PERSPECTIVES IN
Biodiversity
VOLUME 4 / ISSUE 1 / 2026

Published ahead of issue
Received: 25 July 2025
Accepted: 29 September 2025
Published: October 2026

Distribution, abundance and conservation management of two calcicolous bittercress species, *Cardamine integra* and *C. caesiella* (Brassicaceae), in limestone areas of South Canterbury, Aotearoa / New Zealand

Hermann Frank

https://doi.org/10.55457/pibdiv.004103

Distribution, abundance and conservation management of two calcicolous bittercress species, *Cardamine integra* and *C. caesiella* (Brassicaceae), in limestone areas of South Canterbury, Aotearoa / New Zealand by Hermann Frank is licensed under a Creative Commons Attribution-NonCommercial 4.0 International Licence.

This publication may be cited as:
Frank, H. (2026). Distribution, abundance and conservation management of two calcicolous bittercress species, *Cardamine integra* and *C. caesiella* (Brassicaceae), in limestone areas of South Canterbury, Aotearoa / New Zealand. *Perspectives in Biodiversity*, 4(1): 13–30.

Contact:
www.unitec.ac.nz/epress
ePress
Manukau Institute of Technology and Unitec
Private Bag 92025, Victoria Street West
Tāmaki Makaurau Auckland 1142
Aotearoa New Zealand

ISSN 3021–114X

Distribution, abundance and conservation management of two calcicolous bittercress species, *Cardamine integra* and *C. caesiella* (Brassicaceae), in limestone areas of South Canterbury, Aotearoa / New Zealand

Hermann Frank

Affiliation:
South Canterbury Museum, PO Box 522, Timaru 7940, New Zealand

Correspondence: hermann@newfrankland.org
Associate Editor: Professor Peter J. de Lange
Article type: Research paper

Abstract

Cardamine (Brassicaceae) supports numerous species (> 40) in Aotearoa / New Zealand. They are mostly small perennial herbs and grow in diverse habitats, often related to a specific geological substrate or soil type, including limestone outcrops. Two of these calcicolous species, *Cardamine caesiella* and *C. integra*, are endemic to South Canterbury, though the areas of occupancy are disjunct. This study investigates the distribution, abundance and ecology of the two species across limestone outcrops in South Canterbury to identify appropriate conservation management for these threatened plants. Surveys between 2019 and 2022 recorded 773 plants of *C. integra*, comprising 515 mature plants in 13 sub-populations, ten previously unknown. *C. caesiella* were recorded in one isolated limestone area, a population with 929 plants, 638 mature. As the total area of occupancy for both species is below 1 ha, the current threat ranking of 'Threatened / Nationally Critical' should remain. Grazing pressure and competition by introduced weeds and grasses are the main threats for these small herbaceous plants. Experimental conservation work such as weed control and enclosures for small sub-sites has been trialled. Control measures for the widespread, invasive *Sedum acre* have been undertaken in a number of larger limestone areas in the region over successive years.

Keywords

Endemic calcicolous plants, survey, population count, conservation, weed competition, grazing, threat assessment

Introduction

The genus *Cardamine* L., with mostly perennial herbs, is cosmopolitan and currently comprises approximately 261 accepted species (Kew Botanic Gardens 2025). These species are found in diverse habitats worldwide, except the Antarctic, and are commonly known as bittercresses or toothworts. *Cardamine* in Aotearoa / New Zealand are small perennial herbs that show variability in morphology and distributions often influenced by local site conditions, and are often difficult to identify in the field (Heenan 2008). The species *Cardamine debilis* DC., for example, is highly variable and was often treated as an aggregate *C. debilis* agg.

Their typical growth habit is rosettes with basal leaves and single or multiple stems. Shape, form, texture and colour tone of both basal and caudal leaves provide relevant information for identification. The size of leaves can vary considerably in response to local environmental conditions (Heenan 2017). Inflorescences can consist of single or multiple flowers. Flowers usually have four white petals arranged in a cross and six stamens, but plants with only three white petals are not uncommon. The seeds are wingless and are contained in elongated capsules that also vary by species. They have a ballistic dispersal strategy. When mature, capsules split open with recoiling valves, often on touch, and catapult seeds a considerable distance. *Cardamine hirsuta* L., for example, can project seeds up to 5 m (Vaughn et al. 2011), though other research has only noted 50 cm dispersal (Bachman & Whitwell 1995). This species can produce up to 4000 seeds on one plant (Bachman & Whitwell 1995) and has, as with some other introduced *Cardamine* species, become a garden weed in Aotearoa / New Zealand. The reverse has also happened with the endemic *C. corymbosa* Hook.f. that is becoming widespread overseas, e.g., Great Britain (Grace 2025).

A full national taxonomic revision of the genus *Cardamine* was completed in 2016 (Heenan 2017). Heenan recognised 41 endemic taxa and a further four species as naturalised in Aotearoa / New Zealand. More recently, two further endemic species have been described (Heenan & Molloy 2019; Heenan & de Lange 2018). These species can be placed into three broad groups: alpine-montane habitats, forest habitats and an additional group broadly defined as lowland open habitats (Heenan 2017). Some species are widespread and occur both in the North and South Islands, while others have a restricted distribution, especially the lowland species. They can be confined to a small geographic area and/or to a specific substrate such as limestone.

Limestone ecosystems are classified as naturally uncommon, meaning they comprise less than 5% of the country's land area (Williams et al. 2007; Wiser et al. 2013). Owing to high levels of habitat loss and modification, indigenous limestone ecosystems nationally have been assessed as 'Threatened / Nationally Vulnerable' (Holdaway et al. 2012). The vulnerability of limestone ecosystems is compounded by their occurrence in regions where relatively small proportions are protected, namely in acutely threatened land environments (Walker et al. 2008; Walker et al. 2015; Cieraad et al. 2015; Heenan & Rogers 2019). Limestone outcrops are important habitats for indigenous biodiversity. They provide refuges for plants, birds, bats, lizards, invertebrates and micro-snails (Frank 2018), especially in depleted landscapes (Pawson & Holland 2008). This includes threatened endemic species that are adapted to calcium-rich soils (Rogers et al. 2018; Heenan & Rogers 2019; Craw et al. 2024).

Rogers et al. (2018) list five *Cardamine* species restricted to limestone (calcicolous), plus some species that also occur on other substrates (facultative). Two of these calcicolous species, *C. caesiella* and *C. integra*, are endemic to South Canterbury. They are amongst the smallest (< 10 cm) herbaceous plants occurring in limestone habitat and both species are assessed as being 'Threatened / Nationally Critical' using the New Zealand Threat Classification System (de Lange et al. 2024). However, very little data about populations, ecology and threats to these species is available, aside from the information contained in the taxonomic description. The current study aims to provide new information on the distribution, population sizes and general ecology of these limestone endemics in order to assist their conservation management in the field.

Cardamine integra (Rockdale limestone bittercress)

Background

The species was first described by Heenan (2017) and the holotype assigned to collections from the Rockdale limestone outcrop in the Tōtara Valley (https://scd.landcareresearch.co.nz/Specimen/CHR%20636068). Specimens were collected originally from two outcrops on the property, and another specimen by M. Harding from a neighbouring scarp. It was concluded that the



Figure 1. Tōtara Valley (code Carint K), *Cardamine integra* plants on limestone boulder, also limestone fern *Asplenium lyalli* T.Moore, 16 September 2021. All photos by author.

species was restricted to limestone habitats at the Tōtara Valley and Ōpihi River area in South Canterbury (Heenan & Rogers 2019). A threat status of 'Threatened / Nationally Critical' was proposed using the New Zealand Threat Classification System (Townsend et al. 2008; Heenan 2017). The threat ranking was retained for the 2017 and 2023 conservation assessments (de Lange et al. 2018; de Lange et al. 2024). These assessments were based on the criterion A(1) – The total population size is < 250 mature individuals. Also, three qualifiers applied: DPS – Data Poor Size, DPT – Data Poor Trend and OL – One Location.

C. integra is described as a perennial herb most similar to *C. corymbosa* (Heenan 2017, Heenan & Rogers 2019). The basal leaves are up to 70 mm long. The main terminal leaf is oval or somewhat triangular, up to 10 mm long, green, smooth and membranous, usually simple and without hairs. Fine hairs might be present on the leaf edge and especially the leaf stem. The leaf base is right-angled or more often slightly wedge-shaped, and the apex is rounded (Figure 1). Small leaflets below the main leaf can be present, usually in pairs opposite each other on the stem. Flowering stems typically have one flower but can also carry multiple flowers. Seed capsules show the typical narrow cylindrical *Cardamine* shape and are between 9 and 20 mm long and about 1 mm in diameter (Heenan 2017).

The species was not recognised in South Canterbury during earlier limestone surveys, but *Cardamine* taxa were found regularly. From 2002 to 2004, the Canterbury Conservancy of the Department of Conservation (DOC) / Te Papa Atawhai, with support from the Raukapuka / Geraldine District Office, initiated a field survey of plants inhabiting limestone areas of South Canterbury (Pender et al. 2004). This survey covered 34 properties between the Waihao Downs in the south, and Kakahu in the north.

Table 1. *Cardamine integra* in limestone areas of South Canterbury.

Area code	Wider area	Observation years	No. of plants observed	No. of sub-sites	Other *Cardamine*
Carint A	Maungati	2019	30	1	*C. corymbosa, C. hirsuta*
Carint B	Pareora	2019, 2020	24	2	*C. grandiscapa, C. corymbosa*
Carint C	River	2020	103	3	*C. grandiscapa*
Carint D		2019	37	3	*C. grandiscapa*
Carint E	Limestone Valley	2021, 2024	126	6	*C. grandiscapa, C. corymbosa*
Carint F	Cave	2024	3	1	*C. grandiscapa, C. intonsa, C. flexuosa*
Carint G	Tōtara Valley	2021, 2023	86	10	
Carint H		2019, 2021	53	4	*C. corymbosa, C. forsteri*
Carint I		2020	11	1	
Carint J		2019, 2021	46	3	*C. corymbosa*
Carint K		2021	167	13	*C. grandiscapa, C. hirsuta*
Carint L		2021	36	3	
Carint M	Braeburn	2019, 2020	51	2	*C. grandiscapa*
13 locations	**South Canterbury**		**773**	**52**	

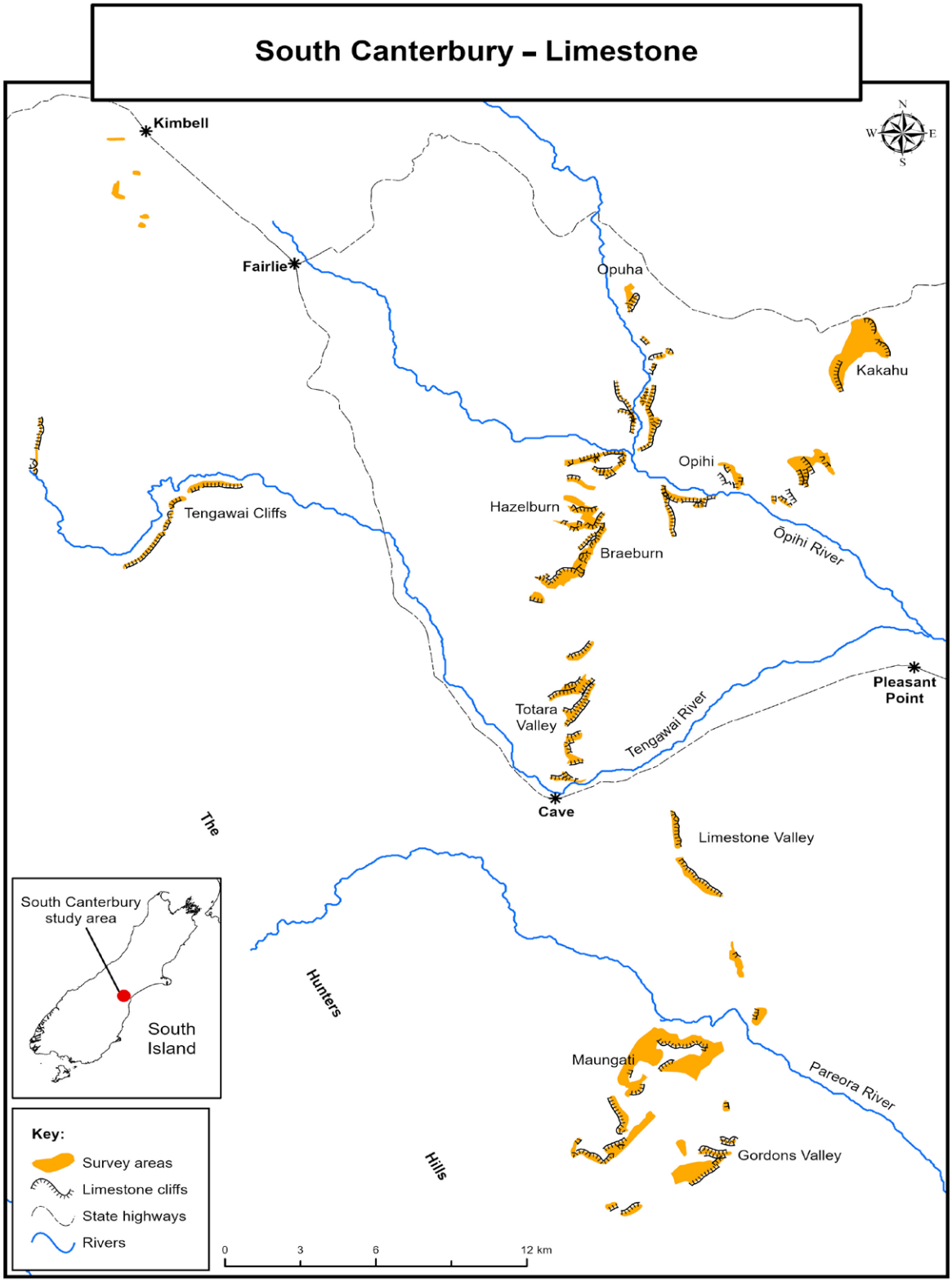


Figure 2. Surveyed limestone areas in South Canterbury. Map: Steve Caswell.

They listed *C. debilis* for 27 of these limestone areas, but it is unclear which current species these records could represent. However, an indigenous *Cardamine* species was found in about 80% of the surveyed limestone areas, despite surveys conducted when *Cardamine* are not in flower. A second undetermined *Cardamine* taxon was also noted for three limestone areas. Two of these areas are identical with areas 'Carint A' and 'Carint E' in Table 1, and these records could represent *C. integra*. Two exotic species were also listed: *C. hirsuta* in nine areas, and *C. flexuosa* in six areas.

From 2005 to 2016, an estimated 90% of limestone habitats in the Timaru District were surveyed as part of the Significant Natural Areas (SNA) mapping programme (Harding 2016). A small number of properties were visited more recently. Of eleven reports available, six mention *C. debilis* agg., two *Cardamine* spp. and one *C. integra*. Limestone habitats along Limestone Valley Road, Taiko, were surveyed by A. Shanks in March 2010. The plant list contains *C. debilis* without any further details (Frank 2024b; Frank 2024c). There is one record on iNaturalist New Zealand which might be *C. integra* (https://inaturalist.nz/observations/64966610). The locality is obscured, but seems to be on South Canterbury limestone.

Study Area and Methods

Limestone outcrops in South Canterbury occur in the hinterland between the coastal lowlands and the foothills of the Kā Tiritiri o te Moana / Southern Alps, but only cover c. 0.2% of the region's land area. They are not a continuous landscape feature, instead occurring naturally as isolated 'island' ecosystems (Figure 2). Except for the small Raincliff Historic Reserve, all limestone areas in South Canterbury are on private land and are used for grazing sheep, cattle or deer. Based on my familiarity with these areas from previous research on lizards (Frank & Wilson 2011), I undertook annual surveys from 2016 to 2022 for three endemic calcicolous taxa: *Gentianella calcis* subsp. *taiko* Glenny & Molloy, *G. calcis* subsp. *manahune* Glenny & Molloy and *Ranunculus callianthus* Molloy & Heenan (Frank 2023a; Frank 2024a).

Initially, this research was centred on these three target plants. However, from 2019 to 2022 the focus shifted to other threatened calcicolous plants (e.g., Frank 2025), including *Cardamine* species, although some smaller limestone areas were not revisited. As the holotype location of *C. integra* is in the Tōtara Valley, limestone locations there and some other places, e.g., Limestone Valley, were visited more than once. A number of sites were also checked in 2023, 2024 and 2025.

In addition, extensive weed control was undertaken annually from 2018 to 2025 to reduce the dominance of invasive stonecrop *Sedum acre* L. on the Tengawai Cliffs and at Tōtara Valley locations. This succulent was very widespread in these locations and control work was undertaken throughout entire limestone territories. It usually involved spraying with a mix of glyphosate, penetrant and dye, either by volunteers or contractors using knapsacks. Professional abseil contractors were employed for places not accessible otherwise. Hand-weeding and spraying with a hand-sprayer were applied near and around threatened plants. This work usually happened during summer months when mature stonecrop plants are flowering. For further details, see Frank (2024a). Threatened native plants found during weed control were noted.

Surveys were generally conducted when *Cardamine* is flowering (September–October) and plants were recorded in relation to individual sub-sites, e.g., boulders, overhangs and outcrops within the wider limestone area. Attempts were made to visit all potential sites, but due to the nature of limestone country, not all sites were accessible, though *Cardamine* plants mostly occur on rocks and in lower shaded places, e.g., overhangs. They are relatively cryptic in many habitats and therefore the numbers recorded are likely to be conservative. For *C. integra*, flowering and non-flowering plants were not recorded separately. Co-ordinates of locations were taken post visit from Canterbury Maps. A small number of plants were held in propagation. These were initially sourced from plants accidentally gathered while hand-weeding stands in the wild.

Results

Cardamine integra was recorded in 13 separate limestone locations (Table 1), mostly in the Tōtara Valley, but also further south at the Limestone Valley, and at limestone outcrops near the Pareora Gorge and near Maungati. The species persists at locations of the specimens at the Allan Herbarium (locations Carint H, I and J). Three new specimens from other areas were deposited in the Allan Herbarium. No plants of *C. integra* were found in limestone areas near the Ōpihi River and further north. In 2018 12 *Cardamine* plants were found in another limestone area of the Tōtara Valley and 15 plants at the Waihao Downs, which were most likely *C. integra*. The distances between sub-populations of *C. integra* in these 13 limestone areas range from 1 to 6 kilometres, beyond the likely pollination or dispersal



Figure 3. Tōtara Valley (code Carint K), south-facing *Cardamine integra* habitat on rock, 15 November 2023.



Figure 4. Tōtara Valley (code Carint K), rock indentations provide hold for *Cardamine integra*, 16 September 2021.



Figure 5. Limestone Valley (code Carint E), *Cardamine integra* with seedheads (left) and two other calcicoles: *Geranium socolateum* Heenan & Molloy with flowers (centre) and *Colobanthus* aff. *brevisepalus* (right), 26 February 2019.



Figure 6. Tōtara Valley (code Carint L), *Cardamine integra* and *Asplenium lyallii* browsed by livestock, 16 September 2021.

distance.

A total of 773 plants at 52 sub-sites were found (Table 1). Data from 2021 was predominantly used, with data from other years drawn upon when no 2021 data for a particular sub-site was available. To assist further work on the species, a more detailed version of Table 1, with observation dates, numbers and GPS co-ordinates for each sub-site, is available from the author or South Canterbury Museum upon request.

The largest population of *C. integra* plants was in a c. 7 ha limestone area in the Tōtara Valley area (Carint K). This area is atypical for limestone formations in South Canterbury, comprising about 50 large scattered boulders, a high number for an area of this size (Figure 3). The rock surfaces are uneven and show irregularly distributed solution cavities, cracks and fissures, which provide microhabitat for calcicolous plants (Figure 4). At 13 sub-sites a total of 167 *C. integra* plants were found. For example, one rock had 50 plants and another 40 plants in 2021. These plants grow on rocks or under associated overhangs, the majority out of reach of grazing stock. Other coexisting calcicolous plants include *Geranium socolateum* Heenan & Molloy, *Colobanthus* aff. *brevisepalus*, *Gentianella calcis* subsp. *taiko* and *Senecio* aff. *matatini* (Figure 5). Away from limestone rocks, these plants cannot get established or persist due to dense pasture or regular grazing by stock, presenting a complex conservation conundrum. Where stock have access, plants are often browsed heavily (Figure 6), a feature of all accessible limestone



Figure 7. Tōtara Valley (code Carint G), prolific seed production of *Cardamine integra* after postponement of grazing, 11 December 2023.



Figure 9. Tōtara Valley (code Carint K), *Cardamine integra* having to compete with exotic plants: here, catsear *Hypochaeris radicata* L., 15 September 2020.



Figure 8. Tōtara Valley (code Carint J), caterpillar of the white butterfly *Pieris rapae* feeding on *Cardamine integra*, 23 March 2020.



Figure 10. Tōtara Valley (code Carint G), heavy competition by stonecrop *Sedum acre*; only spent seedheads of *Cardamine integra* visible, 7 February 2019.

areas in this region.

The second-largest population of *C. integra* is located on the Limestone Valley scarp near Taiko, although the species occurs only at the north end of the scarp (area Carint E). One hundred and twenty-six plants were recorded on six sub-sites in March 2021 and on one additional sub-site found in September 2024. *C. integra* favours shaded sites, usually on the south or west side of rocks, only occasionally facing northeast or northwest, or in crevices where plants have partial shade. Plants growing in more exposed or drier conditions are often small, with thickened leaves. Other *Cardamine* observed in the survey are: *C. corymbosa*, *C. grandiscapa* Heenan, *C. forsteri* Govaerts, *C. intonsa* Heenan, and the exotic species *C. hirsuta* and *C. flexuosa*.

Numbers of *C. integra* plants at individual sub-sites appear to fluctuate yearly. The area with the largest population (Carint K) increased from a total of 138 in 2020 to 167 plants in 2021. This is even more pronounced on other sub-sites. Population expansions over a year occurred on several other rocks, for example, from five to 19 and 15 to 40 plants between samplings. Another site showed large interannual population variation, with 40 plants in 2019, 26 in 2020 and 50 in 2021. There were also marked population declines. A sub-site at the Limestone Valley, consisting of a number of low adjoining rocks, went from 75 plants in March 2021, to 42 in March 2022, to only eight plants in March 2025,



Figure 11. Tōtara Valley (code Carint K), *Cardamine integra* competition by *Geranium socolateum*, 15 September 2020.

mainly due to animal browsing.

Though *Cardamine* are prolific seed producers, browsing often limits plant reproduction. This was demonstrated at one location in particular (Carint H), where *Cardamine* capsules were infrequent or limited to inaccessible plants when the area was grazed, but abundant when grazing was withheld in spring and summer 2023 due to temporary management change in an adjoining paddock (Figure 7). On two occasions, a caterpillar of the white butterfly *Pieris rapae* L. was observed feeding on *C. integra* plants (Figure 8).

Competition from other plants, especially exotic species, was observed in many situations. Exotic plants either out-competed and overtopped *Cardamine* plants (Figure 9) or already occupied potential spaces. At Tōtara Valley locations, the mat-forming succulent stone crop *Sedum acre* L. was also eliminating suitable sites and forming a dense cover in places, creating problems for *Cardamine* establishment and growth (Figure 10). In limited situations, the limestone geranium *Geranium socolateum* seemed to also compete with *C. integra* plants for space (Figure 11).

Discussion

This survey confirmed the continuous presence of *Cardamine integra* in the locations originally sampled in 2014. In addition, the species' known range was expanded across other limestone areas in the Tōtara Valley, further south in the Limestone Valley, and towards the Pareora Gorge. Ten of these 13 sub-populations were previously unknown. The results also support the calcicolous status of the species, which in South Canterbury has not been observed outside of limestone outcrops.

Data collected (2019–24) resulted in a total of 773 plants, a third estimated as immature. This leaves 515 mature *C. integra* plants across its entire range. While fluctuations at a number of sub-sites have been observed, there is no long-term monitoring data available, and it is not possible to ascertain whether the species is stable or in decline.

In the past, these small herbaceous plants might have occupied other sites within the limestone habitat, but today they only occur on small sub-sites each less than 50 m², e.g., rocks and boulders within the 13 separate limestone locations. Cracks, crevices and solution cavities with small limestone fragments and porous residues provide microhabitats with skeletal soils that allow establishment of these calcicolous plants. They can obtain nutrients by extending roots into tiny spaces in the limestone substrates (Craw et al. 2024). However, observations at several sub-sites of *Cardamine* plants having reduced leaf size and leathery appearance show that in some situations calcicolous plants like *Cardamine* struggle in this difficult environment. This could partially explain fluctuations in some locations.

Bittercress plants are highly palatable for livestock, and plants are larger with more seed capsules where grazers are excluded via fencing or natural site characteristics. The extent to which grazing limits recruitment is unknown, as the data suggest most sites maintain juveniles. Another major threat to the persistence of *Cardamine integra* is competition from exotic pasture grasses and invasive weeds. Grasses and weeds are almost certainly smothering indigenous plant communities on limestone (Wotton 2022), especially prostrate herbs, and competing for potential establishment sites. In cultivation, *Cardamine integra* showed effective seed dispersal up to at least 1 metre and readily established from seed where no competition existed (Figure 12), although adult plants may only live for a few years. Due to these multiple threats, *Cardamine integra* cannot persist away from microhabitats on or near rocks that occupy only a small fraction of the available limestone habitat.

A potential new threat for *Cardamine integra* is from invertebrate herbivory. While the occurrence of white butterfly caterpillars feeding on bittercress plants seems to be low, this may increase with forage brassicas becoming more widespread in the agricultural landscape surrounding limestone outcrops.

The available distribution and population data supports the current conservation ranking of



Figure 12. Timaru garden, *Cardamine integra* growing freely from propagated plant seeding with no competition, 25 September 2022.

'Threatened / Nationally Critical' (Rolfe et al. 2022; de Lange et al. 2024). However, it is suggested that the assessment criteria would change to A(3) – The total area of occupancy is ≤ 1 ha, compared to criteria in de Lange et al. (2024), where criterion A(1) was applied. One qualifier would still apply: DPT – Data Poor Trend. A further qualifier is suggested: CR –Conservation Research needed. All limestone areas with *Cardamine integra* present have been identified as Significant Natural Areas in the Timaru District Plan. Two areas in the Waimate District have no formal protection.

Management options for the species at landscape scale are limited. As outlined, where grazing is withdrawn, seed production might increase temporarily, but competition by weeds, especially introduced grasses, will grow substantially. For some limestone species, hand-weeding, where practical, can enhance native dominance of these limestone herbs and also increase the survival, reproduction, and probably seedling establishment (Wotton 2022). However, this level of micro-management can only be achieved at small scales. At some locations, e.g., Carints G, K and L, hand-weeding was undertaken and, away from limestone plants, exotic vegetation, especially stonecrop, was sprayed.

Control measures for stonecrop were undertaken in eight Tōtara Valley limestone areas and are continuing. Funds were made available by the Timaru District Council from their Biodiversity Fund. This work was not specifically to protect *Cardamine* sites, but targeted all sites where stonecrop was present. By eliminating stonecrop, new micro-habitats for calcicolous plants, including *Cardamine*, were potentially made available.

As no monitoring was established, the effect on limestone species is difficult to determine. However, it might be possible to set up a monitoring and conservation programme for selected areas or sub-sites. Smaller separate sub-sites seem to be most useful for this, as they are distinct and allow full monitoring after establishing a baseline. Plot or small-transect-based monitoring seems to be less ideal for this environment. It would also be desirable to research the lifespan of this species. Other conservation measures could include establishment of enclosures and hand-weeding. Ongoing monitoring should assess the efficacy of these measures. Sub-sites at locations Carints E, G and K seem to be suitable for this. Location Carint E does not currently have any stonecrop.

Another practical conservation option would be the establishment of suitable woody vegetation, such as native trees and shrubs. This might provide environments long-term where weeds are suppressed and new micro-habitat for herbaceous plants is created. As *Cardamine integra* prefers shade, or at least is shade tolerant, such steps could be of benefit for the species. However, the establishment of woody vegetation in this extreme environment is difficult. Also, it would require fencing off selected areas. Obviously, all these steps would need approval by landowners.

Cardamine caesiella (Manahune limestone bittercress)

Background

Cardamine caesiella was described by Heenan (2017) from collections in December 2015 at Manahune, a limestone area at the southwest end of the Tengawai Cliffs (Figure 1), southwest of Fairlie in the Mackenzie District (https://scd.landcareresearch.co.nz/Specimen/CHR%20640339). The species was noted as being restricted to limestone habitats near the Tengawai River and a threat status of 'Threatened / Nationally Critical' was proposed (Townsend et al. 2008; Heenan 2017). This conservation status was retained in subsequent revisions (de Lange et al. 2018; de Lange et al. 2024). It was based on the criterion A(2) – There are ≤ 2 sub-populations and ≤ 200 mature individuals in the larger sub-population. Further, four qualifiers were applied: CR – Conservation Research needed, DPR – Data Poor Recognition, DPS – Data Poor Size and DPT – Data Poor



Figure 13. Tengawai Cliffs E, *Cardamine caesiella* plants in rock crack, 18 October 2021.

Trend.

There were no other previous records of the species. Pender et al. (2004) listed *Cardamine debilis* at the west and east ends of the Tengawai Cliffs and it is likely these would have been *C. caesiella*. *C. caesiella* is described as a perennial herb most similar to *C. grandiscapa* (Heenan 2017; Heenan & Rogers 2019). Colour, texture and leaf shape are helpful distinguishing field characteristics. The basal leaves are generally simple, up to 90 mm long, grey-green to blue-green and somewhat leathery (Figure 13). The shape of the main leaf is often heart-like with a rounded end, about 30 mm long and 15 mm wide. Sparse short fine hairs on the leaf edge and leaf stem may exist. Small leaflets below the main leaf can be present, usually in pairs on the stem opposite each other. Flowering stems have one or multiple flowers and the typically shaped seed capsules are about 13 to 25 mm long and 1.5 mm in diameter (Heenan 2017).

Study Area and Methods

The Tengawai Cliffs are a prominent but isolated limestone escarpment of about 7 km in length along the upper reaches of the Tengawai River in the Mackenzie District. The limestone sections of the Tengawai Cliffs run across five private farming properties (here named A–E from northeast to southwest), which mostly undertake pastoral farming with rotational grazing by sheep and cattle. For more detailed descriptions of the Tengawai Cliffs, see Frank (2023a).

The area was surveyed between 2016 and 2019 for *Gentianella calcis* subsp. *manahune* and *Ranunculus callianthus*, which are endemic to this limestone scarp (Frank 2023a). *Cardamine* plants, along with other species, were noted incidentally, especially after 2019, when the focus expanded and other calcicolous plants were recorded systematically. In 2021 comprehensive surveys were conducted on larger sections of the scarp, which focused mostly or entirely on *C. caesiella*. In some instances, surveys occurred in conjunction with monitoring visits for *R. callianthus*. Access to property A was not permitted across later survey years.

As with other bittercress species, plants are most conspicuous during flowering in spring (September–October), therefore non-flowering plants may be underrepresented. Access to the scarp is limited from September to the first half of October because of restrictions associated with lambing. Areas with potentially suitable habitat for *C. caesiella* were therefore surveyed during the later part of the flowering season. All potential locations were searched at least once by the author, except for one day when a team from DOC helped to survey property C. Most co-ordinates were taken post-visit from Canterbury Maps.

Results

Cardamine caesiella were recorded on all properties along the Tengawai Cliffs, but no detailed data exists from property A. On the four other properties, a total of 929 plants were found at 67 sub-sites, 638 were mature and 291 immature plants (Table 2). The strongest sub-population was found on property C, in the middle of the scarp, with a total of 377 plants, comprising 276 mature and 101 immature individuals (Table 2). Eight more specimens from four properties were added to the Allan Herbarium collection. Again, to assist further work on the species, a more detailed version of Table 2 with observation dates, numbers and GPS co-ordinates for each sub-site is available from the author or South Canterbury Museum upon request.

C. caesiella grows in cracks, cavities, solution hollows, on ledges, under overhangs of rocks or outcrops directly on or near exposed limestone (Figures 14–16). A considerable number of sub-sites are at the foot of bigger rocks or boulders extending into grassy areas (Figure 17). Most micro-sites are facing northwest, south or southwest, and are shaded, at least for part of the day. Some south-facing sites might get direct sunshine only through summer months. In a few situations, *C. caesiella* plants grow in the shade of trees such as broadleaf *Griselinia littoralis* (Raoul) Raoul. However, some micro-habitats are exposed to full sun. These plants are generally small, with a strong leathery appearance (Figure 18).

Table 2. *Cardamine caesiella* and *C. corymbosa* in limestone areas of the Tengawai Cliffs (for property index, see study area and methods section).

Location	**Year**	***Cardamine caesiella***			***C. corymbosa***		**Comments**
Tengawai Cliffs		Flowering	Non-flowering	Sub-sites	Plants	Sub-sites	
A	2019	Yes			Yes		
B east	2020, 2021	52	16	8	31	3	10 *C. intonsa*
B mid	2021	56		6			
	2019		22	2			No visit in 2021
B west	2021	40	17	6			
C top	2021	119	28	9			
C below cliffs	2021	157	73	16	116	6	
D	2021	35	27	4	32	1	
	2022	45	51	6			Additional in 2022
E east	2021	78	42	11			
E west	2021	56	15	7			
Tengawai Cliffs	**2019–2022**	**638**	**291**	**75**			



Figure 14. Tengawai Cliffs C, *Cardamine caesiella* habitat on southwest-facing base of boulder, 14 October 2021.



Figure 15. Tengawai Cliffs E, single *Cardamine caesiella* plant in rock crack on top of cliffs, 30 August 2022.

Numbers at sub-sites vary considerably, from a single plant to 65 plants, 21 of these immature, and some very small boulders supported numerous plants. For example, another sub-site at property C on the low side of a high boulder contained 47 plants, 20 of these immature. Sub-sites with 20 to 30 plants were found on all four properties.

Two other endemic *Cardamine* species were observed. One sub-site had ten *C. intonsa* plants and ten sub-sites had a total of 113 mature and 61 immature plants of *C. corymbosa*. In a few cases, identification was difficult, and plants here were grouped with *C. corymbosa*. The exotic species *C. hirsuta* has also been found on properties C, B and D, but seems to be currently restricted to a few sites.

Where livestock can access plants, signs of browsing were noticeable. Browsing may lead to substantial fluctuations at sub-sites, e.g., 65 plants found in 2021 at one sub-site were reduced to only seven in 2024. To exclude the role of mammal grazing, wire netting was



Figure 16. Tengawai Cliffs C, mature *Cardamine caesiella* plant on rock ledge, 22 October 2021.



Figure 17. Tengawai Cliffs C, *Cardamine caesiella* habitat in grassy patch at rock base, 21 October 2021.



Figure 18. Tengawai Cliffs B, *Cardamine caesiella* on open exposed rock site (reduced leaf size with leathery appearance), 4 March 2019.



Figure 19. Tengawai Cliffs B, prolific seed production of *Cardamine caesiella* under wire enclosure, 1 November 2022.

installed at three sub-sites, and all *C. caesiella* plants were recorded during subsequent monitoring. Prolific seed-production was observed (Figure 19), but also stronger competition from pasture species that had increased in growth. Hand-weeding has been trialled within the enclosures and at a few other micro-sites not accessible to stock, and has shown good results (Table 3). At a sub-site on a ledge (Figure 16) not accessible to stock, hand-weeding was carried out in October 2021. The following year, numbers had increased from ten to 19 flowering and 13 to 21 non-flowering plants. As seen at enclosure B (Table 3), there is a flow-on effect of self-seeding of plants into the surroundings of the enclosure.

Hand-weeding generally consisted of mechanically removing exotic weeds close to *C. caesiella* using smaller tools such as knives. Further away, where it was safe, small handheld sprayers could be used. This seemed to be more effective for red fescue grasses, because it was not possible to mechanically remove all roots, and grasses responded well to glyphosate. If necessary, indigenous plants were covered with plastic containers during the spraying.

On four sub-sites, the calcicolous geranium *G. socolateum* competed with the smaller *C. caesiella* (Figure 20). However, the main competition was from exotic plants, especially red fescue, *Festuca rubra* L., which can smother *Cardamine* habitat (Figure 21). Stonecrop *Sedum acre* also had strong populations along the scarp (Figure 22), except for considerable parts on property A and property B. Starting in 2017,

Table 3. *Cardamine caesiella* plant numbers under three enclosures at the Tengawai Cliffs.

Site	2019	2020	2021	2022	2023
B	No data	6	7	Many + three patches outside	7 + many seedlings
C east	No data	4	3	2	11
C top	3	3	2	5	8



Figure 20. Tengawai Cliffs B, *Geranium socolateum* competing with *Cardamine caesiella* (only flowers visible, note only three petals), 17 October 2019.



Figure 21. Tengawai Cliffs E, *Cardamine caesiella* competing with *Festuca rubra*. grasses, 10 October 2019.



Figure 22. Tengawai Cliffs C, stonecrop and other exotic plants occupying potential habitat for calcicolous plants, 17 January 2019.

widespread control measures for stonecrop along the scarp have been carried out using volunteers and contractors accessing areas both on foot and through abseil methods (Frank 2019; Frank 2020; Frank 2023a; Waterhouse 2022). By 2023, stonecrop numbers had been reduced to an estimated 2% to 5% of original numbers, and generally only smaller plants and some new growth remain. The majority of control time now is spent on searching for remaining or new stonecrop plants.

Discussion

Cardamine caesiella is restricted to the Tengawai Cliffs, but is more widespread there than originally thought, frequently found on small sub-sites through limestone areas, both on top of the cliffs or on/near rocks and boulders below the cliffs. The population at property C is particularly strong (377 plants) and appears to be crucial for the survival of the species. On other properties, sub-sites are more scattered, often with considerable distances of up to 400 metres between sub-sites. Property C has a Queen Elizabeth II (QEII) covenant in place for most of the limestone section (Frank 2023b).

The limestone sections of the other properties have some formal protection through the recognition as Outstanding Natural Features in the Mackenzie District Plan. However, no SNA surveys have been carried out.

These surveys present baseline data for *C. caesiella*, and it is therefore not possible to ascertain if the population is stable or in decline. Observations from the few sites that have had multiple visits suggest that the *Cardamine caesiella* population fluctuates significantly more than either of the other two endemic limestone species, *Gentianella calcis* subsp. *manahune* and *Ranunculus callianthus* (Frank 2023a). Like *C. integra*, this *Cardamine* species grows on sub-sites of less than 50 m^2 and the total population occupies only a small percentage (< 1 ha) of the limestone areas on the Tengawai Cliffs. The available data supports the current conservation ranking of 'Threatened / Nationally Critical' (Rolfe et al. 2022; de Lange et al. 2024). However, the criterion would change to A(3) – The total area of occupancy is ≤ 1 ha. Two qualifiers would still apply: CR – Conservation Research needed and DPT – Data Poor Trend.

Field observations indicate that differentiating between *C. caesiella* and *C. corymbosa* may be difficult. Plants seem to develop more or less strong characteristics depending on local conditions and micro-habitats. Peter Heenan commented on some samples sent to him, that "These plants show the type of variation that occurs in natural wild populations where the plants are growing in different positions and sun/shade, fertility and moisture all vary. Accepting that *Cardamine* species can vary in their morphology based on the position/site in which they grow, the most common *Cardamine* on Tengawai scarp is *C. caesiella*, and there will be lesser amounts of *C. corymbosa*" (Peter Heenan, pers. comm., 2 November 2021).

The conservation-management issues for *Cardamine caesiella* are similar to those described for *C. integra*. It seems that stock grazing does affect particular sub-sites, but the current grazing regime, especially on property C, has allowed the persistence of the species at least. Though plants can produce a high number of seeds, browsing affects and reduces seed production in particular. Competition by grasses, especially red fescue, and weeds seems to be the main limiting factor for this small species. On at least two of the properties, aerial topdressing in the last decade might have contributed to faster and thicker growth of exotic vegetation and exacerbated the competition with native herbaceous species. While hand-weeding has shown a good response, it has been limited to selected sub-sites as it is very time-consuming and needs ongoing input.

The invasive stonecrop weed can also outcompete small calcicoles, including *C. caesiella*, and occupy habitat suitable for these to establish. The extensive control of this succulent along the scarp should also benefit *C. caesiella*. Past control has been effective, and has limited direct competition and created more sites for herbaceous plants. Stonecrop control is best carried out by chemical methods in December–January, when mature plants are flowering (Frank 2019; Frank 2020). This control work should continue, as it helps to restore the integrity of the limestone ecosystem overall. Other management strategies suggested for *G. calcis* subsp. *manahune* and *R. callianthus*, such as spraying grasses at selected patches or removing topsoil, could also help to create new sub-sites (Douglas et al. 2007; Frank 2023a; Frank 2024a), as would the establishment of woody vegetation.

As for other calcicoles, micro-sites on top of the cliffs are especially important for the persistence of plants and distribution, as seeds may be more widely distributed by wind. Such micro-sites exposed to browsing should be protected by wire netting, in combination with targeted weeding to maximise seed production and germination. Sites at the bottom of the slope might not contribute much to spreading seeds into suitable habitat, but might serve for collecting seeds. However, care is required when collecting seeds as mature seed capsules explode easily on touch. A more reliable method of seed collection might be to scrape up loose soil around plants that have dispersed seeds already. If seeds become available, they should be sown at suitable sites rather than being grown into seedlings for later replanting, as this is likely to be more successful (Douglas et al. 2007, Baskin & Baskin 2020). However, little is known about using this method for calcicoles and more experimental work is required.

Acknowledgements

I am grateful to Fraser Ross, who introduced me to some limestone areas and kindled my interest in the limestone habitat in general. I would like to thank the following: the landowners for generously allowing access over many years; Peter Heenan, who helped with identification of plants; the funding provided for stonecrop control, both abseil and knapsack work, by QEII National Trust and the Department of Conservation on the Tengawai Cliffs,

and by the Timaru District Council in the Tōtara Valley area; the volunteers who helped with weed control; Tom Waterhouse and other DOC staff who helped with surveys and weed control on the Tengawai Cliffs; Steve Caswell for drawing the maps; John Barkla and Nick Head for their helpful suggestions on an earlier draft of the manuscript; and the two anonymous reviewers for their comments and advice.

Data Accessibility Statement

Detailed versions of tables are available from the author or South Canterbury Museum, Timaru (museum@timdc.govt.nz).

References

Bachman, G., Whitwell, T. (1995). Hairy bittercress seed production, dispersal, and control. *Southern Nurserymen's Association Research Proceedings*, 40: 288–290.

Baskin, C. C., Baskin J. M. (2020). Review: Breaking seed dormancy during dry storage: A useful tool or major problem for successful restoration via direct seeding? *Plants*, 9(5): 636. https://doi.org/10.3390/plants9050636

Canterbury Maps (2024). Available online: https://mapviewer.canterburymaps.govt.nz/ [Accessed: May 2025].

Cieraad, E., Walker, S., Price, R., Barringer, J. (2015). An updated assessment of indigenous cover remaining and legal protection in New Zealand's land environments. *New Zealand Journal of Ecology,* 39: 309–315. https://newzealandecology.org/nzje/3235.pdf

Craw, D., Rufaut, C., Palmer, M. (2024). Geoecology of limestone-hosted dryland calcicolous plants, North Otago, New Zealand. *New Zealand Journal of Geology and Geophysics*, 68(5): 1100–1119. https://doi.org/10.1080/00288306.2024.2350396

de Lange, P. J., Rolfe, J. R., Barkla, J. W., Courtney, S. P., Champion, P. D., Perrie, L. R., Beadel, S. M., Ford, K. A., Breitwieser, I., Schönberger, I., Hindmarsh-Walls, R., Heenan, P. B., Ladley, K. (2018). *Conservation status of New Zealand indigenous vascular plants, 2017.* New Zealand Threat Classification Series 22. Wellington: Department of Conservation. 82 pp. https://www.doc.govt.nz/documents/science-and-technical/nztcs22entire.pdf

de Lange, P. J., Gosden, J., Courtney, S. P., Fergus, A. J., Barkla, J. W., Beadel, S. M., Champion, P. D., Hindmarsh-Walls, R., Makan, T., Michel, P. (2024). *Conservation status of vascular plants in Aotearoa New Zealand, 2023.* New Zealand Threat Classification Series 43. Wellington: Department of Conservation. 105 pp. https://www.doc.govt.nz/globalassets/documents/science-and-technical/nztcs43entire.pdf

Douglas, G. B., Dodd, M. B., Power, I. L. (2007). Potential of direct seeding for establishing native plants into pastoral land in New Zealand. *New Zealand Journal of Ecology*, 31(2): 143–153. https://newzealandecology.org/nzje/2831

Frank, H. (2018). *South Canterbury limestone: Landscape of dreams – nature's treasure chest.* Timaru: South Canterbury Museum Development Trust. 144 pp.

Frank, H. (2019). *Tengawai Cliffs (Willowbridge) – stonecrop control*. Unpublished report held by the Department of Conservation, Raukapuka / Geraldine District Office. 8 pp.

Frank, H. (2020). *Tengawai Cliffs (Willowbridge) – stonecrop control*. Unpublished report. Held by the Department of Conservation, Raukapuka / Geraldine District Office. 8 pp.

Frank, H. (2023a). *Distributions and statuses of three highly threatened calcicolous plants in limestone habitats of South Canterbury, New Zealand*. DOC Research and Development Series 368. Wellington: Department of Conservation. 30 pp. https://www.doc.govt.nz/globalassets/documents/science-and-technical/drds368entire.pdf

Frank, H. (2023b). *Threatened limestone plants at the QEII Willowbridge covenant, Tengawai Cliffs*. Unpublished report held by the Queen Elizabeth II Trust, Wellington. 17 pp. plus separate appendices.

Frank, H. (2024a). *Threatened limestone plants Gentianella calcis* subsp. *manahune, Ranunculus callianthus, Cardamine caesiella and Geranium socolateum and other species at the Tengawai Cliffs: Distribution, threats, management options*. Unpublished report held by the Department of Conservation, Raukapuka / Geraldine District Office. 24 pp. plus seven appendices.

Frank, H. (2024b). *Historical observations of the special limestone flora of the QEII covenants, Limestone Valley, Taiko, Timaru District*. Unpublished report held by the Queen Elizabeth II Trust, Wellington. 35 pp. plus separate appendices.

Frank, H. (2024c). *Revised report of Shanks, A. 2010b: Field notes Taiko threatened plants*. Unpublished report held by the Department of Conservation, Raukapuka / Geraldine District Office. 12 pp.

Frank, H. (2025). Distribution, abundance, ecology and management of the limestone geranium *Geranium socolateum* (Geraniaceae) Heenan et Molloy. *Perspectives in Biodiversity*, 3(1): 15–29. https://doi.org/10.34074/pibdiv.003102

Frank, H., Wilson, D. J. (2011). Distribution, status and conservation measures for lizards in limestone areas of South Canterbury, New Zealand. *New Zealand Journal of Zoology*, 38(1): 15–28. https://doi.org/10.1080/03014223.2010.520326

Grace, J. (2025). Plant of the week – April 21st 2025 – New Zealand bittercress (*Cardamine corymbosa*). Botany in Scotland: Notes and conversations on all things Botanical. Available online: https://botsocscot.wordpress.com/2025/04/20/

Harding, M. (2016). *A report on a district-wide survey of areas of significant indigenous vegetation and significant habitats of indigenous fauna*. Timaru: Timaru District Council. 30 pp.

Heenan P. B. (2008). *Cardamine latior* (Brassicaceae), a new species endemic to the subantarctic Auckland Islands, New Zealand. *New Zealand Journal of Botany*, 46(4): 559–566. https://doi.org/10.1080/00288250809509785

Heenan, P. B. (2017). A taxonomic revision of *Cardamine* L. (Brassicaceae) in New Zealand. *Phytotaxa*, 330(1): 1–154. https://doi.org/10.11646/phytotaxa.330.1.1

Heenan, P. B., de Lange, P. J. (2018). *Cardamine panatohea* (Brassicaceae), a new, threatened, alpine species from New Zealand. *Phytotaxa*, 379(3): 255–260. https://doi.org/10.11646/phytotaxa.379.3.3

Heenan, P. B., Molloy, B. P. J. (2019). Five new and Nationally Threatened taxa of *Brachyscome*, *Cardamine*, *Convolvulus*, *Geranium* and *Ranunculus* obligate to vulnerable limestone habitats, eastern South Island, New Zealand. *Phytotaxa*, 415(1): 32–48. https://doi.org/10.11646/phytotaxa.415.1.2

Heenan, P. B., Rogers, G. M. (2019). *Conserving the plants of eastern South Island limestone: Ngā tipu ō te pākeho*. Christchurch: Canterbury Botanical Society. 228 pp. https://doi.org/10.13140/RG.2.2.20161.10087

Holdaway, R. J., Wiser, S. K., Williams, P. A. (2012). Status assessment of New Zealand's naturally uncommon ecosystems. *Conservation Biology*, 26(4): 619–629. https://doi.org/10.1111/j.1523-1739.2012.01868.x

Landcare Research (2024). Systematics Collection Data, Allan Herbarium. Available online: https://scd.landcareresearch.co.nz/ [Accessed: November 2024].

Pender, R., Buunk, I., Lange, K. (2004). *Limestone survey South Canterbury*. Unpublished reports held by the Department of Conservation, Raukapuka / Geraldine District Office.

Pawson, E., Holland, P. (2008). People, environment and landscape since the 1840s. In: Winterbourn, M., Knox, G., Burrows, C., Marsden, I. (eds), *The natural history of Canterbury*, 3rd edition, 37–64. Christchurch: Canterbury University Press, 924 pp.

Rogers, G. M., Courtney, S. P., Heenan, P. B. (2018). *The calcicolous flora of New Zealand: Life forms, taxonomy, biogeography and conservations status*. Science for Conservation 331. Wellington: Department of Conservation, 37 pp. https://www.doc.govt.nz/globalassets/documents/science-and-technical/sfc331entire.pdf

Rolfe, J., Hitchmough, R., Michel, P., Makan, T., Cooper, J. A., de Lange, P. J., Townsend, A. J., Miskelly, C. M., Molloy, J. (2022). *New Zealand Threat Classification System manual 2022, part 1: Assessments*. Wellington: Department of Conservation. 45 pp. https://www.doc.govt.nz/globalassets/documents/about-doc/oia/2023/december/new-zealand-threat-classification-part-1.pdf

Royal Botanic Gardens, Kew (2025). Plants of the world online. Royal Botanic Gardens Kew. Available online: https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:60436526-2 [Accessed: February 2025].

Townsend, A. J., de Lange, P. J., Duffy, C. A. J., Miskelly, C. M., Molloy, J., Norton, D. A. (2008). *New Zealand Threat Classification System manual*. Wellington: Department of Conservation. 35 pp. https://www.doc.govt.nz/globalassets/documents/science-and-technical/sap244.pdf

Vaughn, K. C., Bowling, A. J., Ruel, K. J. (2011). The mechanism for explosive seed dispersal in *Cardamine* hirsuta (Brassicaceae). *American Journal of Botany*, 98(8): 1276–1285. https://doi.org/10.3732/ajb.1000374

Walker, S., Price, R., Rutledge, D. (2008). *New Zealand's remaining indigenous cover: Recent changes and biodiversity protection needs*. Science for Conservation 284. Wellington: Department of Conservation. 82 pp. https://www.doc.govt.nz/documents/science-and-technical/sfc284entire.pdf

Walker, S., Cieraad, E., Barringer, J. (2015). *The Threatened Environment Classification for New Zealand 2012: A guide for users*. Dunedin: Landcare Research. 27 pp. https://www.landcareresearch.co.nz/assets/Tools-And-Resources/Maps/Threatened-Environment-Classification/Threatened_Environment_Classification_guide.pdf

Waterhouse, T. (2022). *Manahune – D406293000 – management actions to date, 2021–2022*. Internal report, Department of Conservation, Raukapuka / Geraldine Area Office. 10 pp.

Williams, P. A., Wiser, S., Clarkson, B., Stanley, M. C. (2007). New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. *New Zealand Journal of Ecology*, 31(2): 119–128. https://newzealandecology.org/nzje/2829

Wiser, S. K., Buxton, R. P., Clarkson, B. R., Hoare, R. J. B., Holdaway, R. J., Richardson, S. J., Smale, M. C., West, C., Williams, P. A. (2013). New Zealand's naturally uncommon ecosystems. In: Dymond, J. R. (ed.), *Ecosystem services in New Zealand – conditions and trends*, 49–61. Lincoln: Manaaki Whenua Press. 540 pp. https://www.landcareresearch.co.nz/assets/Publications/Ecosystem-services-in-New-Zealand/1_3_Wiser.pdf

Wotton, D. M. (2022). *Does weed control benefit native plants in limestone ecosystems?* Annual Report FY2021/22. Moa's Ark Research Contract Report No. 2022–01. Prepared for Department of Conservation, Wellington. 23 pp.