to occur over the longer term (e.g. within 300 years) are adequately mitigated' (DOC 2020d). Management will be required at a number of physically distant sites to buffer against local extinctions.

1.2 Why invest in research?

A major reason why the management of most taxa is currently insufficient to ensure their long-term persistence is that it is often unclear which pressures need to be managed first and/or there is a lack of tools to mitigate the pressures at the scales needed. The New Zealand Government's Budget 2018 released an additional $76 million of biodiversity funding to DOC over 4 years to slow the biodiversity decline in Aotearoa. Approximately 5% of this funding was allocated for research that will provide the knowledge required to effectively manage Threatened, At Risk, and Data Deficient taxa, and Threatened ecosystems. With this funding, DOC established three new research workstreams in 2018: Threatened Ecosystems (DOC 2020f), Mobile Terrestrial Species (DOC 2021), and Threatened Species (DOC 2018). The Threatened Species Research Workstream is the focus of this report.

Given the considerable gaps in knowledge about how to manage threatened species, it was necessary to take a strategic approach to clearly identify the most important work that needs to be done first, within the constraints of available research funds. The Threatened Species Research Workstream was tasked with prioritising and facilitating research within the scope of four key research themes (Box 1) to inform the development of new or more effective species management plans where required (DOC 2018). Ultimately, new knowledge gained from prioritised research will contribute to the persistence and recovery of threatened species. The first step in the prioritisation process was to undertake a comprehensive RGA to understand the scope, scale, and relative priority of research needed. This was carried out from January to October 2020.

Box 1: Threatened Species Research Workstream themes

Theme 1: Determine the full range of threatened biodiversity that requires management.

a. Work on detection techniques and survey for Data Deficient taxa.
b. Work on taxa needing resolution of their taxonomy in order to undertake appropriate threat listing.

Theme 2: Understand reasons for decline and fill critical knowledge gaps.

Theme 3: Develop and test new management methods.

a. Develop and test new national prescriptions for threatened taxa.
b. Improve existing national prescriptions to increase efficiency (where justified).

Theme 4: Develop methods for detecting threatened taxa and monitoring outcomes of their management.

Adapted from *Strategy for prioritising threatened species research funding* (DOC 2018).

2. Methods

Given the large number of taxa that potentially require research to inform their management, the first step in the RGA process was to develop a strategic list of the highest priority research for those taxa that are currently considered the most threatened. This would be achieved by:

1. identifying and evaluating knowledge gaps for all taxa that had been categorised as Threatened, At Risk – Declining, or Data Deficient in the NZTCS database[4]; and
2. evaluating where efficiencies could be gained by undertaking multi-species, ecosystem, or theme-based research programmes.

2.1 Scope of the RGA

The RGA was intentionally focused on the taxa with the most urgent management needs, that is, taxa (which included species, subspecies, and recognised but not formally described entities) listed in the NZTCS as Nationally Critical, Nationally Endangered, Nationally Vulnerable, or At Risk – Declining[5] as at 13 September 2019. This limited the assessment to 1311 taxa across 18 taxonomic groups (Table 1). The remaining taxa in lower risk categories (i.e. Relict, Naturally Uncommon, and Recovering) were excluded from the RGA but will be considered in the future.

Table 1. Number of taxa prioritised for assessment in the research gap analysis (RGA; unshaded) and number of taxa that will be assessed in future years (shaded) by taxonomic group. NC = Nationally Critical, NE = Nationally Endangered, NV = Nationally Vulnerable, Dec = At Risk – Declining.

TAXONOMIC GROUP	THREATENED			AT RISK	TOTAL
	NC	NE	NV	Dec	
Amphibians			1	2	3
Bats	1		1	1	3
Birds	23	14	33	22	92
Freshwater fishes	4	6	12	11	33
Fungi	48				48
Hornworts and liverworts	8	5	3	3	19
Invertebrates (freshwater)	48	13	18	9	88
Invertebrates (marine)	6	1	4	21	32
Invertebrates (terrestrial)	90	22	54	31	197
Land snails – *Powelliphanta*	7	17	32	8	64
Land snails – other	29	10	8	5	52
Lichens	6	2	7	10	25
Macroalgae	1				1
Marine mammals	4	1	2		7
Mosses	14	4	2		20
Reptiles	8	8	23	27	66
Sharks		1	1		2
Vascular plants	213	75	114	157	559
Total in scope	**510**	**179**	**315**	**307**	**1311**
Number included in RGA	**427**	**167**	**299**	**273**	**1166**

[4] Conservation statuses were checked on 13 September 2019.

[5] At Risk – Declining taxa were included because they can still have relatively high extinction probabilities (10–70% within three generations).

Non-vascular plants, lichens, macroalgae, fungi, and marine invertebrates that were categorised as Threatened or At Risk – Declining were also excluded from the assessment because the necessary expertise to identify knowledge gaps was not available within the timeframe required. These groups will be assessed in the future when experts become available.

The objective for the remaining 1166 taxa that were included in the RGA was to capture data on broad knowledge gaps relevant to their management in order to identify high-priority overarching research needs across all taxonomic groups. Developing detailed research plans was not within the scope of this analysis but will form a subsequent step once priorities for funding are selected each year.

2.2 Data collection

Background information on each taxon and responses to questions about its management (1–8 below) were collated into a spreadsheet.

1. General information (e.g. taxon name, distribution, typical habitat, NZTCS conservation status).
2. Is the taxon 'streamed for management'?[6] (Yes / No)
3. Does the taxon have a written management plan?[7] (Yes / No)
4. Is the management plan fully activated[8] to ensure persistence of the taxon? (Yes / No)
5. Is the taxon subject to active management in at least one place or captured within an active or planned management site? (Yes / No)
6. What type of DOC management unit does the taxon occur in? (EMU / SMU / none / other [specify][9])
7. What is the mean pressure reduction probability (PRP)[10] for the taxon? (%)
8. Does the cause of decline need to be resolved? (Yes / No)

Data for item 1 were obtained from a range of internal and public resources (e.g. published literature, NZTCS) and confirmed with experts. Data for questions 2–8 were extracted from DOC's Species Streaming Database, and Business Planning and Reporting Software.

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[6] Streaming species for management (DOC's Species Streaming Database) is an assessment process that DOC uses to identify species that are ready for management plan development – that is, there is sufficient information about the pressures they face that DOC can start to manage at least some of them.

[7] A management plan, or 'prescription' as it is often referred to by DOC, is the set of management actions required to ensure persistence (i.e. the prevention of extinction). DOC's species management plans do not usually include inventory and monitoring actions, which need to be planned separately.

[8] Management plans can be 'fully activated' (DOC is undertaking all the management actions required for species persistence), 'partially activated' (DOC is undertaking some of the management actions), or 'not activated' (the plan has been developed but is not yet being implemented).

[9] These DOC management unit types denote the areas to be managed: EMU = Ecosystem Management Unit, where the primary aim is to maintain ecological values in representative ecosystem types; SMU = Species Management Unit, where management is focused on an area where a potentially viable population of a taxon can be secured and persist. Other management unit types include marine, freshwater catchment (Ngā Awa), and other reserve types, and sites that form part of the National Predator Control Programme.

[10] The PRP from DOC's Business Planning and Reporting Software is a value (0–100%) that indicates how confident DOC operations teams are that their management under the current management plan will reduce pressures on the taxon in question. A high score indicates high confidence that the methods planned for use will be effective in reducing the identified pressure on that taxon. This data was recorded for internal purposes and is not presented in the final RGA spreadsheet (Supplementary Information, section 3.1).

An expert elicitation process was then run to compile data about what research was required for the management of each taxon (questions 9–16 below).

9. Is research on how to resolve the key cause(s) of decline needed to develop or improve a management plan? (Yes / No)
10. Is research needed to significantly improve an existing management plan? (Yes / No)
11. Why is significant improvement needed? (Open answer)
12. Is research needed to develop and test a new management plan where it does not currently exist? (Yes / No)
13. Is research needed to develop or improve detection or outcome monitoring methods? (Yes / No)
14. Is the research identified for the taxon relevant to other taxa or groups facing similar causes of decline? (Yes / No / None identified)
15. If yes, what taxa or groups is the taxon a potential case study for?
16. What new research is required to understand the cause of decline or to develop or improve the management plan or outcome monitoring method for the taxon, or is taxonomic work required? (Open answer)

Expert advice was provided by DOC staff, primarily Science and Technical Advisors within the Biodiversity Group, as well as individuals based at Crown Research Institutes, museums, universities, and private ecological consultancies (see section 6, Acknowledgements).

With respect to question 10, 'Is research needed to significantly improve an existing management plan?', 'significant improvement' was considered necessary if:

- there was significant uncertainty around identification of the key pressures that impact the taxon and prevent viable populations from being maintained at sites;
- there was significant uncertainty around the levels that key pressures need to be reduced to in order to maintain viable populations at sites (i.e. intervention thresholds);
- effective tools were not available to reduce pressures to the required levels and / or at the scale needed for the taxon; or
- available tools were not feasible or cost effective for use by DOC and others who help manage threatened taxa.

2.3 Prioritising research needs

Each taxon that was identified as requiring research under at least one of workstream themes 2, 3, or 4 (see Box 1) was scored against the following three criteria to determine its relative research priority (criteria are fully outlined in *Strategy for prioritising threatened species research funding* [DOC 2018]).

1. **Urgency:** Taxa were given a score between 1 and 10 according to their status in the NZTCS database.

    10 = Nationally Critical
    7 = Nationally Endangered
    4 = Nationally Vulnerable
    1 = At Risk – Declining

We assumed that conservation status was a proxy for urgency of management because it takes into account the likelihood of extinction at current rates of declines. For example, a Nationally Critical taxon with a >70% probability of extinction within three generations is, by definition, in more urgent need of management (and research if needed) than an At Risk – Declining taxon with a lower (e.g. 10–30%) probability of extinction in three generations.

2. **Knowledge gains:** Taxa were given a score between 1 and 10 based on how many other Threatened or At Risk taxa the identified research would benefit.

   10 = Applicable to managing >100 Threatened/At Risk taxa
   8 = Applicable to managing >50 Threatened/At Risk taxa
   6 = Applicable to managing >20 Threatened/At Risk taxa
   4 = Applicable to managing >10 Threatened/At Risk taxa
   2 = Applicable to managing 6–10 Threatened/At Risk taxa
   1 = Applicable to managing 1–5 Threatened/At Risk taxa

3. **Previous relevant research:** Taxa were given a score between 0 and 10 according to how much research had already been undertaken that was directly relevant to informing their management plans – for example, understanding causes of decline, or developing effective management techniques or monitoring methods.

   10 = No previous research of direct relevance to the taxon's management
   7 = Little previous research (knowledge can be gleaned from other studies/similar taxa/anecdotal information, but considerable evidence-based research is likely to be required)
   5 = Some previous research that would help to identify broad pressures or would be relevant to testing initial management techniques
   3 = Moderate previous research investment, including with similar taxa, which already sets the taxon up for management
   1 = Considerable previous relevant research that sets the taxon up for effective management
   0 = Subject of a current, comprehensive research programme

Undertaking research on taxa with high knowledge gains scores would likely result in knowledge that is relevant to multiple threatened taxa and consequently reflects a more cost-effective approach to solving management problems than working on taxa with singular problems. High urgency scores were considered to reflect a need for work to start sooner, as taxa with such scores are at greater risk of extinction, while high previous relevant research scores indicated that there is little current knowledge available to solve a taxon's management problems.

Scores for the three criteria were summed to determine a final RGA score between 2 and 30. This score indicated a taxon's priority with respect to research needs and the wider benefits of the identified research (2 = little research needed, 30 = highest need and greatest benefit across multiple taxa). We could have weighted criteria to emphasise differences in their relative importance or included more criteria to create a more sophisticated priority index. However, research has shown that while more complicated systems for ranking or prioritisation may provide varying rankings for 'middling' priorities, most approaches give similar results for the highest and lowest priorities (Kaya 2020). Therefore, we intentionally chose a relatively simple prioritisation system that would be transparent and easy to replicate.

Once the data had been collated and the RGA scores had been determined, the identified research needs were reviewed and grouped into common topics to reflect where taxa and taxonomic groups shared similar pressures or needed similar management methods developed for them.

The description and scope of the common research topics identified were refined by a Threatened Species Research Advisory Group (TSRAG). The TSRAG included DOC experts on each of the taxonomic groups assessed, threatened species monitoring, and threatened species management. This resulted in a set of strategic research programmes that encompass and describe the highest priorities for the future allocation of threatened species research resources to achieve the goals of *Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy* (DOC 2020e).

3. Results and discussion

3.1 Number of taxa requiring research

The RGA was completed for 1068 (92%) of the 1166 taxa prioritised for assessment in 2020 (Table 1 and Online Supplementary Information [https://www.doc.govt.nz/globalassets/documents/science-and-technical/threatened-species-research-gaps.xlsx]). Experts were unavailable to assist with the analysis of the remaining 98 taxa within the required time frame.

Only 83 taxa (8%) were identified as requiring no significant new research, including 42 that currently do not have management plans (Appendix). These 83 taxa comprised 44 plants, 18 *Powelliphanta* snails, 2 other land snails, 17 birds, 1 reptile, and 1 freshwater invertebrate.[11] Specific examples included some well-studied birds such as takahē (*Porphyrio hochstetteri*) and whio (*Hymenolaimus malacorhynchus*), which have clear management actions that are considered sufficient for their recovery (Wickes et al. 2009; Glaser et al. 2010). For these taxa, this means that while there are always more interesting questions to be answered, there is already sufficient knowledge to undertake effective management. The 83 taxa not requiring research to improve their management also included some taxa for which pressures have been identified from knowledge of related taxa and standard management techniques are already available to counter those pressures (e.g. multiple *Powelliphanta* land snails, whose management actions are already specified in their recovery plan; Walker 2003).

Most taxa (n = 964, 90%) were identified as requiring research under at least one of four broad categories (Fig. 1). An additional 21 taxa (2%) required research towards taxonomic resolution or a formal description only, and it was considered most appropriate to prioritise work on these taxa as part of DOC's research on Data Deficient taxa (Programme 1, section 4, below).

Overall, 472 (90%) of the 523 taxa considered ready for management (i.e. those 'streamed for management') were identified as requiring research to either develop or improve their management plans (Fig. 1). A total of 421 (39%) of the assessed taxa have management plans (Table 2); however, only 92 (22%) of these are fully activated by DOC. Of the taxa with management plans, 381 (90%) were identified as requiring research to significantly improve the effectiveness of management actions (Fig. 1).

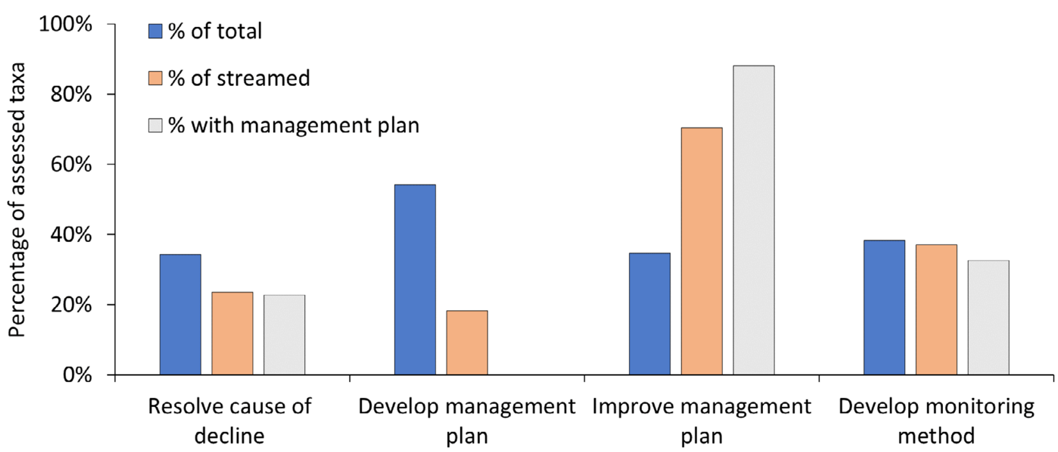

Figure 1. Percentage of assessed taxa identified as requiring research in four broad categories as a percentage of all 1068 taxa assessed (blue), taxa that are streamed for management (orange), and taxa that currently have a management plan (grey).

[11] This freshwater invertebrate (*Xanthocnemis sinclairi*) has recently been recognised as a synonym of *Xanthocnemis zealandica*, so will not be listed as Threatened in the next freshwater invertebrate conservation status assessment (2023) (T Drinan, DOC, pers. comm.).

Table 2. Management details and number of taxa identified as requiring research to develop or improve management plans within the Threatened Species Research Workstream. The number of taxa with fully activated management plans are given in parentheses. DOC MU = Department of Conservation Te Papa Atawhai management unit (Ecological Management Units, Species Management Units, marine reserves, and management units for general conservation work on public conservation land or the National Predator Control Programme; see footnote 8 for more detail).

GROUP	TOTAL ASSESSED	STREAMED FOR MANAGEMENT	HAVE MANAGEMENT PLAN	INCLUDED IN A DOC MU	RESEARCH NEEDS			
					RESOLVE CAUSES OF DECLINE	DEVELOP MANAGEMENT PLAN	IMPROVE MANAGEMENT PLAN	DEVELOP MONITORING METHODS
Amphibians	3	3	2 (0)	3	2	1	2	1
Bats	3	3	3 (1)	3	2	0	3	1
Birds	92	81	49 (16)	70	32	33	41	16
Coleoptera	50	32	16 (5)	35	43	34	16	48
Freshwater fishes	33	33	33 (1)	26	33	0	33	33
Freshwater invertebrates	88	21	0 (0)	0	85	87	0	84
Land snails – *Powelliphanta*	64	51	50 (16)	55	1	5	26	4
Land snails – other	7	5	5 (0)	5	4	2	3	0
Lepidoptera	80	36	22 (3)	52	38	57	22	78
Marine mammals	7	6	0 (0)	1	0	7	0	1
Orthoptera	9	5	5 (0)	5	9	4	5	9
Reptiles	66	46	45 (7)	45	4	21	44	36
Sharks	2	0	0 (0)	0	2	2	0	2
Spiders	4	3	2 (0)	3	3	2	2	3
Stick insects	1	1	0 (0)	0	1	1	0	1
Vascular plants	559	197	189 (43)	166	106	323	174	93
Total count	**1068**	**523**	**421 (92)**	**469**	**365**	**579**	**371**	**410**
% of total assessed		**49%**	**39% (9%)**	**44%**	**34%**	**54%**	**35%**	**38%**

3.1.1 Resolving the causes of decline

34% of the assessed taxa require research to understand their cause of decline

Causes of decline were understood for many taxa, but this was not consistent across all taxonomic groups. Understanding the causes of decline was identified as a limited need for reptiles (6%), *Powelliphanta* snails (2%), and vascular plants (19%), but as a significant need for freshwater fishes (100%), freshwater invertebrates (97%), and terrestrial arthropods excluding Lepidoptera (88%), as well as sharks (100%), frogs (67%), and bats (67%) – although these latter three groups included only two or three taxa each (Table 2 and Box 2).

Box 2: Examples of research needs focused on causes of decline, as identified by the research gap analysis expert elicitation process

1. Teviot flathead galaxias (*Galaxias* "Teviot"; Nationally Critical)
    - Understand the impacts of fish passage barriers, catchment impacts, water quality, habitat manipulation, invasive species, pest fish, cattle grazing and trampling, artificial structures, and edge effects.
    - Determine flow preferences and current curves, habitat preferences, and spawning habitat and timing / cues.

Teviot flathead galaxias (*Galaxias* "Teviot"). *Photo: Rod Morris*

Rangitata skink (*Oligosoma hoparatea*). *Photo: James Reardon*

2. Chatham Island tāiko (*Pterodroma magentae*; Nationally Critical)
    - Understand the impacts of heavy metals on reproduction.
3. Wood rose (*Dactylanthus taylorii*; Nationally Vulnerable)
    - Understand the impacts of aging forest remnants and succession, human collection, cattle / deer trampling, and declines in or the loss of its natural pollinator the short-tailed bat (*Mystacina tuberculata*), which is also threatened.
4. Rangitata skink (*Oligosoma hoparatea*; Nationally Critical)
    - Understand the impacts of mammalian predators including mice (*Mus musculus*).
5. Tūturuatu / shore plover (*Thinornis novaeseelandiae*; Nationally Critical)
    - Understand the impacts of cats (*Felis catus*), cattle grazing and trampling, mice, rats (*Rattus* spp.), and stoats (*Mustela erminea*), adjacent land use, and genetics.

Data in DOC's Species Streaming Database indicated that the cause of decline was unknown for only 4% of the assessed taxa; considerably fewer than the 34% identified through this expert elicitation process. This inconsistency was, in part, a result of the streaming process requirement that a taxon's causes of decline are understood before it can be streamed for management. This means that any taxa for which the causes of decline are not understood will not be considered for management. To deal with this requirement in the streaming process, the panel sometimes assumed the causes of decline for an individual taxon based on similar, better-understood taxa, or that the causes were understood sufficiently to manage at least one pressure. This means that such taxa can be included in the pool of taxa that DOC classifies as 'being ready for management' before all the pressures acting against them are fully understood.

We consider that 34% is still likely to be an underestimate of the proportion of taxa that need research into their causes of decline to achieve effective management. Our analysis of the research needs identified indicated that the question about the cause of decline was interpreted inconsistently during the expert elicitation process. In particular, research needed on the relative impacts and intervention thresholds required for known pressures (e.g. different types of predators) were not always considered within this question. These inconsistencies are addressed in section 4, where each taxon's research needs are considered in more detail within selected research programmes.

It was found that 95% of taxa requiring research into their causes of decline also required research to develop a management plan or to improve their existing plan.

3.1.2 Developing new management plans

54% of taxa require research to develop a management plan

In total, 54% of the assessed taxa required research to develop a management plan, representing 89% of the 647 taxa that are currently without a plan (Table 2). This indicates that developing new management plans usually requires some level of research, and the information required often cannot be, or is not being, inferred or adapted from existing plans for other taxa. We expect that this percentage is so high because many taxa that are currently without plans belong to numerically large taxonomic groups (e.g. freshwater and terrestrial invertebrates) that do not have a sound foundation of conservation science in Aotearoa or elsewhere. As this foundation is built, we expect that the number of taxa needing specific individual research will decline because the ability to build management plans by transferring knowledge gained for one taxon to multiple other related taxa will increase.

Of the assessed groups, *Powelliphanta* snails had the lowest need for research to develop management plans (only 6 of 14 taxa without a plan required research), reflecting the relatively high effort already invested in developing science-based management plans for taxa in this genus (50 other *Powelliphanta* snail taxa have plans; Table 2) and the transferability of management methods, once developed, across the many taxa in the group. For birds, a group with a very solid history of conservation science in Aotearoa, 33 (76%) of 43 taxa without a plan were still identified as needing further research to develop effective management plans. These were mainly seabirds, which have benefited less from the vast amount of research supporting the management of terrestrial bird taxa.

3.1.3 Improving management plans

35% of taxa require research to improve their existing plans

Experts indicated that 35% of the assessed taxa or 88% of the 421 taxa that currently have a management plan require further research to improve that plan (Table 2). This indicates that experts lacked confidence in the ability of most plans in their current state to achieve long-term persistence of the taxa even if fully implemented.

Taxa requiring research to improve their management plans were numerically dominated by vascular plants, reptiles, and birds (Table 2). The only fully assessed group that was not reported to need widespread research to improve existing plans was the *Powelliphanta* snails, with only 26 of the 50 taxa with plans being identified as requiring research for plan improvement.

For those taxa that required research to improve their management plans, the previous relevant research scores ranged across the full spectrum, from 1 (there has been extensive previous research) to 10 (there has been no relevant research that sets DOC up to effectively manage the taxon). Scores were highest for invertebrates and freshwater fishes, reflecting the fact that there has been little previous research relevant to the management of these groups, while vascular plants and vertebrates scored lower (Fig. 2). The fact that some of the taxa requiring further research had low previous relevant research scores indicates that even when there has been a moderate or large amount of research in the past, there is often still a need for additional research to improve management. This may be because the experts questioned did not have confidence that current management is effective or that all relevant pressures are fully understood. By contrast, some taxa are managed despite a lack of underpinning research because doing something, even if it is not well tested, is essential when a taxon is declining dramatically.

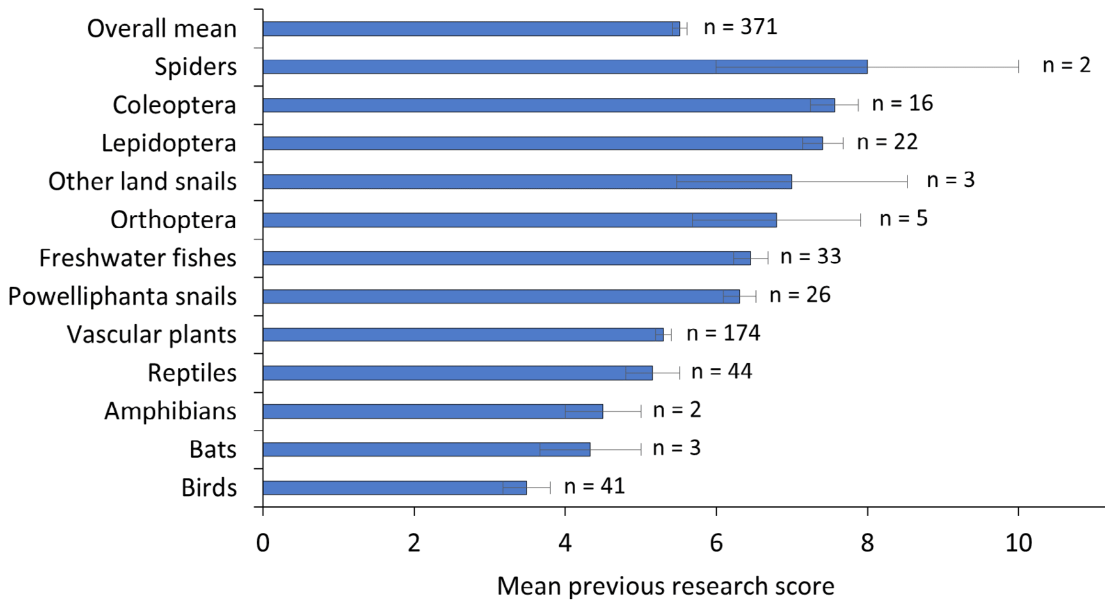

Figure 2. Mean (± SE) previous relevant research score by taxonomic group for the 371 taxa identified as requiring research to improve their management plans. Taxa were scored from 1 (considerable previous relevant research) to 10 (no relevant previous research). Sharks, freshwater invertebrates, marine mammals, stick insects, and other land snails (non-*Powelliphanta* taxa) are not included because none of the assessed taxa in these groups have a current management plan.

3.1.4 Developing detection and outcome monitoring methods

38% of taxa require research to develop detection and/or monitoring methods

Having robust monitoring methods for threatened taxa is essential so that DOC can measure whether management is achieving the objective of maintaining and increasing populations. Monitoring is ideally applied in an adaptive management framework so that the effectiveness of different management methods can be compared and their cost-effectiveness can be improved.

There were 410 taxa requiring research to develop detection and/or monitoring methods, which included 194 taxa that are streamed for management and 137 taxa that already have a management plan (Table 2). There were no taxa for which the need to develop monitoring methods was the only knowledge gap identified. The development of monitoring methods was identified as a need for the two assessed shark taxa and >95% of the terrestrial arthropods (stick insects, Orthoptera, Coleoptera, Lepidoptera, and spiders), freshwater invertebrates, and freshwater fishes assessed (Fig. 3). The number of taxa requiring research into monitoring methods is expected to be significantly higher for groups that have not yet been assessed (i.e. those groups that were out of scope for this assessment) because they include many small, cryptic, and/or naturally uncommon organisms (e.g. lichens, fungi). This is consistent with the large number of invertebrates that were found to require research into monitoring methods. A lack of effective detection and monitoring methods was identified as less of a knowledge gap for birds (only 17% of taxa require research into monitoring methods), vascular plants (17%), and *Powelliphanta* snails (6%). None of the seven land snail taxa assessed were identified as requiring research into detection and monitoring methods.

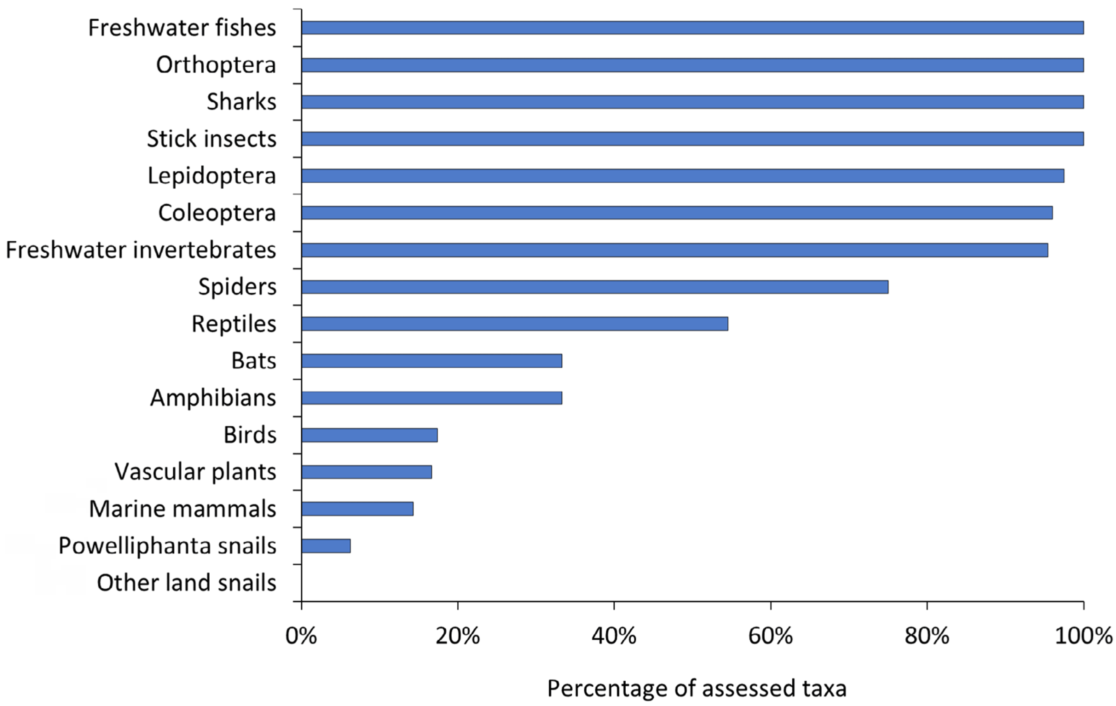

Figure 3. Percentage of taxa in each group identified as requiring research to develop or improve detection and/or outcome monitoring methods. See Table 2 for *n* values for each taxonomic group.

It is important here to explicitly distinguish between *inventory* and *outcome monitoring* methods. *Inventory* methods are procedures that can be used to search for and detect a taxon or to determine its distribution (often called *surveys*) and are often one-off assessments. *Outcome monitoring* requires methods that can be used to detect changes in population trends in response to management, so it relies on repeated counts undertaken in a standardised manner. Such methods can also be used to detect changes in the absence of management or in response to environmental changes. During expert elicitation, the distinction between inventory and outcome monitoring often had to be explicitly clarified before monitoring methods were recognised as a research need, particularly when inventory methods were considered well defined. Therefore, the proportion of taxa identified as requiring the development of monitoring methods is likely an underestimate because of the inconsistencies in experts' interpretation of the question or knowledge of outcome monitoring needs.

Effective inventory and outcome monitoring methods are lacking for entire taxonomic groups, such as moths and beetles. Research to develop such methods should be prioritised for taxa that are considered to be on the brink of extinction and groups of related taxa for which very similar methods can be expected to be effective. For example, if a suitable monitoring method was developed for the ground beetle *Mecodema chiltoni* (Carabidae, At Risk – Declining), it could potentially be adapted for the 22 other large, threatened carabid beetles, which include 16 Nationally Critical taxa that may be too rare themselves to use in the development of new monitoring methods. Given the vast number of taxa in need, a strategic approach to developing outcome monitoring tools is needed to make efficient use of research and species management budgets. This could include work on the selection of surrogate and indicator taxa to monitor as a means of measuring the outcomes of management actions applied across landscapes and management units containing many individual threatened taxa, such as small, cryptic invertebrates or plants.

3.2 Identifying taxa with the highest priority research needs

Most of the 985 taxa that were found to require research were in the most urgent threat category, Nationally Critical (n = 352, 36%), followed by Nationally Vulnerable (n = 256, 26%), At Risk – Declining (n = 231, 23%), and Nationally Endangered (n = 146, 15%).

The knowledge gains scores for individual taxa, which indicate the total number of other Threatened and At Risk taxa that would benefit from resolving the knowledge gap identified for that taxon, spanned the full range of possible scores (1–10). For 114 individual taxa (11% of those assessed), it was predicted that resolving the knowledge gaps identified in the expert elicitation process would assist the management of >50 or >100 other taxa. However, for most taxa (almost 80% of those assessed), the individual research needs identified were predicted to be applicable to the management of <10 other taxa. Overall, the mean knowledge gains score was only 3.8, indicating that addressing any one knowledge gap identified would likely benefit c. 10 other taxa on average. This shows that for many taxa, individually tailored research is needed, but there are also many instances where knowledge gained from research on one or a few taxa would be transferrable to multiple other taxa facing similar pressures.

The highest knowledge gains scores were reported for the terrestrial and freshwater invertebrate groups and the reptiles (Fig. 4). This means that research on taxa in these groups would benefit the most taxa overall, because similar taxa within these groups are likely to share common pressures. For example, research into the impacts and control of mice, hedgehogs (*Erinaceus europaeus*), and wasps was recommended for many reptiles and for insects across several orders. By contrast, vascular plants had relatively low knowledge gains scores compared with other groups, despite being a large group. This reflects the diversity of pressures plants face and a perception that plants have more taxon-specific management needs requiring research, such as methods for propagation and pollination, which may only be relevant to very closely related taxa.

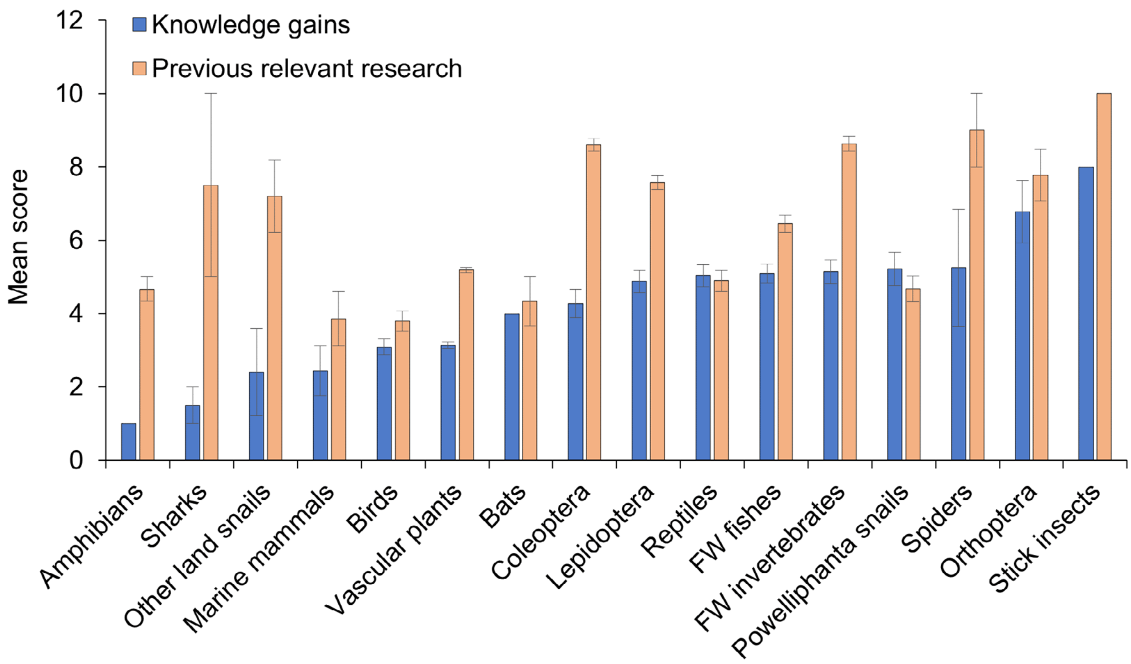

Figure 4. Mean (± SE) knowledge gains (blue) and previous relevant research (orange) scores for each taxonomic group assessed. Knowledge gains score: 1 = knowledge gains only relevant to single taxon, 10 = relevant to > 100 taxa; previous relevant research score: 1 = considerable previous relevant research, 10 = no previous relevant research. See Table 2 for *n* values for each taxonomic group. FW = freshwater.

The overall mean previous relevant research score was 5.8, reflecting a relatively normal distribution of scores, with many taxa having received moderate previous research and small numbers having received either a lot or very little (Fig. 4).

The combined RGA scores (i.e. sum of the urgency, knowledge gains, and previous relevant research scores) for taxa requiring research ranged from 2 to 28 with a mean of 15.5. The cumulative number of taxa with increasing scores rose at a relatively linear rate up to a point of inflection (the point where the curve flattens to an asymptote) at around 21, after which there was less differentiation among the scores of individual taxa (Fig. 5). This smooth accumulation of scores indicates that the scoring process performed reasonably well to differentiate the research priority among individual taxa, with few gaps or clumping along the scale.

A total of 216 (20%) of the 1068 taxa assessed had an RGA score of 21 or above (i.e. above the asymptote; Fig. 5A). These taxa included at least one representative from each of the major taxonomic groups except for frogs (highest score = 9), sharks (highest score = 16), and bats (highest score = 19), each of which was represented by only a few taxa and therefore tended to have a lower knowledge gains score. In addition, considerable previous research has been undertaken for frogs and bats, resulting in low previous relevant research scores for these groups.

The highest scores were dominated by terrestrial and freshwater invertebrates, which scored highly across all three criteria (Fig. 5B and Fig. 6). Vascular plants, the largest group assessed, accounted for almost half of all scores below 21, and 54% of those taxa required no research. The remaining taxa requiring no research were 18 *Powelliphanta* snails, 17 birds, 2 other land snails, 1 reptile (Te Kakahu skink [*Oligosoma tekakahu*]), and 1 freshwater invertebrate (the damselfly *Xanthocnemis sinclairi*).

The mean RGA scores for the major taxonomic groups ranged from 7.7 (frogs, *n* = 3) to 28 (spiders, *n* = 4). Each of the terrestrial arthropod groups (Coleoptera, Orthoptera, Lepidoptera, stick insects, spiders) and freshwater invertebrates scored above the overall mean RGA score of 15.5 (Fig. 6B).

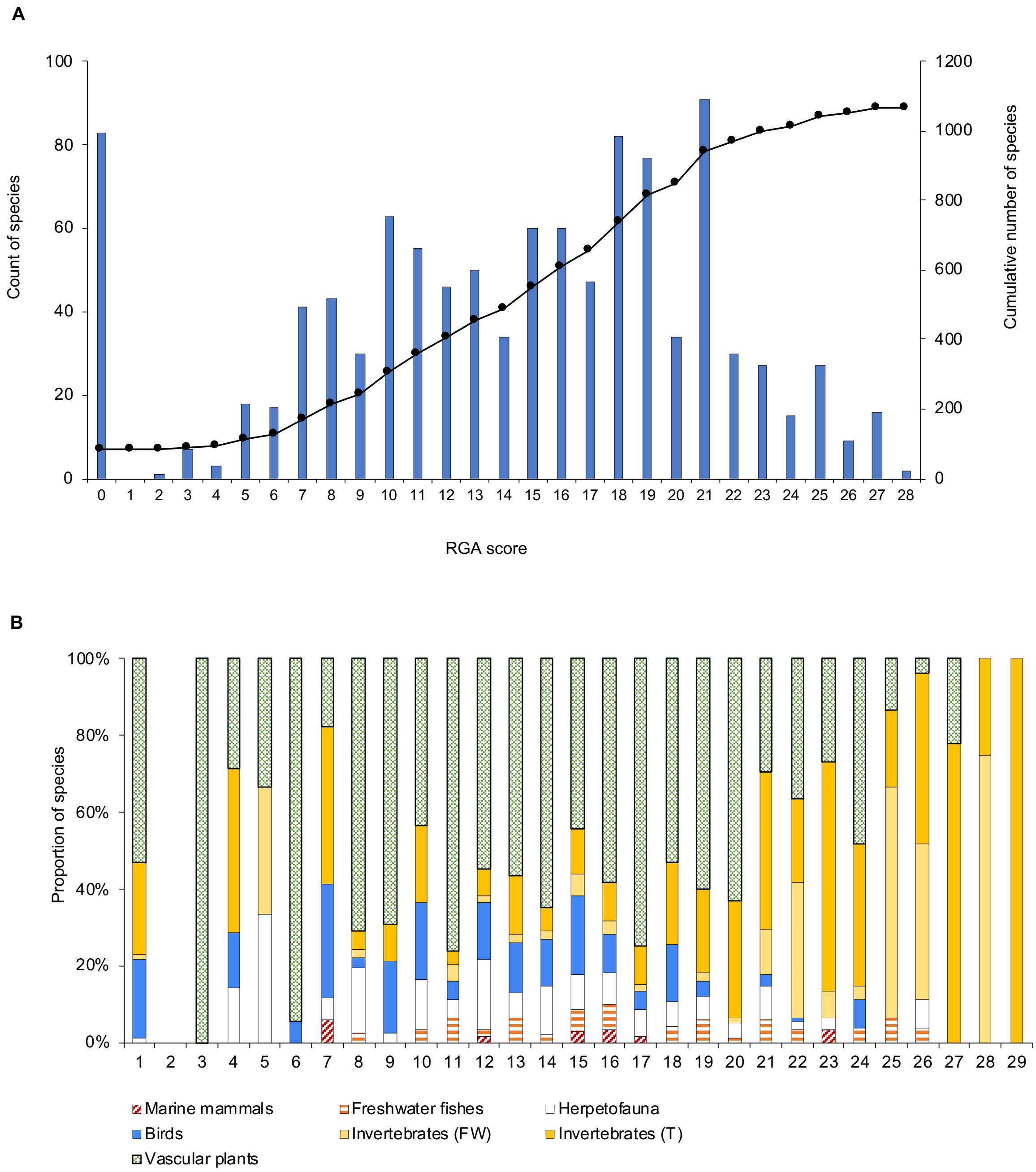

Figure 5. (A) Cumulative count (black line) and frequency distribution (bars) of research gap analysis (RGA) scores. Note the relatively smooth accumulation curve indicating that the method was effective at separating research priorities. (B) Contributions of the taxonomic groups (excluding bats and sharks) to each of the RGA scores. T = terrestrial invertebrates (all Lepidoptera, Orthoptera, Coleoptera, stick insects, spiders, *Powelliphanta* snails, and other land snails); FW = freshwater invertebrates. Herpetofauna includes all reptiles and amphibians.

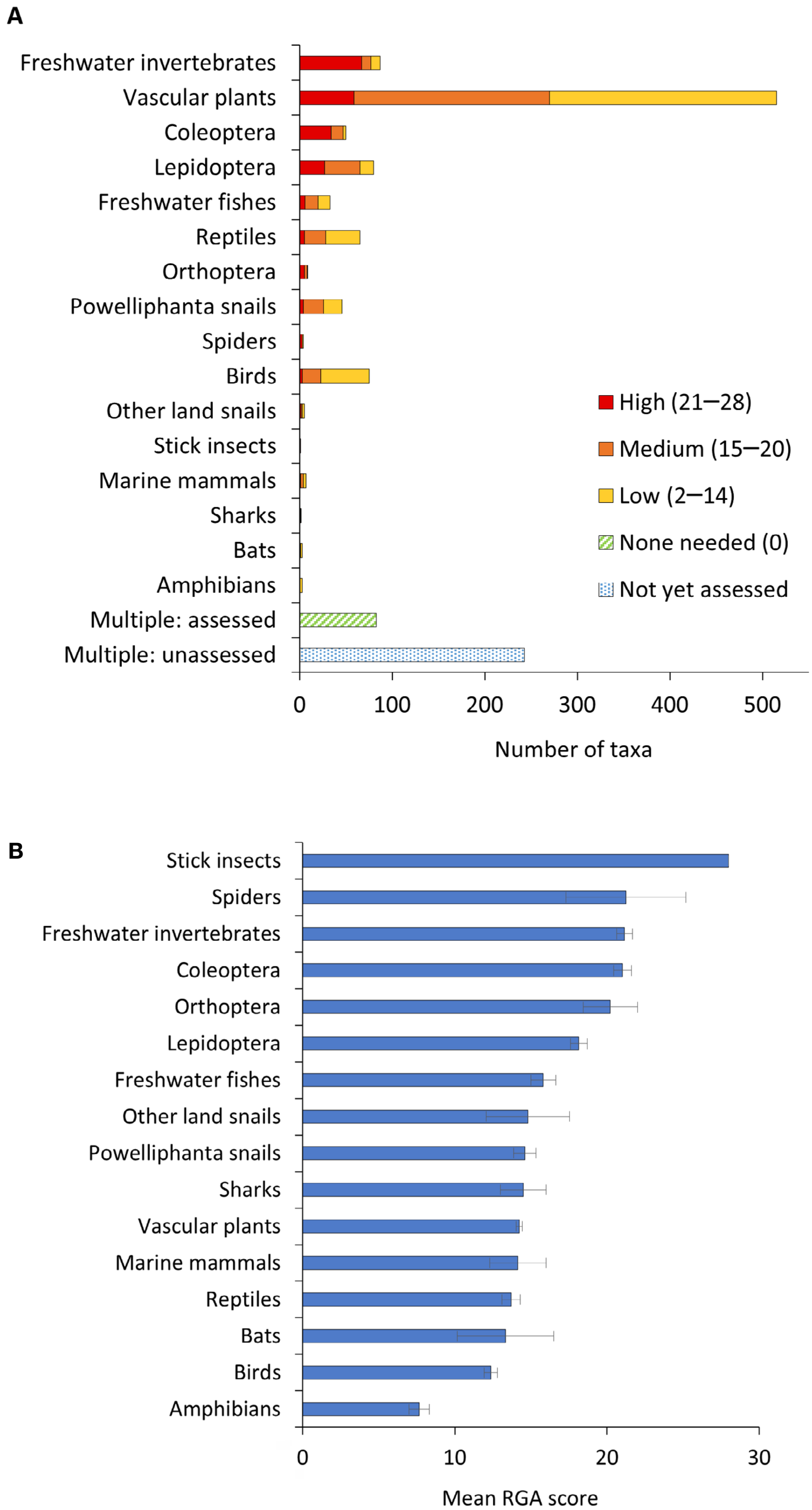

Figure 6. (A) Number of taxa per group with low (2–14), medium (15–20), and high (≥ 21) research gap analysis (RGA) scores. Taxa with no research needs (green; n = 83) include representatives from multiple taxonomic groups (birds, freshwater fishes, *Powelliphanta* snails, other land snails, reptiles, and vascular plants). The number of taxa within scope of this RGA that have not yet been assessed (blue; n = 243) includes taxa of non-vascular plants, lichens, macroalgae, fungi, marine invertebrates, and several orders of terrestrial invertebrates. (B) Mean (± SE) RGA score (out of a maximum of 30) for each of the main taxonomic groups assessed to date. See Table 2 for n values for each taxonomic group.

The research needs of taxa were spread quite evenly across the four categories of developing monitoring methods, developing or improving management plans, and identifying causes of decline (Fig. 7). For the taxa with the highest RGA scores, the research needs were spread evenly across understanding the causes of decline, developing new plans, and developing detection and monitoring methods, but fewer taxa required work for plan improvement (Fig. 7).

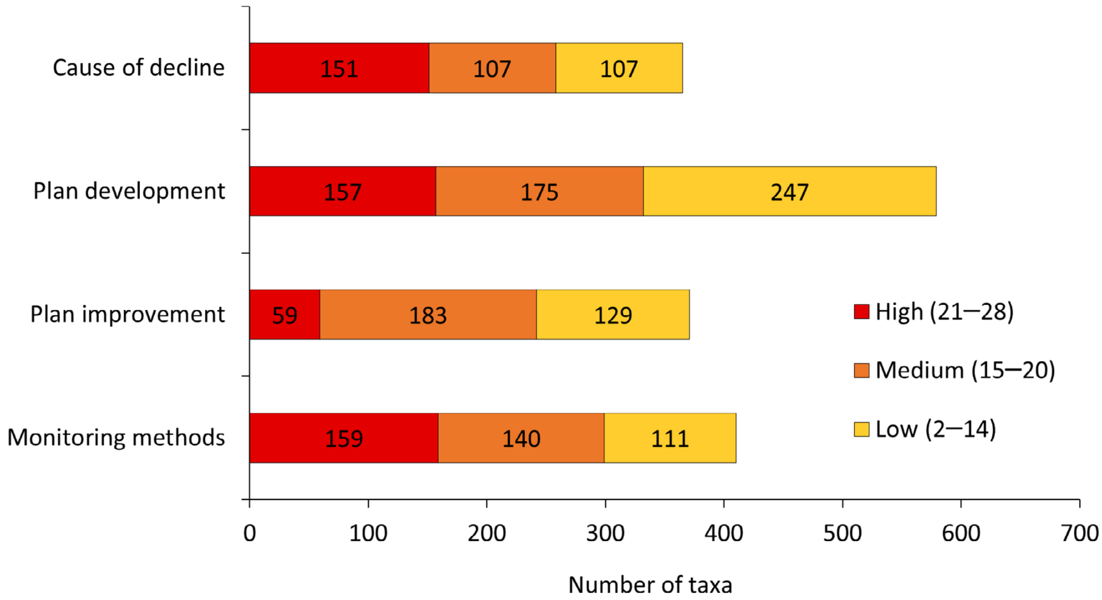

Figure 7. Number of taxa with high (≥ 21), medium (15–20), and low (2–14) research gap analysis (RGA) scores within each of the four broad research categories.

3.3 Common research needs by topic

The research needs of the most highly scoring taxa (those with RGA scores ≥ 21) were analysed to identify common research topics. The knowledge gaps captured within each of these topics are briefly described below (not in order of priority).

- **Impacts and control of predators:** Understanding the impacts of mice, hedgehogs, weasels (*Mustela nivalis*), and several wasp species, and developing tools and regimes to control these predators sufficiently for species recovery to occur, were consistently identified as knowledge gaps for reptiles, several groups of invertebrates, and some birds. In addition, experts identified the issue of meso-predator release (where controlling one predator may inadvertently increase the pressure from another predator) and the issue of how to manage that risk. How to control feral cats was a knowledge gap that was relevant to most taxonomic groups. How to control rats and pigs (*Sus scrofa*) on a landscape scale in warm backcountry forests was an important knowledge gap for large and medium-sized snails (e.g. *Powelliphanta*), as were developing methods to effectively manage the introduced song thrush (*Turdus philomelos*) and potentially weka (*Gallirallus australis*) at key snail sites.
- **Survey and taxonomic work:** Understanding distributions and abundances were identified as knowledge gaps for many threatened taxa across multiple groups, but particularly for vascular plants, and terrestrial and freshwater invertebrates. For almost every freshwater invertebrate, surveys to assess distribution and monitoring to determine population trends were priorities, above the need to determine the relative impacts of broader pressures. In addition, the taxonomy of many taxa still needs to be studied to enable the correct assessment of their conservation status and priority for management. Resolving taxonomy was identified as a significant priority for several groups of vascular plants (e.g. *Craspedia* and *Myosotis* spp.).
- **Vulnerability to climate change:** Understanding the impacts of climate change, including how to manage taxa at high elevations, in riverine systems, and in coastal habitats, was a common knowledge gap identified for most taxonomic groups. Research to underpin the development of climate change adaptation and mitigation tools was a broadly identified research need.
- **Weed impacts and control:** How to control sward-forming grasses and herbaceous weeds was a major knowledge gap identified for threatened vascular plants and numerous ground-dwelling invertebrates of threatened dryland, coastal, and wetland ecosystems. The need to develop effective weed management methods was a major gap for braided river birds, as they rely on open, weed-free areas for nesting and weeds also provide cover for predators.
- **Managing pressures in freshwater habitats:** Five main knowledge gaps and limitations to freshwater species management have already been comprehensively described by Drinan et al. (2020). The same knowledge gaps were captured in this analysis for freshwater fishes and invertebrates. Development or refinement of outcome monitoring methods is needed for most taxa. This was the key driver of the high knowledge gains scores for these groups, as similar methods are expected to be applicable to multiple taxa within this group. Knowledge gaps for freshwater fishes were broad but consistent across most taxa. These included the need to understand water flow preferences and current curves; habitat preferences; spawning habitat and timing/cues; ecotoxicology and physiology; distribution; and the impacts of fish passage barriers, catchment impacts, water quality, habitat manipulation, invasive species, pest fish, cattle grazing and trampling, artificial structures, and edge effects.

- **Managing disturbance:** For many vascular plants, determining how to manage successional processes and disturbance was a common knowledge gap. Basic ecological studies are needed for many taxa to better understand habitat requirements, pressures, and how to increase recruitment.
- **Marine pressures:** A lack of understanding of a large number of pressures in the marine environment was noted as a key knowledge gap by many experts. Developing tools to reduce the bycatch of birds from fisheries at sea was a major research need, while other gaps included understanding complex changes in resource availability and understanding and managing disease risks.
- **Managing mobile threatened taxa:** How to manage taxa that use the environment at regional, national, and international scales was a common knowledge gap identified for many mobile taxa. These taxa move, often on a seasonal basis, across rohe (areas), takiwā (regions), and territorial authority jurisdictions to exploit discontinuous feeding and breeding resources. Understanding habitat use and requirements at this scale was identified as a need for many bird and fish taxa. DOC has recently established mobile species research programmes to address this gap (DOC 2021), so it is not discussed in detail here.

4. Translating knowledge gaps into research programmes

The knowledge gaps identified by experts for individual taxa were condensed into 10 overarching research programmes, each with a distinctive theme, which will form the strategic basis of the threatened species management research portfolio within the Threatened Species Research Workstream in the future (Fig. 8 and Table 3). While these programmes are described separately below, it is likely that some research projects will need to straddle multiple programmes because rarely do individual taxa face only one pressure. Where possible, building an understanding of mātauranga Māori (traditional knowledge) will be incorporated throughout the workstream (see section 4.6). DOC's TSRAG will oversee the prioritisation of work and recommendations on which projects should be invested in annually under each programme, facilitated by appointed Programme Leads.

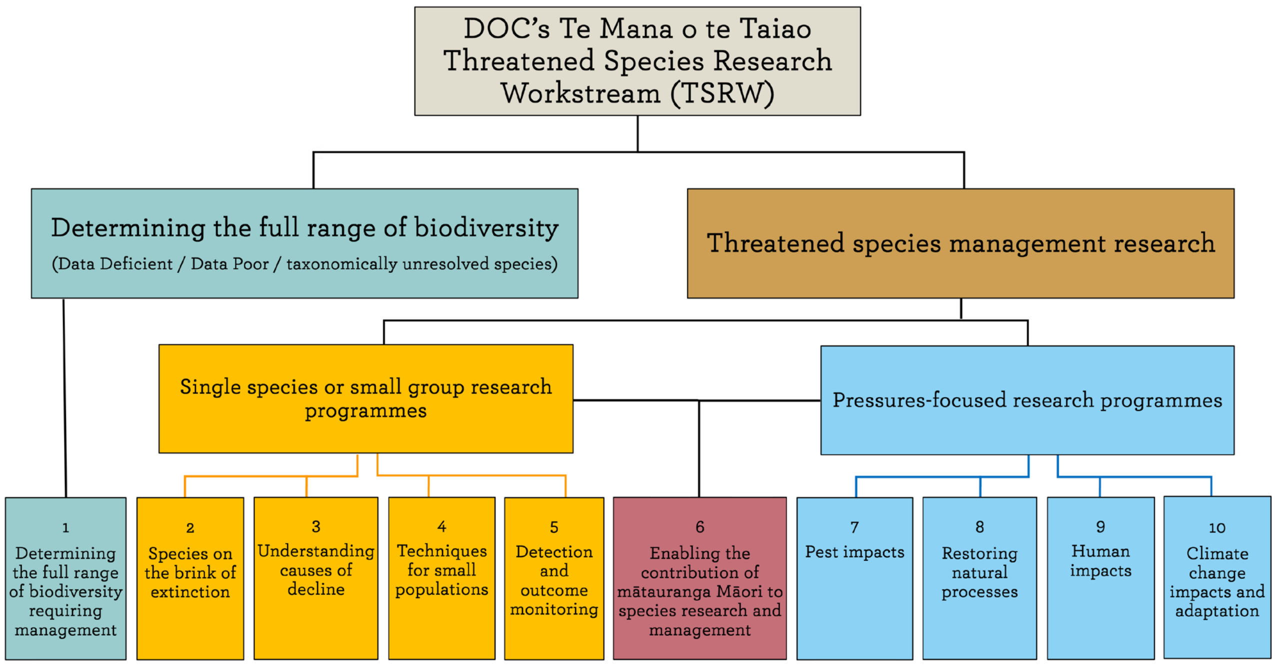

Figure 8. Recommended structure of strategic research programmes within the Threatened Species Research Workstream to address knowledge gaps identified as limiting the effective management of Threatened and At Risk taxa for persistence.

Table 3. Research programmes needed to address knowledge gaps for Threatened and At Risk – Declining taxa identified during the research gap analysis

RESEARCH PROGRAMME	EXAMPLES OF RESEARCH ACTIONS IDENTIFIED
Determining the full range of biodiversity requiring management	• Complete basic surveys to determine the current distribution and conservation status of Data Deficient and Data Poor taxa, and / or undertake taxonomic work for those with unresolved taxonomies.
Species on the brink of extinction	• Integrate research into adaptive management experiments to develop and improve management methods, detection, and outcome monitoring for taxa predicted to become extinct in the near future (e.g. develop and test captive breeding, propagation, cultivation, or translocation methods).
Understanding causes of decline	• Undertake targeted ecological studies to determine factors influencing productivity and survival (i.e. determine causes of decline and their relative impacts).
Techniques for small populations	• Develop techniques to sustain very small, vulnerable populations. For example, techniques for: – translocation to create new populations – genetic management of founder populations – captive breeding / cultivation – effective seed banking – effective disease management – managing inbreeding – managing hybrids and hybrid swarms – enhancing productivity.
Detection and outcome monitoring	• Design, test, and calibrate methods for detection, inventory, and outcome monitoring.
Enabling the contribution of mātauranga Māori to species research and management	• Test management approaches that use traditional knowledge and co-design to solve threatened species problems where appropriate. This may be embedded in other research programmes where appropriate or may be undertaken independently.
Pest impacts	• Undertake targeted studies to understand which pests are the most important to focus on to support the recovery of threatened taxa. • Adapt and improve existing pest management methods. • Develop new tools to control specific pests and / or pest guilds at appropriate geographical scales. • Determine under what circumstances pest control leads to meso-predator release and the likely impacts of meso-predator release. • Determine the lethal and non-lethal non-target impacts of toxin use (herbicides, pesticides, social acceptance). • Determine the effectiveness of best practice rodent and mustelid control for species groups and habitats that are not currently the target of existing best practice guidelines. • Develop and test early pest detection and control methods for island biosecurity and the control of invaders at very low densities. • Undertake studies to understand social issues, including a social licence to use different approaches for pest control.
Restoring natural processes	• Determine how to restore, improve, or create habitat, and increase habitat connectivity. • Determine the role and management of disturbance to aid regeneration and to avoid weed succession / encroachment. • Develop tools for nutrient management of soils. • Identify and restore essential biotic interactions (pollinators / hosts / dispersers). • Determine *how* pressures impact indirectly on taxa by affecting essential interactions.
Human impacts	• Determine the impacts of vehicles, people, pets, stock, land development, fire, nutrients, accidental harvest (e.g. non-target bycatch), lighting, and noise disturbance, and develop techniques to mitigate these impacts. • Determine the sub-lethal impacts of pollutants (e.g. heavy metals, plastics, herbicides). • Undertake studies to understand the impacts of water abstraction and degradation (hydrological issues). • Develop effective mitigation methods for water management.
Climate change impacts and adaptation	• Undertake studies to understand and predict the impacts of climate change on threatened taxa. • Develop and test approaches to mitigate climate change impacts on taxa.

4.1 Programme 1: Determining the full range of biodiversity requiring management

The objective of this programme will be to collect the necessary data on the status, trend, and pressures faced by taxa classified as Data Deficient or Data Poor, and those with unresolved taxonomies, to determine their conservation status and management needs. At the time this analysis commenced (September 2019), 4987 taxa were listed as meeting these criteria under the NZTCS. It is likely that many more taxa will be in scope for research within this programme because some of the most data deficient taxonomic groups (e.g. terrestrial invertebrates, lichens, mosses) have not been fully assessed within the NZTCS and in many cases new taxa are still being discovered. Data Deficient taxa are often known from very few historical records and may be very rare and/or highly cryptic. Often, the challenge with these taxa is to determine the best places to survey and how much effort to put into confirming their presence or absence.

For 21 of the taxa assessed in the current RGA, resolving their taxonomies was the only research need identified. However, 341 (35%) of the 964 Threatened and At Risk – Declining taxa that were assessed as requiring research to directly improve their management have a Data Poor qualifier. This signals that confidence in their threat classification assessment is low because of an inability to locate or identify the taxa or a lack of data on trends and pressures. In these cases, additional inventory and population monitoring may be required to confirm or determine a more appropriate conservation status, and subsequently their management needs. Often, this will need to be preceded by the development of effective monitoring methods (see Programme 5).

Taxonomically unresolved (sometimes called 'indeterminate') taxa are those that need their taxonomy to be described adequately and to have formal names accepted. It is important to determine if these taxa are distinctive from other closely related taxa since the misclassification of a threatened taxon as another non-threatened taxon may result in extinctions because the urgency of management may not be recognised. Similarly, it would be inappropriate to direct valuable conservation resources into the management of taxa that are, in fact, not distinct or threatened. As with Data Deficient and Data Poor taxa, the actual number of taxonomically unresolved taxa is likely much greater than currently listed in the NZTCS database because experts have yet to fully appraise the level of taxonomic uncertainty within some groups. Therefore, this research programme will need to be flexible enough to include work on taxa or taxonomic groups that have not already been assessed within the NZTCS framework.

Targeted expert elicitation and judgement will be used to prioritise research in this programme because it is not possible to meaningfully score work for urgency without already knowing the conservation status of each taxon that is in scope. Priority will be given to projects that have greater measurable benefits (e.g. will be able to simultaneously resolve the conservation status, taxonomy, or management needs of multiple taxa), have higher feasibility (probability of success), and are scientifically robust. Feasibility includes the availability of experts to partner with DOC to undertake specialist work.

One of the main outcomes of research undertaken in this programme will be new or revised conservation status recommendations based on new information on population size, distribution, and trend. Individual taxa could ultimately be assessed as anything from Nationally Critical to Not Threatened. If the research concludes that a taxon should be classified as Threatened or At Risk and requires more research to support its management, it will be included in the pool of taxa that are in scope for research within other appropriate research programmes.

4.2 Programme 2: Species on the brink of extinction

A small number of Nationally Critical taxa are thought to be on the brink of extinction,[12] but there is currently insufficient knowledge to manage the pressures they face and of the methods needed to increase their numbers where pressures have been removed. Examples include taxa that have been known to occur in incredibly small numbers for some time (e.g. numerous threatened plants with 20–50 individuals remaining) and others that have only recently been recognised as undergoing dramatic declines (e.g. matuku-hūrepo / Australasian bittern [*Botaurus poiciloptilus*]).

Because the research needs identified for these taxa are often expected to benefit only one or a few taxa, giving them a low relative knowledge gains score, many 'species on the brink' did not score highly in the RGA analysis. This was the case for taxa that are taxonomically unique at a high level (e.g. the only representative at the order or family level) or restricted to habitats / regions where there are few other similar threatened taxa. Many of these taxa have received little or no research investment or management in the past.

Other taxa that are in scope for this programme scored low in the RGA because they have received significant research effort in the past, however, this has not led to their recovery because crucial knowledge gaps remain. In some of these cases, a modest investment in additional research would likely allow a fully effective management plan to be developed and implemented. Failure to invest in filling the remaining knowledge gaps may negate the benefits gained from previous investment and, at worst, may increase the risk of extinction.

Research within this programme will be focused on those specific threatened taxa that meet the above definitions, as agreed by expert elicitation. Alternatively, surrogate taxa may be used where it is not feasible to work directly with the target, such as when the threatened taxon cannot be detected in sufficient numbers to undertake the research with rigour, or the research required could harm individuals and potentially hasten extinction of the taxon.

Examples of research that is within scope for this programme include:

- carrying out an urgent reassessment of the status, pressures, or distribution for taxa with an imminent risk of extinction to identify key sites and actions for management
- developing captive rearing, propagation, cultivation, or translocation methods to temporarily secure the taxon ex situ or to increase its numbers by establishing a population at a new protected site.

4.3 Programme 3: Understanding causes of decline

Over one-third of the taxa assessed in the RGA require research to understand the causes of their population declines. For some, there is currently no understanding of the causes of decline, while for many others, the pressures are known or assumed but understanding of their relative impact and importance as drivers of decline is poor. With limited resources, it is essential that the most critical pressures are addressed first and to levels that ensure long-term population viability and a reduced risk of extinction.

Examples of research that is within scope for this programme include:

- identifying critical factors limiting the viability of populations (e.g. predation, recruitment failure, lack of pollinators, reasons for range restriction)
- assessing how pressures vary and their relative importance as drivers of population trends from site to site

[12] Species on the brink of extinction represent the most critically threatened taxa within the Nationally Critical category. Unless urgent work and resources are instigated immediately, it is inevitable that these taxa will decline to irretrievable levels, or become extinct, within c.5 years.

- determining the thresholds at which threatening agents both begin and cease to impact on populations
- understanding how pressures impact indirectly on taxa by affecting essential interactions (e.g. pressures on a key pollinator affecting plant productivity or impacts on food availability from disrupted food webs)
- determining the relative risks of extinction for different populations to prioritise management effort at different sites.

Much of the research within this programme will revolve around understanding the basic biology and ecological requirements of individual taxa and how these vary in space and time. However, where appropriate, efficiencies will be maximised by prioritising research with the potential to resolve the cause of decline for groups of closely related or ecologically similar threatened taxa, or by working on understanding the spatial and temporal variation in pressures that are expected to impact on multiple taxa.

4.4 Programme 4: Techniques for small populations

Taxa that are not covered under Programme 2 (Species on the brink of extinction) but require research to manage risks associated with small population size are in scope for this programme. While there is some overlap in the scope of Programmes 2 and 4, Programme 2 is reserved for those taxa with the most urgent needs regardless of their overall RGA scores. Approximately 310 taxa have been identified as needing research under Programme 4 at present, including 230 vascular plants.

Extremely small and/or fragmented populations of threatened taxa are subject to heightened genetic and stochastic risks. This programme will primarily focus on understanding and informing management of these risks through research into:

- captive breeding and translocation methods
- seed banking, propagation, and cultivation methods
- disease management
- managing population genetic issues.

Many of the taxa that are in scope for this programme have a One Location qualifier in the NZTCS database (n = 127 taxa), which puts them at high risk of extinction without effective management at that location. This research programme will seek to improve their management. Many other taxa have small, fragmented populations that suffer from a lack of gene flow, which is likely affecting their genetic diversity, fitness, effective population sizes, breeding systems, and social structures that are necessary for maintaining populations (Jamieson et al. 2008). While the importance of considering genetics when conserving populations of threatened taxa is now broadly understood, the circumstances under which genetic management needs to be applied are less clear and need to be resolved for taxa in Aotearoa (Jamieson et al. 2008). In addition, the way in which social cohesion and metapopulation dynamics are maintained in small populations is poorly understood for many species. Predicting the minimum number of effective local populations required to maintain metapopulations is one of the new challenges of population modelling (Hanski and Simberloff 1997), and the impacts of climate change on population structure will also need to be considered in future research.

The opportunity to transfer knowledge gained from research on individual taxa to other larger groups of taxa may be limited within this programme, especially since suitable inventory and monitoring techniques do not exist for many of the in-scope taxa. However, for some groups, such as freshwater and terrestrial invertebrates, there has been so little previous work in the four areas listed above that any taxon-specific studies will help to develop methodology that is fundamental to the management of the broader groups.

4.5 Programme 5: Detection and outcome monitoring

Effective detection and monitoring methods are essential tools for understanding the status and trends of taxa and for measuring the effectiveness of management. Understanding trends enables DOC to assess whether management is successful or whether changes or improvements are required. Monitoring also enables the prioritisation of conservation investment – targeting management towards taxa and populations with the most urgent needs and preventing taxa from heading closer to extinction. Population trend information supports the assessment of the conservation status of taxa through the NZTCS process and helps fulfil DOC's obligation to report on conservation outcomes to the Government and the public.

A lack of monitoring methods was repeatedly identified as a factor hindering understanding of the effectiveness of conservation management of a wide range of threatened taxa across all taxonomic groups. Often, survey methods to establish a taxon's presence do exist but are not suitable to assess population status or trend. For some taxa, potentially useful monitoring methods are available, but it is not fully understood how to interpret results obtained using these methods – for example, when monitoring some vascular plants, it can be difficult to determine individuals, so the extent of vegetation cover is used as a proxy. For other taxa, there are no monitoring methods, or existing methods are extremely time consuming, expensive, or difficult to implement over appropriate spatial and temporal scales.

Priority research within this programme will lead to new or improved, efficient, and scientifically robust methods and will include:

- developing detection methods for individual, or groups of, threatened taxa
- developing detection and monitoring methods that are applicable to multiple taxa with appropriate adaptation
- developing monitoring methods to detect changes in population distribution, status, and trend in response to environmental change and/or management actions
- developing the knowledge and tools to interpret the results of population and outcome monitoring with confidence
- determining how to detect and monitor rare, naturally uncommon taxa that occur at very low densities, including those that are widely distributed but aggregated in unpredictable habitat patches.

At least 406 taxa have been identified as requiring research under this programme. Many of the taxa that were identified as requiring the development of tools for their detection or for understanding their population trends are cryptic or have highly dispersed or small populations. This includes many invertebrates, lizards, and bats. Many of these taxa are currently classified as Data Poor under the NZTCS. Improved detection and monitoring techniques may result in new information that allows their conservation status to be determined with confidence.

4.6 Programme 6: Enabling the contribution of mātauranga Māori to species research and management

There are many definitions of mātauranga Māori. A particularly useful explanation can be found in Sir Hirini Moko Mead's seminal book *Tikanga Māori: living by Māori values* (Mead 2003), which draws on the insights of fellow scholar Whatarangi Winiata. His insights speak to the enduring but also constantly evolving nature of mātauranga:

> Mātauranga Māori is a body of knowledge that seeks to explain phenomena by drawing on concepts handed from one generation of Māori to another. Accordingly, mātauranga Māori has no beginning and is without end. It is constantly being enhanced and refined. Each passing generation of Māori make their own contribution to mātauranga Māori. The theory, or collection of theories, with associated values and practices, has accumulated mai i te Ao Māori / from Māori beginnings and will continue to accumulate providing the whakapapa of mātauranga Māori is unbroken.
>
> (Mead 2003, p. 337)

Many of today's Māori researchers and scientists are adept at working across knowledge systems, incorporating mātauranga Māori as well as the knowledge sets of their disciplines (Kukutai et al. 2021).

This programme will aim to understand and meet Te Tiriti o Waitangi (Treaty of Waitangi) obligations and opportunities with respect to supporting Māori involvement in the threatened species research space. Mātauranga Māori can help to collectively build a more comprehensive understanding of the biodiversity of Aotearoa and the pressures it faces. Infusing mātauranga Māori across all the research programmes proposed here, where appropriate, will result in a more holistic knowledge base and offer additional opportunities for whānau (families), hapū (subtribes), and iwi (tribes) to be engaged with threatened species research and management.

Undertaking research that is guided by mātauranga Māori will contribute to generating and sharing knowledge. Research leaders will identify issues, aspirations, and outcomes that are imperative for effective Māori partnership to achieve positive conservation outcomes in species management and research. Ideally, research will be co-designed with whānau, hapū, and iwi so that it focuses on issues that mutually need to be resolved and benefits those involved in the long term.

4.7 Programme 7: Pest impacts

Over 700 (>65%) of the assessed taxa were identified as requiring research to understand how, and to what level, pests that threaten them need to be managed. For most threatened taxon–pest combinations, density-impact functions and the thresholds above or below which pest management is required remain unknown. Many pests are likely to interact with each other, so there is a need to understand their relative importance, with the view that not all pests may require management to the same level.

For the purposes of this programme, 'pests' are defined as species that threaten the viability of threatened taxa and are unnatural residents of their habitats or reside at a place in artificially inflated abundances due to human impacts. They are most often introduced species such as mammalian predators, browsers, and weeds, but also include pathogens.

While some pests are well studied (e.g. possums [*Trichosurus vulpecula*]; Montague 2000), the direct and indirect impacts of other pests on threatened taxa are less well understood (e.g. the impacts of mice, sward-forming grasses, honey bees, and introduced wasps). Any of these pests may have direct effects, such as when the pest itself is killing the threatened taxon, or indirect effects where the pest sets off a cascade of effects that impacts the threatened taxon.

An example of an indirect effect that our experts identified as needing to be better understood was the hypothesis that hare (*Lepus europaeus*) faecal pellets may increase soil nutrient levels that promote the growth of introduced swarding grasses, which in turn limit the growth of indigenous threatened herbs.

Experts stated that while it was often known that pests were a significant cause of decline for a threatened taxon, there was uncertainty about the pest population levels (thresholds) that should trigger pest control and/or how much control was needed before suppression could cease. The most common best practice protocols that are currently available were developed for a very specific group of threatened taxa and may be wrongly assumed to benefit all threatened taxa in a given environment. For example, standard pest management protocols that were developed to benefit threatened birds may not be sufficient to protect equally threatened lizards, invertebrates, amphibians, or plants (e.g. Monks et al. 2023). An improved understanding of the levels of pest control required, and how to manage pests at a variety of scales, will result in more cost-effective management actions and represent a positive step towards slowing the decline of threatened taxa.

This research programme will focus primarily on pest species that have received limited previous research and/or affect a wide range of threatened taxa across habitats (e.g. hedgehogs, mice, weasels, wasps, ants, herbaceous weeds, sward-forming grasses).

Research priorities within this programme will include:

- determining the impacts of pests on threatened taxa, intervention thresholds, and levels to which pests may need to be reduced to benefit threatened taxa
- developing methods to manage the direct and indirect effects of pests on threatened taxa.

4.8 Programme 8: Restoring natural processes

Threatened taxa in Aotearoa have been affected by habitat loss, fragmentation, and degradation both directly and indirectly because of the resulting loss of natural ecological and evolutionary processes. For example, only c. 30% of the original forest area remains in Aotearoa, and wetlands have been reduced to 10% of their original extent nationally, and to far lower levels in some regions (Hall and McGlone 2006; Ausseil et al. 2011). Similarly, river flows and aquifer levels in some regions have been reduced by >100 m^3/year because of human use (Ministry for the Environment 1997). The remaining areas of natural habitat are often small, isolated, and subject to continued loss and degradation through edge effects, colonisation by introduced species, and human land use.

The composition and abundance of native taxa, and the ecosystem processes they rely on in the remaining natural areas, are different from those they have evolved with, and the current habitats may no longer provide for their persistence. Every part of mainland Aotearoa is affected by this. While previous habitat changes cannot be reversed, it is important to understand which critical components and processes need to be in place to sustain populations of threatened taxa, especially in the face of a changing climate (see Programme 10 below). This will enable habitats to be maintained and restored to provide conditions that are suitable for the persistence of these taxa.

Research needs that are within scope for this programme were identified for 472 taxa across all major taxonomic groups, and vascular plants made up more than 70% of these. Methods to manage succession driven by invasive weeds was the most common need identified.

Research priorities within this programme will include:

- developing methods to restore, improve, or create habitat and habitat connectivity for threatened taxa
- determining the role of disturbance in maintaining habitat for threatened taxa and how to adaptively manage disturbance to aid regeneration and avoid weed encroachment for plants and invertebrates
- understanding nutrient management of soils for seabirds and associated plants and invertebrates
- identifying the loss of essential biotic interactions (pollinators / hosts / dispersers) and developing or adapting tools to restore these interactions (for plants, invertebrates, and birds).

This programme will be closely aligned with and complementary to DOC's Threatened Ecosystem Research Workstream. It will differ in that it will prioritise research that has taxon-specific outcomes rather than a 'whole-of-system' focus.

4.9 Programme 9: Human impacts

Humans have a multitude of direct and indirect impacts on threatened taxa. However, in the context of Aotearoa, many of these impacts are assumed based on anecdotes or examples from other countries and have not yet been tested or confirmed. Impacts are often associated with the development of infrastructure, and mitigation methods are required to avoid or minimise these impacts, but many of these methods also remain untested (e.g. Jones et al. 2019).

A wide range of research needs associated with human impacts were identified for threatened taxa. For example, for some taxa, understanding the direct impacts of disturbance by people, their pets, and their vehicles was identified as an important knowledge gap. Understanding the indirect impacts of harvest by humans was considered equally important. For example, human-induced reductions in fish stocks have driven the loss of seabird and seal colonies (Furness 2003; Stenson et al. 2020), which has had flow-on effects for threatened plants such as *Lepidium* spp. that rely upon these colonies for their nutrient inputs and disturbance. However, no methods are currently available to mitigate these losses. In another example, research in other countries has shown that the reproductive success of seabirds may be impacted by heavy metal accumulation, but this is not well understood for many taxa (Goutte et al. 2014). Understanding factors such as these and developing management techniques to address these impacts is fundamental to the management of threatened taxa.

Research priorities within this programme will include:

- improving understanding of the impacts of land development and associated activities by humans on threatened taxa and, where there is an effect, determining the threshold where this reduces population viability
- developing and testing mitigation techniques for the effects of development and associated activities by humans on threatened taxa, especially bats, lizards, and freshwater fishes
- understanding the indirect effects of development and associated activities by humans on threatened taxa, and developing techniques to manage / mitigate these
- understanding the impacts of environmental pollution caused by humans, their livestock and pets, and industry, particularly for terrestrial birds, seabirds, marine mammals, vascular plants, and mammals.

4.10 Programme 10: Climate change impacts and adaptation

Climate change has been identified as a general and increasingly significant risk to the persistence of many threatened taxa in Aotearoa. For most taxa, however, the risks posed by climate change are poorly understood and their relative importance compared to other, often immediate, pressures are largely unknown. In many instances, climate change is likely to exacerbate existing threats that already need to be managed. Thus, we recommend linking climate change research with other research programmes.

Research priorities within this programme will include:

- predicting the likely direct and indirect impacts of climate change on all threatened taxa
- developing and testing approaches to manage the impacts of climate change on the persistence of taxa.

This programme will focus on determining which threatened taxa are at greatest risk from climate change and whether action is required to mitigate the risk in the short or medium term. This will be done by completing structured trait-based climate change vulnerability assessments (CCVAs), which provide relative scores of vulnerability by assessing the sensitivity, adaptive capacity, and exposure of taxa to projected changes in climate.

Research will also focus on taxa, groups, or appropriate surrogates for which climate change has been identified as a key and imminent threat to persistence with reasonable confidence based on either the results of a CCVA or knowledge that the taxon is restricted to habitats currently being impacted by climate change. For example, plants and flightless invertebrates that are restricted entirely to coastal splash zones, ephemeral wetlands, or alpine margins where there is no opportunity for habitat or taxon range shifts to occur. The programme will also focus on taxa that are physiologically adapted to environmental conditions which may be lost, fragmented, or reduced as a result of climate change.

The outputs of this research programme will help to anticipate, pre-empt, and respond to pressures driven by climate change when developing and improving management plans. Alignment with DOC's Climate change adaptation action plan 2020–2025 (Christie et al. 2020) and *Climate Change Adaptation Science Plan* (DOC 2020c) will be essential to refine this programme in the short term.

5. Limitations and future applications of the RGA process

5.1 Adequacy of the RGA process

The sheer number of Threatened and At Risk taxa that require research to inform management plans that will ensure their persistence (likely > 9000) necessitates a strategic approach to prioritising research and allocating research funding. Recognising that most taxa are likely to have important research needs, we used the RGA process to identify which research should be prioritised to support the development of management plans. The results confirmed our assumption that many taxa (92% of all the taxa assessed) do require research to develop effective plans or significantly improve existing management practices.

Poorly designed scoring systems in which the scoring criteria fail to differentiate well among the assessed taxa are of little use for scaling relative priorities. Our approach aimed to differentiate higher from lower priorities, and the linear accumulation of RGA scores from 2 to 28 with few gaps or clumping along the scale indicates that the scoring criteria and expert elicitation process performed reasonably well in differentiating research priority among individual taxa. This meant we were able to successfully apply the RGA method across taxonomic groups, compile research needs for each taxon, and identify common needs and therefore potential efficiencies.

While we were able to prioritise taxa, and the knowledge gaps that need to be filled for many taxa, into programmes in a way that was fit for our purpose, there are other priorities within DOC that may influence decisions on research programmes elsewhere within the organisation. For example, when assigning RGA scores, we did not consider the 'iconic' status of a taxon, or whether it was charismatic or a keystone species. Nor did we consider the relationship the wider community in Aotearoa may have with a taxon. Funding streams may be available from other sources that have other priorities. We also did not include feasibility, costs, or leveraging opportunities in our scoring because our priority was to focus purely on research gaps that needed to be filled and published reviews assessing methods for priority setting have highlighted the importance of remaining independent of economic and political influences when developing research priorities (Tomlinson et al. 2011). However, these factors are likely to be important to include in the assessment of individual research proposals once a portfolio of specific projects has been developed in response to this gap analysis.

5.2 Limitations arising from use of the NZTCS

The RGA urgency score was reliant on the NZTCS classification of each taxon. However, the NZTCS was not designed to specifically inform research and is not equally comprehensive across taxonomic groups. Just over 14,000 taxa have been assessed using the NZTCS, but c. 80,000 taxa are estimated to be present in Aotearoa (Ministry for the Environment 2007). In particular, a large number of terrestrial fungi, lichens, insects, centipedes, millipedes, and flatworms, and a wide range of marine taxa are yet to be assessed. The groups with the least coverage within the NZTCS are also the most poorly understood and will almost certainly have high, and potentially completely different, research needs.

5.3 Interpreting RGA scores

When several research needs were identified for an individual taxon (as was usually the case), the knowledge gains score was based on the need that would benefit the most taxa. Prioritising the research needs that were identified for taxa with high knowledge gains scores (e.g. a high proportion of terrestrial and freshwater invertebrates, freshwater fishes, and reptiles) will provide the highest efficiencies in gathering the necessary knowledge to develop or improve the greatest number of management plans. However, this score does not always reflect the relative importance of research needs for individual taxa, or the order in which the proposed research should be undertaken. For example, the need to develop a method to control pests, such as mice or sward-forming grasses, may generate a high knowledge gains score, but other actions may be crucial first steps for individual taxa, despite only benefiting those particular taxa. This highlights the importance of prioritising multiple streams of work across the 10 complementary research programmes suggested by this analysis (see Fig. 8). Taxonomic groups with few taxa (e.g. amphibians, sharks, and bats) may have low knowledge gains scores by default but should not be excluded from research investment *where it is justified*.

In many cases, surrogate taxa or taxonomic groups with lower RGA scores than the target taxa may be more appropriate subjects for research to answer key questions. This is particularly likely when high-scoring taxa are so rare that they cannot be found in great enough numbers to test new tools or methods in a scientifically robust manner. In many cases, the research need will also have been identified for the surrogate, but that taxon may have a lower NZTCS ranking, reducing its urgency score. The approach of using surrogate taxa has been applied with success in DOC's Mobile Threatened Species Research Workstream (MTSRW), through which researchers are establishing whether shorebirds within Aotearoa use specific flyways that require additional conservation measures. For example, while the most urgent needs are to identify flyways for Nationally Critical and Nationally Endangered taxa such as tara iti / New Zealand fairy tern (*Sternula nereis davisae*) and tara pirohe / black-fronted tern (*Chlidonias albostriatus*), new-generation GPS transmitters are still too large to deploy for these taxa. Instead, the existence and locations of flyways are being investigated for the larger tōrea / South Island pied oystercatcher (*Haematopus finschi*; At Risk – Declining) because this species can carry heavier transmitters (E. Williams, MTSRW Lead, pers. comm.). Trialling this research method on larger, more robust taxa will allow any issues to be 'ironed out' prior to trialling them on more vulnerable taxa.

5.4 How the RGA is being applied

It is important to emphasise that we intend for the RGA score to be used as a starting point (or decision support tool), not a ranking system. It provides a means to identify the highest priority taxa and knowledge gaps to be considered for funding with the appropriate level of transparency. *It should not be seen as a list of taxa that should be worked on in rank order.*

The primary use of the RGA is as a tool to aid in the identification and prioritisation of DOC's strategic research to support funding allocation and, ultimately, help meet goals related to threatened taxa in *Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020* (DOC 2020e, goals 10.7.1 and 10.7.2). This tool provides transparency and support for research funding decisions. Given that the amount of research required far exceeds DOC's capacity, the RGA spreadsheet and associated data (see Online Supplementary Information [link]) are intended as an open resource to also help others identify research opportunities. We envisage that other agencies and individuals will be able to use this to facilitate complementary and collaborative research that will help meet the goals of *Te Mana o Te Taiao*. For example, the data held in the spreadsheet could be used by early career scientists and postgraduate students looking for research topics that will push the frontiers of science while also having immediate practical value to the conservation of threatened taxa. It can equally be used by those interested in individual taxa, whole taxonomic groups, or collective conservation challenges across groups to identify research questions and priorities.

5.5 Alignment and collaboration

To successfully address the large number of priority knowledge gaps identified through this RGA process, it will be essential to work collaboratively across science and operations teams within DOC, as well as with whānau, hapū, and iwi, and the wider national and international science community.

Seeking and taking opportunities to form partnerships and collaborations will increase capacity to do the core work of managing species while simultaneously increasing the rigour and efficiency of the research that needs to be undertaken to improve that management. Research should ideally address needs that are mutually identified by the collaborating parties as being key to improving species outcomes.

This RGA process has allowed us to begin to identify research needs from a species persistence and recovery perspective. DOC's investment in postgraduate research and engagement with universities on key knowledge gaps has been shown to have a high benefit-to-cost ratio and brings the added benefits of engaging external expertise; increasing the dissemination of knowledge gained to the public and the wider scientific community via publications and presentations; and increasing future workforce capability. Partnerships with universities and research institutions often result in significant in-kind contributions and provide opportunities for financial leveraging that increase the resource invested into conservation science as a whole. This ultimately leads to achieving more of the collective biodiversity goals.

5.6 Future improvements

The results of the RGA should be interpreted with the understanding that this was a first attempt at compiling research needs in a consistent format for a very large number of taxa. Not all taxa could be assessed in the time available largely because of the small numbers of experts who are knowledgeable about some taxonomic groups in Aotearoa. These taxonomic gaps need to be filled.

We found that the knowledge gains score, which attempted to infer how many taxa would accrue benefits if the identified research took place, was the least rigorous of the scores we applied. This was because of its dependence on the experts' understanding of the relevance of the research need for the taxon being assessed to other taxa and taxonomic groups. Therefore, the continued use of this score will require ongoing moderation. Once research needs have been compiled for most taxa, it will be possible to estimate the number that will benefit from particular work with greater confidence.

The experts who were involved in the RGA were concerned that some taxonomic groups, particularly the terrestrial and freshwater invertebrates, had not been fully assessed within the NZTCS. They worried that because of this, many taxa that are likely to be threatened and require research to inform their management were not captured in this RGA process. It is unlikely that these taxa and their research gaps will be identified until significant work on the conservation status of Data Deficient taxa is completed. We hope that the programmes outlined in section 4, particularly Programme 1, will start to address this.

The RGA and associated data are intended to be updated regularly and made available as an open resource. The major knowledge gaps identified across taxonomic groups are unlikely to be resolved in the short term, so a full annual review of the RGA itself is not considered necessary. However, specific research needs and priorities for individual taxa will change and should be updated over time as:

- new information comes to light about the taxon;
- research projects are completed, and new knowledge or tools are put into practice; and
- taxonomic groups are reviewed as part of the regular NZTCS cycle.

Research needs for groups or organisms that have not yet been assessed should be added as they become available. We recommend that the importance of newly identified gaps is assessed regularly, particularly as new technologies and monitoring methods for species management become available. The size of each research gap (i.e. whether it would take considerable, or few, resources to complete) was not quantified by the experts. However, gathering these data may be possible in future gap assessments.

5.7 Principles for allocating research funding

Filling all the knowledge gaps that were identified in this RGA is a priority if the biodiversity crisis is to be reversed. Investing across the 10 programmes proposed in section 4 is essential to the protection and management of threatened taxa, and to the functioning of the ecosystems of which they are integral components. Taxa with high overall RGA scores were often found to have complex needs under more than one programme. As such, there is no intention to prioritise the programmes themselves, but in any given funding round, individual research projects across the programmes may be identified as high or lower priority. These priorities will be reviewed and developed by an advisory group – currently the Te Mana o Te Taiao TSRAG – who will make annual recommendations for funding to DOC management. We recommend that decisions about priority research are based on the following principles:

- The research is a critical stepping stone or leads directly towards the development of management plans resulting in new or significant improvements in management.
- Research that clearly benefits the management of multiple taxa or addresses widespread shared pressures within and/or across taxonomic groups is prioritised.
- Research investment is spread across taxa and programmes because all programmes are essential to achieving species recovery.
- Research that uses the most appropriate combinations of taxa/groups is prioritised, noting that these may not necessarily be the highest scoring taxa (e.g. the use of surrogate taxa may be an efficient method for addressing some issues).
- Mātauranga Māori is braided into research approaches when appropriate.
- Opportunities are taken to maximise external collaborations and cost sharing where appropriate.

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7. References

Ausseil A-GE, Chadderton WL, Gerbeaux P, Stephens RTT, Leathwick JR. 2011. Applying systematic conservation planning principles to palustrine and inland saline wetlands of New Zealand. Freshwater Biology. 56:142–161.

Christie J, Pearce P, Phifer P, Parsons S, Tait A. 2020. Department of Conservation climate change adaptation action plan | Te Papa Atawhai he whakamahere hātepe urutau mō te huringa āhuarangi: 2020/21 – 2024/25. Wellington: Department of Conservation.

[DOC] Department of Conservation. 2018. Strategy for prioritising threatened species research funding. Christchurch: Department of Conservation (unpublished; docCM-6347797).

[DOC] Department of Conservation. 2020a. Annual Report Pūrongo-ā-tau for the year ended 30 June 2020. Wellington: Department of Conservation. www.doc.govt.nz/globalassets/documents/about-doc/annual-reports/annual-report-2020/annual-report-2020.pdf.

[DOC] Department of Conservation. 2020b. Biodiversity in Aotearoa: an overview of state, trends and pressures. Wellington: Department of Conservation. www.doc.govt.nz/globalassets/documents/conservation/biodiversity/anzbs-2020-biodiversity-report.pdf.

[DOC] Department of Conservation. 2020c. Climate Change Adaptation Science Plan: Climate change research to support the Department of Conservation Climate Change Adaptation Action Plan. Wellington: Department of Conservation. www.doc.govt.nz/globalassets/documents/our-work/climate-change/climate-change-adaptation-science-plan.pdf.

[DOC] Department of Conservation. 2020d. National status and trend reports 2019–2020: Number of managed indigenous species. Wellington: Department of Conservation. www.doc.govt.nz/our-work/monitoring-reporting/national-status-and-trend-reports-2019-2020/indigenous-species-2019-2020.

[DOC] Department of Conservation. 2020e. Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020. Wellington: Department of Conservation. www.doc.govt.nz/globalassets/documents/conservation/biodiversity/anzbs-2020.pdf.

[DOC] Department of Conservation. 2020f. Workstream 1.1a EMU/SMU – Research. Strategy for prioritising naturally rare and threatened ecosystems research funding. Christchurch: Department of Conservation (unpublished; docCM-6349495).

[DOC] Department of Conservation. 2021. Workstream 1.2a Mobile Terrestrial Threatened Species Programme: research gap analysis, priorities and implementation strategy. Christchurch: Department of Conservation (unpublished; docCM-6338723).

Drinan TJ, Grainger NPJ, Harding JS, Collier KJ, Smith BJ, Death RG, Makan T, Rolfe JR. 2020. Analysis of the conservation status of New Zealand freshwater invertebrates: temporal changes, knowledge gaps, impediments, and management implications. New Zealand Journal of Zoology. 48(1):81–96.

Dunn NR, Allibone RM, Closs G, Crow S, David BO, Goodman J, Griffiths MH, Jack D, Ling N, Waters JM, et al. 2018. Conservation status of New Zealand freshwater fishes, 2017. New Zealand Threat Classification Series 24. Wellington: Department of Conservation.

Furness RW. 2003. Impacts of fisheries on seabird communities. Scientia Marina. 67(S2):33–45.

Glaser A, van Klink P, Elliott G, Edge K-A. 2010. Whio/blue duck (*Hymenolaimus malacorhynchus*) recovery plan 2009–2019. Threatened Species Recovery Plan 62. Wellington: Department of Conservation.

Goutte A, Barbraud C, Meillère A, Carravieri A, Bustamante P, Labadie P, Budzinski H, Delord K, Cherel Y, Weimerskirch H, et al. 2014. Demographic consequences of heavy metals and persistent organic pollutants in a vulnerable long-lived bird, the wandering albatross. Proceedings of the Royal Society B: Biological Sciences. 281(1787):20133313.

Hall GMJ, McGlone MS. 2006. Potential forest cover of New Zealand as determined by an ecosystem process model. New Zealand Journal of Botany. 44:211–232.

Hanski I, Simberloff D. 1997. The metapopulation approach, its history, conceptual domain, and application to conservation. In: Hanski I, Gilpin ME, editors. Metapopulation biology: ecology, genetics and evolution. San Diego: Academic Press; p. 5–26.

Innes J, Kelly D, Overton JM, Gillies C. 2010. Predation and other factors currently limiting New Zealand forest birds. New Zealand Journal of Ecology. 34:86–114.

Jamieson IG, Grueber CE, Waters JM, Gleeson DM. 2008. Managing genetic diversity in threatened populations: a New Zealand perspective. New Zealand Journal of Ecology. 32:130–137.

Jones C, Borkin K, Smith D. 2019. Roads and wildlife: the need for evidence-based decisions; New Zealand bats as a case study. New Zealand Journal of Ecology. 43(2):3376.

Kaya G. 2020. The use of multi-criteria decision-making methods to support risk prioritisation. Proceedings of the 5th NA International Conference on Industrial Engineering and Operations Management; August 9 – 11, 2020; Detroit, Michigan, USA. IEOM Society. p. 140–146.

Kukutai T, McIntosh T, Boulton A, Durie M, Foster M, Hutchings J, Mark-Shadbolt M, Moewaka Barnes H, Moko-Mead T, Paine S-J, et al. 2021. Te Pūtahitanga: a Tiriti-led science policy approach for Aotearoa New Zealand. Auckland: Ngā Pae o te Māramatanga.

MacDiarmid A, McKenzie A, Sturman J, Beaumont J, Mikaloff-Fletcher S, Dunne J. 2012. Assessment of anthropogenic threats to New Zealand marine habitats. New Zealand Aquatic Environment and Biodiversity Report No. 93. Wellington: Ministry of Agriculture and Forestry.

McGlone MS. 1989. The Polynesian settlement of New Zealand in relation to environmental and biotic changes. New Zealand Journal of Ecology. 12:115–129.

Mead HM. 2003. Tikanga Māori: living by Māori values. Wellington: Huia Publishers.

Ministry for the Environment. 1997. The State of New Zealand's Environment 1997. Wellington: Ministry for the Environment and GP Publications.

Ministry for the Environment. 2007. Environment New Zealand 2007. Wellington: Ministry for the Environment.

Monks JM, Besson AA, O'Donnell CF. 2023. Landscape scale control of selected mammalian predators fails to protect lizards. Biological Invasions. 1–12. https://doi.org/10.1007/s10530-023-03160-x.

Montague TL. 2000. The brushtail possum: biology, impact and management of an introduced marsupial. Lincoln: Manaaki Whenua Press.

O'Donnell CFJ, Clapperton BK, Monks JM. 2015. The impacts of introduced mammalian predators on indigenous birds of freshwater wetlands in New Zealand: a review. New Zealand Journal of Ecology. 39:19–33.

Stenson GB, Haug T, Hammill MO. 2020. Harp seals: monitors of change in differing ecosystems. Frontiers in Marine Science. 7:569258.

Tomlinson M, Chopra M, Hoosain N, Rudan I. 2011. A review of selected research priority setting processes at national level in low and middle income countries: towards fair and legitimate priority setting. Health Research Policy and Systems. https://doi.org/10.1186/1478-4505-9-19.

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

Walker KJ. 2003. Recovery plans for *Powelliphanta* land snails. Threatened Species Recovery Plan 49. Wellington: Department of Conservation.

Wickes C, Crouchley D, Maxwell J. 2009. Takahe (*Porphyrio hochstetteri*) recovery plan 2007–2012. Threatened Species Recovery Plan 61. Wellington: Department of Conservation.

Appendix

Threatened taxa with sufficient knowledge to manage their pressures

Expert assessors indicated that the 83 threatened taxa included in the table below do not require significant new research because enough is known to manage their pressures. This list includes 42 taxa that do not currently have a formal Department of Conservation Te Papa Atawhai management plan but require one. Note that the scientific names provided in this table were correct as at September 2019.

BIOWEB ID	SCIENTIFIC NAME	COMMON NAME	TAXONOMIC GROUP	MANAGEMENT PLAN WRITTEN?
10994	*Ardea alba modesta*	kōtuku, white heron	Bird	No
11102	*Acanthisitta chloris granti*	tītipounamu, North Island rifleman	Bird	No
11018	*Anas nesiotis*	Campbell Island teal	Bird	Yes
11014	*Anas superciliosa*	pārera, grey duck	Bird	No
11114	*Anthus novaeseelandiae steindachneri*	Antipodes Island pipit	Bird	No
11137	*Coenocorypha aucklandica meinertzhagenae*	Antipodes Island snipe	Bird	No
13439	*Coenocorypha aucklandica perseverance*	Campbell Island snipe	Bird	Yes
10869	*Eudyptula minor albosignata*	kororā, white-flippered blue penguin	Bird	No
10870	*Eudyptula minor minor*	kororā, southern blue penguin	Bird	No
11021	*Hymenolaimus malacorhynchos*	whio, blue duck	Bird	Yes
11126	*Mohoua albicilla*	pōpokatea, whitehead	Bird	No
11062	*Petroica australis australis*	kakaruai, South Island robin	Bird	Yes
11061	*Petroica longipes*	toutouwai, North Island robin	Bird	No
11058	*Petroica macrocephala chathamensis*	Chatham Island tomtit	Bird	No
11173	*Porphyrio hochstetteri*	South Island takahē	Bird	Yes
10923	*Pterodroma axillaris*	ranguru, Chatham petrel	Bird	Yes
11228	*Strigops habroptila*	kākāpō	Bird	Yes
30050	*Oligosoma tekakahu*	Te Kakahu skink	Herpetofauna	Yes
12639	*Paryphanta busbyi watti*	pūpū rangi, kauri snail	Invertebrate	Yes
30365	*Placostylus ambagiosus watti*	pūpū whakarongotaua, flax snail	Invertebrate	Yes
29754	*Powelliphanta augusta*	Mount Augustus snail	Invertebrate	Yes
12749	*Powelliphanta fiordlandica*	large land snail	Invertebrate	Yes
12755	*Powelliphanta gilliesi brunnea*	large land snail	Invertebrate	Yes

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BIOWEB ID	SCIENTIFIC NAME	COMMON NAME	TAXONOMIC GROUP	MANAGEMENT PLAN WRITTEN?
12757	*Powelliphanta gilliesi fallax*	large land snail	Invertebrate	Yes
12762	*Powelliphanta gilliesi subfusca*	large land snail	Invertebrate	Yes
12771	*Powelliphanta lignaria johnstoni*	large land snail	Invertebrate	Yes
12772	*Powelliphanta lignaria lignaria*	large land snail	Invertebrate	Yes
12775	*Powelliphanta lignaria rotella*	large land snail	Invertebrate	Yes
12778	*Powelliphanta marchanti*	large land snail	Invertebrate	Yes
12731	*Powelliphanta patrickensis*	large land snail	Invertebrate	Yes
12781	*Powelliphanta spedeni lateumbilicata*	large land snail	Invertebrate	Yes
12782	*Powelliphanta spedeni spedeni*	large land snail	Invertebrate	Yes
12789	*Powelliphanta traversi florida*	large land snail	Invertebrate	Yes
12790	*Powelliphanta traversi koputaroa*	large land snail	Invertebrate	Yes
12791	*Powelliphanta traversi latizona*	large land snail	Invertebrate	Yes
12792	*Powelliphanta traversi otakia*	large land snail	Invertebrate	Yes
12793	*Powelliphanta traversi tararuaensis*	large land snail	Invertebrate	Yes
12794	*Powelliphanta traversi traversi*	large land snail	Invertebrate	Yes
33619	*Xanthocnemis sinclairi*	damselfly	Invertebrate	No
3968	*Bulbinella modesta*		Plant	No
32169	*Cardamine porphyroneura*	magnesite cress	Plant	Yes
5200	*Carex fretalis*	curly sedge	Plant	No
5246	*Carex tenuiculmis*	red-leaved swamp sedge	Plant	No
7575	*Chionochloa juncea*	North Westland snow tussock	Plant	No
7579	*Chionochloa ovata*	Fiordland snow tussock	Plant	No
6900	*Coprosma intertexta*	coprosma	Plant	No
6932	*Coprosma virescens*	coprosma	Plant	No
6724	*Discaria toumatou*	tūmatakuru, matagouri	Plant	No
5400	*Dracophyllum densum*		Plant	No
5402	*Dracophyllum fiordense*		Plant	No
32116	*Empodisma robustum*	wire rush	Plant	No
11643	*Gentianella scopulorum*	Charleston gentian	Plant	Yes
30924	*Geranium sessiliflorum* var. *arenarium*	short-flowered cranesbill	Plant	No
26081	*Helichrysum* aff. *intermedium* (c) (*Helichrysum selago* var. *tumidum* Cheeseman; WELT SP058412)		Plant	No
4398	*Leptinella traillii* subsp. *pulchella*		Plant	No

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BIOWEB ID	SCIENTIFIC NAME	COMMON NAME	TAXONOMIC GROUP	MANAGEMENT PLAN WRITTEN?
8148	*Mazus novaezeelandiae* subsp. *novaezeelandiae*	dwarf musk	Plant	No
7409	*Melicytus flexuosus*		Plant	Yes
11723	*Melicytus venosus*		Plant	No
1194	*Mentha cunninghamii*	hīoi, New Zealand mint	Plant	No
8153	*Montia drucei*		Plant	No
33142	*Myoporum semotum*		Plant	No
33143	*Myosotis chaffeyorum*	forget-me-not	Plant	No
4663	*Myosotis oreophila*	forget-me-not	Plant	No
6186	*Neomyrtus pedunculata*	rōhutu	Plant	No
26099	*Olearia adenocarpa*		Plant	Yes
8160	*Olearia fimbriata*		Plant	Yes
895	*Olearia traversiorum*	hakapiri, Chatham Island akeake	Plant	Yes
11837	*Pimelea mesoa* subsp. *macra*		Plant	No
7808	*Poa aucklandica* subsp. *rakiura*	Mount Anglem poa	Plant	Yes
7843	*Poa spania*	Awahokomo poa	Plant	Yes
11523	*Pomaderris apetala* subsp. *maritima*	tainui, New Zealand hazel	Plant	No
34186	*Ranunculus* aff. *royi* (a) (AK 295116; Lake Rakeinui)	buttercup	Plant	No
6714	*Ranunculus viridis*	buttercup	Plant	Yes
30962	*Rytidosperma horrens*		Plant	No
11828	*Tmesipteris horomaka*	Banks Peninsula fork fern	Plant	Yes
7383	*Urtica perconfusa*	swamp nettle	Plant	No
11705	*Veronica* aff. *treadwellii* (a) (CHR 394533; Bald Knob Ridge)	hebe	Plant	No
8122	*Veronica bishopiana*	Waitakere rock hebe	Plant	Yes
7143	*Veronica lavaudiana*	Banks Peninsula sun hebe	Plant	No
7100	*Veronica pareora*	hebe	Plant	No
30598	*Veronica saxicola*	Maungaraho Rock hebe	Plant	Yes
11787	*Veronica scopulorum*	hebe	Plant	Yes
7945	*Zoysia minima*	prickly couch	Plant	No