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Distribution, abundance, ecology and management of the limestone geranium *Geranium socolateum* (Geraniaceae) Heenan et Molloy

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Abstract

Limestone ecosystems provide habitat for several endemic, calcicolous, herbaceous plants, many of which are threatened. South Canterbury, Te Wai Pounamu / South Island, Aotearoa / New Zealand has at least six such taxa. This study surveyed limestone habitats in South Canterbury for one of these taxa, the limestone geranium *Geranium socolateum*. At the time of its taxonomic description in 2019, a threat status of Threatened / Nationally Critical was proposed using the 2008 iteration of the New Zealand Threat Classification System. In 2024 this was changed to Threatened / Nationally Vulnerable by the New Zealand Indigenous Vascular Plant Threat Listing Panel. These assessments have been based on limited data about the range, distribution and population sizes of the species. This paper reports on a study that found a wider geographical range and higher number of plants in sub-populations and overall than was known previously. The majority of the field work was carried out between 2019 and 2022 and recorded 6,330 plants of *G. socolateum* in 28 subpopulations in South Canterbury and two in North Otago. It is estimated that about 4,835 of these records were mature plants. Thus, the data supports the current threat ranking of Nationally Vulnerable for *G. socolateum*.

Keywords

Endemic calcicolous plants, survey, population count, South Canterbury, conservation ranking, conservation.

Introduction

Limestone outcrops in South Canterbury are a distinct landscape feature. They occur in the hinterland between the coastal lowlands and the foothills of the Southern Alps / Kā Tiritiri o te Moana but only cover c. 0.2% of the region's land area. They are not a continuous landscape feature and consequently form naturally insular ecosystems (Figure 2). These are historically rare and have been classified as Nationally Vulnerable (Holdaway et al. 2012, Wiser et al. 2013). Much of their indigenous vegetation has been modified and depleted in the last few centuries, particularly through land development and ecological changes caused by introduced exotic plants (Pawson & Holland 2008). The remaining indigenous limestone vegetation is acutely threatened (Walker et al. 2008, Walker et al. 2015, Cieraad et al. 2015, Heenan & Rogers 2019). These remnants exhibit high biotic diversity, providing habitats for plants, birds, bats, lizards, invertebrates and micro-snails (Worthy 1997, Frank 2018). They may support relict populations of rare plant and animal species.

The calcareous substrate provides conditions for a range of plants that are adapted to or need a high level of calcium. They show a high degree of endemism due to variations in formation and substrate composition, aspect, altitude, weather conditions, microclimate, and especially the fragmentation and isolation of limestone ecosystems by surrounding landforms (Rogers et al. 2018, Heenan & Rogers 2019). This is particularly true of the herbaceous plants that occur here.

Figure 1. Tōtara Valley area (code Gs L). Young *G. socolateum* plants with one *Colobanthus* aff. *brevisepalus* plant, 7 February 2019. Photo: author.

Six endemic calcicolous herbs are currently recognised for the South Canterbury region (Heenan & Rogers 2019). One of them is the limestone geranium *Geranium socolateum*, which also has small populations at two locations in North Otago. It was described formally in 2019 (Heenan & Molloy 2019). Prior to the species' formal taxonomic recognition, it was known by the tag names *Geranium* "Pareora" (Cameron et al. 1993), *Geranium* (a) (CHR 518296; Pareora River) (de Lange et al. 1999), *Geranium* aff. *brevicaule* (Heenan & Molloy 2019, Rogers et al. 2018) and *Geranium* aff. *sessiliflorum* (Frank 2024b, Frank 2024c, Pender et al. 2004). It is a perennial herb with low, often prostrate stature and is related to *G. brevicaule* (Mitchell et al. 2009). Field diagnostics are the finely haired, grey-green to blue-green leaves with a distinct brownish marginal band (Heenan & Molloy 2019) (Figure 1). It grows in cracks on limestone outcrops and thin soils above limestone pavements.

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. This places restrictions on access and might be one of the reasons these outcrops have seldom been surveyed in the past. Brian Molloy, then with the Botany Division of the Department of Scientific and Industrial Research (DSIR), was one of the first botanists to visit limestone sites in the region, from the early 1980s onwards (Fraser Ross, personal communication, Heenan & Rogers 2019), and to draw attention to the unique biodiversity of this ecosystem, particularly the limestone-obligate plants. In the late 1990s, he observed and collected the *Geranium*, then undescribed, from the Tengawai Cliffs, a 7 km-long limestone scarp located west of Albury. In later years, Peter Heenan (Manaaki Whenua / Landcare Research) also collected some plants from there. Most of the specimens at the Allan Herbarium (https://www.landcareresearch.co.nz/tools-and-resources/collections/allan-herbarium/) are from this scarp.

From 2002 to 2004, the Canterbury Conservancy of the Department of Conservation (DOC) / Te Papa Atawhai, with support from DOC's Raukapuka / Geraldine District Office, initiated a field survey of plants inhabiting limestone areas of South Canterbury (Pender et al. 2004). This survey aligned with property boundaries and covered 34 properties between the Waihao Downs in the south and Kākahu in the north. However, survey work was limited to just one visit per site during the summer months, and access was not possible to some important limestone habitats. The report for each

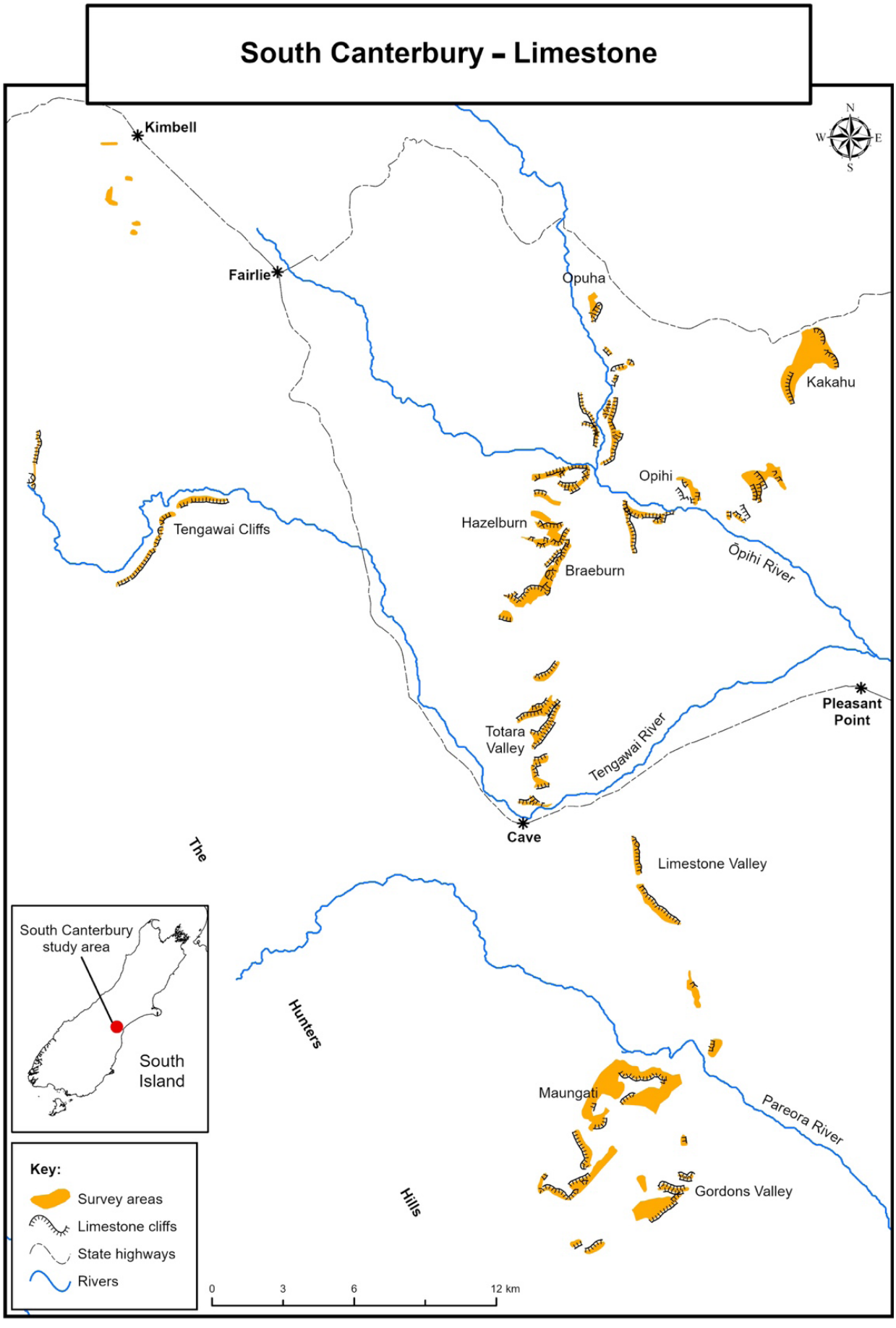

Figure 2. Limestone areas surveyed in South Canterbury. Map: Steve Caswell.

property usually only provided a general description of the area and a species list. Pender et al. (2004) listed *G.* aff. *sessiliflorum* for 27 of 34 surveyed properties. This included three records for the four limestone areas near the Waihao River southwest of Waimate. However, they have no record of *Geranium brevicaule* for any of the limestone properties.

From 2005 to 2016, an estimated 90% of limestone habitats in the Timaru District were visited by a plant ecologist as part of the Significant Natural Areas (SNA) mapping programme and a report was written for each surveyed property (Harding 2016). A small number were surveyed in later years. These reports are usually not available to the public and data from most of these surveys could not be accessed. I have been able to access eleven SNA reports that include limestone habitats. Two mention the taxon, either as *G.* aff. *brevicaule* or *G.* aff. *sessiliflorum*, and four list *G. brevicaule*, which might have been *G. socolateum*. One more recent report lists *G. socolateum*. Wildland Consultants surveyed the Queen Elizabeth II Trust (QEII) covenants at the Limestone Valley scarp near Taiko in 2007 on behalf of the QEII National Trust (Lloyd 2007a, Lloyd 2007b). The reports do not list the taxon. DOC contracted Alice Shanks (QEII) to survey the same area in 2010 (Frank 2024b, Frank 2024c, Frank 2024d). She recorded low numbers of the taxon as *G.* aff. *sessiliflorum* (glaucous form) at three sites. In 2015, Peter Heenan found nine plants in total at Anatini, a limestone outcrop in North Otago (Heenan & Molloy 2019).

The taxon first appeared in a national threatened vascular plant list in 1993 (Cameron et al. 1993) under the tag name *Geranium* "Pareora". This and the following assessments were:

- 1993: listed as *Geranium* "Pareora" and Endangered (Cameron et al. 1993). This publication used a different classification system than later assessments.
- 1999: listed as *Geranium* (a) (CHR 518296, Pareora River) and Endangered (de Lange et al. 1999).
- 2004: listed as *Geranium* (a) (CHR 518296, Pareora River) and At Risk – Range Restricted (de Lange et al. 2004). Threat assessments from this year and later used the classification system developed in 2001 (Molloy et al. 2002)
- 2008: listed as *Geranium* (a) (CHR 518296, Pareora River) and At Risk – Naturally Uncommon (de Lange et al. 2009)
- 2012: listed as *Geranium* (a) (CHR 518296, Pareora River) and Taxonomically Indistinct (de Lange et al. 2013)
- 2017: not listed (de Lange et al. 2018)

The latest assessment of 2023 placed *Geranium socolateum* in the category Threatened / Nationally Vulnerable (de Lange et al. 2024). This is based on the criteria: - Population State = unnatural, - Population Trend = Declining 10-30%, - Population Size = 1,000–5,000 mature individuals, - Qualifiers = Data Poor Trend, Range Restricted. The information for this assessment came from a meeting run by panel member Jane Gosden that comprised Canterbury botanists (Peter de Lange, personal communication, 20 December 2024). However, no detailed information has been provided.

This evaluation differs from the threat ranking at the time of the taxonomic description, when its conservation status was suggested as being Nationally Critical (Heenan & Molloy 2019, p. 41). Their assessment was based on observations that "populations of *Geranium socolateum* are typically small and sparsely distributed throughout its range" and "the total population is estimated to be fewer than 1,000 individuals". Therefore, two of the Nationally Critical B sub-criteria applied to *G. socolateum*: (B1) 250–1,000 mature individuals and (B3) total area of occupancy ≤ 10 hectares (Townsend et al. 2008). Some factors seemed to indicate a declining population trend. However, it was also stated that "numerous areas remain unsurveyed", "empirical population trend is lacking" and "the qualifier DP (data poor) also applies". It appears the threat classification of *G. socolateum* was based on limited information regarding range, distribution, population sizes and threats. The current study aims to provide additional population data for the species.

Study Area and Methods

From 2016 to 2022, I undertook annual surveys for three endemic calcicolous taxa: *Gentianella calcis* subsp. *taiko*, *G. calcis* subsp. *manahune*, and *Ranunculus callianthus* (Frank 2023a, Frank 2024a). These surveys included all limestone areas in South Canterbury except for some at the Waihao Downs and a number of smaller ones near Kimbell, about 6–9 km northwest of Fairlie. I was familiar with these localities due to a lizard survey I had undertaken in 2008 (Frank & Wilson 2011). Because two of the original target plant species were located at the Tengawai Cliffs, this prominent scarp received more attention compared to other limestone areas. Further details about South Canterbury limestone areas and

Figure 3. Tengawai Cliffs (code Tcliff C). Medium-sized *G. socolateum* plant with both flowers and seed heads, 17 March 2021. Photo: author.

methods used for these surveys are in Frank (2023a).

Initially, the focus of this research has been on the three target plants listed above. However, from 2019 to 2022, the focus shifted and other threatened calcicolous plants, including *G. socolateum*, were recorded systematically, although some smaller limestone areas were not revisited. In addition, extensive weed control was undertaken to control the widespread invasive stonecrop weed *Sedum acre* L. at the Tengawai Scarp and Tōtara Valley locations from 2018 onwards (e.g., Frank 2020, Frank 2019, Waterhouse 2022). Threatened native plants found during weed control were noted. From the summer season 2018–19 to the season 2021–22, I spent about 200 hours surveying the Tengawai Cliffs and about 450 hours surveying other limestone areas in South Canterbury. Generally, surveys were carried out by walking through areas searching all potentially suitable habitats. During the same period, close to 400 hours were spent on stonecrop control at the Tengawai Cliffs and just over 500 hours in other locations, mainly at the Tōtara Valley. Other volunteer and contractor hours were in addition to this. Data collected during infrequent visits to some sites in 2023 and 2024 is also included.

While *G. socolateum* plants can be detected outside its flowering season due to their size and distinctiveness, the best time for surveys is during flowering. The majority of plants flower during December to February, but the flowering season appears to be relatively long and can last from November to March. Both flowers and developing seed heads can be present during the later part of the flowering period (Figure 3). Plants can be large, up to 25 cm in diameter, but often it is difficult to determine whether these large specimens are single or multiple plants. Generally, when more than ten plants were observed at a site, numbers were estimated. GPS data for sites was occasionally taken at the site, but more often post-visit using Canterbury Maps (https://mapviewer.canterburymaps.govt.nz/). Due to the relatively high number of plants on many sites, no distinction between mature and immature plants has been made. Results were recorded according to each site within defined limestone areas. These areas generally aligned with property boundaries, but in some cases there were several disjunct areas on the same property.

During these surveys, it became evident that *G. socolateum* had particularly strong populations on the Tengawai Cliffs (Figures 1, 4). This is a prominent, isolated escarpment of about 7 km in length west of Albury along the upper reaches of the Tengawai River. The limestone sections of the Tengawai Cliffs are part of 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). On three occasions, surveys were conducted on larger sections of the scarp, which focused mostly or entirely on the species. On three other dates, smaller parts were surveyed. For the remainder of the scarp, numbers were estimated based on general exploration of these areas.

In late October 2018, two days were spent searching one limestone area north of the Waihao River, though the main focus was on other plant species. In March 2021, five smaller limestone areas near Kimbell were visited, but it was not possible to access all places in that vicinity, especially not to a small but notable scarp on the north side of the Ōpihi River. In the same month, a separate survey for *G. socolateum* was undertaken at the Anatini limestone area in North Otago by Alice Shanks and the author. Observations on iNaturalist NZ (https://inaturalist.nz/observations?taxon_id=928316) were searched for further records from North Otago and are included with permission of the observer.

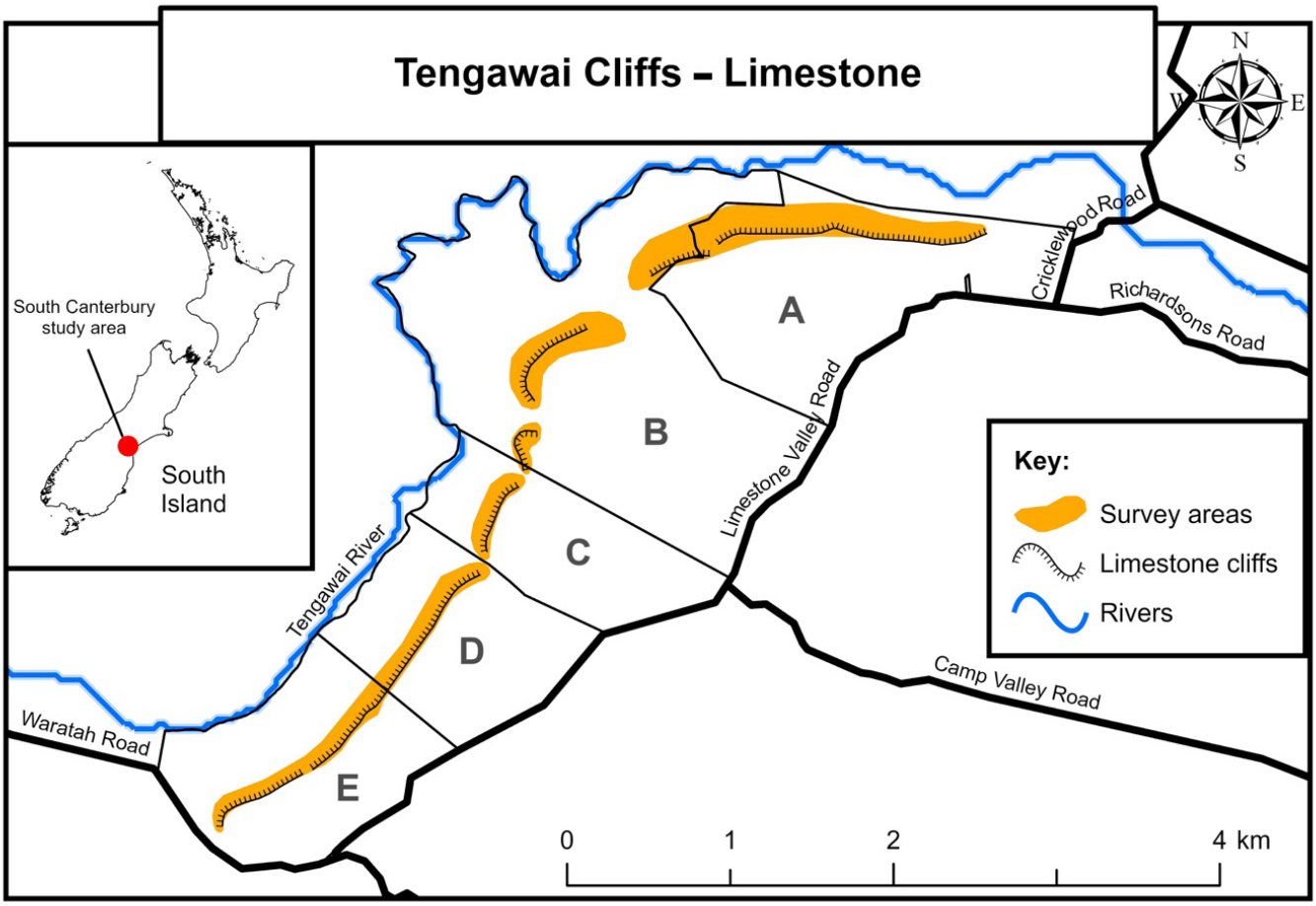

Figure 4. Property boundaries and limestone areas on the Tengawai Cliffs. Map: Steve Caswell.

Results

Out of 41 limestone areas surveyed in the South Canterbury region, *Geranium socolateum* was found in 26, i.e., 63% of them. This does not include the Tengawai Cliffs and a small limestone area northwest of Fairlie, as these are discussed separately. From Gordons Valley in the south to Rocky Ridges (Kākahu) in the north, 2,775 plants were observed at 155 specific sites, i.e., single rocks, outcrops, and shallow soils on slopes within these 26 wider locations (Table 1). To assist further work on the species, a more detailed version of Table 1 with numbers at each site and GPS co-ordinates is available from the author or South Canterbury Museum upon request.

There was a wide range both in the number of sites and number of plants in each area. Seven locations had only one site with two to 30 plants. One location in the Tōtara Valley had 25 sites and a total of about 700 plants, though this is the most varied of all limestone locations. Two other areas in the Tōtara Valley respectively had 19 sites with 511 plants and 12 sites with 390 plants. In contrast, the most extensive limestone scarp in the Limestone Valley near Taiko had seven sites with about 160 plants – and about 90 of them resembled a hybrid form with *G. brevicaule*.

Plants generally grow in sunny, open situations, but occasionally are found in shady aspects. They grow bigger on sites out of reach of browsing animals, but the species seems able to cope with grazing to some degree (Figure 5). Although individual plants have not been marked, it is evident that the species is perennial and persists over many years. Plants show some level of die-back in winter and start growing again from September onwards.

Nineteen properties where Pender et al. (2004) had listed the taxon are comparable to this current study. *G. socolateum* was confirmed in fifteen of these properties, although only *G. brevicaule* was observed at two limestone locations where Pender et al. (2004) had recorded *G.* aff. *sessiliflorum*. The species was confirmed on all six properties where Harding (2016)

Table 1. *Geranium socolateum* in limestone areas of South Canterbury (without the Tengawai Cliffs and one smaller outlying location).

Area code	Wider area	Observation years	Plants observed	Number of sub-sites
Gs A	Maungati	2008	30	1
Gs B		2020	59	4
Gs C		2020, 2021	30	3
Gs D	Pareora River	2020	20	1
Gs E		2020	5	2
Gs F	Limestone V	2020, 2021	161	7
Gs G	Tōtara Valley	2021	97	6
Gs H		2019, 2021, 2023	52	3
Gs I		2020, 2021, 2024	390	12
Gs J		2023	7	2
Gs K		2021	51	6
Gs L		2021	86	13
Gs M		2019, 2020, 2021	699	25
Gs N		2020, 2021, 2023	73	4
Gs O		2019, 2021, 2022	511	19
Gs P		2019, 2021, 2022	88	8
Gs Q	Hazelburn	2019	120	12
Gs R		2020	88	7
Gs S	Ōpihi	2019	20	1
Gs T		2018	2	1
Gs U		2019	22	5
Gs V		2019	27	6
Gs W		2020	106	4
Gs X		2020	4	1
Gs Y	Ōpūha	2019	20	1
Gs Z	Kākahu	2019	7	1
26 locations	South Canterbury		2,775	155

had listed the taxon, plus on two more. At a limestone location near Kimbell, about 90 *G. socolateum* plants were found, though some could be hybrids with *G. brevicaule*. Two samples from the location were sent to the Allan Herbarium, and Hamish Maule (Manaaki Whenua / Landcare Research) noted on 11 March 2021: "The specimens seem less 'robust' than the description for *G. socolateum* suggests: compact growth habit, small leaves and small sepals (a flower/pod fragment is in the sample). Although it does have brown margin in the leaves, a *G. socolateum* trait" (https://scd.landcareresearch.co.nz/Specimen/CHR 20667501). About 45 plants that clearly showed *G. brevicaule* traits, i.e., more compact, smaller leaves, uniform green leaf colour and no brown margin, were found in the wider area. Plants with similar traits to *G. brevicaule* were also observed at three sites in the Limestone Valley scarp near Taiko and some sites in the Tōtara Valley area. Anecdotal observations

Figure 5. Tōtara Valley area (code Gs M). *G. socolateum* plants in limestone cracks spreading low in grazed area, 23 March 2020. Photo: author.

could suggest that the characteristic trait of brownish leaf margins for *G. socolateum* are better developed in mature plants and sites with a longer establishment.

The presence of *G. socolateum* at Anatini in North Otago was confirmed, with about 55 plants documented on four sites at that location. A separate survey in 2023 recorded about 60 plants at five sites in this area (Aalbert Rebergen, personal communication, 28 October 2024). Recently, the species has also been reported from a second location in North Otago, Elephant Rocks, less than 1 km north of Anatini. Of 14 observations on iNaturalist NZ, 12 are from this limestone area. The most detailed reports are by Aalbert Rebergen, who observed more than 60 plants on six sites in December 2023. Similar to observations made in several South Canterbury locations, photos of plants from these North Otago sites indicate that some could be *G. brevicaule* or a hybrid form.

As mentioned earlier, for this study the Tengawai Cliffs warrant special attention and results are presented separately (Table 2). However, it was not practical to define sites, as the species was widespread throughout the area. In November 2019, the west part of property E, which lies at the western end of the scarp, was surveyed and 454 geranium plants in an area of about 3 ha were counted. On another visit in 2020 the species was found throughout. On the east part of the same property, the geranium was throughout. On property D, it was seen along the top part, right through in good numbers, even in grazed areas. In January 2021 a rough count of parts of the top of property D was undertaken. About 250–300 plants were found in a stretch of about 150 m in the west part of the mid-paddock, around 15% of the limestone exposures on this property.

The most detailed survey of the species was undertaken in the top part of the limestone area on property C in March 2021 (Shanks 2023, Frank 2023b). This survey recorded approx. 1,770 *Geranium* plants within an area of about 4.5 ha. Not included in the above area is the exposed limestone near the boundary to property B. This small area of about 0.1 ha had about 50 *Geranium* plants in December 2020. The population had a mix of various sizes, from large old plants to young plants. Plants were found on exposed sites in cracks within the cliffs and outcrops. However, the highest number of plants, i.e., at least 95%, within this area were on the grassy edges around exposed limestone pavements extending into grass environments, apparently on shallow soils above pavements. These grassy sites had been grazed, but *Geranium* plants seemed to adjust to being grazed by spreading low to the ground (Figure 6). Also, they appeared to cope with competition from higher grasses to some degree in some situations. In fact, in some places, *G. socolateum* plants caused competition to smaller calcicolous plants such as *Cardamine caesiella* Heenan (Figure 7).

The slope below the cliffs was not directly searched for the species, but incidental data exists. There are scattered locations with around 20 plants each. Numbers seem to be increasing on older sites and new sites are becoming established. For example, for one rock that has been visited regularly for weed control, no geranium plants had been recorded in earlier years. In December 2022, 25 plants, mostly small ones, were observed. By October 2024, the number of plants had increased further to 46 plants, about two thirds of them immature.

In 2020, the west paddock of property B, which borders property C, had about 150 *G. socolateum* plants in an area of 0.3 ha. The species also occurs on other parts of property B, but in lower density. It is not common on property A, which is at the eastern end of the scarp. On visits in 2019 and 2020, it was only found in a small area of the west part, with around 20 plants. By 2022 the number in the same area had increased to about 60 plants.

Altogether, the counts and estimates for plants present on the Tengawai Cliffs total a minimum of 3,400 *G. socolateum* plants. Therefore, the total number of *G. socolateum* plants in South Canterbury is about 6,330 plants. In addition, there are at least two locations in

Table 2. *Geranium socolateum* at the Tengawai Cliffs and one location near Kimbell (both Mackenzie District) plus two North Otago sites.

Locations	Observation year	Plants observed	Number of sub-sites
Tengawai Cliffs			
Tcliff A	2022	60	n/a
Tciff B east	Estimate 2022	200	n/a
Tciff B west	18.1.2020	150	n/a
Tcliff C top	17.3.2021	1,820	n/a
Tcliff C low	Estimate 2021	50	n/a
Tcliff D east	Estimate 2021	150	n/a
Tcliff D mid	Estimate 2021	200	n/a
Tcliff D west	16.1.2021	300	n/a
Tcliff E east	Estimate 2020	80	n/a
Tcliff E west	22.11.2019	454	n/a
Total		3,464	
Kimbell	8.3.2021	92	3
North Otago			
Anatini	1.3.2021	55	4
Elephant Rocks	2023	60	6

Figure 6. Tengawai Cliffs (code Tcliff C). *G. socolateum* plants on grassy sites on limestone pavements showing signs of grazing, but still producing flowers, 6 January 2025. Photo: author.

Figure 7. Tengawai Cliffs (code Tcliff C). *G. socolateum* plants competing with *Cardamine caesiella* (only flower visible), 16 October 2019. Photo: author.

North Otago with around 115 plants. Although mature and immature plants have not been recorded separately, an estimate that at least 25% of the total might be expected to be immature plants would give about 4,835 mature plants within the range of the species.

Discussion

The limestone geranium *G. socolateum* occupies a wider range and has a larger population than previously suggested. It occurs in about two thirds of limestone areas in South Canterbury with good sub-populations in some, e.g., Tōtara Valley, though other areas have only small numbers. It has large populations at the Tengawai Cliffs, right along the scarp, with the exception of the property at the eastern end, where it might have become established more recently. The population on property C, in the middle of the scarp, is particularly robust. Plants occur on rocky outcrops and boulders, but the highest numbers are at less steep parts on top of the cliffs. This is also seen on other sections of the scarp. Shallow soils over limestone pavements may provide the most suitable habitat. These grassy sites are generally grazed in rotation, but the species appears to be able to cope both with grazing and some competition by weeds and grasses, certainly better than other calcicolous plants. This has been observed on property D, where plants grow in both ungrazed and grazed parts (Figure 8). Another indication for this ability is that the species "is rather 'weedy' in cultivation" and "continues to germinate freely and increase its range in the paths away from the limestone garden", as observed in the Christchurch Botanic Gardens (Luke Martin, personal communication, 19 September 2024).

There is little older census data for comparison, and it is unclear whether sub-populations are stable, decreasing or increasing. The information from Pender et al. (2004) could suggest that plants had disappeared on some properties since then. However, the data for the taxon from these lists has limited value for comparison as they did not provide any detailed information, and at least some of these records are likely to be *G. brevicaule*.

Smaller sites might be affected by heavy grazing and further intensification of land use. One isolated site on a property in the Tōtara Valley had 61 plants in February 2021. Only 34 plants were found in October 2024 and the area showed signs of heavy grazing. In contrast, Peter Heenan observed four plants at Rockdale (Tōtara Valley) in February 2014 (Heenan & Molloy 2019).

Figure 8. Tengawai Cliffs (code Tcliff D). *G. socolateum* plants growing along the margin of exposed limestone into stands of long grass (ungrazed), 10 January 2024. Photo: author.

This study recorded 86 plants at the same location. At another limestone area nearby, Harding (2016) had not recorded any *Geranium* sp., but a visit in 2023 located seven plants on two sites. It is unlikely that Harding overlooked these plants, as this was a relatively small area and he recorded all other plant species present. At Anatini, Peter Heenan had found two sites 300 m apart with four and five plants each. The visit in March 2021 recorded about 55 plants on four sites and about 60 plants were found on five sites in 2023. No known observations from Elephant Rocks exist despite this being a regularly visited area. The observations from 2023 could indicate the establishment of the species in a new location.

When Heenan & Molloy (2019, p. 41) described the taxon, they stated: "The largest population of *G. socolateum* appears to be at Manahune (South Canterbury), where there may be about 300 plants present." This opinion seems to be based on observations during site visits at Manahune in 2007 and 2015, when the specimens were collected. Either this assessment considerably underestimated numbers or numbers have increased substantially since then. Both these statements might be true. Observations during this study on sites below the cliffs on the Tengawai scarp suggest that new sites might have become established in recent years. Forty more plants were noted in the west part of property A in 2022 compared to earlier years and numbers increased on some rock sites. These observations could be an indication that at least some sub-populations of *G. socolateum* might be increasing. The data available does not suggest that there is a general decline in recent years.

The data from my study supports a threat status for *G. socolateum* of 'Nationally Vulnerable'. The following criteria for this assessment would apply: "Naturally small population that is forecast to be stable ± 10% over the longer of the next 10 years or three generations" and two sub-criteria:

- "The total population size is 1,000–5,000 mature individuals and
- The total area of occupancy is 10–100 ha" (Rolfe et al. 2022, p. 29).

There is also the consideration that the species occurs only on limestone, i.e., a Nationally Vulnerable ecosystem, and it is endemic to South Canterbury and North Otago, a small subregion in Aotearoa / New Zealand. In addition, sub-populations might be affected by grazing pressure and by competition from weeds and grasses. It is therefore suggested that the threat status of 'Nationally Vulnerable' as assessed under the New Zealand Threat Classification System is retained.

The species does not currently warrant conservation intervention. However, it is recommended to monitor selected sub-populations long term to obtain data about population trends. Some of the surveyed sites on the Tengawai Cliffs would be suitable, and on other limestone areas that are easily accessible and where landowners would be agreeable. On sites where plants with less robust or hybrid appearance occur, further studies might reveal whether these plant characteristics change over time.

Data accessibility statement

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

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