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Te kaitiakitanga o te taiao o Te Tāhuhu o Te Ika-a-Māui

Conservation of the great supporting spine of the North Island

Aorangi, Remutaka, Tararua, Ruahine and Kaweka Forest Parks.

A review of deer impacts on forest regeneration, soil compaction, alpine grasslands, threatened and at risk plant species, rongoā and monitoring.

*He uri nō Ngāti Rākaipaaka me Ngāti Mutunga

Key findings – Ngā Take Matua

1. Deer are exceptionally efficient browsers. Even at low densities, they have disproportionate impacts on chronically depleted forests and tussock grasslands. Throughout Te Tāhuhu* canopy regeneration has been suppressed at the stand scale by red and sika deer (*Cervus elaphus* and *C. nippon*). In some valleys, this has progressed to large-scale collapse, turning forest and alpine grassland into browse-tolerant shrubland. If deer populations remain above 1 km^{-2}, continued collapse over coming decades is likely – reducing biodiversity, carbon storage and soil conservation.

2. Deer compact soils throughout Te Tāhuhu. Trampling appears to increase soil density by 5–20%. Compacted soils store less water. They have greater surface runoff and suspended sediment erosion. Particularly on steep, shallow, stony soils with limited plant and litter cover. As extreme rainfall events become more common, any increase in flood flows will have costly consequences. By removing palatable plants deer reduce root biomass, and the quantity and quality of forest litter. This probably alters hydrological processes, potentially compounding the effects of trampling on flood flows. Reduced soil water storage makes kāmahi forests more prone to drought-induced collapse. Effects of deer on root biomass and litter are highly variable, and inadequately understood.

3. While intuitive, and supported by evidence, the effects of soil compaction are unclear. Reported increases in surface runoff, flooding and soil erosion with compaction vary widely. Key questions remain: how deer compact soils across different slopes and vegetation types; how this alters hydrology, nutrient loss, surface runoff and suspended sediments; the flow-on effect of deer-induced depletion of forest un-

* Te Tāhuhu covers the North Island axial mountain ranges and includes Aorangi, Remutaka, Tararua, Ruahine and Kaweka Forest Parks (FPs). The Great Supporting Spine of the Fish of Maui.

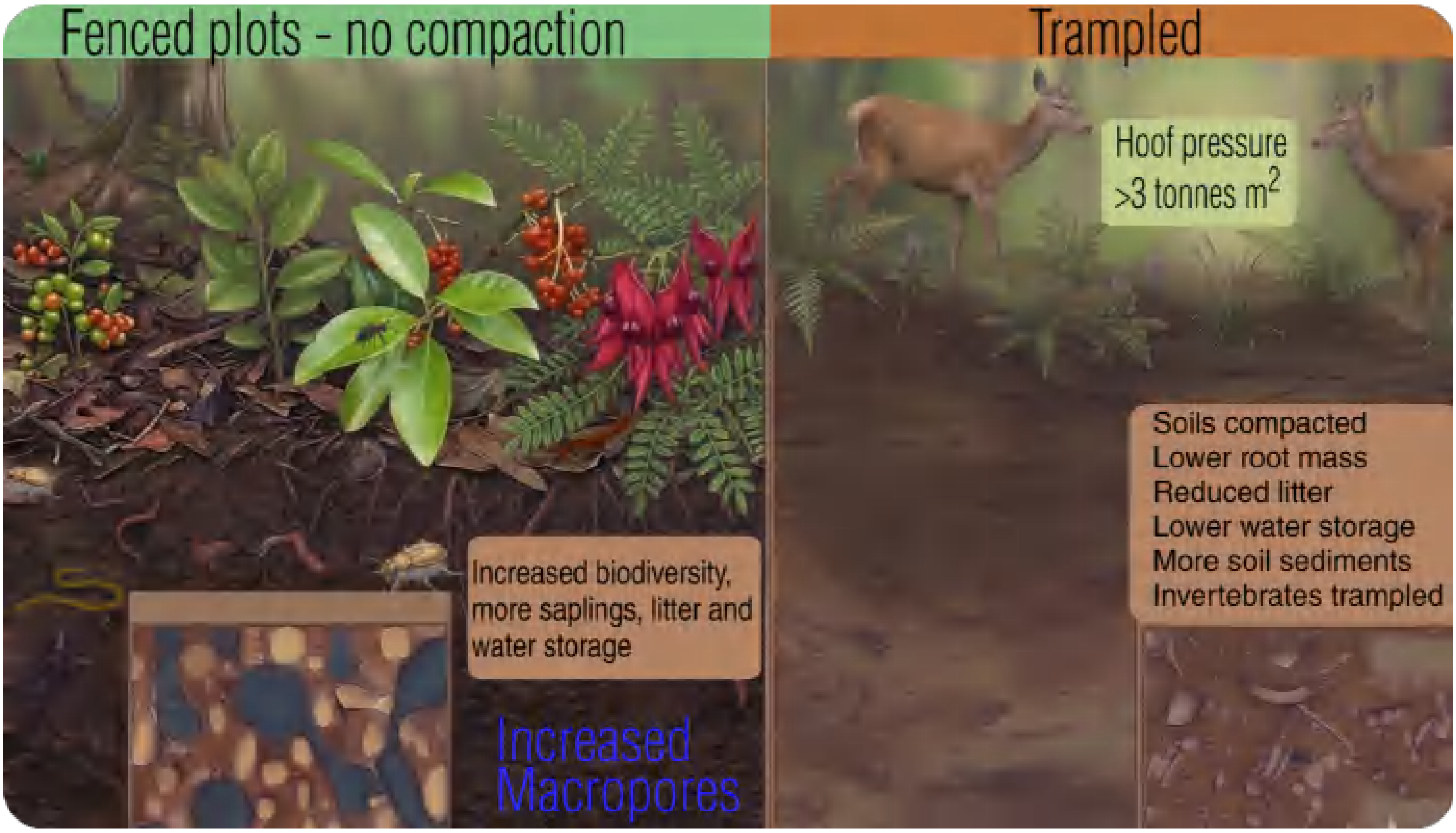
derstories and reduced litter inputs on soil properties; and whether soil compaction can be reversed following successful deer control.

4. When considered as a whole, Aorangi, Remutaka, Tararua, Ruahine and Kaweka FPs have >40 threatened and at risk vascular plant species. Although Te Tāhuhu alpine grasslands are restricted in area, they have a high proportion of these species. Many are rongoā and kai rākau important to Māori. Four plants not found outside of Tararua FP are at risk from deer browsing and trampling. Our knowledge of their status is poor.

5. Despite decades of recreational, commercial and government-funded hunting, deer remain at very high densities in many parts of Te Tāhuhu (>5 deer km^{-2}). Forest regeneration is failing widely. Alpine plants appear to be in long-term decline. To avoid repeating past management failures, deer populations must be reduced and maintained there for decades. Achieving this will require a fundamentally different approach to deer culling than has been used previously.

6. The effectiveness of conservation management is greatest when it is guided by credible monitoring. What gets measured gets managed. Forest regeneration should be measured directly rather than inferred from uninformative indices. Counting deer faecal pellets and using indirect indices of deer impacts are unlikely to provide good value because they are only loosely related to actual forest regeneration. Changes in deer numbers can be better gauged by recording hunter encounter rates and fawning success in a scientific manner. By knowing numbers of deer killed and the proportion of hinds fawning, the population size can be calculated.

7. Two complementary monitoring tasks would provide essential information on Te Tāhuhu: monitoring deer-induced soil compaction in existing paired fenced and unfenced deer exclosure plots; and remeasurement of existing forest and alpine grassland plots. Each task could be delivered for <$100,000 per year.



Paired exclosure plots highlight the effects of browsing and trampling by deer on forest soils. Hoof pressure reduces air pores in soils (Duncan and Holdaway, 1989; Kardol et al., 2014), which decreases water storage. Small tree and sapling root biomass are lowered through browsing (Allen et al., 2023). Soil macro invertebrate biomass is consistently lowered by trampling (Wardle et al., 2001). The quantity and quality of soil humus and litter is lowered (NZ Forest Surveys unpublished data, Appendix I). This may mean that during high rainfall events surface run-off and suspended sediments increase, increasing the likelihood of flooding and soil erosion. But these processes are unconfirmed, inconsistent and not properly understood.

	Fenced plot	Deer trampled
Soil bulk density (0–10 cm deep, Mg ha^{-1})	366 ± 32	389 ± 56
Litter (Mg ha^{-1})	16.8 ± 1.9	15.4 ± 4.5
Litter total P (mg kg^{-1})	488 ± 37	430 ± 24
Humus (Mg ha^{-1})	44.6 ± 8.4	36.0 ± 6.8
Small trees roots	1.99 ± 0.36	1.17 ± 0.21
Saplings roots	0.18 ± 0.02	0.11 ± 0.02

Effects of deer on soil compaction in fenced and unfenced plots. Roots are the proportion of the carbon pool reported 26 paired 20 m × 20 m plots (Allen et al., 2023). Other comparisons are from NZ Forest Surveys unpublished data from 18 paired 20 m × 20 m deer fenced and unfenced plots from Ruahine FP and Marlborough (Appendix I).

Recommendations – Ngā Tūtohutanga

This review confirms that deer suppress forest regeneration through browsing (Section 1, Background – Papamuri), and have the potential to alter soil hydrology through trampling (Section 2, Soil Hydrology – Te Wai me ngā Oneone). Deer culling will have maximum benefit where there is no current control, where other pest control already occurs, where negative effects are greatest, and where conservation values are highest (Section 3, Threatened Plants – Ngā Tipu Onge). Monitoring of alpine grasslands has been neglected, but there are indications of ongoing decline (Section 4, Alpine Grasslands – Ngā tipu o ngā maunga). Many plants threatened by deer browsing and trampling are important to Māori (Section 5, Rongoā, Appendix II). Keeping these issues in mind, we identify Tararua and northern Ruahine Forest Park as critical sites for deer control. Maintaining monitoring systems that support dynamic decision-making and ongoing adaptive management is essential in Te Tāhuhu (Section 6, Monitoring – Te Aroturuki). Ideally deer and possum numbers would be lowered as much as possible through all of Te Tāhuhu, but we believe that Tararua and northern Ruahine FPs are the most critical.

1. **Measure soil compaction, fine-scale hydrology, litter and forest regeneration in paired fenced and unfenced deer exclosure plots.**
   There were ≈30 paired deer exclosure plots established in Te Tāhuhu between 1970 and 1985, which remain intact. All thirty paired plots should be remeasured at an estimated ≈$100,000. They represent >$1 million in previous government spending (present value). Soil compaction, water storage in soils, litter, soil fertility and tree growth should be compared between fenced and unfenced plots. The experiment is great, the sample size is good, the investment mostly already made, and the effects of deer will become apparent.

2. **Survey threatened plants**
   Our knowledge of the distribution of threatened, at risk and uncommon plants in Te Tāhuhu has massive gaps. Species at risk of extinction that were present, may be no longer. The threat status of these plants in Te Tāhuhu needs to be updated. The decline in the employment of professional field botanists is now showing. Formal surveys by professionals need to be funded. There are also citizen science opportunities that should be encouraged, particularly in Tararua and northern Ruahine FP's alpine zones where over 20 uncommon and declining plant species are found. Seven plant species are endemic (Tararua tupere, Tararua koromiko, Tararua tāramea, Tararua bellflower, *Myrsine umbricola*, *Acaena*

rorida and *Hebe colensoi*). Further intensive survey work may shift their threat status – either up or down. Field searches by tramping clubs and botanical societies should be supported.

3. **Determine threat status of common rongoā**
   Many common plant species in Tāhuhu are in decline. kāpuka, kāmahi, kanono are examples of deer palatable plants that have had their regeneration suppressed for a century. Continued decline may lead to increase risk of local extinction in some cases. The threat status of common rongoā should be determined.

4. **Plan deer control**
   The most cost-effective way to restore Te Tāhuhu forest and alpine grasslands, and at risk species, is to undertake aerial possum and hare control on a 4–8 year cycle, and sustained deer control annually. A strategy that consistently implements pest herbivore management among the five forest parks is required. With adequate funding, both possum and deer densities could be held to near zero densities over all of Te Tāhuhu. Existing deer control is inconsistent among the five forest parks, and is not closely related to areas with the highest presence of endemic plants most threatened by browsing. Culling in Kaweka FP has been delegated to the Game Animal Council as part of a Herd of Special Interest. Their culling avoids stags, regardless of the cost to overall effectiveness. A Ruahine FP Adaptive Wild Deer Management Plan already exists, with culling and subsidised WARO in some areas and not others. Aorangi FP and part of Kaweka FP are gazetted Recreational Hunting Areas. Current deer management in Te Tāhunu is inconsistent, often ineffective, and largely dictated by existing policy and legislation.

5. **Deer control is most critical in two regions in Te Tāhuhu: Tararua and northern Ruahine alpine grasslands.**

   We recommend that deer control is commenced in Tararua FP, where there are large areas of alpine grasslands, herb-fields and shrub belts in urgent need of attention. Kāmahi forests are widespread, relatively intact and highly vulnerable. There is existing goat and possum control, but only commercial and recreational hunting for deer. Over ≈10% of Tararua FP's 114,993 ha is alpine zone, where at risk plants are concentrated[1*]. Alpine grasslands, shrub-lands and herb-fields are slow growing, and consequently highly vulnerable to deer browsing and trampling. Aerial deer control using thermal scopes and targeting deer on alpine grasslands, shrub-lands and slips could be undertaken for $200,000–$300,000 year. That could be subsidised with venison recovery. Recreational hunters should be encouraged to increase hunting effort in forest and on river flats. These areas are productive for ground hunters, but less efficient to aerially hunt, even with thermal cameras and sights.

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   We recommend that deer control is intensified in northern Ruahine FP and extended into adjacent Nga Whenua Rahui land. Current deer and possum control needs to sustain pests at near zero density. The alpine

1* **At risk of extinction in the Tararua alpine zone, in part from deer trampling and browsing:** *Botrychium australe* (pātotara, parsley fern), *Myosotis eximia* and *venosa* (forget-me-nots), *Euphrasia drucei* (Tararua tupere), *Veronica truncatula* (hebe) and *evenosa* (Tararua koromiko), *Ourisia modesta* (foxglove), *Aciphylla dissecta* (Tararua tāramea), *Wahlenbergia pygmaea* subsp. *tararua* (Tararua mountain harebell), *Anaphalioides subrigida* (mountain everlasting daisy), *Leptinella tenella* (button daisy), *Senecio colensoi* (groundsel), *Agrostis pallescens* (bentgrass), *Amphibromus fluitans* (floating swamp grass), *Anthoxanthum cupreum* (copper sweet vernal), *Carex tahoata* (mountain teasel sedge), *Chaerophyllum ramosum* (myrrh), *Carex obtusifolia* (fine-leaved bastard grass), *Celmisia spectabilis* subsp. *lanceolata* (taipo), *Luzula banksiana* var. *rhadina* (coastal woodrush) and *Euchiton paludosus* (cudweed). **Threatened or at risk of extinction in Tararua forests, some by possum, hare and deer browsing:** *Metrosideros robusta* (northern rātā), *Syzygium maire* (swamp maire), scarlet, red and white mistletoes (korukoru, pikirangi, kohuorangi), *Brachyglottis kirkii* var. *kirkii* (kohurangi), *Myrsine umbricola* (Tararua matipo), *Prasophyllum elegantissimum* (elegant leek orchid), *Pterostylis irwinii* (greenhood orchid), *Caladenia atradenia* (Bronze fingers), *Pterostylis tasmanica* (plumed greenhood orchid) and *Corybas dienemus* (helmet orchid). Details are in Appendix III. Data Deficient species are listed in Appendix IV. Many of the threatened or at risk species listed in Appendix III are Data Poor, which means expert opinion was used to make an assessment in the absence of data. Some threatened and at risk species such as *Acaena emittens*, *Ourisia modesta*, *Pimelea hirta*, *Ranunculus simulans* (buttercup), *Scandia rosifolia* (koheriki) not currently known in the Tararua Range may be found with further field survey.

zone, bogs and tussock grasslands of the northern Ruahine ranges are a critical area for conservation. Currently deer control is limited to 50 hours of DOC funded aerial hunting and limited subsidy of commercial recovery on DOC land.

Introduced deer, possums and pest plants do not respect land title boundaries. Deer control needs to be extended into adjacent privately owned forest and tussock grassland, especially where threatened plants are present. Sika deer need to be prevented from colonising northern Ruahine. In Kaweka FP localised beech forest regeneration has been prevented through sika deer browsing (Husheer, 2003; Husheer et al., 2006). There are a suite of alpine plants with threat statuses requiring immediate attention[2*], with threatened and at risk plant diversity highest in northern Ruahine and private iwi land adjacent to the Mangaohane plateau and Aorangi. The heads of Reporoa, Ohutu, Makirirkiri and Waiokotore Streams are particular hotspots. Critically threatened plants such as *Acaena rorida*, *Hypericum minutiflorum* and *Scandia rosifolia* are inadequately protected and surveyed.

Sika deer are currently colonising northern Ruahine FP (Ruahine Corner, 2025).

2* Threatened or at risk of extinction in the northern Ruahine alpine zone and montane bogs, in part from deer and possum trampling and browsing: *Acaena emittens*, *Acaena rorida*, *Agrostis pallescens*, *Anaphalioides subrigida*, *Anthoxanthum cupreum*, *Carex tahoata*, *Carex obtusifolia*, *Carmichaelia nana*, *Euphrasia disperma*, *Myosotis eximia*, *Ourisia modesta*, *Ourisia vulcanica*, *Pimelea hirta*, *Scandia rosifolia* (koheriki).

6. **Remeasure existing alpine grassland and forest monitoring plots.**
From 1958–1984 >200 alpine grassland plots were established above Tararua, Ruahine and Kaweka treelines. These plots should be remeasured, along with additional representative plots. From 1974–2012 a network of 20 m × 20 m forest plots was established in Te Tāhuhu to monitor the effects of deer on forest regeneration. These plots should be remeasured on an annual rotation over a decade, for minimal annual cost. Any additional deer control in Tararua FP would prompt plot measurement there, with a focus on plots in kāmahi forest (Appendix VII).

	Annual Cost	
Tararua Forest Park		
Deer control Tararua FP	\$200,000–\$300,000	Ongoing over ten years.
Measurement of thirty 20 m × 20 m plots on 13 random lines (2–9 plots a line).	≈\$20,000	Completed in 2–4 years
Additional plots (10–20) in Tararua kāmahi forest.	≈\$10,000	Completed in 2–4 years
All Te Tāhuhu		
Inspect and maintain paired exclosure plot fences	\$10,000	One month in 2026
Determine forest regeneration, soil compaction and water storage in sixty fenced and unfenced plots (30 pairs)	≈\$100,000	Completed in 1–2 years
Grassland plots, >200 remeasured & >100 new random plots.	≈\$20,000	Completed in 2–5 years
Measurement of ≈100 existing 20 m × 20 m forest plots on a 5–10 year rotation in Aorangi, Remutaka, Ruahine and Kaweka FPs	≈\$60,000	Completed in 5 years

Contents – Ngā Ihirangi

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1 Background – Papamuri

Browsing by red and sika deer removes fast-growing seedlings of large-leaved tree species in the Forest Parks encompassing the axial ranges of the lower North Island. To surrounding iwi the mountain ranges are Te Tāhuhu o Te Ika-a-Māui, or Te Tāhuhu[3*]. Even at low deer densities ($<$1 deer km^{-2}) species such as kāmahi (*Pterophylla racemosa*), large-leaved coprosma (*Coprosma grandifolia*), mahoe (*Melicytus ramiflorus*), three finger (*Raukaua simplex*), and broadleaf (*Griselinia littoralis*) are prevented from regenerating in Te Tāhuhu. When deer densities were reduced by up to 90% during previous periods of intensive commercial harvesting (between 1970 and 1985), palatable species did not have enough time to grow high enough to escape future browsing. This pattern has been consistently documented in many studies using 20 m $\times$ 20 m forest monitoring plots (Husheer et al., 2005; Urlich et al., 2007; Wright et al., 2012; Allen et al., 2023; Hawcroft et al., 2024). In New Zealand indigenous forests, even "fast-growing" species grow very slowly. In montane forests, typical height growth rates are only 5–10 cm year^{-1}. At sea level, growth of $\approx$20–40 cm year^{-1} can be observed. As a result, deer densities probably need to be reduced to near zero for at least two decades before even fast-growing palatable species have a realistic chance of growing above the browse tier ($>$2 m). These densities are incompatible with successful recreational hunting.

Without adequate regeneration, some forest types are at risk of canopy collapse within the next few decades. Well-documented examples include tall kāmahi forest in the Ruahine Ranges that has been converted to fern and scrubland through combined deer and possum browsing (e.g. Crump 1960; Rogers and Leathwick, 1997; Appendix IX) and mountain beech forest collapse in Kaweka FP (Husheer and Tanentzap, 2024; Figure 1). Large-scale beech forest decline in the Ruahine Range over the last two centuries has coincided with distinct climatic "erosion periods" driven by storms, gales and drought rather than by animal impacts alone (Grant, 1991). Tararua FP kāmahi forests have not widely collapsed. This could be because factors other than possum and deer browsing are more important, or localised collapse is occurring but is not understood due to inadequate monitoring. Husheer (2005) concluded that ongoing deer browsing in Tararua kāmahi forest was preventing canopy regeneration,

the Department of Conservation Kaihautuu Matarautaki Lower North Island Region.

3* The Great Supporting Spine of the Fish of Maui. Te Āti Awa, Ngāti Kahungunu, Rangitane, Ngāti Raukawa, Ngāti Toarangatira, Ngāti Tūwharetoa are large iwi who have interests in Aorangi, Remutaka, Tararua, Ruahine and Kaweka Forest Parks (FPs), which are the main DOC motu protecting Te Tāhuhu.

and that large scale natural disturbance would lead to long term loss of tall forest. Tier 1 monitoring plots suggest that kāmahi forest is declining nationally, with continued suppression of regeneration by deer browsing likely to be a major contributing factor (MacLeod et al., 2024). This decline is already having a large and measurable effect on the amount and value of carbon stored in kāmahi and kāmahi-podocarp forests (declining at >0.3 tonnes ha^{-1} yr^{-1}; Bufford et al., 2025). Because even fast-growing species take many decades to fill canopy gaps, claims of rapid and substantial carbon gains (i.e. within decades) following deer culling in intact tall forests are tenuous (Allen et al., 2023). In contrast, reducing deer numbers for several decades will be critical for century-scale carbon sequestration in regenerating forests, or in tall forests that are already collapsing. Continued failure of canopy regeneration will inevitably have major impacts on carbon storage, flood flows, hydrological processes and soil erosion, although these processes typically unfold over decades to centuries (Peltzer and Nugent, 2023; Norton et al., 2016). It is also intuitive that soil compaction, loss of ground cover, and canopy collapse will influence flood flows, but these effects remain poorly understood and are likely to vary between catchments.

Deer control in Te Tāhuhu has been inconsistent, with multiple agencies failing to hold deer to low numbers. DOC has never spent more than 300 professional hunter days or 80 helicopter hours controlling deer in any year in all of Te Tāhuhu over the past three decades. In most years DOC has relied on recreational hunters, and little useful effort has been expended. Acclimatisation Societies were originally responsible for the introduction and protection of deer up until the 1930 "Deer Menace Conference", when responsibility was passed to the Wildlife Branch of the Department of Internal Affairs who initiated limited deer culling in selected valleys (Hunter, 2009). Following the introduction of the Noxious Animals Act 1956 (and the Wild Animal Control Act 1977) the New Zealand Forest Service tended to treat the five parks in Te Tāhuhu as a single entity. They established a network of 2, 4 and 6 bunk huts, tracks and roads in Te Tāhuhu to aid deer culling (S86 Dog Box Bivs and S81 4 bunk >30; S70 >30; Kelly, 2007).

While record keeping has been poor, perhaps one hundred thousand deer were shot by Forest Service ground hunters in Te Tāhuhu between 1956 and 1987, with a similar number harvested by commercial hunters during the deer recovery boom from 1968 to 1984. Ground hunting was largely unsuccessful at restoring forest regeneration because too few competent and motivated hunters were available to reduce deer densities to very low levels (Appendix X). Sustaining high hunting effort becomes increasingly difficult once deer densities fall below $\sim$1 km^{-2}, where even highly experienced professional hunters with well-trained indicating dogs may encounter only one deer every 1–2 days. In these conditions, most recreational hunters would encounter a deer only about once a week and have roughly half the probability of shooting it (Husheer, 2018). Only a small proportion of hunters are successful at low deer densities because they work hard and are more skilled. Over 80% of deer are shot by fewer than 30% of hunters (Nugent, 1988, 1992; Rowland et al., 2023). Unskilled hunters are generally successful only when deer densities exceed 5 deer km^{-2}, and those 70–80% probably lack the physical ability to hunt effectively throughout Te Tāhuhu. Commercial deer recovery has also failed to provide sustained control. Venison prices exceeded \$1 kg^{-1} in the 1970s ($\sim$\$20 today) and \$5 kg^{-1} in the 1980s ($\sim$\$16 today). Over the past three decades, prices have generally remained below \$5 kg^{-1}, making commercial harvesting uneconomic. Consequently, deer populations have increased, and aerial CPU rates remain high (Table 1). In some 1 $\times$ 1 km cells in Kaweka and Kaimanawa FPs, deer densities may even exceed 40 deer (CNIS, 2026).

Recreational hunters are ageing and their physical fitness is declining. The recruitment of younger hunters has not offset this demographic shift (Fraser and Sweetapple, 1992; Nugent and Fraser, 2005; Apollonio et al., 2010; New Zealand Government, 2013; Ministry for Primary Industries, 2020). Hunters are less able to undertake demanding hunting and access remote terrain, so the ability of the average recreational hunter to contribute to effective deer population control is declining. At the same time, recreational hunter organisations have become increasingly influential at advocating for restrictions on deer control operations aimed at reducing deer to zero density (Austin et al., 2013; Diefenbach et al., 2021; Lovelock et al., 2022). All of Aorangi FP and part of Kaweka FP are gazetted as Recreational Hunting Areas (RHA). Deer control in Kaweka FP is managed by hunter groups as part of a protected herd under the Game Animal Council Act 2013. Deer control is opposed in Recreational Hunting Areas, with for example lobbying by The Aorangi Hunters Group (Ozarski, 2015). Previous studies suggest that commercial and government-funded culling can remove more deer from New Zealand forests than recreational hunters, because interest in sport hunting declines as deer populations are reduced. For example, $>$1 deer km^{-2} year^{-1} have been removed by commercial and government cullers in forests vs. $<$1 deer km^{-2} year^{-1} where only sport hunting is allowed (e.g Nugent and Fraser, 1993; Peltzer and Nugent, 2023). The combination of sport hunting and culling stabilised wild deer densities in most New Zealand forests by 2000 at $\approx$5 deer km^{-2} (likely range 1–20 deer km^{-2}) , following peaks $>$50 deer km^{-2} (Challies, 1977; Nugent et al., 1987, 1997, 2011). Despite unrestricted recreational hunting throughout New Zealand public conservation land, deer densities have increased in the past two decades following reductions of both commercial and government-funded hunting due to increased costs, reduced funding, greater restrictions and lower commercial returns (Moloney et al., 2021; Leathwick and Byrom, 2023).

Figure 1: Paired exclosure plot at Te Pukeohikarua in Kaweka FP in May 2017, established 1998. This is an extreme example of canopy collapse, mountain beech regeneration failure, and the increased dominance of browse-resistant turfs and small-leaved shrubs.

Forest Park	**Year**	**Hours flown**	**Deer shot**	**CPU**	**Source**
Kaweka	2026	38			Hours allocated
Ruahine	2024/25	48.7	727	14.9	DOC, 2025c
Kaimanawa	2024	35	317	9.1	Sika Foundation, 2025
Kaimanawa	2023	40	343	8.6	Sika Foundation, 2024
Kaweka	1998–2016	22–76	58–495	2.4$\pm$0.2	Husheer, 2018
Tararua	1975			12	Husheer, 2005

Table 1: Numbers of hunting hours in aerial deer culling operations, numbers of deer shot, and source of results. Kaweka 1998–2016 is the range of annual hours flown, deer killed and mean CPU (deer shot hour^{-1} flown, range 0.8–4.1). CPU declined in Kaweka from 2010 when culling becomes selective for small stags and hinds. Flying costs were $2,300 hour^{-1} in Ruahine in 2025. CPU is catch per unit effort, or the number of deer killed (not recovered) for each hour flown including ferry time to the area. Kaweka and Kaimanawa hunting was focused on forest.

2 Soil Hydrology – Te Wai me ngā Oneone

There is strong inferential evidence linking soil compaction by deer in Te Tāhuhu forests with reduced pore size in soils, which in turn leads to reduced water storage, increased surface water flow in flood events, increased suspended sediment and nutrient loss, and increased soil erosion. There is also inferential evidence that dense litter layers and intact forest canopies reduce peak flood flows and soil erosion. There are no empirical studies directly connecting wild-deer trampling and reductions in soil litter specifically to compromised catchment-scale hydrology in New Zealand. The main evidence is built by combining New Zealand deer exclosure data on soil bulk density with international soil compaction and hydrology literature drawn from pastoral and forestry studies. Given projected increases in storm intensity (Sigid et al., 2026) and the already-high natural erosion rates of New Zealand's steep terrain (Hicks et al., 2000; Korup et al., 2004), Te Tāhuhu soils remain at risk of erosion. Reduced soil water storage makes Te Tāhuhu forests more vulnerable to widespread drought-induced canopy collapse, just when climate change is making extreme drought events more common. There is an urgent need to undertake research on the direct links between soil compaction by deer, canopy cover, litter quality and quantity, root biomass, and water storage, peak flood flows and soil erosion.

2.1 Effects on soil bulk density and compaction

Until the 1980s, high deer densities in New Zealand's mountains were widely believed to accelerate bedrock erosion, trigger landslides, and increase gravel yields by removing protective vegetation (New Zealand Forest Service, 1950; Holloway, 1950; Wardle, 1961; coarse gravel being >10–25 mm). The perceived problem was taken so seriously that the NZ Forest Service undertook exotic planting programmes in Kaweka and Ruahine Forest Parks on "problem sites" where erosion was observed in catchments critical for flooding (e.g. the Ngaruroro, Tutaekuri and Pohangina Rivers; Cunningham, 1965, 1974, 1979). Subsequent research showed that although deer can strongly influence forest regeneration, their direct impact on landscape-scale geological processes is minor compared with the effects of tectonic uplift, intense rainfall and extreme storm events (Caughley, 1983; McSaveney and Whitehouse, 1989; Williams, 1991; Bellingham and Lee, 2006).

In contrast, deer trampling has well-documented effects on soil physical properties. Deer consistently compact forest soils through hoof trampling in New Zealand. Kardol et al. (2014) reported soil bulk density ≈9% higher in unfenced plots than paired deer exclosures (0.48 ± 0.05 vs. 0.43 ± 0.05 g cm^{-3};

including Aorangi, Remutaka and Kaweka Forest Parks, and Boundary Stream Scenic Reserve). This is associated with declines in plant growth, reductions in the positive effect of arbuscular mycorrhizal fungi, organic content and soil health (Lehmann et al., 2020; Obalum et al., 2017; Bünemann et al., 2018). Data from other New Zealand paired exclosure plot studies in conservation forests showed a similar pattern, with soil bulk density $\approx$12% higher outside fenced plots (389.4 vs. 346.3 Mg ha^{-1}; Appendix I; including Ruahine Forest Park). The primary mechanism is hoof-induced compression, where concentrated point loads deform soil aggregates and collapse macropores (Duncan and Holdaway, 1989; Horn and Lebert, 1994). Compaction is greatest when soils are wet and depends on animal size and vegetation cover (Taboada et al., 2011). Because soil bulk density and porosity are inversely related, trampling substantially reduces soil pore space (Håkansson and Lipiec, 2000; Stolf et al., 2011). Macropores may be $<$2% of soil volume but make up nearly all of water storage, so small increases in soil density can have large effects (Alaoui and Helbling, 2006).

Results from New Zealand indigenous forests are consistent with agricultural and international studies. Trimble and Mendel (1995) reviewed grazing studies reporting $\approx$8% increases in soil bulk density under heavy grazing. Drewry (2006) synthesised decades of research from New Zealand and Australia, showing that livestock trampling consistently increased bulk density while reducing macroporosity, particularly on poorly drained soils and during wet periods. Similar mechanisms are likely to operate in native forests and alpine ecosystems affected by introduced ungulates such as red and sika deer. In Fiordland, larger wapiti (*C. canadensis*) are likely to exert even greater trampling pressures. Gass and Binkley (2011) recorded a 25% increase in bulk density under intensive elk grazing in the Rocky Mountains, together with 23–25% declines in soil carbon and nitrogen relative to fenced exclosures.

The ecological consequences of soil compaction are far-reaching. Deer can reduce soil organic matter and nutrient concentrations, including phosphorus and nitrogen (Kumbasli et al., 2010; Maillard et al., 2021). Reduced observed mycorrhizal performance in compacted soils may result from poorer soil aeration and restricted hyphal growth caused by changes in pore-size (Nadian et al., 1998; Drew et al., 2003). The most consistent effect of deer reported by Wardle et al. (2001) was a reduction in a wide range of macroinvertebrates through trampling. Collembola, Curculionidae, Hydrophilidae, Isopoda, Araneae, Opiliones and Chilopoda all showed substantially lower abundance where deer were present (Appendix XI).

2.2 Consequences for infiltration and water storage

Soil compaction and reduced infiltration are universal consequences of grazing systems worldwide, reducing water storage while increasing flood flows and soil erosion (Stavi et al., 2009; Kgosikoma et al., 2013; Mihailou and Massaro, 2021). Compaction reduces macroporosity, infiltration capacity and plant-available water storage (Alaoui et al., 2018; Xu et al., 2018), increasing the proportion of rainfall converted to surface flow and thereby promoting runoff, erosion and sediment delivery to waterways (Asner et al., 2004). Where erosion is substantial, losses of soil C, N and P may also be important, although these have rarely been quantified. Effects are likely to be greatest on wet soils with low litter inputs, in steep terrain and where ungulate densities are high. Forest-compaction studies show reductions in saturated hydraulic conductivity of up to 40% following mechanical compaction, with effects persisting for years without full recovery (Nazari et al., 2021).

In New Zealand, Curran Cournane et al. (2011) found that compaction reduced soil aeration, and increased surface runoff and losses of suspended sediment and phosphorus. New Zealand landscapes are inherently susceptible to erosion because of their steep topography, erodible lithology and high-intensity rainfall. Deforestation and the introduction of grazing mammals have further accelerated erosion rates (Basher, 2013). Climate change is projected to increase soil erosion in soft-rock hill country in the future (Neverman et al., 2023). Consequently, any trampling-induced increase in surface run off between hillslopes and streams is likely to become increasingly important as storm intensity increases. The available evidence strongly indicates that deer increase soil compaction and are likely to influence nutrient loss, water storage, erosion and flood generation in Te Tāhuhu. The remaining question is: what is the magnitude of these effects relative to other drivers including forest type, geology, drought and extreme rainfall events?

2.3 Water storage and drought

During droughts, deer may deliver a double blow to forests already close to their physiological limits, through both trampling and browsing. Trampling reduces the capacity of soils to store water by decreasing pore space, while browsing-induced reductions in vegetation and litter cover can further increase evaporative losses (Patiño et al., 2021; Fleischner, 1994). Ngo-Cong et al. (2021) showed that relatively modest (10–20%) increases in bulk density reduced cumulative infiltration by >50% and plant-available water storage by up to 50%. Compaction effects have been recorded to depths of 30 cm (Lai and Kumar, 2020; Appendix I). Owuor et al. (2016) showed that compaction-induced reductions in infiltration and hydraulic conductivity also reduce groundwater recharge, demonstrating that the hydrological consequences of trampling extend beyond the near-surface. Similar processes have been documented in alpine ecosystems in the European Alps, Rocky Mountains and Tibetan Plateau, suggesting that alpine environments in Te Tāhuhu may be likewise affected (Williard et al., 1999; Gobet et al., 2003; Teng et al., 2020; Ma et al., 2022).

Historical droughts have caused widespread canopy dieback in New Zealand forests (Jane and Green, 1983; Wyse et al., 2018; Bellingham and Peltzer, 2024). Future increases in drought severity may therefore be exacerbated by deer-induced reductions in soil water storage. For example, remnant kāmahi forests in Hawkes Bay and Wairarapa may be close to their drought tolerance limits (Singers and Rogers, 2014), so a combination of soil compaction, lowered litter inputs, possum browsing and increased water deficits may increase canopy dieback. Kāmahi is highly palatable to deer, so is unlikely to regenerate following canopy collapse.

3 Threatened Plants – Ngā Tipu Onge

New Zealand is a global priority for biodiversity conservation because of its exceptionally high endemism, particularly among alpine plants and seabirds (Tables 2 and 3, Appendix XII). Our threatened and at risk biota are vulnerable to climate change, weeds, habitat loss and introduced mammals (Lee et al., 2005; Myers et al., 2000). Consequently, New Zealand is consistently identified as one of the world's highest conservation priorities. Although the <100 species of birds restricted to forests often receive the greatest conservation funding, they contribute relatively little to global prioritisation. New Zealand supports >1,300 endemic vascular plant species (of >2,800 total vascular plant species; de Lange et al., 2009), vs. 216 resident native bird species (nearly 100 are seabirds, and >175 are classified as threatened or at risk; DOC, 2020). In most parts of the world plant richness declines with altitude. But our alpine zone is a particular hotspot for plants. There are >600 endemic vascular plants occurring in New Zealand's alpine and sub-alpine zones (Mark, 2021), of which ≈250 are threatened or at risk. Despite this, alpine plant conservation receives comparatively little funding. New Zealand's remarkable alpine endemism (>90% of species) arose largely through rapid Pleistocene speciation, as repeated glaciations isolated populations and promoted diversification. Only one known plant species has become extinct since European colonisation, but 59 birds have become extinct since human colonisation (≈1280 AD; Robertson et al., 2017a). The extinction process for birds may have peaked, but for plants appears to be currently accelerating.

Conservation prioritisation also tends to overlook the North Island alpine zone. Although small in area (Table 4), it supports a disproportionately high number of threatened species. Botanical research has focused primarily on the South Island, possibly because it contains about 80% of New Zealand's alpine flora, compared with only 50% in the North Island. The more extensive alpine environments of the Southern Alps, together with mountain uplift, glaciation and geographic isolation, have driven high species diversity and rapid speciation.

Te Tāhuhu supports numerous threatened forest plants. All four showy mistletoes are classified as at risk–declining: *Peraxilla tetrapetala* (red mistletoe); *Peraxilla colensoi* (scarlet mistletoe); *Tupeia antarctica* (white mistletoe); and *Alepis flavida* (yellow mistletoe). Additional survey effort may locate further uncommon and threatened species, including the North Island cliff tussocks *C. flavicans* and *C. beddiei*, and the herbs *Hypericum minutiflorum*, *Ranunculus recens*, *Atriplex cinerea* and *Acaena rorida*. Species such as kākābeak *Clianthus* *maximus* could be re-introduced following effective pest control. Browsing and trampling threaten not only common forest and grassland species but also many uncommon plants. The relatively small alpine areas of Tararua, Ruahine and Kaweka contain approximately 8 of the 16 threatened plant species recorded from Te Tāhuhu, and 25 of its 34 At Risk species. Tararua FP supports four alpine species found nowhere else (Figure 2. Northern Ruahine is a hotspot for small and innocuous threatened and at risk plants. Many of these plants are vulnerable to trampling, while some may actually require disturbance to release them from competition (Figure 3).

The number of professional field botanists employed by DOC has declined. This has lead to a tragic decline in our awareness of the status of threatened species. The tier 1 monitoring program has provided excellent training opportunities for a new generation of botanists. Beyond that, there are few opportunities for them to develop into professional threatened species field botanists. Members of botanical and tramping clubs are aging and becoming less active. Promotion of young field botanists, who know how to survey for and identify threatened plants, needs to be encouraged. The permitting procedure for plant surveying and procedure needs to be more efficient, as some botanists report unnecessary delays in permitting.

Genus	**Family**	**Number of species**
*Aciphylla**	Apiaceae	$\sim$40
*Celmisia**	Asteraceae	>60
*Chionochloa**	Poaceae	$\sim$25
Epilobium	Onagraceae	$\sim$35
*Hebe**	Plantaginaceae	$\sim$90
*Leptinella**	Asteraceae	>30
Myosotis	Boraginaceae	$\sim$45
Ourisia	Plantaginaceae	$\sim$20
Poa	Poaceae	>40
Ranunculus	Ranunculaceae	$\sim$40

Table 2: Number of indigenous vascular plant species for important genera contributing to alpine diversity in New Zealand. An asterisk (*) indicates a genera strictly endemic to New Zealand. Several genera (e.g., *Celmisia*, *Aciphylla*, *Hebe*, *Myosotis*, and *Ranunculus*) contain major radiations with high levels of endemism at the species and sub-species, particularly in the alpine zone. >80% of New Zealand's >2,359 vascular plants are endemic, along with $\approx$65 endemic genera. The only family of vascular plants strictly endemic to New Zealand is Ixerbaceae, containing only *Ixerba brexioides* (tāwari; if not merged with Strasburgeriaceae).

Figure 2: All four plants endemic to Tararua are classified as nationally at risk of extinction: *Euphrasia drucei* (Tararua tupere); *Hebe evenosa* (Tararua koromiko, *Veronica*); *Aciphylla dissecta* (Tararua tāramea); and *Wahlenbergia pygmaea* subsp. *tararua* (Tararua bellflower). There are no records of these species outside Tararua FP. Recent survey work is entirely inadequate and their status within their restricted range in the Tararua alpine zone is uncertain. The Tararua forest *Myrsine umbricola* (Tararua matipo) is classified with the more serious threat status of nationally vulnerable to extinction. There are two known populations; one in Ruahine FP, and the main population in a 10 ha area of Tararua montane silver beech forest (*Lophozonia menziesii*; 800–1200 m a.s.l.; Enright et al., 2026). There may be <500 plants in the wild, with regeneration suppressed by deer (Heenan and De Lange, 2004). It appears to be more palatable than the closely related *Myrsine divaricata* and may also be browsed by possums and hares. Status information and photos are copied from www.nzpcn.orgnz.

Figure 3: Several plants found in the northern Ruahine range have threatened status of critical. While some may benefit from deer disturbed soils, they are also vulnerable to trampling. *Acaena rorida* is found only on the Mangaohane plateau. Status information and photos are copied from www.nzpcn.orgnz.

Region	Regional endemic species richness	Threatened species	Distinctive habitats	Example species
Te Tāhuhu – North Island Axial Ranges + surrounding areas	∼25–40	∼10–15	Alpine-tussocklands, greywacke-mountains, sub-alpine shrublands	*Wahlenbergia pygmaea*[3,4] (two subspecies), *Senecio colensoi*[2,3], *Scandia rosifolia*[1,4], *Raoulia albosericea*[3,4] and *rubra*[2,3,4], *Ranunculus nivicola*[4], *Parahebe hookeriana*[3,4] and *spathulata*[3,4], *Ourisia vulcanica*[2,3,4], *Myosotis eximia*[2,3,4], *Hypericum minutiflorum*[1,3], *Hebe colensoi*[2,3], *Hebe tetragona*[3,4] (two subspecies), *Gaultheria colensoi*[3,4], *Euphrasia drucei*[2,3,4], *Anaphalioides subrigida*[2,3,4] *Aciphylla dissecta*[2,3,4]
Northwest Nelson & Kahurangi	∼60–70	∼15–25	Marble and limestone karst, ultramafic, isolated ranges	*Pachycladon exile*, *Celmisia allanii*, *Ranunculus tenuicaulis*, *Myosotis spathulata*
Eastern Marlborough (Molesworth)	∼50–60	∼15–25	Dry basins, limestone ranges, screes, alluvial outwash plains	*Carmichaelia hollowayi*, *Aciphylla ferruginea*, *Myosotis brockiei*, *Lepidium oblitum*
Eastern Otago & Canterbury Drylands	∼40–50	∼20–30	Schist tors, loess bluffs, dry terraces, braided riverbeds	*Carmichaelia curta*, *Lepidium sisymbrioides*, *Myosotis pygmaea*, *Cardamine sciaphila*
Canterbury–Westland Southern Alps	∼35–45	∼10–15	Alpine fellfields, snowbanks, glacial valleys, high screes	*Ranunculus godleyanus*, *Haastia pulvinaris*, *Aciphylla dobsonii*, *Myosotis uniflora*
Fiordland	∼15–30	∼2–5	Wet alpine herbfields, snowbanks, wet cliffs	*Dracophyllum fiordense*, *Hebe catarractae*, *Hebe notialis*, *Aciphylla takahea*
New Zealand region-endemic seabirds	∼20–25	∼15–20	Subantarctic islands, offshore islands, coastal cliffs, island refugia, pelagic breeding colonies	Hutton's shearwater, Westland petrel, Whenua Hou diving petrel, Yellow-eyed penguin, Stewart Island shag, Chatham petrel, Magenta petrel

Table 3: Comparison of New Zealand regions with high plant endemism and species richness, in part due to the presence of alpine grasslands. Te Tāhuhu includes Aorangi, Rimutaka, Tararua, Ruahine and Kaweka Forest Parks. Kahurangi, Marlborough and eastern drylands have higher diversity due to their larger area and more complex geology. More detail in Appendix III

Endemic richness counts are of species restricted to that region (subspecies and varieties excluded); threatened endemics are species with NZ threat classifications found in that region (but not neccesarily restricted to it; de Lange et al., 2024).
1 Threatened. **2** At Risk. **3** Endemic to general region of Te Tāhuhu and central NI. **4** listed in Mark "Above the Treeline".
Scandia rosifolia and *Hebe colensoi* are absent from Mark (2021). Although they are more commonly found on low to sub-alpine cliff faces, they meet the inclusion criteria for an alpine plant as they may be absent from alpine bluffs due to browsing from deer and hares (Elder, 1938). Lists for species include DOC (2025a); Allan (1961); Webb et al. (1988); Wardle (1991); Wilson (2013); Robertson et al. (2017b); Heather and Robertson (2005); Marchant and Higgins (1990); Scofield and Stephenson (2013); BirdLife International (2025); New Zealand Birds Online (2025); DOC (2025b).

4 Alpine Grasslands – Ngā tipu o ngā maunga

Rather than pursuing deer eradication to protect alpine grasslands, DOC has maintained a free-ranging deer population throughout Te Tāhuhu. Current management resembles a poorly run deer farm operated for the benefit of several thousand recreational hunters, more than nature conservation aimed at protecting endemic plants at risk of extinction. Deer control is largely limited to intermittent aerial culling (Table 1). Relying on a combination of commercial and recreational hunters has not reduced populations, and deer across Te Tāhuhu are poorly controlled. Hunter effort and harvest rate, deer numbers and their reproductive rates are all unknown. The available forage and dietary requirements of deer browsing on alpine plants are unknown. Most importantly for conservation, the impacts on protected alpine plants are unknown, with no plans for monitoring in place. You cannot know whether management is succeeding unless you first know what is changing (Kelvin, 1889). The $\approx$30,000 ha of tussock grassland could probably sustain $>$3,000 or 1 deer km^{-2}, making this a substantial deer farm in its own right – equivalent to a 1,000–2,000 ha commercial farm (Table 4). Unlike a commercial deer farm, deer are sustained within a protected ecosystem of high conservation value, where browsing threatens internationally significant alpine vegetation. Farms, managed with productive pasture and selective breeding for animal health and trophy quality provide substantially better deer for hunters than the depleted alpine environments of Te Tāhuhu. If DOC continues to provide hunting opportunities rather than reducing deer impacts, a more effective approach would be to redirect some of the resources currently spent maintaining huntable populations in remote conservation land towards supporting access to purpose-managed deer farms. Such an approach would also address the practical challenges facing most recreational hunters, including increasing age and declining fitness, and the increasing cost of helicopter access to remote huts (Parkes, 2003; Hansson-Forman et al., 2020; MOH, 2024; MSC, 2025). The alpine grasslands of the North Island's axial ranges are no place for a deer farm.

Name	Area (ha)
Kaweka Forest Park	4,376
Ruahine Forest Park	14,834
Tararua Forest Park	7,690
Te Tāhuhu	26,901
North Island	88,340
South Island	3,322,518

Table 4: Estimated size of alpine zones. Defined by mean annual temperature $<6.5\,^{\circ}$C.

Likely decline in alpine vegetation

Alpine herbfields and tussock grasslands appear to have deteriorated over the past six decades in the three Te Tāhuhu forest parks with alpine zones (Section 6, Appendix XIII). A century of browsing in Tararua, Ruahine and Kaweka FPs appears to have reduced snow tussock cover, diminishing the shelter it provides for alpine herbs such as *Raoulia*, *Ranunculus* and *Myosotis*. Wardle (1961) observed that on some slopes steeper than 30° in the Tararua subalpine zone, deer had eliminated *Olearia colensoi*, leaving bare ground, browse-resistant turf communities and the unpalatable *Chionochloa conspicua*. Husheer (2005) reported on a 1985 re-measurement of Tararua plots, and his results supported Wardle (1961). Between 1958 and 1985 there was a decline in *Olearia colensoi*, and increases in *Chionochloa conspicua* subsp. *cunninghamii*, *Phormium cookianum*, *Poa colensoi* and *Viola filicaulis*. It was unclear from his unsophisticated analysis if there were any changes in *Chionochloa flavescens*, *C. pallens* or *Celmisia spectabilis*.

The strongest evidence for ungulate impacts on New Zealand alpine vegetation comes from the Murchison Mountains, northern Fiordland and the central Southern Alps. Rose and Platt (1987) showed that after helicopter hunting reduced red deer numbers between 1969 and 1984 in Fiordland, recovery occurred primarily in heavily browsed, fertile *Chionochloa pallens* snow tussock grasslands. Less palatable communities dominated by *C. crassiuscula* and *C. acicularis* changed little. Large herbs such as *Ranunculus lyallii*, *Anisotome haastii*, *Celmisia verbascifolia*, *Celmisia holosericea*, *Dolichoglottis lyallii* and *Ourisia macrocarpa* remained vulnerable to browsing. They continue to decline throughout Fiordland (Whitehead et al., 2024). Experimental work by Lee et al. (1988) concluded that full recovery may require decades even after browsing pressure is removed. Using permanent plots in the Murchison Mountains, Tanentzap et al. (2009) similarly found increases in snow tussock height and shrub stature, but little recovery of most palatable species. They concluded that even low deer densities continued to suppress regeneration through selective browsing. Browsing by introduced Himalayan tahr (*Hemitragus jemlahicus*) in the Southern Alps continues to suppress regeneration of snow tussocks (*Chionochloa* spp.), mountain buttercups (*Ranunculus* spp.) and speargrasses (*Aciphylla* spp.), with contemporary vegetation still reflecting historical over-browsing (Cruz et al., 2017). Husheer and Moore (2024) showed the gradual reduction in native herbaceous plant cover and biomass on Molesworth tussock grasslands with grazing, and that recovery would take decades. Where grazing is prevented or reduced in South Island drylands, native species richness can slowly increase (Mark et al., 2011; Walker et al., 2014; Whitehead et al., 2014). Following reductions in deer, introduced hares (*Lepus europaeus*) may become the dominant vertebrate browsers in alpine grasslands. Hare browsing suppresses regeneration of snow tussocks and other palatable alpine species, although their effects vary among habitats and remain less well quantified than those of deer and tahr (Rose and Platt, 1992; Wong and Hickling, 1999; Perry, 2003). Collectively, these studies show that alpine vegetation recovers only slowly following deer control, with recovery largely confined to productive *C. pallens* grasslands and remaining incomplete for many highly palatable alpine herbs.

5 Rākau kai me rongoā – food and medicinal plants

Rongoā Māori and kai rākau are medicinal and food plants known to Māori, particularly tohunga rongoā. We compiled lists of common, at risk and threatened plant species that occur in Te Tāhuhu (Appendix II and Appendix III), and mapped their distributions (Appendix V and Appendix VI). From known literature and the whakapapa of Kerenapu, rongoā species were listed. Identifying rongoā among uncommon and threatened plants was challenging because many traditional names refer to groups of plants, rather than formally described species. For well-known plants such as puka, pirita and taramea, correspondence between Māori and scientific names was generally straightforward. Because botanical nomenclature has changed over time, with many species transferred to different genera, historical references were cross-checked against the New Zealand Plant Conservation Network (NZPCN) database to determine currently accepted names and synonyms.

Relatively little information is available on alpine rongoā species. Nevertheless, several genera represented in the alpine flora, including *Hebe*, *Brachioglottis*, *Pimelea*, *Acaena* and *Senecio* have documented medicinal uses. Most rongoā plants described in the literature are common species, but closely related alpine species may have served similar purposes. More knowledge may be retained within local hapū and iwi traditions.

Riley (1994) provides several historical accounts linking medicinal plants with particular regions. One example concerns taramea from the Tararua Range. Although the species is not named, the location strongly suggests either *Aciphylla colensoi* or possibly *Aciphylla dissecta* (Tararua taramea).

Where individual species lacked documented rongoā uses, evidence at the genus level was considered. Geographic distributions described in historical accounts were compared with the known distributions and altitudinal ranges of threatened species to assess whether a particular species was likely to have been used. For example, Riley (1994) describes several species of koromiko (*Hebe*) and records multiple regional Māori names. Given their close morphological similarity, it is plausible that alpine species resembling lowland koromiko were used in comparable ways by travelers crossing mountain ranges, particularly for treating gastrointestinal ailments such as diarrhea, constipation, and stomach complaints.

Several endemic orchid species were recorded as food plants, with their underground tubers eaten. Similarly, many grasses, rushes, and tussocks were not valued as medicines, but as important natural resources. Their waterproof foliage was widely used for thatching shelters and for weaving rain capes.

Many rongoā are also canopy dominants. They can form grassland, forest, wetland and shrubland canopies. They can help regulate hydrological processes and are important stores of carbon. Nationally, estimates of carbon stocks in tall forest appear to show decline for forest types known to include rongoā (e.g kāmahi, podocarp and beech forests: tawhai, tawhairaunui, tawhairauriki).

Use of ancient sedimentary DNA can extend our understanding of rongoā to centuries or millennia. Sediment cores contain ancient DNA that can be compared with reference genomes to show how abundance has changed over long periods.

6 Monitoring – Te Aroturuki

Te Tāhuhu has a high-quality forest and alpine grassland monitoring network that meets modern scientific standards. It is comprised of 20 m $\times$ 20 m permanent forest plots (including representative plots on lines and paired exclosures n $>$ 900) and 40.2 m alpine grassland plots (n $>$350), that were established throughout Te Tāhuhu between 1958 and 1986 (Tables 5, 6 and 7, Appendix VII). The network is representative, directly measures vegetation change and regeneration, is properly replicated statistically, and uses well-tested standardised methods. Following remeasurement, even a subset of plots will immediately provide local operations managers with a record of forest and grassland health spanning more than five decades. The network has largely been overlooked by DOC. Instead, resources have been directed towards expensive and inefficient national monitoring programmes designed to justify policy, despite providing little useful operational guidance. Measurement of alpine grassland plots in Te Tāhuhu ceased following the formation of DOC in 1987, along with a decline in survey effort for uncommon, data deficient, threatened and at risk plants. The network was established to answer the same questions on tussock grassland and forest regeneration that remain key to contemporary deer management.

Forest plots (n = 884) were established at $\approx$200 m intervals along representative lines (n = 281) that run from a randomly selected point on a stream to the nearest ridge or treeline. The network was established during the period of New Zealand Forest Service deer culling to monitor the impacts of deer and possums on forest regeneration. The forest plot protocol proved to be a winner, and has since become a trusted method for monitoring indigenous forests in New Zealand (Hurst et al., 2022a). Several thousand permanent plots have been established using this approach. The protocol has been refined, extensively tested, and the resulting data have supported more than one hundred scientific publications ($>$160 citations). In contrast, a number of alternative monitoring methods have either proven too expensive to sustain, have been abandoned, or failed to provide useful information. Examples include Tier 1 monitoring where remeasurement cost has exceeded initial expectations, now forgotten *Fuchsia* foliar browse index plots in Tararua, deer faecal pellet counts, and seedling ratio index plots.

More than 350 alpine grassland and scrub monitoring plots were established throughout Te Tāhuhu. Although daily labour costs when the plots were established were approximately half of what they are now, they still represent over $300,00 of investment (Appendix XV). Each plot uses a standardised frequency intercept method where the presence of plants are recorded within

100, 6″ ⌀ intercepts along a 40.2 m transect (Wraight, 1960, 1963). A number of plots were located below the natural treeline and have often transitioned to shrubland. When these plots are next remeasured, vegetation cover, shrub density, and tussock height should also be recorded within a 20 m $\times$ 20 m plot centred on each transect (Appendix XVI). In Ruahine (1975–76) and Tararua (1974–75) Forest Parks, the height and basal diameter of up to 16 tussocks were measured in each plot. The distance from each of eight fixed points to the nearest tussock, and from that tussock to its nearest neighbour of the same species, was measured following (Wiser and Rose, 1997). Repeating these measurements would provide a direct assessment of changes in tussock stature over the past four decades. Comparisons of repeat photographs from grassland monitoring plots suggest that tussocks have declined in size and cover and have been progressively replaced by browse-resistant shrubs (Appendix XIII and Appendix XIV). This is speculative, and can only be confirmed following plot re-measurement.

Table 5: Numbers of permanent 20 m $\times$ 20 m forest plots established by NZ Forest Service on randomly located lines in Te Tāhuhu between 1974 and 1986 using the method described by Allen and McLennan (1983) and updated by Hurst et al. (2022a).

Park	1974-1975	1975	1978-1979	1979-1980	1981-1982	1982-1983	1983	1983-1984	1984	1984-1985	1985-1986
Aorangi				18							150
Kaweka					95						
Pohangina		98					1				
Raukumara						13			17		
Rimutaka				108					25		8
Ruahine			45				4	59			
Tararua	176									70	
Tukituki							25				

Table 6: Numbers of Frequency Intercept alpine grassland plots established by NZ Forest Service in Te Tāhuhu between 1958 and 1984 using the method described by Wraight (1960).

Park	1958	1959	1960	1961	1963	1975	1980	1981	1984	Total
Kaweka								6		6
Ngaruroro			76				1			77
Rangitikei								48		48
Ruahine				156		1				157
Tararua	17	18			7				1	43
Tutaekuri			21							21

A series of paired exclosure plots were built in forests between 1970 and 1985. The same 20 m $\times$ 20 m protocol was used to measure each fenced plot and the adjacent unfenced paired control. Between 2004 and 2010 and NZ Forest Surveys re-measured most of these plots and maintained the fences. All fences were intact at that time due to the quality of their initial construction. These plots could be used to assess the effects of deer on hydrological processes through the use of portable infiltrometers and lab-based measurements of soil and litter samples.

Table 7: Numbers of paired 20 m $\times$ 20 m deer fenced and unfenced plots established by NZ Forest Service in Te Tāhuhu between 1970 and 1985 using the method described by Hurst et al. (2022a), and known to NZ Forest Surveys staff (there may be others). The total remaining intact is at least 24. Another set of paired 10 m $\times$ 10 m fenced and unfenced plots was established between 1997 and 1999 in Kaweka Forest Park (Husheer and Tanentzap, 2024).

Park	Paired plots (N)	Locations
Aorangi	7	Stonewall, Kawakawa, Pararaki, Washpool, Turanganui, Tauanui, Waihora
Remutaka	1	Orongorongo
Tararua	1	Roaring Stag
Ruahine	16	Alphabet, Cabinet, Pohangina, Peg Creek, Triangle, Waterfall, Wakelings, Maropea Forks, Ruahine Cnr, Dead Dog, No Mans, Lake Colenso, Maharahara, Whakarekau, Takapari, Diggers
Kaweka	4	Lotkow, Ihaka, Te Puke, Mohaka

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9 Declarations – Ngā Tauākī

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Conflicts of interest. The authors declare no conflicts of interest.

10 Appendices – Ngā Āpitihanga

Table 1. Comparisons of mineral soil parameters for 18 paired deer exclosure plots in central New Zealand measured between July 2008 and July 2009. Results of paired *t*-tests comparing differences between fenced and unfenced plots for mineral soil bulk density, total carbon, total nitrogen, total C/ha, P concentration following HNO_3 extraction, Olsens P and Organic P (fraction of P extracted with H_2SO_4 following ignition – unignited) are displayed. Soil samples were not available for the 10-20 cm tier from one site and from the 20-30 cm tier for two sites. The number of plots required to detect a difference in means between paired fenced and unfenced plots for sd of difference between paired plots, α=0.05, β=0.8 is presented (N). © Sean Husheer (New Zealand Forest Surveys).

	Fenced			Unfenced			Difference					
	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM	Paired t_{17}	P	N
Soil 0-10 (<2mm)												
Bulk density (tonnes ha)	346.3	135.8	32.0	389.4	236.5	55.7	43.1	161.6	38.1	-1.132	0.273	112
C concentration %	8.3	3.8	0.9	8.5	4.8	1.1	0.2	3.2	0.8	-0.296	0.771	1617
N concentration %	0.4	0.2	0.1	0.4	0.3	0.1	0.0	0.2	0.0	0.040	0.969	88634
Total C (tonnes/ha)	25.6	11.0	2.6	25.9	10.9	2.6	0.2	9.6	2.3	-0.095	0.925	88634
P concentration (mg/kg)	502.4	176.6	42.8	472.8	164.5	39.9	-29.6	99.5	24.1	1.226	0.238	91
Olsens P (mg/ml)	35.6	32.4	7.6	26.7	26.4	6.2	-8.9	29.1	6.9	1.297	0.212	86
Organic P (mg/ml)	472.2	451.6	106.4	356.9	163.1	38.4	-115.3	474.0	111.7	1.032	0.317	135
Soil 10-20												
Bulk density (tonnes ha)	455.6	194.5	47.2	510.4	275.3	66.8	54.8	212.0	51.4	-1.066	0.302	119
C concentration %	5.7	2.8	0.7	6.0	3.9	0.9	0.3	2.0	0.5	-0.665	0.516	304
Total C (tonnes/ha)	22.8	10.3	2.5	24.7	15.6	3.8	1.9	8.9	2.2	-0.895	0.384	169
Soil 20-30												
Bulk density (tonnes ha)	442.1	153.1	38.3	504.6	231.2	57.8	62.5	241.3	60.3	-1.037	0.316	119
C concentration %	4.6	2.1	0.5	4.5	3.1	0.8	-0.1	2.1	0.5	0.270	0.791	1729
Total C (tonnes/ha)	18.8	8.0	2.0	19.0	8.3	2.1	0.2	7.5	1.9	-0.130	0.898	7407

Table 2. Comparisons of key overstorey, understorey, humus and litter parameters for 18 paired deer exclosure plots in central New Zealand measured between July 2008 and July 2009. Results of paired *t*-tests comparing fenced and unfenced plots are displayed. © Sean Husheer (NZFS).

	Fenced			Unfenced			Difference					
	Mean	SD	SEM	Mean	SD	SEM	Mean	SD	SEM	Paired t_{17}	P	N
Overstorey												
Basal area (m^2/ha)	56.3	35.9	8.5	54.3	51.4	12.1	-2.1	42.2	9.9	0.208	0.838	3277
Density (stems/ha)	3440	3556	838	2201	2148	506	-1239	3060	721	1.717	0.104	50
Tree height (m)	7.2	3.1	0.7	7.1	3.3	0.8	-0.1	3.6	0.8	0.113	0.912	11139
Species composition (DCA)	1.55	1.49	0.35	1.11	1.08	0.25	-0.45	1.26	0.30	1.501	0.152	65
Understorey												
Sapling density/ha	11337	18803	4855	4972	6019	1554	-6366	18645	4814	1.322	0.207	69
Sapling composition (DCA)	2.2	1.7	0.4	1.8	1.5	0.4	-0.4	0.7	0.2	2.247	0.041	25
Seedling density/ha	105544	60649	15162	131314	60157	15039	25771	68095	17024	-1.514	0.151	57
Seedling composition (DCA)	2.3	1.5	0.4	2.2	1.2	0.3	-0.1	0.5	0.1	0.536	0.600	438
Litter												
Dry weight (tonnes/ha)	16.8	8.0	1.9	15.4	4.5	1.1	-1.4	8.1	1.9	0.737	0.471	262
C concentration %	42.4	4.6	1.1	41.1	3.9	0.9	-1.2	4.3	1.0	1.235	0.234	95
N concentration %	0.85	0.21	0.05	0.78	0.14	0.03	-0.06	0.16	0.04	1.640	0.119	55
P concentration (mg/kg)	488	157	37	430	100	24	-58	115	27	2.147	0.047	33
S concentration (mg/kg)	586	264	62	529	193	45	-57	136	32	1.776	0.094	47
Total C (tonnes/ha)	7	3	1	6	2	0	-1	3	1	0.834	0.416	205
C/N ratio	53	15	4	54	11	3	1	13	3	1.776	0.094	1512
C/N/P ratio	126720	70860	16702	137507	60819	14335	10787	50262	11847	-0.911	0.375	172
C/N/P/S ratio 10^3	273359	204467	48193	295178	171499	40423	21819	128271	30234	-0.722	0.480	273
Humus (<2mm soil + >2mm organic)												
Dry weight (tonnes/ha)	44.6	35.5	8.4	36.0	28.7	6.8	-8.5	32.6	7.7	1.112	0.282	116
C concentration %	24.6	9.2	2.2	24.6	9.0	2.1	0.0	6.8	1.6	-0.013	0.990	814837
N concentration %	0.9	0.3	0.1	0.9	0.3	0.1	0.0	0.3	0.1	-0.088	0.931	18097
C (tonnes/ha)	11.0	9.4	2.2	8.3	5.8	1.4	-2.7	9.5	2.2	-0.088	0.931	99
P concentration (mg/kg)	610	157	37	617	166	39	7	200	47	-0.157	0.877	5729
S concentration (mg/kg)	674	241	57	652	262	62	-21	220	52	0.408	0.688	850
Olsens P (mg/ml)	154	86	20	146	114	27	-9	94	22	0.384	0.705	958
Organic P (mg/ml)	494	156	37	550	152	36	56	130	31	-1.806	0.089	45
CEC me/100g	33	8	2	31	10	2	-3	6	1	1.775	0.094	47
Ca me/100g	23	12	3	20	13	3	-3	9	2	1.466	0.161	68
Ph (water)	5.2	1.1	0.3	5.2	1.2	0.3	-0.1	0.6	0.1	0.417	0.682	813
C/N ratio	28.1	8.5	2.0	27.9	6.4	1.5	-0.2	8.3	2.0	0.126	0.901	8839
C/N/P ratio	49981	20092	4736	52264	31337	7386	2284	38548	9086	-0.251	0.805	2239
C/N/P/S ratio 10^3	95494	78961	18611	97524	82140	19361	2030	99907	23548	-0.086	0.932	19017
Loss on Ignition	53.0	18.6	4.4	49.2	18.9	4.4	-3.8	12.3	2.9	1.307	0.209	85

Appendix I

Table 3: Common plant species in Te Tāhuhu recognised as Rongoā. Listed in evolutionary order of each family. We listed rongoā and kai rākau of importance to Maori from the mātauranga whānau of one of the authors, and from published records (Kerenapu Pomana - tohunga rongoā rākau; whakapapa = mātauranga whānau o te rongoā; MWLR = Manaaki Whenua Landcare Research, 2023; Best = Best, 1898; Riley = Riley, 1994; Volz = Volz, 2020; Brooker = Brooker et al., 1987; Dalefield = Dalefield, 2017; Beattie = Beattie and Anderson, 1994; Buchanan = Buchanan, 1868).

Species	Family	Range	Habitat	Name	Rongoa
Leptopteris hymenophylloides	Osmundaceae	NI, SI, St, C	Forest	heruheru	Whakapapa, MWLR, Best
Cyathea medullaris	Cyatheaceae	NI, SI	Forest	Mamaku	Best
Asplenium gracillimum	Aspleniaceae	NI, SI	Forest	mouku kura	Riley
Dacrycarpus dacrydioides	Podocarpaceae	NI, SI	Forest	Kahikatea	Best, Whina Cooper
Dacrydium cupressinum	Podocarpaceae	NI, SI	Forest	Rimu	Best
Podocarpus totara	Podocarpaceae	NI, SI	Forest	Tōtara	Best
Prumnopitys ferruginea	Podocarpaceae	NI, SI	Forest	Miro	Best
Prumnopitys taxifolia	Podocarpaceae	NI, SI	Forest	Mataī	Best
Libocedrus bidwillii	Cupressaceae	NI, SI	Forest	kaikawaka	MWLR
Piper excelsum	Piperaceae	NI, SI	Forest	Kawakawa	Best
Ranunculus insignis	Ranunculaceae	NI, SI	Alpine	korikori	Riley
Ranunculus nivicola	Ranunculaceae	R, SI	Alpine	mātātā	Riley
Melicytus ramiflorus	Violaceae	NI, SI	Forest	mahoe	MWLR
Hoheria sexstylosa	Malvaceae	NI, SI	Forest	Houhere	Best, White
Aristotelia serrata	Elaeocarpaceae	NI, SI	Forest	makomako	Whakapapa, MWLR
Pterophylla racemosa	Cunoniaceae	NI, SI	Forest	kamahi	MWLR, Brooker
Fuscospora cliffortioides	Nothofagaceae	NI, SI	Forest	tawaki rauriki	
Fuscospora fusca	Nothofagaceae	NI, SI	Forest	tawhai raunui	
Fuscospora solandri	Nothofagaceae	NI, SI	Forest	tawhairauriki	
Lophozonia menziesii	Nothofagaceae	NI, SI	Forest	tawhai	
Sophora microphylla	Fabaceae	NI, SI	Forest	Kōwhai	Best
Alectryon excelsus	Sapindaceae	NI, SI	Forest	Tītoki	Best, White
Corynocarpus laevigatus	Corynocarpaceae	NI, SI	Forest	Karaka	Best
Kunzea robusta	Myrtaceae	NI, SI	Scrub	Kānuka	Best
Leptospermum scoparium	Myrtaceae	NI, SI	Scrub	Mānuka	Best
Ileostylus micranthus	Loranthaceae	NI, SI, St	Forest, Scrub	pirinoa - green mistletoe	Riley
Griselinia littoralis	Griseliniaceae	NI, SI	Forest	kapuka	Riley
Griselinia lucida	Griseliniaceae	NI, SI	Forest	puka	Riley
Pittosporum eugenioides	Pittosporaceae	NI, SI	Forest	Tarata	Best, Frost
Pseudopanax arboreus	Araliaceae	NI, SI	Forest	whauwhaupaku	MWLR, Riley
Pseudopanax colensoi	Araliaceae	NI, SI	Forest	orihau	
Raukaua simplex	Araliaceae	NI, SI	Forest	raukawa	MWLR, Buchanan
Schefflera digitata	Araliaceae	NI, SI	Forest	pātē	Riley, MWLR
Gaultheria colensoi	Ericaceae	R, K, TT	Scrub, Cliff, Alpine	pāpapa	Riley
Solanum laciniatum	Solanaceae	NI, SI	Forest	Poroporo	Best
Myoporum laetum	Scrophulariaceae	NI, SI	Forest	Ngaio	Best
Hebe stricta	Plantaginaceae	NI, SI	Forest	Koromiko	Best
Hebe tetragona	Plantaginaceae	T, R, K, SI	Cliff, Alpine	whipcord hebe	Riley
Ourisia macrophylla subsp. *macrophylla*	Plantaginaceae	T, R, K, TT	Alpine, Wet	mountain foxglove	
Parahebe hookeriana	Plantaginaceae	K, M, TT, SI	Alpine, Wet	koromiko-taranga	
Typha orientalis	Typhaceae	NI, SI	Forest	Raupō	Best
Bulbinella gibbsii var. *balanifera*	Asphodelaceae	T, R, SI	Alpine	maori onion	Riley
Phormium tenax	Asphodelaceae	NI, SI	Forest, Wet	Harakeke	Best
Anemanthele lessoniana	Poaceae	NI, SI	Forest, Scrub, Alpine	wind grass	
Chionochloa flavescens subsp. *flavescens*	Poaceae	T, Ri, SI	Alpine	wī - broad-leaved tussock	
Chionochloa flavicans	Poaceae	NI	Coastal, Cliff	tussock	
Chionochloa pallens subsp. *pallens*	Poaceae	NI, K	Alpine	mid-ribbed snow tussock	
Chionochloa rubra subsp. *rubra*	Poaceae	NI, SI	Alpine, Wet	red tussock	

Appendix II

Table 4: Threatened and at risk vascular plant species occurring in Te Tāhuhu. Includes Aorangi (A), Rimutaka (Ri), Tararua (T), Ruahine (R) and Kaweka (K) Forest Parks. *Brachyglottis kirkii* refers to var. *kirkii* and *Wahlenbergia pygmaea* refers to subsp. *tararua*. The range of most species listed extends beyond Te Tāhuhu, to Maungaharuru (M), Tongariro-Taupo (TT), Hawkes Bay (HB) and Wairarapa (W), and some are scattered throughout the South (SI) and North (NI) Islands. *Atriplex cinerea* is common in Australia.
Habitat is classified as Alpine (alpine and subalpine grass- and tussock-land, montane bluffs and wetlands to as low as 1000 m asl), Forest (trees >5 high), Low (Lowland forest <1000 m), Cliff (cliffs and rocky outcrops/fellfield), Wet (wetlands, tarns, bogs, seeps streamsides <1000 m asl), Coast (plants tolerant of coastal habitat) and Scrub (shrubland <5 m high). The locations extracted from iNaturalist (2026) are mapped in following appendicies (Appendix V and Appendix VI).
Threatened species are at critical risk of extinction (Critical), are endangered or vulnerable to extinction (Endangered or Vulnerable). At risk species are declining (Declining), or have stable but small populations (Uncommon).The populations of uncommon species may have stabilised at low numbers after historical decline, or they may have naturally small populations.
Compiled from plant lists available online (de Lange et al., 2024; New Zealand Plant Conservation Network, 2025, 2024; de Lange et al., 2009).

Species	Family	Range	Habitat	Status	Name	Rongoa
Botrychium australe	Ophioglossaceae	T, K, SI	Alpine	Declining	pātotara	MWLR, Colenso
Asplenium subglandulosum	Aspleniaceae	K, HB, SI	Cliff, Low, Alp	Declining	blanket fern	Riley
Ranunculus macropus	Ranunculaceae	NI, SI	Wet	Declining	raoriki	Riley
Ranunculus recens	Ranunculaceae	TT	Alpine	Vulnerable	mātātā	Riley
Ranunculus simulans	Ranunculaceae	R, K, SI	Forest, Scrub, Alpine	Uncommon	mātātā	Riley
Dactylanthus taylorii	Balanophoraceae	T, NI	Forest	Vulnerable	hupiro	Riley
Hypericum minutiflorum	Hypericaceae	K, TT	Wet, Stream, Alpine	Critical	small-flowered St. Johns wort	Volz
Pimelea hirta	Thymelaeaceae	M, K, R	Cliff, Alpine	Uncommon	soft-tufted pohuehue	Dalefield
Pimelea longifolia	Thymelaeaceae	A, R, T	Forest, Scrub, Alpine	Data Deficient	long-leaved pimelea	
Acaena emittens	Rosaceae	K, R, TT	Alpine	Uncommon	piripiri	Riley
Acaena rorida	Rosaceae	R	Alpine, Wet	Critical	piripiri	Riley
Carmichaelia nana	Fabaceae	K, R, TT	Low, Alpine	Uncommon	mākaka	
Metrosideros robusta	Myrtaceae	NI, SI	Forest	Declining	northern rātā	MWLR, Beattie
Syzygium maire	Myrtaceae	NI, SI	Forest	Vulnerable	maire tawake	
Alepis flavida	Loranthaceae	NI, SI	Forest	Uncommon	pirita - yellow mistletoe	Riley
Peraxilla colensoi	Loranthaceae	T, R, K, SI	Forest	Declining	korukoru - scarlet mistletoe	Riley
Peraxilla tetrapetala	Loranthaceae	NI, SI	Forest	Declining	pikirangi - red mistletoe	
Tupeia antarctica	Loranthaceae	NI, SI	Forest	Declining	kohuorangi - white mistletoe	Riley
Pittosporum turneri	Pittosporaceae	NI	Forest, Scrub, Alpine	Uncommon	turners kohuhu	
Aciphylla dissecta	Apiaceae	T	Cliff, Alpine	Uncommon	Tararua tāramea	Riley
Chaerophyllum ramosum	Apiaceae	NI, SI	Alpine, Wet	Data Deficient	myrrh	
Scandia geniculata	Apiaceae	A, SI	Coastal, Cliff	Declining	angelica/nz aniseed	Riley
Scandia rosifolia	Apiaceae	NI, R, SI	Forest, Scrub, Alpine	Critical	koheriki	Riley
Myrsine umbricola	Primulaceae	TR	Forest	Vulnerable	Matipo	
Coprosma rubra	Rubiaceae	R, Ri, T	Forest, Scrub, Alpine	Declining		
Myosotis brevis	Boraginaceae	W, NI, SI	Coast, Cliff	Vulnerable	forget-me-not	
Myosotis eximia	Boraginaceae	T, R, K, SI	Cliff, Alpine	Uncommon	forget-me-not	
Myosotis glauca	Boraginaceae	K, SI	River	Uncommon	forget-me-not	
Myosotis venosa	Boraginaceae	T, R, SI	Alpine	Data Deficient	forget-me-not	
Euphrasia disperma	Orobanchaceae	R, SI	Alpine, Wet	Uncommon	tutae kiore	
Euphrasia drucei	Orobanchaceae	T	Alpine, Wet	Uncommon	tupere	
Hebe colensoi	Plantaginaceae	K, R	Cliff, Alpine	Uncommon	hebe	Riley
Hebe truncatula	Plantaginaceae	Ri, A	Cliff, Alpine	Uncommon	koromiko	Riley
Ourisia modesta	Plantaginaceae	R, SI	Alpine, Wet	Uncommon	mountain foxglove	
Ourisia vulcanica	Plantaginaceae	R, K, TT	Alpine, Wet	Uncommon	mountain foxglove	
Veronica angustissima	Plantaginaceae	T	Cliff	Uncommon	narrow-leaved hebe	
Veronica evenosa	Plantaginaceae	T	Alpine, Wet	Uncommon	koromiko	
Wahlenbergia pygmaea	Campanulaceae	T	Alpine	Uncommon	bellflower	
Anaphalioides subrigida	Asteraceae	R, T, SI	Alpine	Uncommon	mountain everlasting daisy	
Brachyglottis kirkii	Asteraceae	T, W	Forest, Cliff, Scrub	Uncommon	kohurangi	
Celmisia hieraciifolia var. *oblonga*	Asteraceae	R, T, SI	Alpine	Data Deficient	Mountain daisy	
Celmisia spectabilis subsp. *lanceolata*	Asteraceae	NI	Coastal Cliff, Alpine	Data Deficient	taipo - mountain daisy	
Euchiton paludosus	Asteraceae	NI, SI	Alpine, Wet	Data Deficient	cudweed	
Leptinella tenella	Asteraceae	T, NI, SI	Cliff, Alpine	Uncommon	button daisy	Whakapapa
Raoulia rubra	Asteraceae	T	Alpine	Uncommon	vegetable sheep	
Rytidosperma nudum	Asteraceae	R, T	Alpine	Data Deficient	bristle grass	
Rytidosperma pulchrum	Asteraceae	T	Alpine	Data Deficient	bristle grass	
Senecio colensoi	Asteraceae	T, HB	Cliff, Alpine	Uncommon	groundsel	Riley
Shawia cheesemanii	Asteraceae	T		Declining	streamside tree daisy	
Caladenia atradenia	Orchidaceae	NI, SI	Forest, Scrub, Alpine	Vulnerable	Bronze fingers	
Corybas dienemus	Orchidaceae	T, NI, SI	Forest, Scrub, Alpine	Vulnerable	helmet orchid	
Prasophyllum elegantissimum	Orchidaceae	T, K, W, SI	Forest, Wet	Vulnerable	elegant leek orchid	
Pterostylis irwinii	Orchidaceae	R, SI	Forest	Vulnerable	greenhood orchid	
Pterostylis tasmanica	Orchidaceae	T, NI, SI	Forest, Scrub, Alpine	Vulnerable	plumed greenhood	
Luzula banksiana	Juncaceae	T, SI	Forest, Scrub, Alpine	Data Deficient	coastal woodrush	
Carex longifructus	Cyperaceae	R, T		Uncommon	hook sedge	
Carex obtusifolia	Cyperaceae	T, R, SI	Alpine, Wet	Uncommon	fine-leaved bastard grass	
Carex tahoata	Cyperaceae	T, R, SI	Alpine, Wet	Uncommon	mountain teasel sedge	
Agrostis oresbia	Poaceae	T, R, SI	Alpine	Data Deficient	bentgrass	
Agrostis pallescens	Poaceae	T, R, SI	Alpine	Uncommon	bentgrass	
Amphibromus fluitans	Poaceae	NI, SI	Alpine, Wet	Declining	floating swamp grass	
Anthoxanthum cupreum	Poaceae	T, R, K, SI	Alpine	Declining	copper sweet vernal	
Chionochloa beddiei	Poaceae	A	Coastal, Cliff	Vulnerable	Cook Strait tussock	
Pentapogon micranthus	Poaceae	A		Critical	purple plume grass	
Atriplex cinerea	Amaranthaceae	A, SI	Coast, Wet	Critical	grey saltbush	

Appendix III

Table 5: Plant species in Te Tāhuhu recognised as Data Deficient, with expert botanists unable to ascribe a status. Many threatened and at risk species are also defficiently understood and urgently require further survey. With further survey Data Deffucient species may be resolved as very rare and highly threatened, and present in Tāhuhu. Listed in evolutionary order of each family.

Species	Family	Range	Habitat	Name
Pimelea longifolia	Thymelaeaceae	A, R, T	Forest, Scrub, Alpine	long-leaved pimelea
Chaerophyllum ramosum	Apiaceae	NI, SI	Alpine, Wet	myrrh
Myosotis venosa	Boraginaceae	T, R, SI	Alpine	forget-me-not
Celmisia hieraciifolia var. *oblonga*	Asteraceae	R, T, SI	Alpine	Mountain daisy
Celmisia spectabilis subsp. *lanceolata*	Asteraceae	NI	Coastal Cliff, Alpine	taipo - mountain daisy
Euchiton paludosus	Asteraceae	NI, SI	Alpine, Wet	cudweed
Rytidosperma nudum	Asteraceae	R, T	Alpine	bristle grass
Rytidosperma pulchrum	Asteraceae	T	Alpine	bristle grass
Luzula banksiana	Juncaceae	T, SI	Forest, Scrub, Alpine	coastal woodrush
Agrostis oresbia	Poaceae	T, R, SI	Alpine	bentgrass

Appendix IV

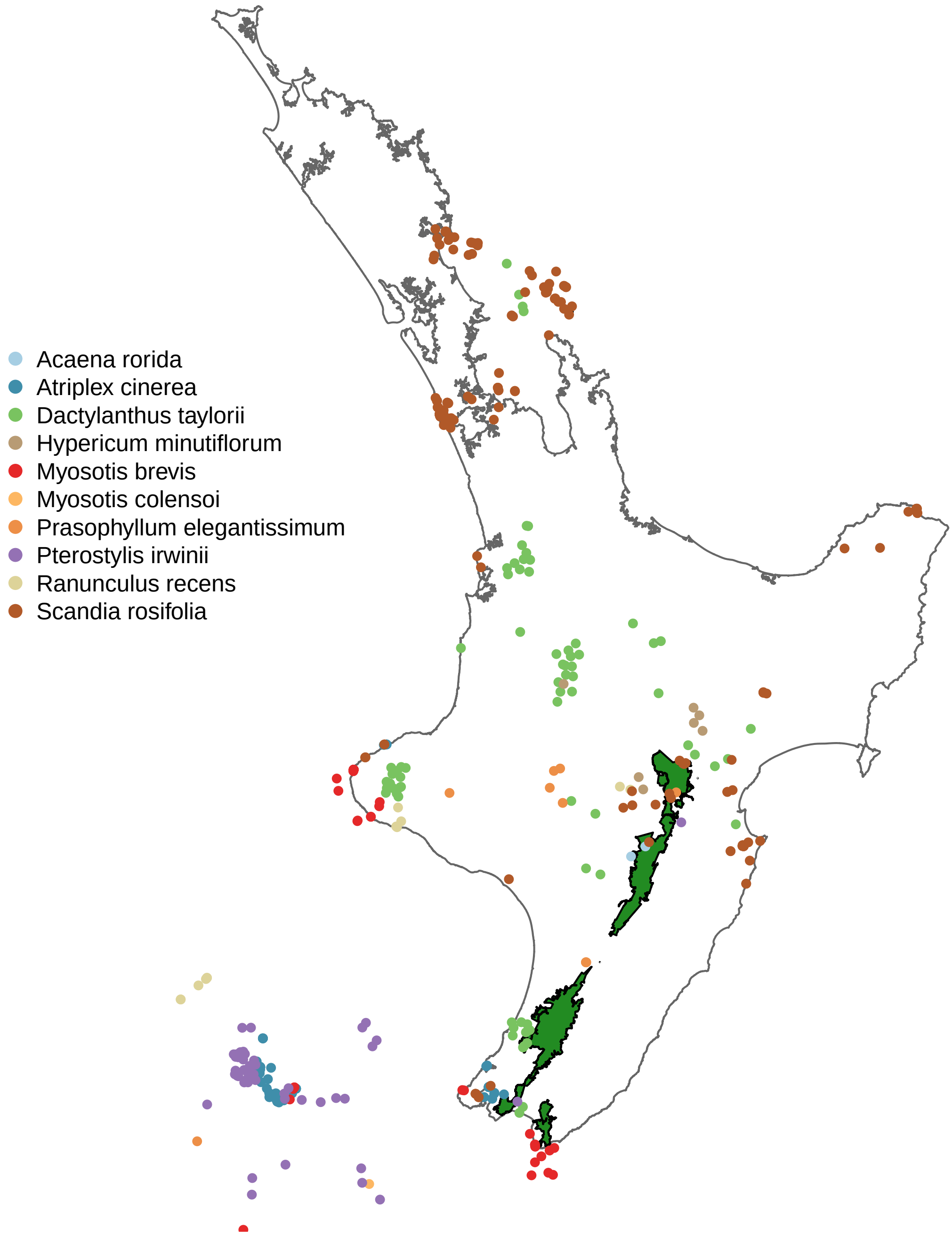


Figure 4: Locations of threatened species extracted from iNaturalist (2026) and listed in Appendix III. A large location error is built in.

Appendix V

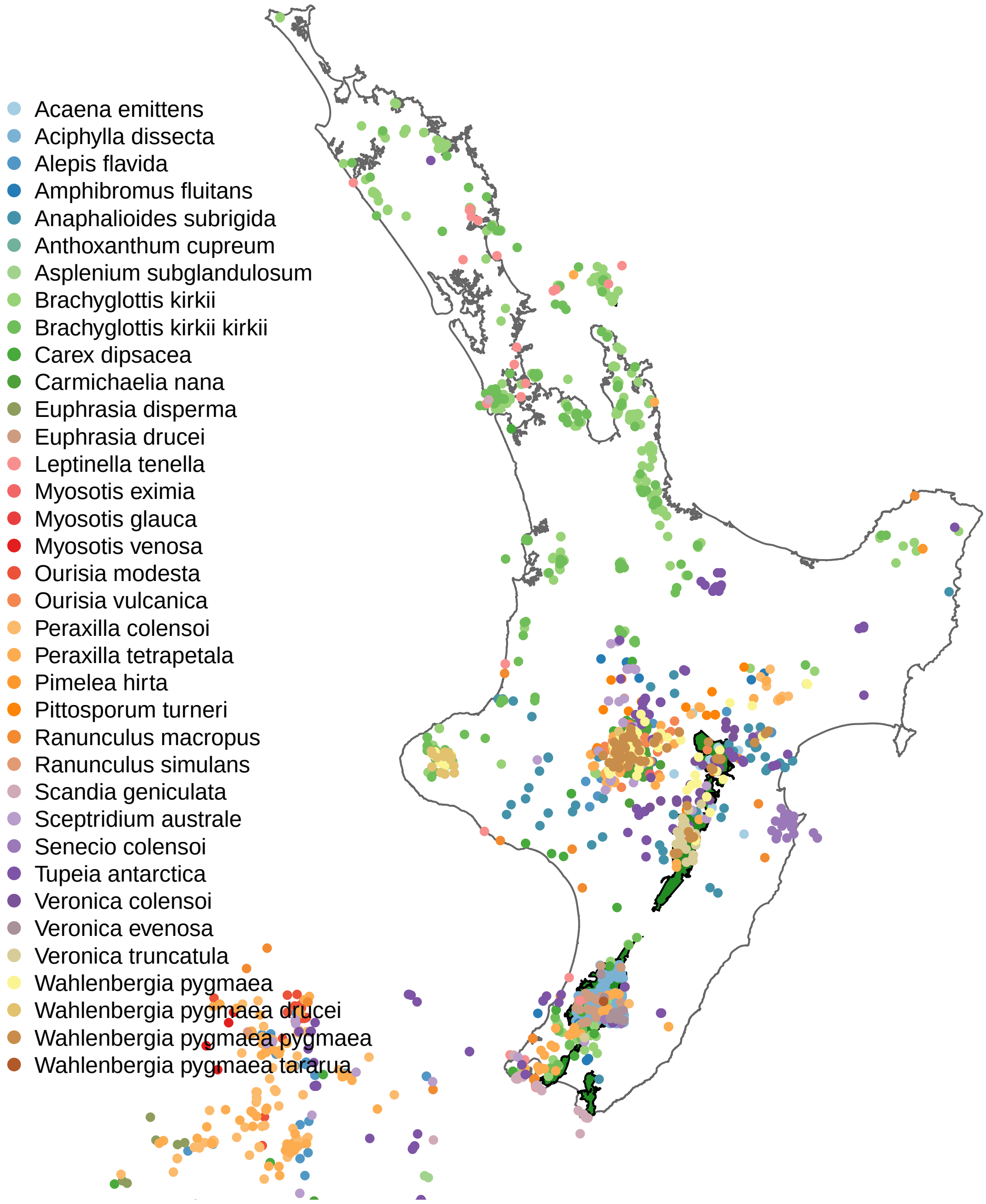
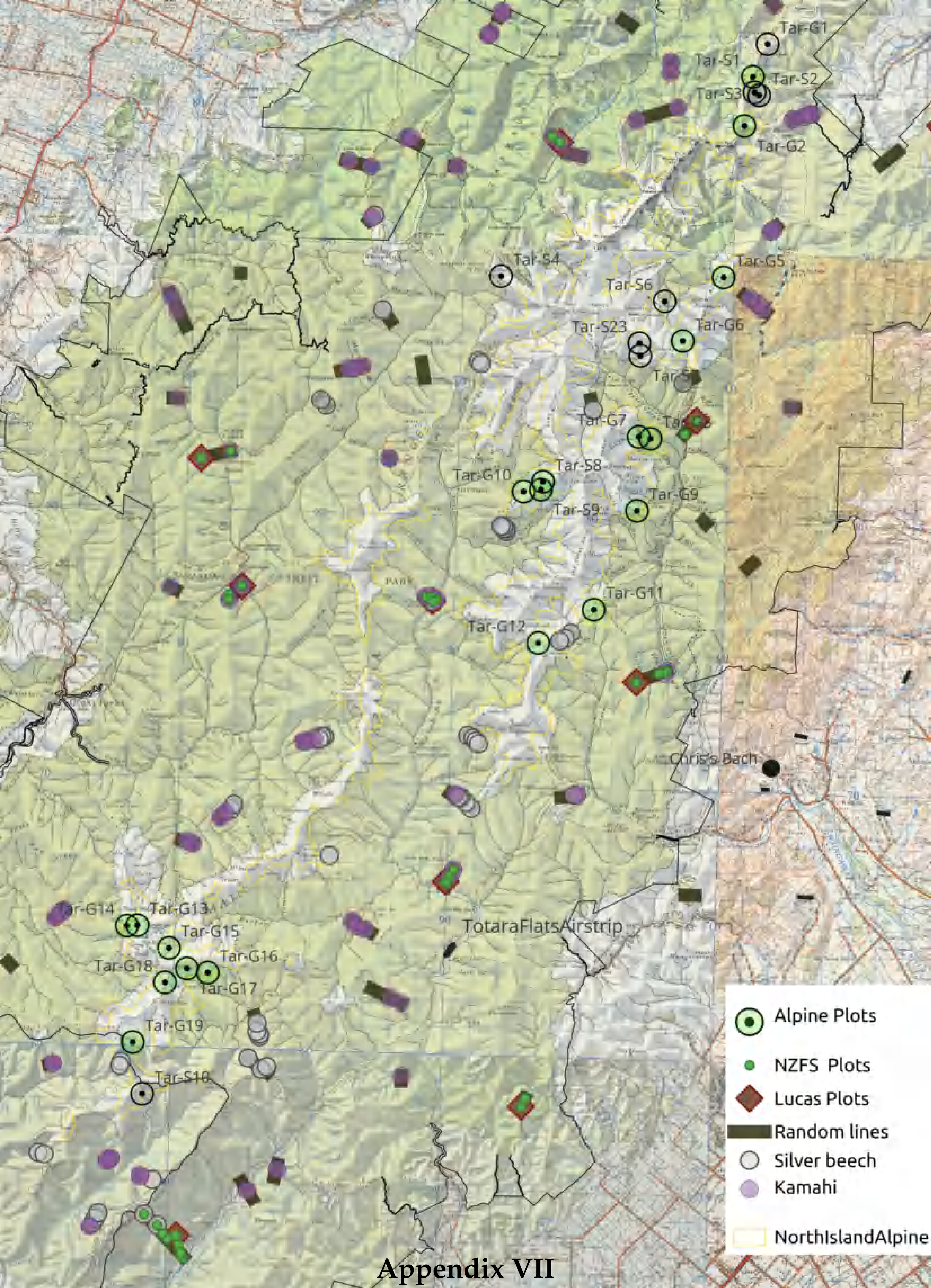
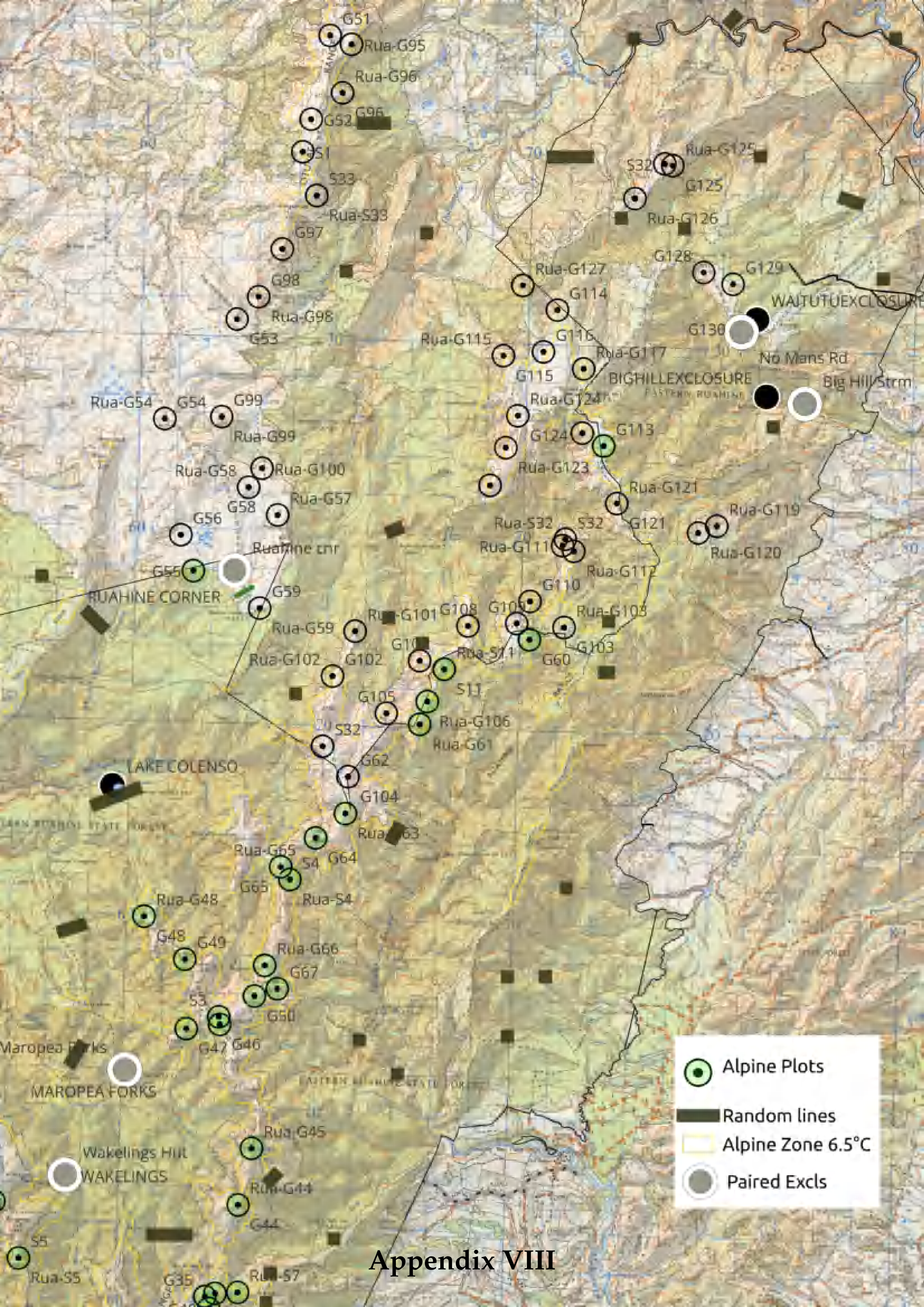


Figure 5: Locations of at risk species extracted from iNaturalist (2026). A large location error is built in.

Appendix VI



Appendix VII



Appendix VIII

Edited extract from *A Good Keen Man* Barry Crump 1960

Chapter 3, "The Healthy Outdoor Life." From his experiences as a Wildlife Branch, Department of Internal Affairs culler in Te Tāhuhu from 1952.

The deer I shot, the pigs my crackerjack dog caught, the loads I carried, and the rivers I crossed that first season doubled themselves effortlessly in the public bars I hunted in for the next three weeks. A thirsty audience gave me all the encouragement I needed to recount everything worth recounting – with trimmings. The image that emerged was of a tough, hard-drinking deer culler. Crafty old boars and 12-pointer stags fell all over the place. Rifle barrels sizzled with the heat as I slipped on mounting piles of empty shells – and instantly corrected my aim. I strewed the Urewera from one end to the other with carcasses while my audience listened with an occasional, "Go on . . . did you?" and willingly drank my beer.

After three weeks of town life, Jim rescued me from a bar and sent me to a possum block in the Ruahines for the winter. "There'll be some good keen men with you this time, Crump," he said.

There were four of us, Allan, Jack, Mike and myself. Working from the same hut for the next few weeks, my new mates and I turned experience upside down. In town we'd cut a swathe in the bush, in the bush we conquered town. We laid cyanide lines along the ridges, returning a few days later to collect ears from the dead possums as proof of kill. Sometimes a line yielded 300 possums, though about half that was more usual.

Like most animals introduced to New Zealand, possums had become a pest. According to a shepherd from down the river there hadn't been a possum in the district five years earlier, but by the time Jim classed it as a critical area the bush faces were spotted with the dead branches of trees the fast-breeding animals had stripped bare. There wasn't a live five-finger or mahoe left in the valley.

Once it had been difficult to climb through dense undergrowth on the ridges, but a few generations of deer, eating young trees before they were more than a few inches high, browsing the undergrowth, and chewing bark from smaller trees, had changed that. Pigs, scoffing roots and berries and breaking up the ground, had triggered soil erosion. Then possums, crawling over the older trees, eating the bark and stripping the leaves, completed the job of turning fine bush into potential desert.

You could stand almost anywhere in this forest and see at least 100 yards through trees completely unsupported by undergrowth or saplings. The old forest was being killed off, and the new one literally nipped in the bud.

Appendix IX

3- OCT

NEW ZEALAND FOREST SERVICE,
WELLINGTON.

5 September 1962.

DISTRIBUTION AS BELOW:

ALL CONSERVANCIES.

SELECTING HUNTER TRAINEES.

All Protection Forestry staff are expected to be recruiting officers and to keep an eye open for likely men. To assess the capabilities of a stranger in an interview lasting only half an hour or so is leaving much to chance or first impressions and the following points are defined to assist you in making your recommendations. Remember that only good suitable men are wanted.

Points to look for in selecting an intake :

(1) Overseas applicants bad bets. Most Head Office - Auckland applicants are overseas types (Grade poor to good U.S. - Australia - U.K. - European)

(2) Weight and height - Good weight for height usually indicates muscle developed through hard work.

(3) Married or single - Again, married men poor bets - get homesick - usually lazy around camp - don't like isolation etc.

(4) Age. Our experience men 34 or older physically unsuited.

(5) Work history - unemployed at time of interview in majority of cases don't acknowledge telegram to report or advise change of address.

(6) Old injuries - muscle or joint troubles always recurr.

(7) Physical - eyesight one disability where those with such physical fault rarely capable of target shooting or good identification in the field.

(8) Claims of years hunting experience mean nothing. Period spent hunting means more.

(9) Where vague mention of general area is made in "areas hunted" it is certain applicant has little experience.

(10) Occupation - drivers-clerks usually poor bets.

(11) Hometown - Applicants from small towns above Taupo usually well below average of those from towns southern North Island, who are in turn usually poorer applicants than those from South Island country towns.

(12) Recent Army experience means feet at least hard, usually applicant above average physical fitness.

(13) Those who state "change of job wanted", or joining up because "prefer outdoor life" are the commonplace.

(14) Those who state want to make money, or hunt, the better applicant.

(15) Those who have sheathknife, boots, rifle etc. always well ahead of those without such gear.

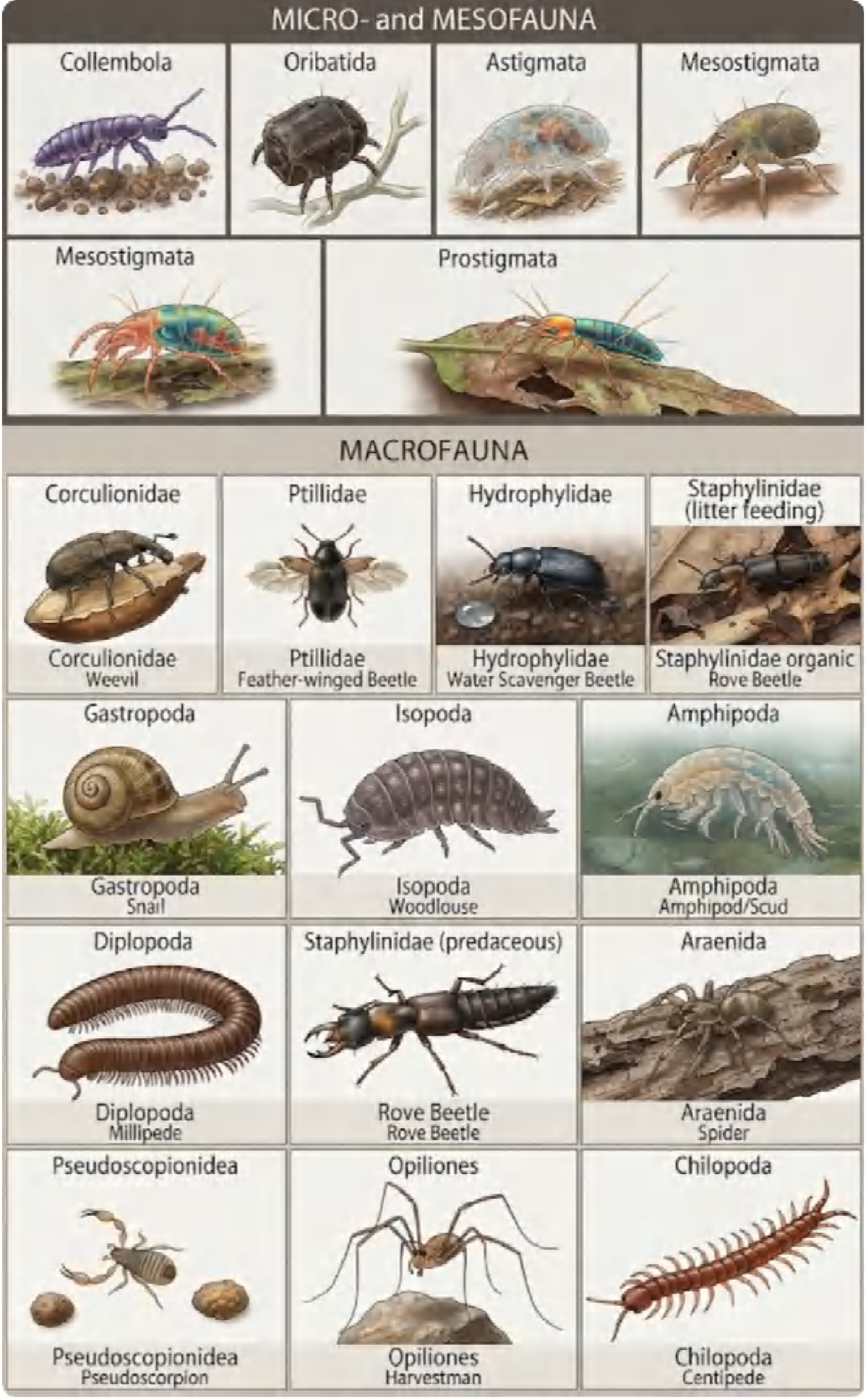
(16) Tradesmen usually good types - more stable.

(17) Those aged 20-22 usually bulk of postings.

(18) Single with dependents; unreliable and rarely suitable.

(19) Pig hunters rarely good deer hunters.

Appendix X

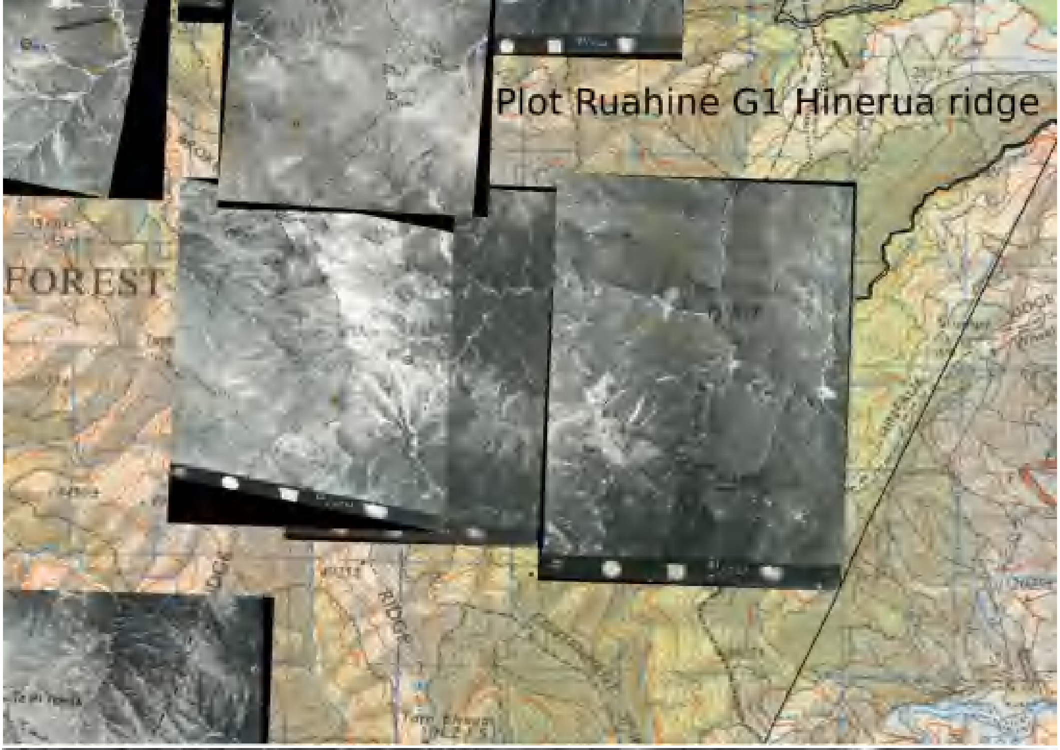

MICRO- and MESOFAUNA
Collembola
Oribatida
Astigmata
Mesostigmata
Mesostigmata
Prostigmata
MACROFAUNA
Corculionidae
Corculionidae
Weevil
Ptillidae
Ptillidae
Feather-winged Beetle
Hydrophylidae
Hydrophylidae
Water Scavenger Beetle
Staphylinidae (litter feeding)
Staphylinidae organic
Rove Beetle
Gastropoda
Gastropoda
Snail
Isopoda
Isopoda
Woodlouse
Amphipoda
Amphipoda
Amphipod/Scud
Diplopoda
Diplopoda
Millipede
Staphylinidae (predaceous)
Rove Beetle
Rove Beetle
Araenida
Araenida
Spider
Pseudoscopionidea
Pseudoscopionidea
Pseudoscorpion
Opiliones
Opiliones
Harvestman
Chilopoda
Chilopoda
Centipede

Appendix XI

New Zealand ranks as a biodiversity hotspot because of a high number of threatened endemic species in a small landmass.
The alpine zone covers <20% of New Zealand's landmass, and has >600 endemic vascular plant species.
To meet Conservation Internationals criteria if must have >1,500 endemic vascular plant species (there are >1,800), and lost >70% of natural vegetation cover.

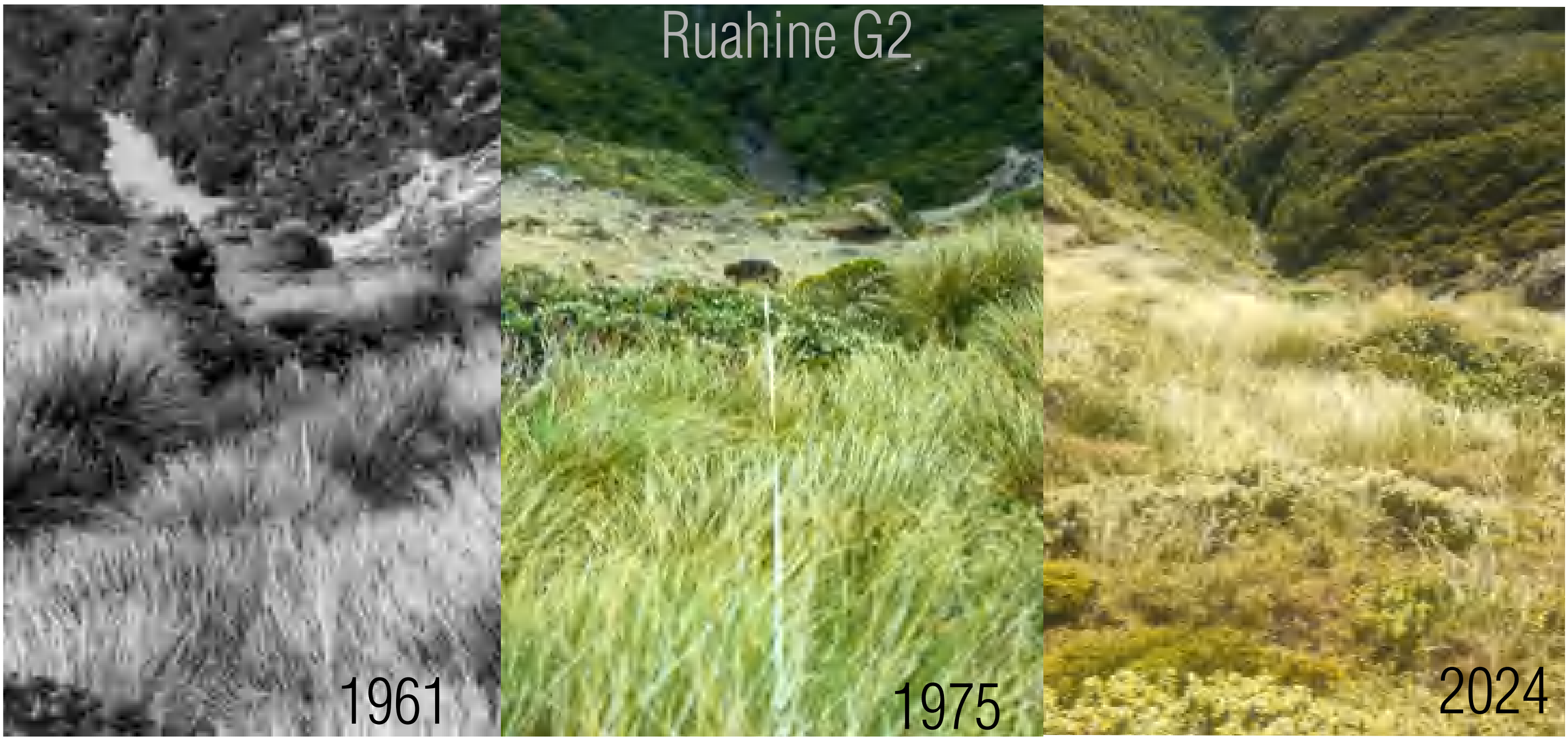
Molesworth 180,500 ha. >20 threatened vascular plant species. One endemic.

Appendix XII



Appendix XIII

Spion Kop Kaweka FP. Ngaruroro survey plot G35.
1960 and 2017. 1380 m a.s.l. Increase in woody plants.



Appendix XIV

Table 6: Historical daily labour costs to measure grassland plots from 1958–1984, assuming each plot takes 1 person day to measure. Present value of the cost to establish plots for annualy compounding NZ government bond yields. \$2 = £1. Total present value cost is $\approx \$151,000$. Sources include Hawke (1985); Briggs (2003); Statistics New Zealand (2025a,b); Reserve Bank of New Zealand (2025, 2026); Organisation for Economic Co-operation and Development (2026).

Year	N plots	Daily labour cost	Adjusted 2025 labour cost	Inflation	Bond yield	Present value
1958	17	\$5.00 (£2 10s)	\$9.90	~3.9% p.a.	6.5%	\$5,540
1959	18	\$5.20 (£2 12s)	\$10.27	~3.9% p.a.	6.5%	\$5,860
1960	97	\$5.60 (£2 16s)	\$10.34	~3.9% p.a.	6.5%	\$33,300
1961	156	\$6.00 (£3)	\$10.53	~3.8% p.a.	6.6%	\$58,100
1963	7	\$6.80 (£3 8s)	\$11.03	~3.8% p.a.	6.6%	\$2,430
1975	1	\$9.00	\$24.39	~4.7% p.a.	7.6%	\$350
1980	1	\$26.00	\$48.39	~4.1% p.a.	7.8%	\$760
1981	54	\$32.00	\$55.56	~4.0% p.a.	7.7%	\$43,800
1984	1	\$56.00	\$75.00	~3.6% p.a.	7.4%	\$1,020
2025		\$313.40	\$313.40			

Appendix XV

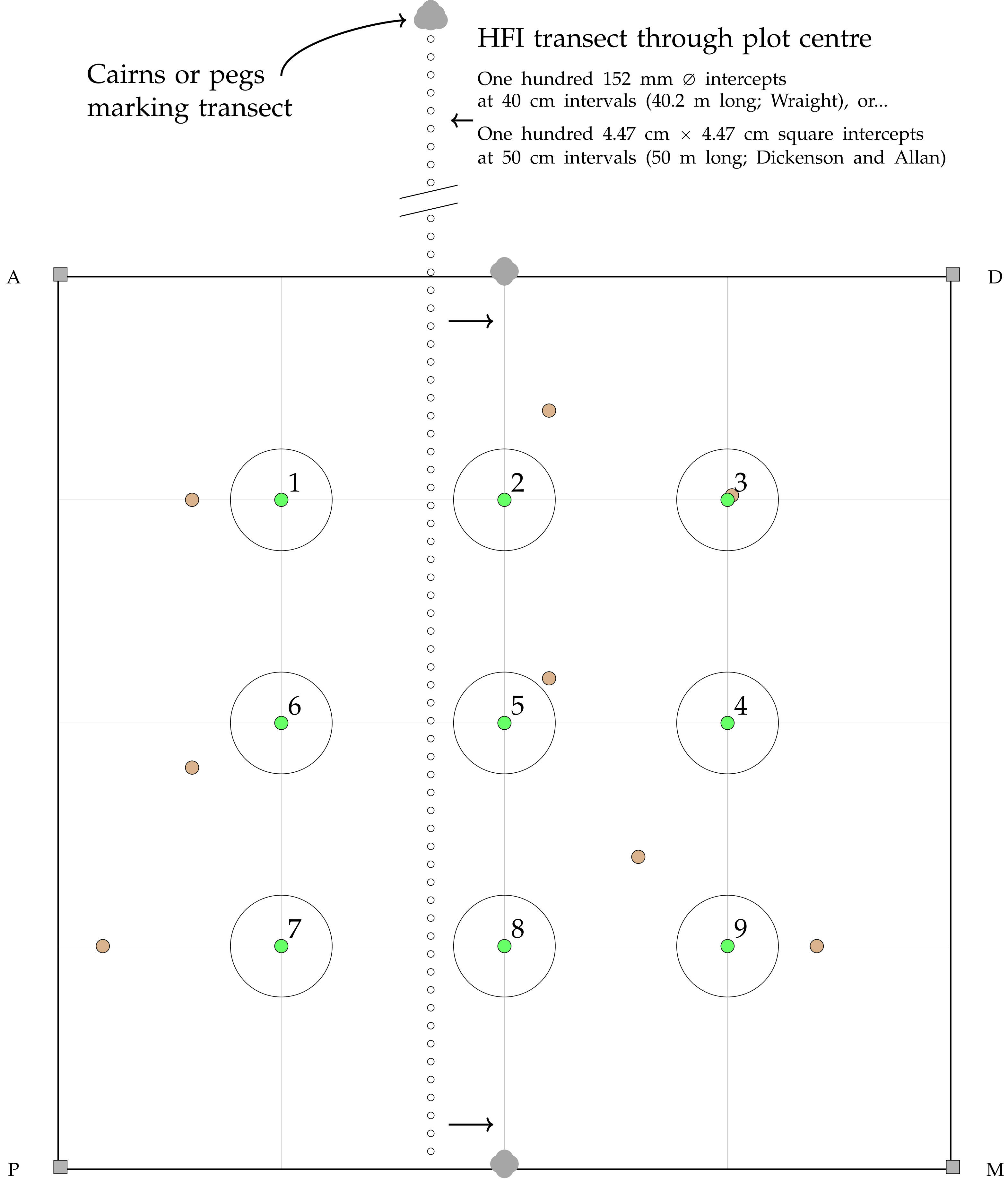


Figure 6: Layout of 20 m × 20 m plots (total area = 400 m^2; Hurst et al., 2022a), showing sixteen 5 m × 5 m overstorey sub-plots. There are usually twenty-four 49 cm radius circular seedling sub-plots in each plot, but when seedling density is low (<50 per plot) this is a very small area, and nine 114 cm radius milli-acre seedling sub-plots are better (4 m^2 v 0.75 m^2). Also shown are 8 tussock nearest neighbour points using a irregular layout (brown points), and a more systematic layout (green points).

Appendix XVI

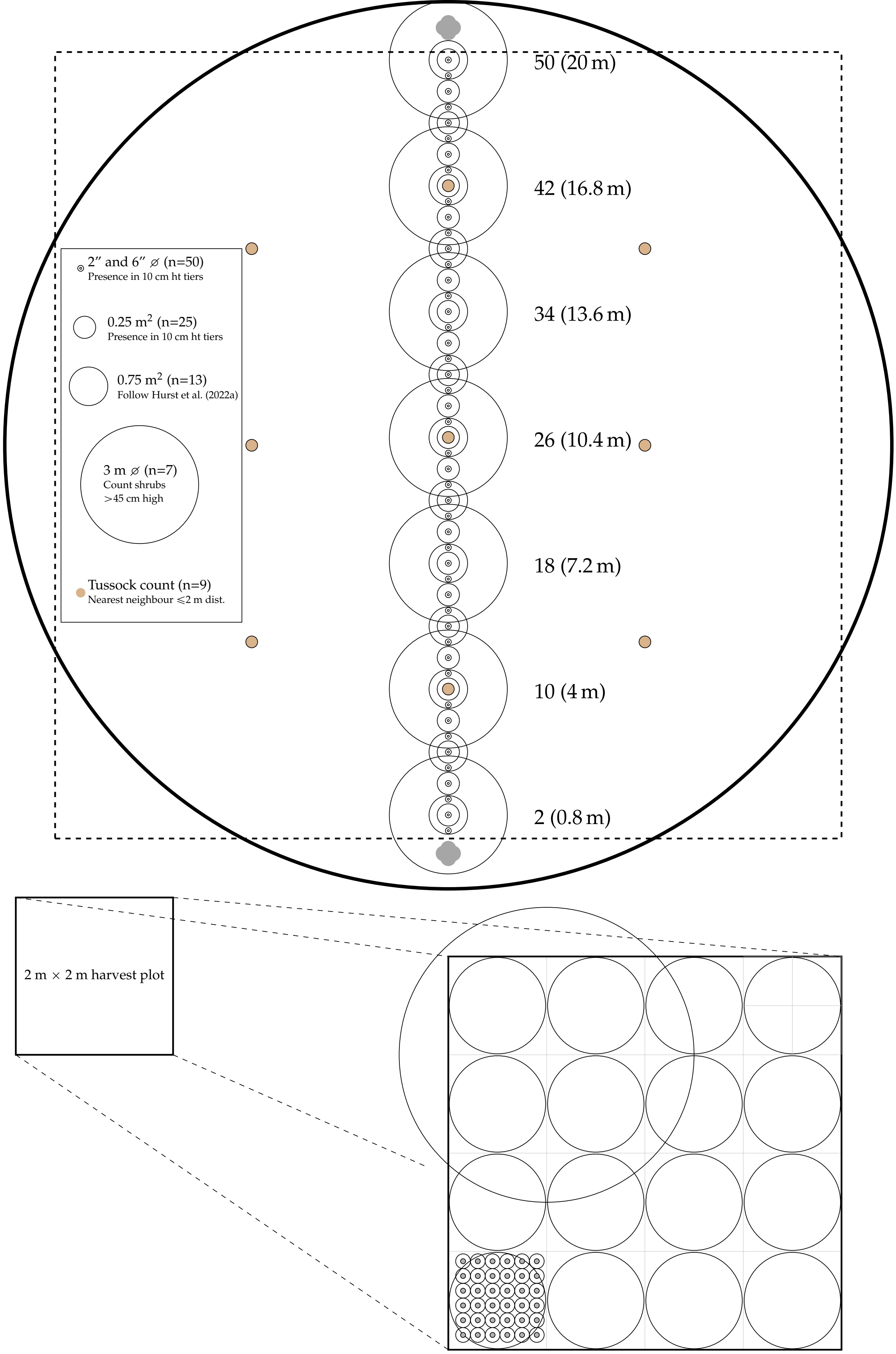


Figure 7: Layout of alpine grassland plot and associated 2 m × 2 m harvest plot. The central transect has fifty intercepts spaced at 40 cm intervals (6"⌀, Wraight, 1960, 1963; 2"⌀, Scott, 1965), twenty five 0.25 m^2 sub-plots spaced at 80 cm intervals (56.4 cm ⌀, (Duncan et al., 2001)), thirteen 0.75 m^2 subplots at 1.6 m intervals (49 cm radius, Hurst et al., 2022a) and seven 3m ⌀ subplots at 3.2 m intervals. The presence of plant foliage in 10 cm height intervals is recorded in subplots up to 0.25 m^2. Nine systematically located tussock count nearest neighbour points and a 400 m^2 circular bounded grassland recce plot (22.6 m ⌀, Hurst et al., 2022b) are also shown. In the 2 m × 2 m harvest plot, vegetation is harvested and weighed by species in 64 0.25 m^2 sub-plots. There are a total of nine 2" and 6"⌀ intercepts in each of these 64 sub plots. The harvest plot also has 16 0.75 m^2, and four 3m ⌀ subplots where all tussocks and shrubs are harvested (following height and diameter measurements).

Appendix XVII