

Results of a survey of spring annual herb species on Bendigo and Ardgour Stations, 2025 (updated)

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[REDACTED]

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Reviewed by:

[REDACTED]

Senior Researcher
Bioeconomy Science Institute

Approved for release by:

[REDACTED]

Senior Researcher and Research Priority Area Leader
Bioeconomy Science Institute

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Summary

Project and client

- Matakanui Gold Limited (MGL) has applied for consent to mine areas of land on Bendigo and Ardgour Stations (hereafter 'Bendigo' and 'Ardgour') in Central Otago. The proposed mine is known as the Bendigo Ophir Gold Project (BOGP). MGL contracted the Bioeconomy Science Institute (BSI) to identify and map the locations of populations of native spring annual herbs in the spring of 2025. This report provides the results of these surveys.
- The four species targeted were *Ceratocephala pungens* (classified as Threatened – Nationally Critical), *Myosotis brevis* (Threatened – Nationally Vulnerable), the mousetail *Myosurus minimus* subsp. *novae-zelandiae* (At Risk – Declining), and *Myosotis antarctica* subsp. *antarctica* (At Risk – Naturally Uncommon).

Objective

- Identify and map the location of populations of native spring annual herbs across potential habitat on Bendigo and Ardgour.

Methods

- The surveys covered potential habitat on Bendigo and Ardgour Stations in two 5-day periods (late September to early October 2025, and late October to early November 2025). They were undertaken by six staff using a consistent survey method.
- Parts of the proposed mine direct disturbance footprint (DDF) on Bendigo were surveyed (87 hectares in the first survey, 36 hectares in the second), but access was not granted to parts of the DDF on Ardgour used for lambing. Lower-elevation parts of Ardgour outside the DDF were surveyed in the first BSI survey (235 hectares). Areas on Bendigo Station outside the DDF were also surveyed (148 hectares in the first survey and 84 hectares in the second survey) and (300 hectares) outside and west of Bendigo Station ('Bendigo West') were surveyed in the second BSI survey.
- A subset of 13 survey blocks (12 in the DDF on Bendigo and one on Ardgour, totalling about 50 hectares of the approximately 900 hectares total survey area) was surveyed twice using the same method.
- Maps and relevant tables in this report were updated after the correct DDF was provided by MGL in February 2026. All references to the DDF this report refer to the DDF as submitted in the BOGP Consent Application.

Results

- Surveys over accessible parts of the DDF located many more individuals of *C. pungens*, *M. brevis*, and *M. minimus* subsp. *novae-zelandiae* than had been found by RMA Ecology in 2024 as part of their broad botanical survey. Plants were found in a range of non-woody and woody habitats, which share the characteristics of soil moisture being briefly available in the spring but severely restricted later in the growing season, and a lack of perennial grass.
- *C. pungens* plants on Bendigo and Ardgour Stations make up a large proportion of all plants recorded to date.
- About 40% of the estimated number of all *C. pungens* plants found in both BSI surveys occurred within those parts of the DDF that BSI was able to search.
- The highest concentration of *C. pungens* plants was within the searched area of the DDF where we estimated 51 plants per hectare searched in the first survey (across 87 hectares) and 18 plants per hectare searched in the second survey (across 36 hectares).

- *C. pungens* was also found on Ardgour Station outside of the DDF and east of Shepherds Creek. However *C. pungens* was extremely rare on land on Bendigo, west of the DDF, at the time of the surveys (only three location points were recorded).
- *M. brevis* plants within the surveyed portion of the DDF on Bendigo Station accounted for about 21% of the estimated total numbers located across the general Bendigo–Ardgour area in the two surveys. Areas searched on Ardgour outside the DDF and east of Shepherds Creek supported comparatively few *M. brevis*. The highest numbers of *M. brevis* plants were present outside and west of Bendigo Station (i.e. Bendigo West) in the second survey.
- In the first survey (470 hectares) an average of 42 *M. brevis* plants were estimated to occur per hectare searched, with the highest concentration recorded within the searched part of the DDF (87 hectares) where 151 *M. brevis* plants were estimated to occur per hectare.
- In the second survey (total area 427 hectares) the average number of *M. brevis* plants estimated was 140 per hectare, and the highest concentration of plants was in the Bendigo West area (300 hectares) where we estimated 178 plants occurred per hectare searched.
- *M. minimus* subsp. *novae-zelandiae* plants within the parts of the DDF that were surveyed on Bendigo Station make up about 24% of estimated total number found across the general Bendigo–Ardgour area in the two surveys. Areas surveyed on Ardgour east of Shepherds Creek supported fewer plants overall, although there were relatively large numbers of plants in a few locations. Numerous *M. minimus* subsp. *novae-zelandiae* plants were present on Bendigo outside and west of the DDF.
- *M. minimus* subsp. *novae-zelandiae* was much more prevalent in the second survey than the first. In the first survey (470 hectares) an average of 68 plants per hectare were estimated, versus 306 plants per hectare in the second survey (427 hectares). The highest concentrations of plants were recorded in the Bendigo DDF (169 and 663 plants per hectare in the first and second surveys respectively).
- *M. antarctica* subsp. *antarctica* was recorded across many parts of the survey area, including areas inside and outside the DDF.

Conclusions

- *C. pungens* plants were recorded within and outside the DDF on Bendigo Station, on Ardgour Station, and in the Bendigo West area, mainly between 300 m and 800 m in elevation, but occasionally lower or higher. The highest concentration of plants (i.e. numbers of plants per hectare) was within the DDF on Bendigo Station.
- There was strong evidence of a turnover of *C. pungens* plants throughout the growing season (i.e. the areas occupied by live plants varied through the spring). This has important implications for the survey effort required to confirm the presence or absence of the species and its habitat, because absence in one survey period does not necessarily indicate absence either earlier or later in the spring.
- Both *M. brevis* and *M. minimus* subsp. *novae-zelandiae* were recorded within and outside the DDF on Bendigo Station, on the parts of Ardgour Station within the search area, and in the Bendigo West area, between 200 m and 700 m of elevation. More points were recorded and a higher estimated number of plants were estimated on Bendigo Station and in the Bendigo West areas than on Ardgour Station.
- *M. antarctica* subsp. *antarctica* was recorded across the survey areas.
- All four species were mainly found on sparsely vegetated silty soils, in shallow hollows on ridges and just off the tops of ridges, in cushionfield and in other open non-grassy vegetation. *M. brevis* and *M. minimus* subsp. *novae-zelandiae* were also found in kānuka woodlands.
- All four spring annual species were recorded by RMA Ecology in November 2024 in parts of the DDF that could not be accessed by BSI in 2025 due to lambing, and they are likely to still be present there.

Recommendations

Preliminary recommendations for future survey and research to guide the protection, expansion and restoration of the spring annual species include the following:

- Survey *C. pungens* between early August and mid-October, and *M. brevis* and *M. minimus* subsp. *novae-zelandiae* between mid-September and mid-November. To accurately estimate population size of *C. pungens* multiple surveys are needed within a single year and access is needed to all areas across the full early August to mid-November period.
- The search area for the surveys of all three species should include north and northwest facing slopes and ridge tops with bare silty soils or sparse vegetation cover in early spring (August to October) focusing on kānuka woodlands and cushionfield habitats and areas with bare ground (including bare understoreys). A map of recommended search areas is included (Appendix 2).
- As *C. pungens* is the rarest of the spring annuals, we suggest focusing research on this species. Research is needed over the next decade to understand *C. pungens* phenology, year to year variation in phenology and plant numbers, habitat variation, seed viability and dispersal. Such research should be concentrated in the areas with highest populations.
- Map, control and prevent spread of stonecrop (*Sedum acre*) and musky storksbill (*Erodium moschatum*) across areas of Ardgour and Bendigo stations where spring annuals are being conserved. Undertake an assessment of other herbaceous weeds that could potentially threaten spring annual habitats.

1 Introduction

Matakanui Gold Limited (Santana Minerals, hereafter MGL) contracted the Bioeconomy Science Institute (BSI) to identify and map the location of populations of native spring annual herbs across potential habitat on Bendigo and Ardour Stations in two 5-day surveys by six staff in the spring of 2025. The first survey was undertaken from 29 September to 3 October, and the second survey from 28 October to 1 November. This report provides the results of those two surveys, including maps.

2 Background

MGL has applied for consent to mine areas of land on Bendigo and Ardour stations (hereafter 'Bendigo' and 'Ardour') in Central Otago. In November 2023 *Myosotis brevis* was discovered at one location within the Direct Disturbance Footprint (DDF, the maximum area that is proposed to be disturbed) of the proposed mine. In November 2024 RMA Ecology recorded four species of Threatened or At Risk spring annual herbs within the DDF¹ of the proposed mine on both stations (Alliance Ecology 2024; Milner et al. 2025). One of these herbs (*Ceratocephala pungens*, in the buttercup family) is ranked Threatened – Nationally Critical (de Lange et al. 2024). *M. brevis* (a forget-me-not in the borage family) is ranked Threatened – Nationally Vulnerable; the mousetail *Myosurus minimus* subsp. *novae-zelandiae* (also in the buttercup family) is ranked At Risk – Declining; and *Myosotis antarctica* subsp. *antarctica* is ranked At Risk – Naturally Uncommon (Figure 1).

Spring annual herb species in dryland environments such as lowland Central Otago spend most of the year as seeds. Plants emerge when soil moisture levels are seasonally high in spring and are present as detectable plants only for a limited time. November (the period of observations by RMA Ecology in 2023 and 2024) is considered late in the season to observe spring annuals, and there is a risk that many plants would have set seed and died back by that time. MGL therefore sought more comprehensive survey information in the spring of 2025 to provide greater certainty about where these plants do and do not occur. This survey was the first step in a proposed applied research programme for the spring annual species.

The timings of emergence and die-off of plants are likely to vary across the four species, both from year to year depending on the weather conditions, and across microsites and habitats, which are determined by a variety of local microclimatic factors (e.g. temperature, light levels, the levels and duration of moisture and nutrients in the soils, and local disturbance regimes). Also, because the plants are extremely small and the areas that need to be searched are large, observers may not detect all of the plants present.

In response, the Bioeconomy Science Institute (BSI) proposed two successive surveys of the same areas, spaced 1 month apart. Conducting two surveys was intended to improve the chances of finding most of the target plant species if they were present, and to provide more certainty about where they do *not* occur (lowering the likelihood of false absences). The two surveys were also intended to provide preliminary information about the timing and duration of the vegetative stages in the four plant species, and about population turnover (the extent to which plants occur in different places within the growing season).

¹ The DDF has changed through the mine planning process. The DDF footprint in this report uses shapefiles 'DisturbanceAggregatedFootprint_190625_ST2040.zip' provided by Mary Askey on 16 February 2026



Figure 1. Examples of the four spring annual plant species targeted in the two surveys in 2025.

Note the tiny yellow flowers in *M. brevis* and the plant's highly compact form, with flowers and bracts tucked well down into rosette leaves. *M. antarctica* subsp. *antarctica* has larger flowers and is of generally larger size and more lax growth, but these characteristics are less apparent early in the spring and before the flowers have fully emerged. Brown forms of *M. antarctica* also occur.

3 Objective

The project objective was to identify and map the location of populations of native spring annual herbs across potential habitat on Bendigo and Ardgour.

4 Methods

4.1 Pre-field methods

Areas of likely habitat for spring annuals on Bendigo and Ardgour stations were identified and mapped, based partly on the areas of 'mixed depleted herbfield (cushionfield) and grassland'

identified within the ecological study area of RMA Ecology (Milner et al. 2025) and similar areas of open grassland and shrubland vegetation visible in aerial imagery. In total about 700 hectares of potential habitat were identified.

For the second BSI survey a further area of approximately 360 hectares was mapped as a potential further survey area. This further area (referred to as 'Bendigo West') was identified because it contained low cushionfield, herbfield and shrubland vegetation that is potentially spring annual habitat. Bendigo West lies mainly west of the DDF on Bendigo Station and includes undeveloped areas among vineyards and smallholdings, and parts of Bendigo Historic Reserve. An additional search area (of about 70 hectares) was mapped partially within the DDF on Bendigo, covering a high-elevation area that was identified as cushionfield in the ecological study area of RMA Ecology in 2024. Survey of this high-elevation area was needed to test whether the upper elevation limit of the spring annual species had been identified.

In both BSI surveys, blocks for searching were defined and mapped using obvious topographic features such as gullies and ridges that would assist navigation on the ground within the likely habitat areas. A grid of numbered points at 100 m spacing was overlaid over those blocks to help observers cover the full spatial extent of each block and to allocate search time across the block. The block boundaries and points were uploaded onto the hand-held GPS devices used by the team.

4.2 Field methods

Observers carrying global positioning system (GPS) devices were allocated to blocks, usually singly or in pairs. They traversed potentially suitable as well as unlikely habitat in each block, searching for plants, while recording their tracks via GPS.

Four spring annual species were recorded: *Ceratocephala pungens*, *Myosurus minimus* subsp. *novae-zelandiae*, *Myosotis brevis*, and *M. antarctica* subsp. *antarctica*. Other species were not recorded.

Detailed location information was collected for *C. pungens*, *M. minimus* subsp. *novae-zelandiae* and *M. brevis*. Where plants of any of these three species were observed, a point location was recorded for each species. At each point location, observers roughly estimated the number of individual plants of that species within an approximate 10 m radius of that point. Note that all numbers are rough estimates because time did not permit accurate counts. Observers were initially asked to provide estimates in broad bands (0–10, 10–50, 50–100, 100–500, 500–1,000, 1,000–5,000, 5,000–10,000), but most were more comfortable with simply estimating a rough actual number (e.g. 5, 200, 2,000). Those rough actual number estimates were back-converted to an associated band, and we took the mid-point of the band as the datum for each point. This allowed for the consistent mapping of broad abundance bands and comparisons of the relative numbers of each species observed among the searched locations.

To help estimate the spatial extent and number of plants in large continuous patches of any species, observers were told to record points with a minimum distance of 20 m between points (e.g. if a searcher walked through a patch 60 m across, they would record three points, with estimates of the number of plants in a 10 m radius around each point).

A different and less detailed method was used to record *M. antarctica* subsp. *antarctica*, which has a less threatened status and in 2024 was observed to be more locally common than any of the other three spring annuals. Observers recorded *M. antarctica* subsp. *antarctica* as either present or absent within a block (i.e. waypoints were not recorded for each individual or group detected, and counts were not made).

Photographs were taken when identification was uncertain (e.g. *M. brevis* vs *M. antarctica*) and at other points as determined by the observer. All photographs of spring annual plants taken at recorded points were noted and could be associated with the point at which they were found.

Myosotis samples were collected and dried for potential future DNA analysis where there was uncertainty over species (*M. brevis*, *M. antarctica* and *M. glauca* are all likely to be present), and each sample was identified to a sampling point or time of collection.

4.3 Surveys

The first survey by BSI (also referred to as 'Time 1' on maps) was conducted over 5 days from 29 September to 3 October 2025. Before the first BSI survey, 91 blocks had been mapped as potential search areas. Most of these initially mapped blocks could not be accessed, either at all or in part, due to lambing on Ardgour. A further few accessible blocks were not sampled due to low suitability (e.g. a block had recently been developed into intensively managed pasture or crops and was unlikely to support spring annuals). In total, over 5 days 50 of the 91 initially mapped blocks were sampled, and these blocks covered about 470 hectares (235 hectares on Bendigo Station of which 87 is within the DDF, 148 is outside the DDF, and about 235 hectares is on Ardgour Station outside the DDF; see Table 1 & Figure 2). The work involved 140 person hours of searching by the team.

Table 1. Approximate areas (in hectares) searched in the two surveys

Survey	Bendigo Station DDF	Bendigo Station (outside DDF)	Ardgour (outside DDF)	Bendigo West	Total area
Time 1	87	148	235		470
Time 2	36	84	7	300	427

The second BSI survey was undertaken over 5 days from 28 October to 1 November 2025 (referred to as 'Time 2' on maps and in Table 1). On the first day of the second survey 12 blocks on Bendigo (about 50 hectares) were resampled using the same method as the first survey, but swapping observers among the blocks to limit their familiarity and ensure an independent and unbiased count. Later in the second survey one further 6.6 hectares block on Ardgour was resampled using the same method as the first survey.

The second BSI survey accessed (in full or in part) 42 of the 45 blocks that had been mapped beyond the first BSI survey area. This area included about 69 hectares at high elevation adjacent to the DDF in Rise and Shine Valley on Bendigo, and 300 hectares across Bendigo West on cushionfield and kānuka shrubland adjacent to vineyards (including a small additional unmapped block on the flat land beside the Bendigo Loop Road on Bendigo). Permitted search areas and timing of access to the 42 blocks were confirmed by MGL, who liaised directly with landowners and managers, including the Department of Conservation (DOC).

In total the second BSI survey involved about 130 person hours of searching and covered about 430 hectares (Figure 2).

4.3.1 Notable weed observations

The weed *Sedum acre* is presently rare in the DDF and on Ardgour. It was noted where seen.

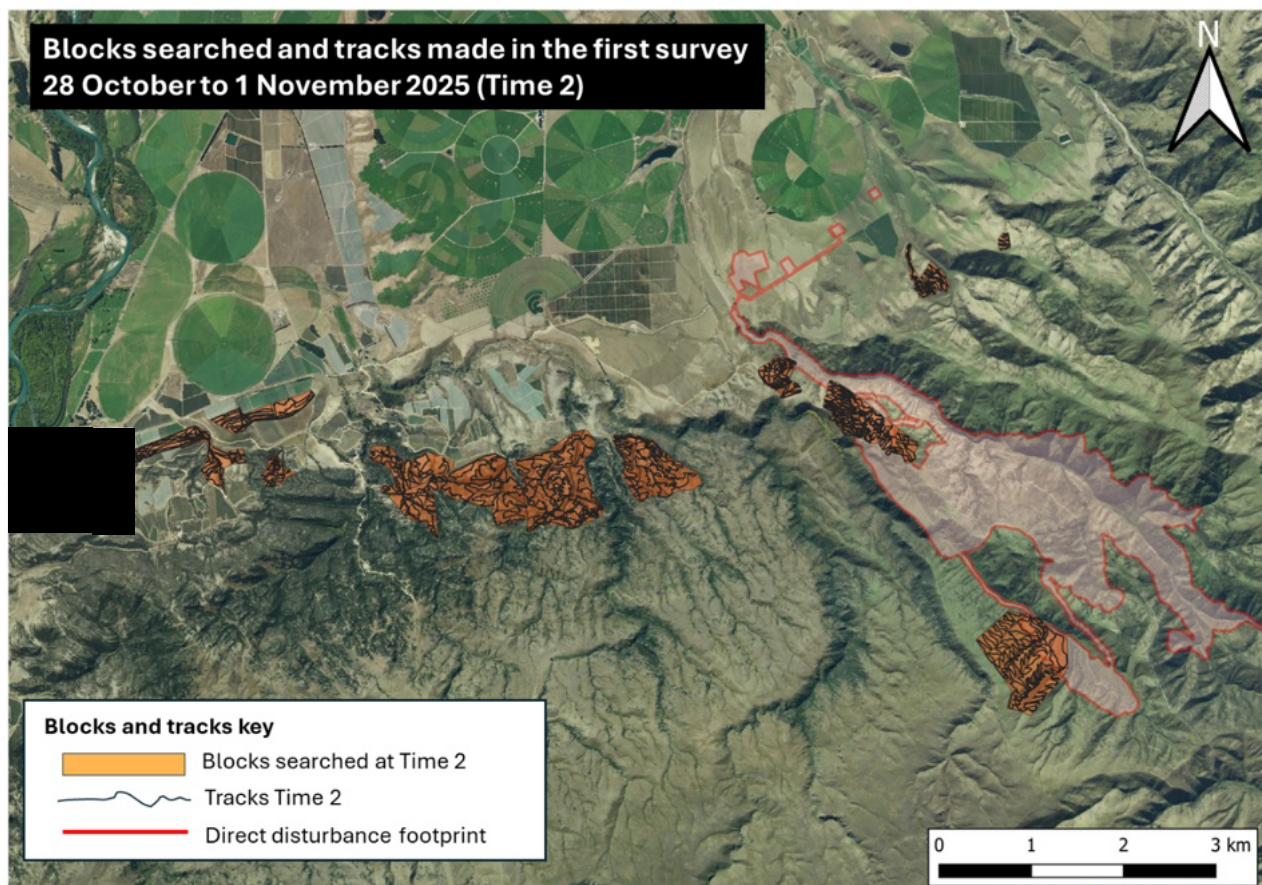
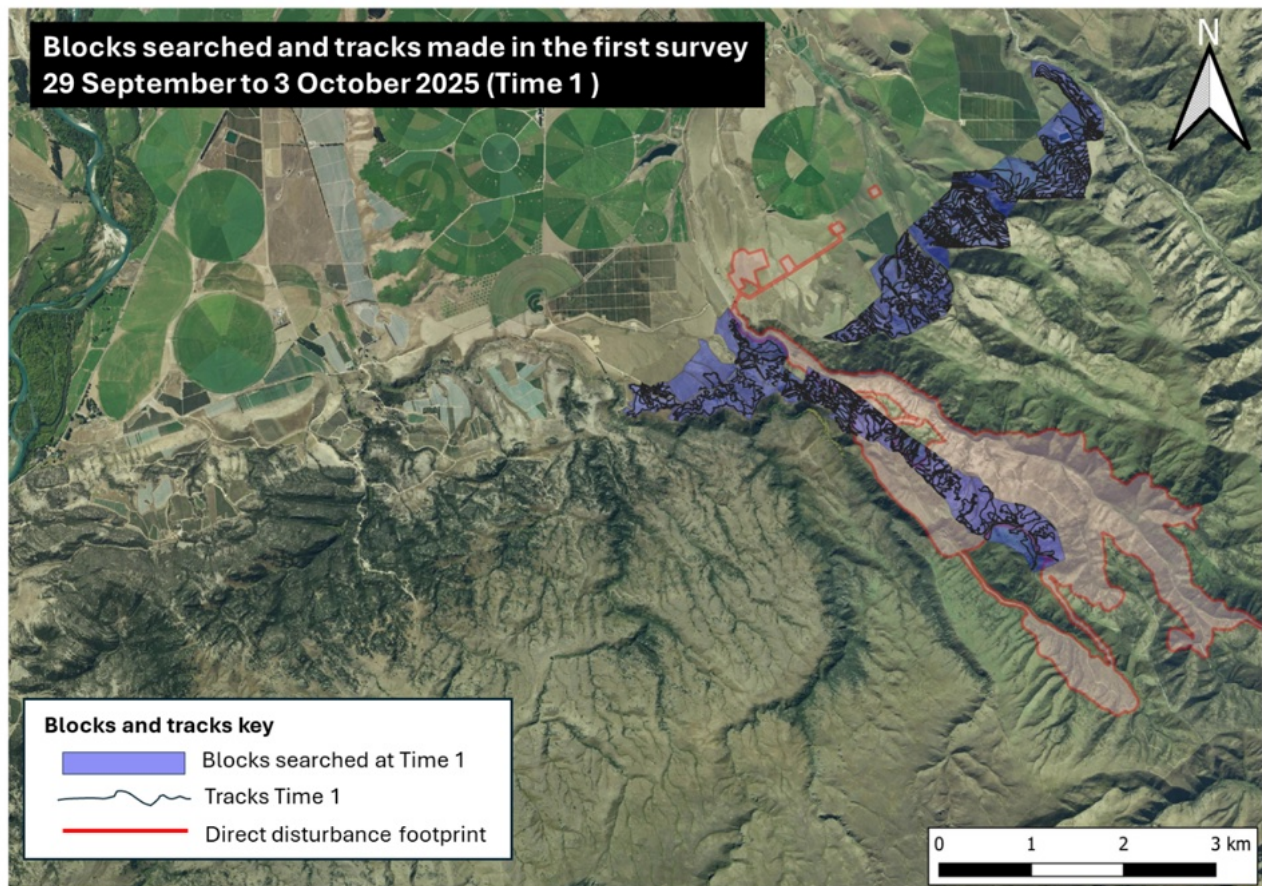


Figure 2. Blocks searched and tracks made in the first survey (upper map) and the second survey (lower map). The red line shows the direct disturbance footprint (DDF). Points to the west of the DDF are in the Bendigo West search area and those to the east of the DDF are on Ardgour.

4.3.2 Quality assurance

To assure consistency between the two BSI surveys, five of the six experienced people were employed in both surveys.

On the first day of the first survey all observers were trained together in a block with high densities of the three more threatened spring annual species. More experienced observers were paired with less experienced observers for the first few days. In the repeat surveys of blocks in the second survey period, observers were switched between blocks so that individuals did not carry over previous experience and focus on particular areas where plants had previously been found while neglecting others.

Observers were instructed and reminded regularly to cover both the areas they judged subjectively to be likely habitat and those they judged to be unlikely, to limit individual observer biases and biases towards particular habitats. The 100 m grid of points across the blocks also ensured that observers covered each block thoroughly.

The second BSI survey followed a significant but brief spring snowfall, and snow-covered areas were not sampled until all snow had melted.

4.3.3 Targeted phenology and *C. pungens* specimen collection

During the second BSI survey period three locations of points were targeted where large numbers (hundreds) of *C. pungens* had been found in the first survey. Two locations were on Ardgour and one was on Bendigo.

These three targeted visits were undertaken to better understand the ecology of the species and help to inform the recommended timing of future surveys. At each location point locations were recorded and the number of *C. pungens* found was noted, along with whether or not some individual plants remained *in situ* after having died back. The targeted visits were also used to collect small numbers of *C. pungens* plants at different stages of their growth and seeding cycles to better understand their structure and biology.

The blocks visited for the three targeted locations were not included in the set of resurveyed blocks (i.e. the 12 blocks on Bendigo revisited in the second BSI survey and surveyed using the same method as in the first BSI survey, described under Field methods above). Inclusion would not be appropriate because the targeted visits did not cover an entire block but deliberately searched only, or mainly, within formerly identified locations. This meant the observations were biased towards previously located groups of plants, and new locations elsewhere across the block could not have been identified had plants emerged elsewhere. Bias would have been accentuated because the observers in the revisits were the same individuals who had gained experience with the same block in the previous survey.

4.4 Mapping and data

Search areas and tracks were mapped, and data summary tables and heatmaps² prepared, based on the two BSI 2025 surveys. Mapped points for spring annuals from the two BSI surveys were also able to be compared informally and visually with those of RMA Ecology (Milner et al. 2025) collected within their ecological survey area in 2024.

The data are held by MGL. The data set includes an Excel file with all point locations along with estimates of number of plants, and shapefiles with tracks and search areas for both surveys.

² A heatmap is a data visualisation tool that represents numerical values using colours, allowing for the quick identification of trends, densities, or user behaviour.

5 Results

Across both BSI surveys the search area covered about 900 hectares, with a total of 270 hours of search time. The search areas and tracks in each survey are shown in Figure 2.

All four spring annual species were found in both BSI surveys, although their distributions varied among the species. No spring annuals were recorded in the higher-altitude blocks on Bendigo searched in the second BSI survey, and spring annual encounters were very few in the most northeastern blocks searched on Ardgour in the first BSI survey.

Spring annual plants occurred across a variety of habitats in the survey areas, including open and low-statured cushionfield and herbfield, kānuka shrubland and woodland, and saline-influenced areas. These habitats had sparse ground cover in early spring, and occurred mostly across an elevation range from 200 to 800 m. *C. pungens* was the only species recorded in a few locations at elevations higher than 800 m.

Maps showing the point locations of each of the three spring annual species targeted for detailed survey in each survey period, along with those identified by RMA Ecology in 2024 (Milner et al. 2025), are provided in Appendix 1. A full set of the GPS locations recorded is provided as an electronic appendix to this report. Table 2 shows the estimated numbers of *C. pungens*, *M. brevis*, and *M. minimus* subsp. *novae-zelandiae* found in the different parts of the BSI survey areas that were covered using the standard sampling methodology; and Table 3 compares average numbers of estimated plants per hectare across the different parts of the BSI survey areas.

Table 2. Rough estimates of the numbers of individual spring annual plants of *C. pungens*, *M. brevis*, and *M. minimus* subsp. *novae-zelandiae* in all areas searched in the two BSI surveys. Time 1 is the first survey period and Time 2 is the second survey period.

Survey	Bendigo Station DDF	Bendigo Station (outside DDF)	Ardgour (outside DDF)	Bendigo West	Total estimate
Time 1	(87 ha)	(148 ha)	(235 ha)		
<i>Ceratocephala pungens</i>	4,470	2,465	4,950		11,885
<i>Myosotis brevis</i>	13,160	5,470	1,130		19,760
<i>Myosurus minimus</i> subsp. <i>novae-zelandiae</i>	14,670	11,165	6,085		31,920
Time 2	(36 ha)	(84 ha)	(7 ha)	(300 ha)	
<i>Ceratocephala pungens</i>	655	225	125	15	1,020
<i>Myosotis brevis</i>	3,415	2,555	240	53,365	59,575
<i>Myosurus minimus</i> subsp. <i>novae-zelandiae</i>	23,860	47,905	130	58,740	130,635

Table 3. Estimates of the numbers of plants per hectares of spring annual plants of *C. pungens*, *M. brevis*, and *M. minimus* subsp. *novae-zelandiae* in all areas searched in the two BSI surveys. Time 1 is the first survey period and Time 2 is the second survey period.

Survey	Bendigo DDF	Bendigo Station	Ardgour Station	Bendigo West	Total survey
Time 1	(87 ha)	(148 ha)	(235 ha)		(470 ha)
<i>Ceratocephala pungens</i>	51	17	21		25
<i>Myosotis brevis</i>	151	37	5		42
<i>Myosurus minimus</i> subsp. <i>novae-zelandiae</i>	169	75	26		68
Time 2	(36 ha)	(84 ha)	(7 ha)	(300 ha)	(427 ha)
<i>Ceratocephala pungens</i>	18	3	18	0.05	2
<i>Myosotis brevis</i>	95	30	34	178	140
<i>Myosurus minimus</i> subsp. <i>novae-zelandiae</i>	663	570	19	196	306

Table 4 shows the estimated numbers of *C. pungens*, *M. brevis*, and *M. minimus* subsp. *novae-zelandiae* plants found across the parts of the survey areas that were covered twice (in both Time 1 and Time 2) using the standard sampling methodology. Table 5 compares average numbers of plants per hectare across the parts of the survey areas that were covered twice.

Table 4. Estimates of the numbers of individual plants of *C. pungens*, *M. brevis*, and *M. minimus* subsp. *novae-zelandiae* in the approximately 57 hectares searched in both BSI surveys. Time 1 is the first survey period and Time 2 is the second survey period.

Species	Time 1	Time 2
<i>Ceratocephala pungens</i>	4,585	1,005
<i>Myosotis brevis</i>	16,200	6,210
<i>Myosurus minimus</i> subsp. <i>novae-zelandiae</i>	19,775	71,895

Table 5. Estimates of the numbers of plants per hectares of spring annual plants of *C. pungens*, *M. brevis*, and *M. minimus* subsp. *novae-zelandiae* in the approximately 57 hectares searched in both BSI surveys. Time 1 is the first survey period and Time 2 is the second survey period.

Species	Time 1	Time 2
<i>Ceratocephala pungens</i>	80	15
<i>Myosotis brevis</i>	284	105
<i>Myosurus minimus</i> subsp. <i>novae-zelandiae</i>	347	1258

M. antarctica subsp. *antarctica* was recorded in 26 of the 70 blocks during the first survey and 15 of the 60 blocks during the second survey. In the blocks that were resurveyed, *M. antarctica* subsp. *antarctica* was recorded in the same blocks both times.

5.1 *Ceratocephala pungens*

C. pungens is usually found on bare and recently disturbed silty soils, including within shrubland. Key habitats include hollows on ridge crests, the tops of ridges, and gently sloping cushionfields on side slopes where there is some depth of silty soil. In the survey this plant was often observed associated with rabbit burrows and scratchings and other recent disturbances, which could include earthworks undertaken for roads, tracks, and drill sites.

Across the entire search area in the first survey (470 hectares) on average 25 *C. pungens* plants were estimated to occurred per hectare searched (Table 3). The highest concentration of plants was within the DDF search area (87 hectares), where we estimated that 51 *C. pungens* occurred on average per hectare searched. In the second survey (427 hectares) on average only 2 *C. pungens* plants were recorded per hectare searched, with the highest concentration (18 plants per hectare on average) again recorded in the Bendigo DDF search area (36 hectares).

Figure 3 shows hexagonal heatmaps mapping the estimated numbers of *C. pungens* plants within areas sampled in the first and second BSI survey periods (with the heatmap for the second period showing only the eastern areas sampled in the second survey). For legibility, heatmaps for the second period in Figure 3 exclude the highest and most southern areas sampled in the second sampling period (see Figure 1), where no spring annuals were found and the heatmap therefore has no coloured cells.

Figure 4 shows the point locations of *C. pungens* in areas surveyed twice (i.e. in both survey periods) using the same method. Figure 5 shows hexagonal heatmaps mapping the estimated numbers of *C. pungens* plants for each survey period in the areas that were sampled twice.

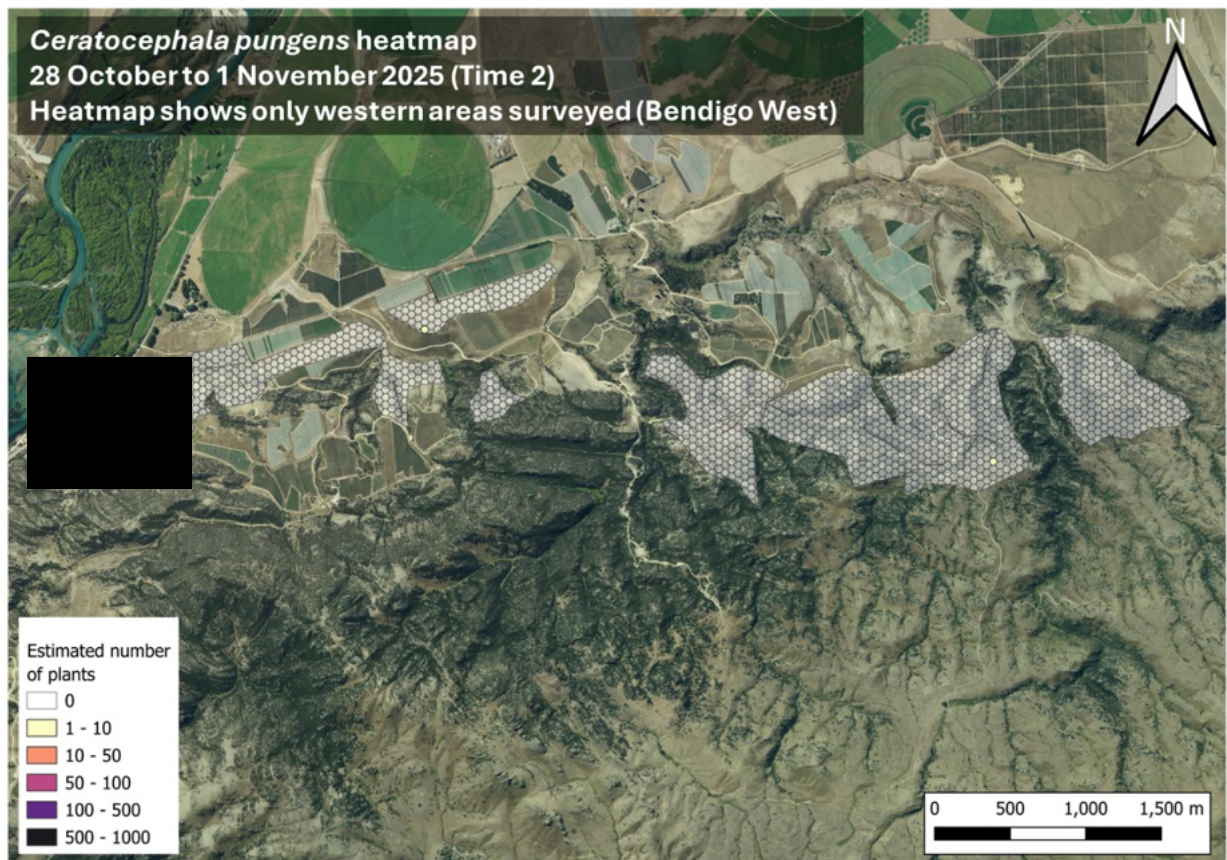
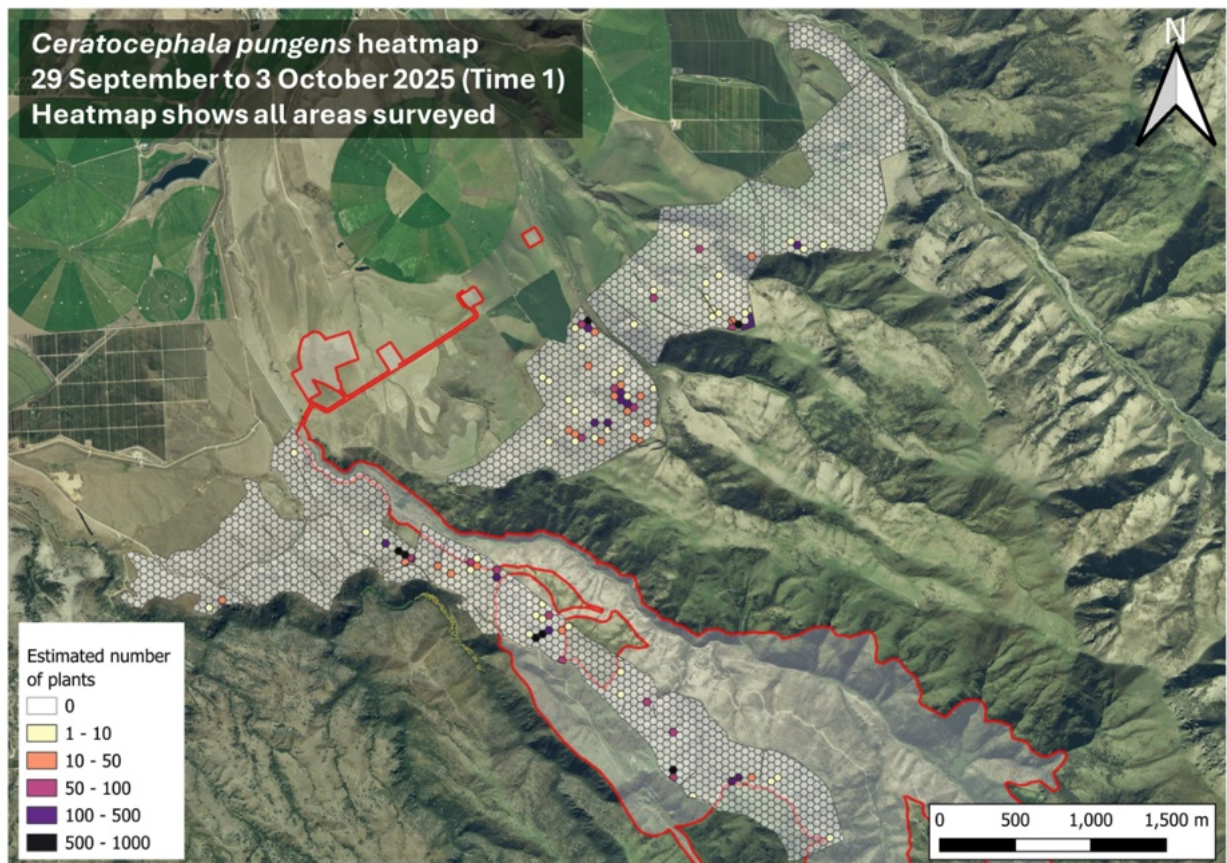


Figure 3. Hexagonal heatmaps of estimated numbers of *C. pungens* plants recorded in the first survey (upper image) and the western portion of the second survey (Bendigo West) (lower image, with only three points recorded, two with single plants). The red line shows the DDF. Each hexagon has a short diagonal distance of 50 m and an area of about 0.217 hectares.

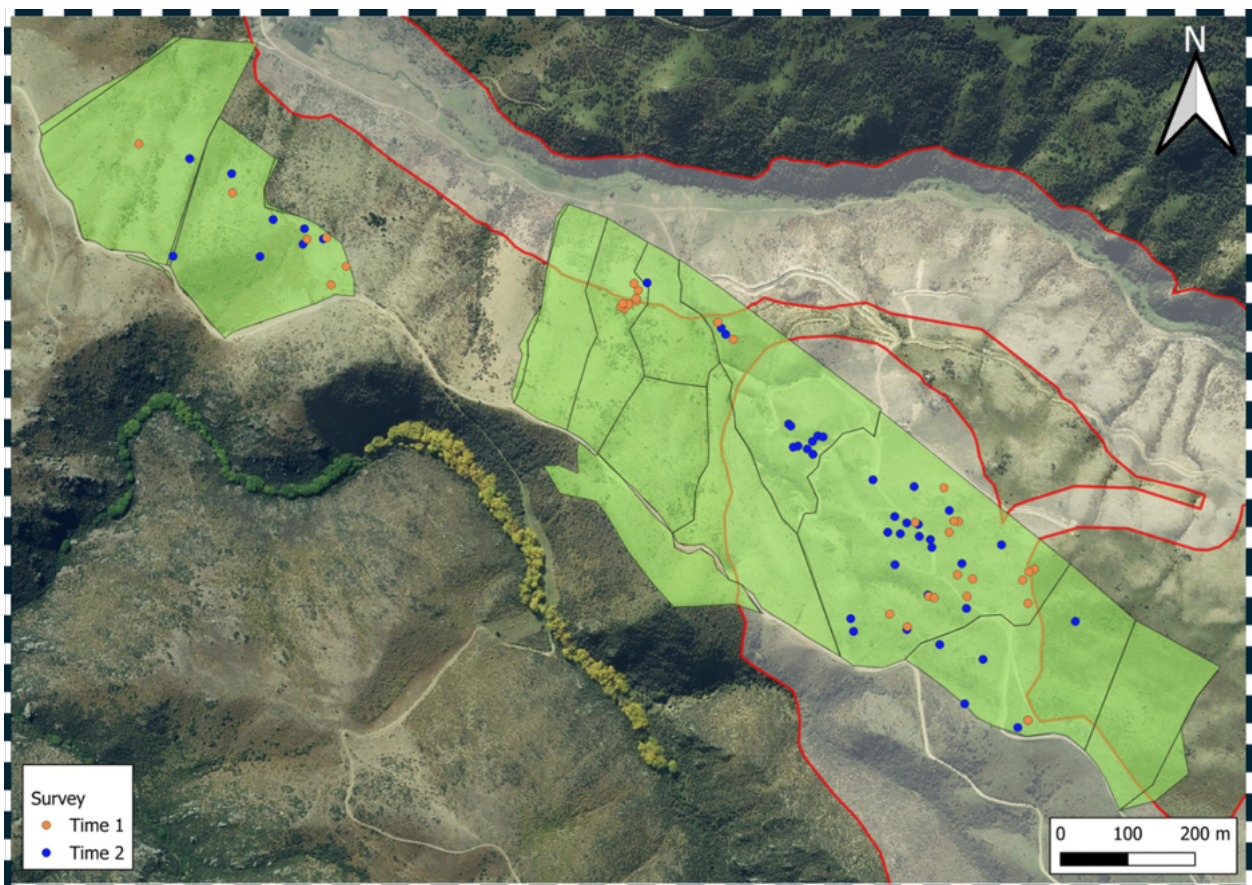
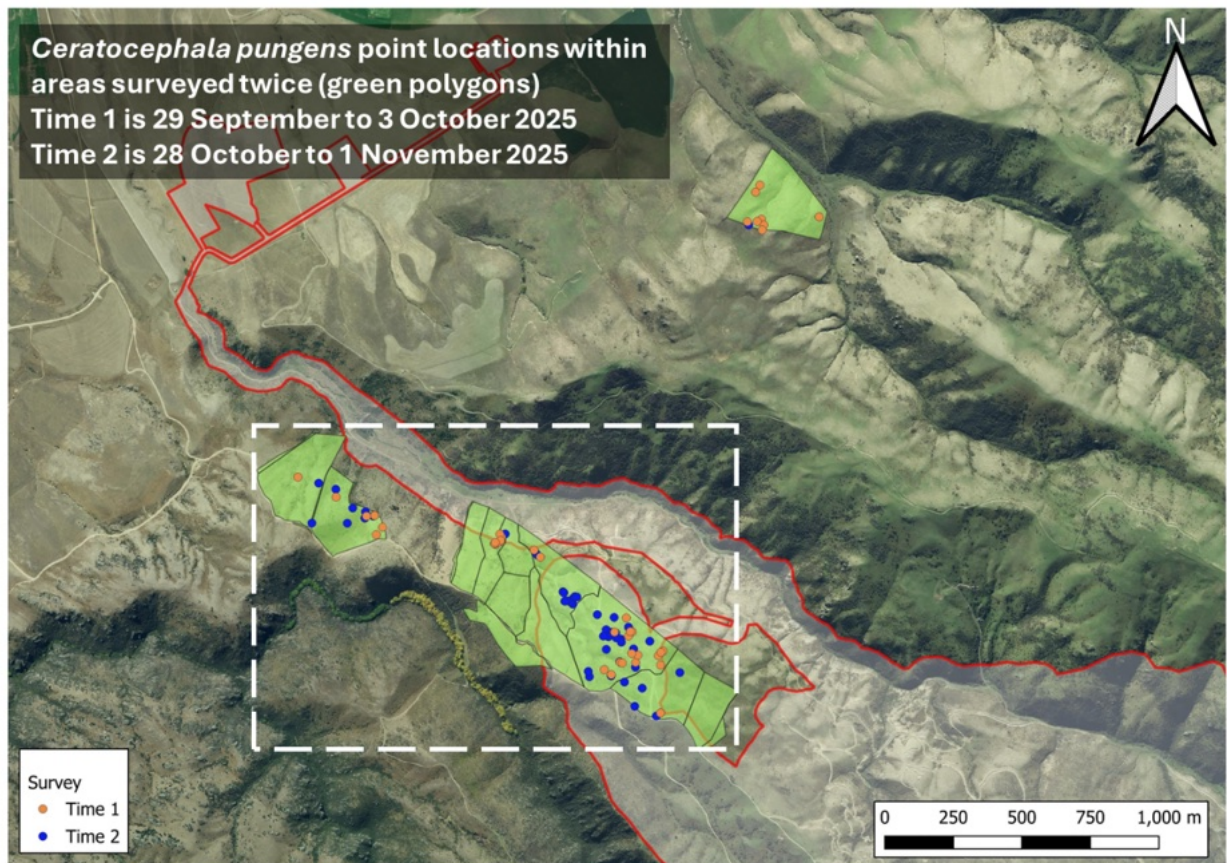


Figure 4. Point locations of *C. pungens* recorded in the first and second surveys. The lower image zooms in to better show point locations within the areas surveyed twice on Bendigo. The red line shows the DDF.

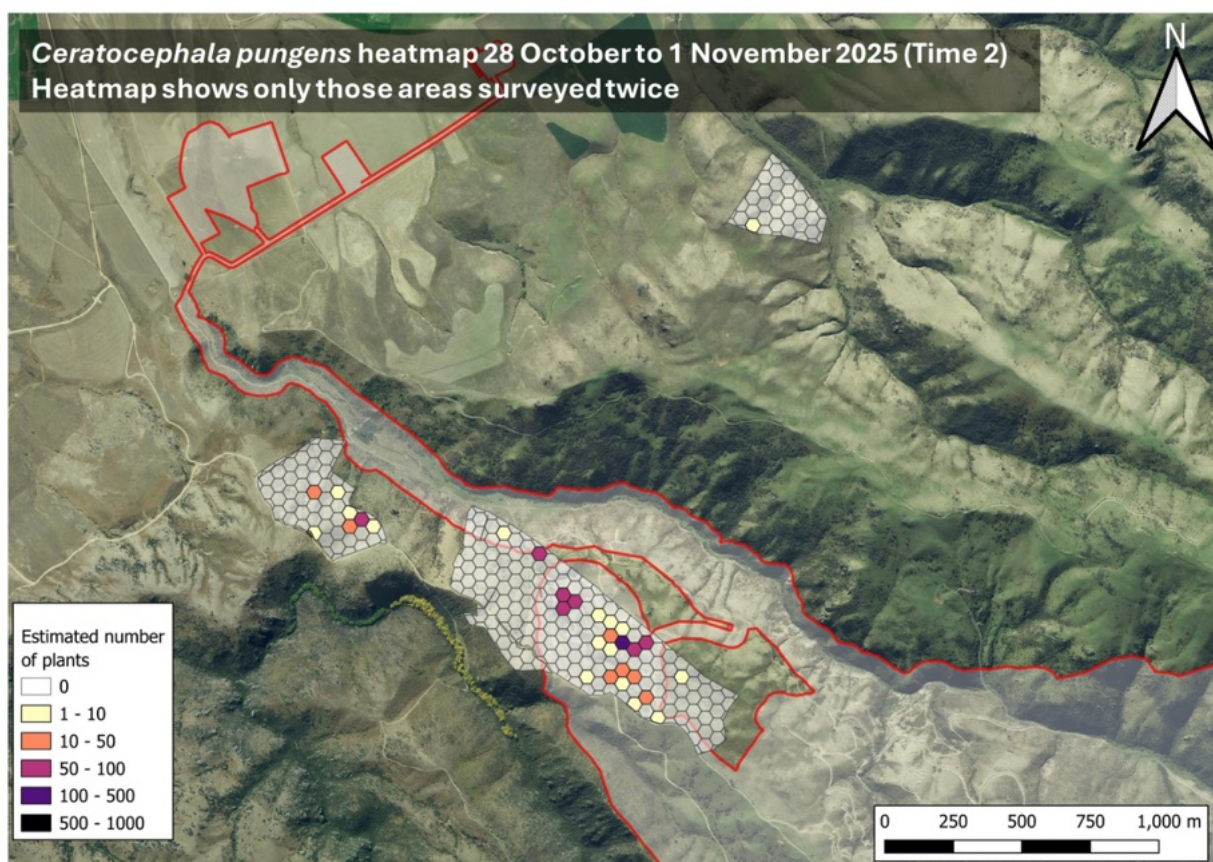
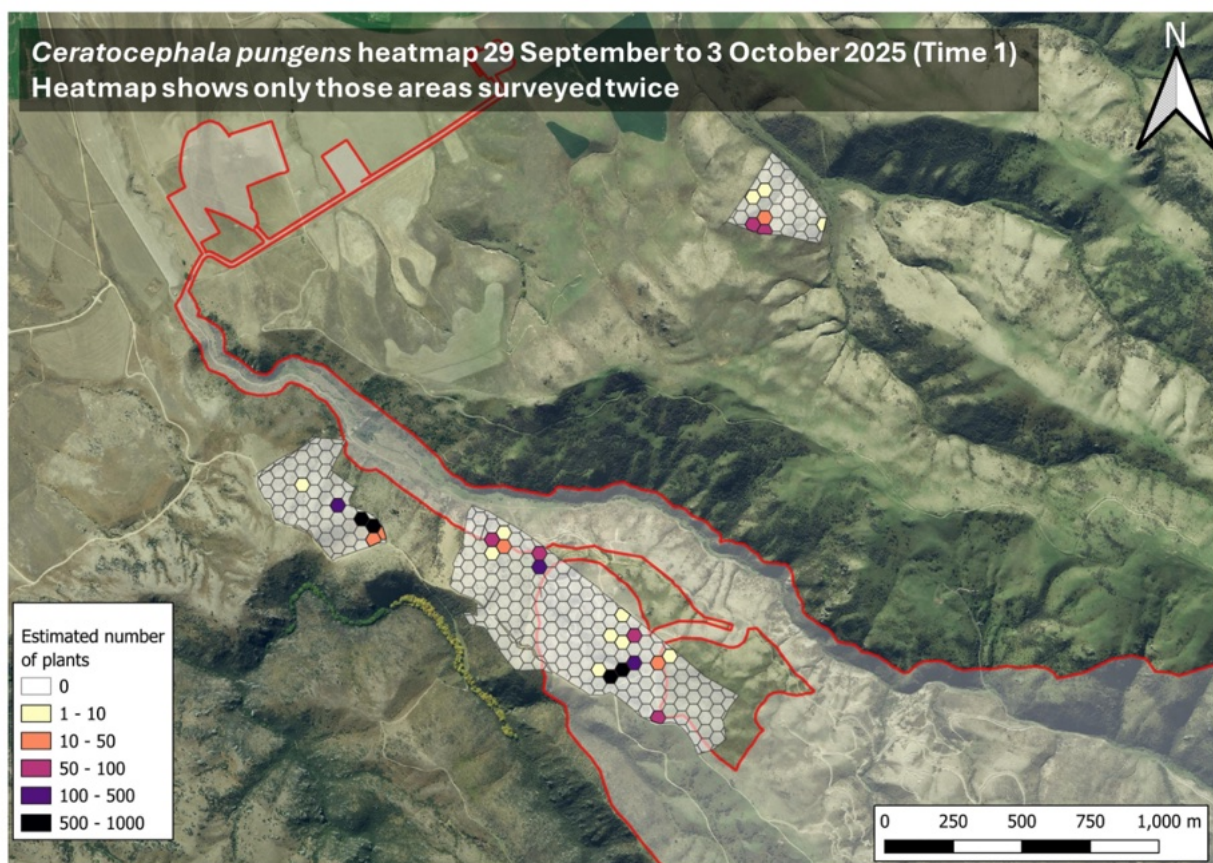


Figure 5. Hexagonal heatmaps of estimated numbers of *C. pungens* plants recorded in the first survey (upper image) and second survey (lower image) within the areas surveyed twice on Bendigo. The red line shows the DDF. Each hexagon has a short diagonal distance of 50 m and an area of about 0.217 hectares.

5.2 *Myosotis brevis*

Habitats of *M. brevis* included open cushionfield, especially on ridge crests, and it was occasionally found growing within *Raoulia* cushions themselves. Kānuka woodland was a characteristic and common habitat, especially west of the DDF, where the plant was typically growing on the sheltered and shaded aspects of kānuka shrubs on otherwise bare or slightly mossy silty ground but was absent from the more wind-deflated,³ north-facing, and gravelly substrates.

In the first survey (470 hectares) on average across the whole survey area 42 *M. brevis* plants were estimated per hectare searched, with the highest concentration recorded within the DDF (87 hectares) where on average 151 plants of *M. brevis* were estimated to occur per hectare (Table 3). In the second survey (total of 427 hectares searched) 140 *M. brevis* plants were estimated to occur per hectare on average, with the highest concentration of plants in the Bendigo West area (300 hectares searched) where 178 plants on average per hectare searched were estimated to occur.

Figure 6 shows hexagonal heatmaps mapping the estimated numbers of *M. brevis* plants within areas sampled in the first and second survey periods (with the heatmap for the second period showing only the eastern areas sampled in the second survey). Note that the legend scale is different from that for the rarer *C. pungens*. As for *C. pungens* in Figure 3, the heatmaps in Figure 6 for the second survey period exclude high southern areas where no spring annuals were found.

Figure 7 shows the point locations recorded *M. brevis* in areas surveyed twice (i.e. in both BSI survey periods) using the same standard survey method. Figure 8 shows hexagonal heatmaps mapping the estimated numbers of *M. brevis* plants for each survey period, within those areas that were sampled twice. Note that the legend scale (i.e. differentiating the colours on the heatmap) is different from that for *C. pungens* to reflect the higher maximum densities of *Myosotis brevis* plants.

³ Wind-deflated surfaces are areas where wind erosion has removed loose, fine-grained soil and sediment, leaving behind coarser gravels and rocky material. Within the survey area these typically occur on north-west facing slopes.

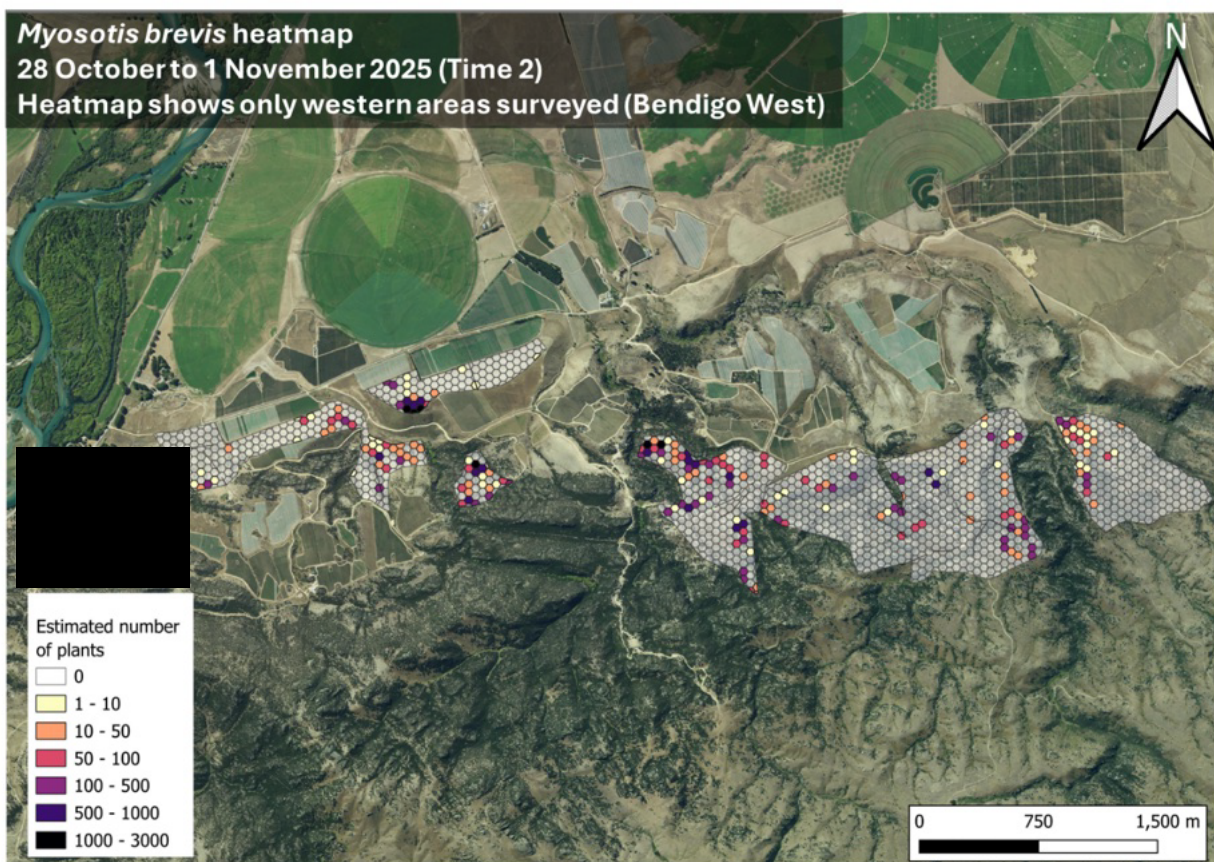
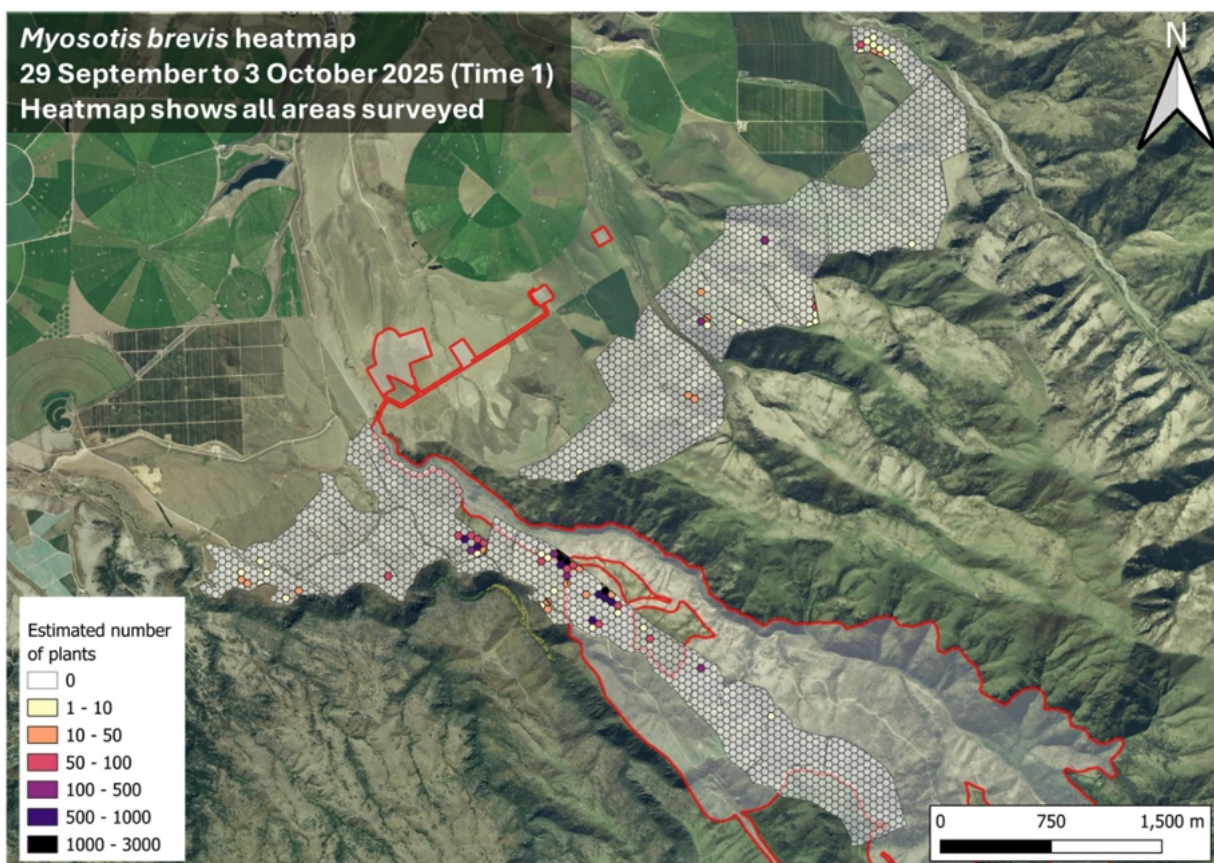


Figure 6. Hexagonal heatmaps of estimated numbers of *M. brevis* plants recorded in the first survey (upper image) and the western portion of the second survey (Bendigo West) (lower image). The red line shows the DDF. Each hexagon has a short diagonal distance of 50 m and an area of about 0.217 hectares.

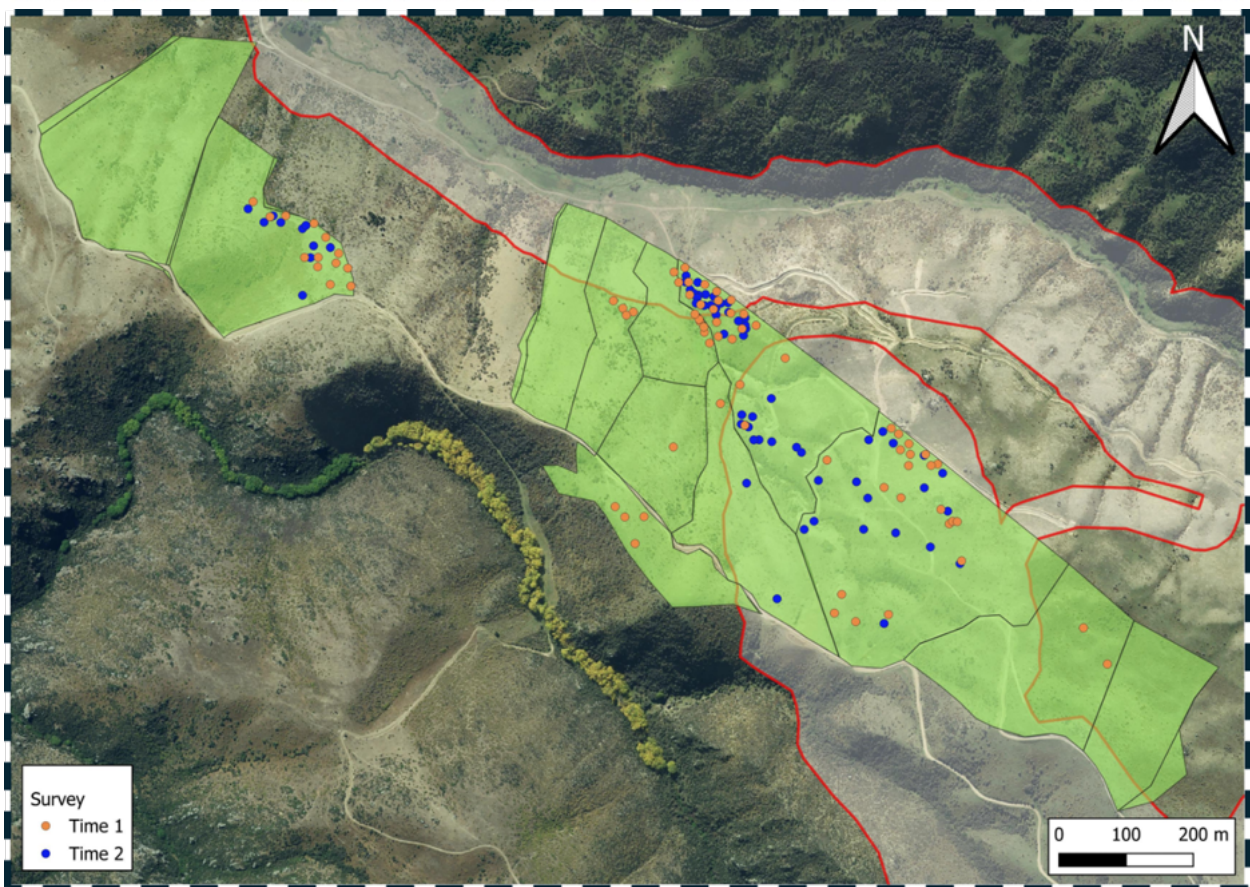
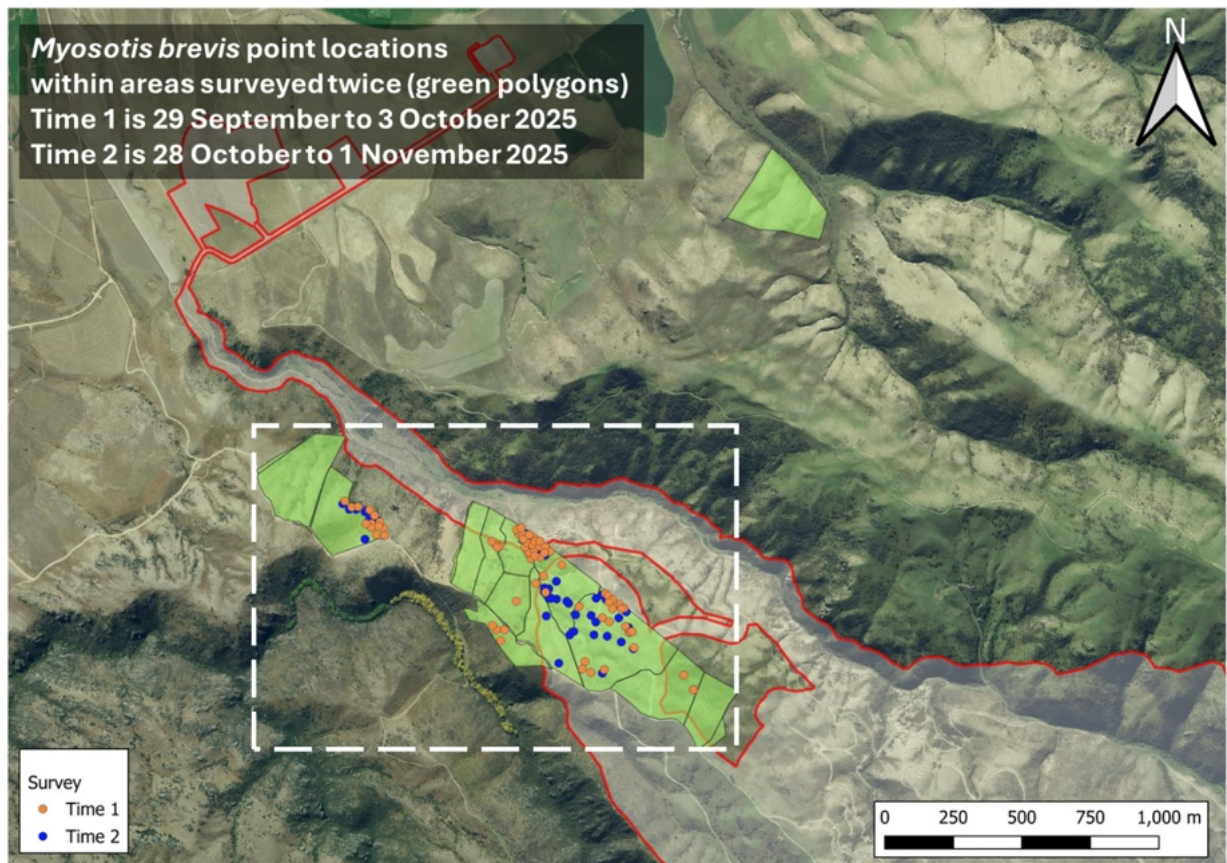


Figure 7. Point locations of *M. brevis* recorded in the first and second surveys. The lower image zooms in to better show point locations within the areas surveyed twice on Bendigo. The red line shows the DDF.

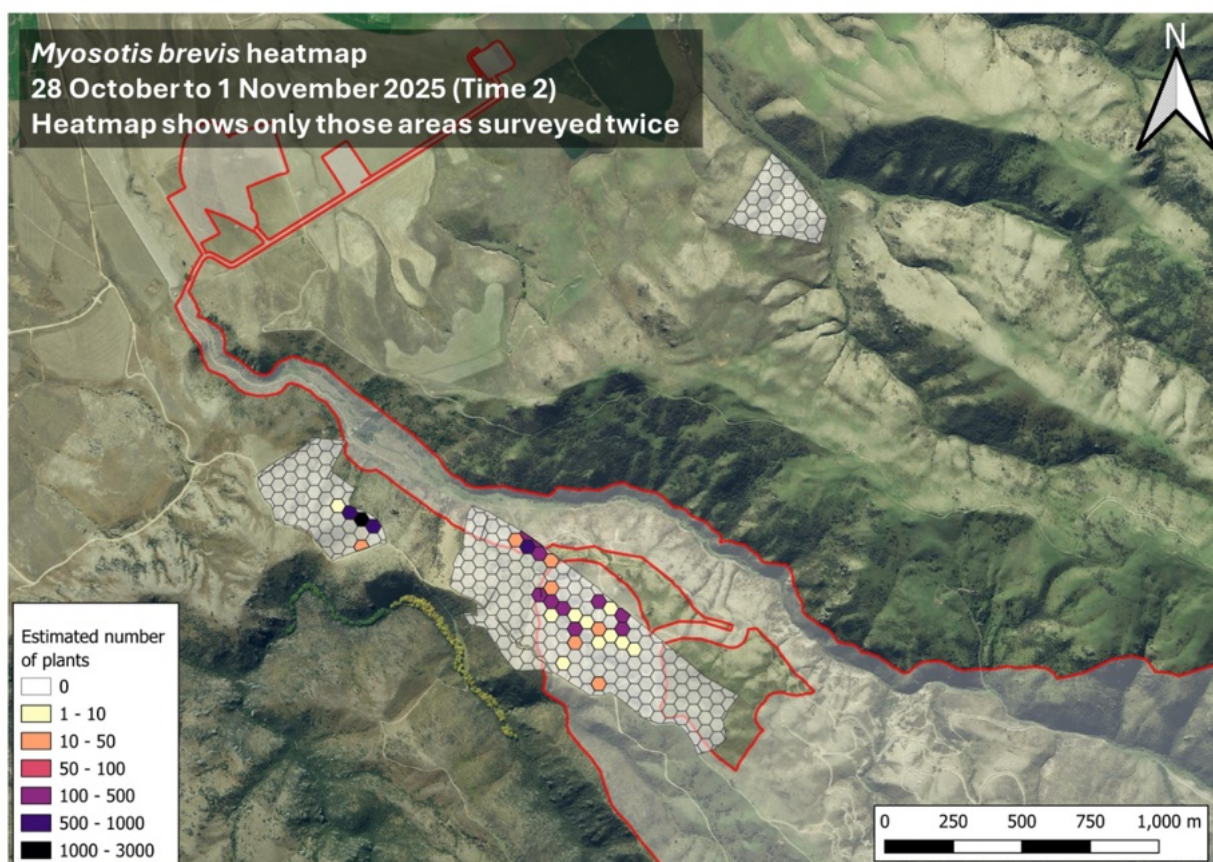
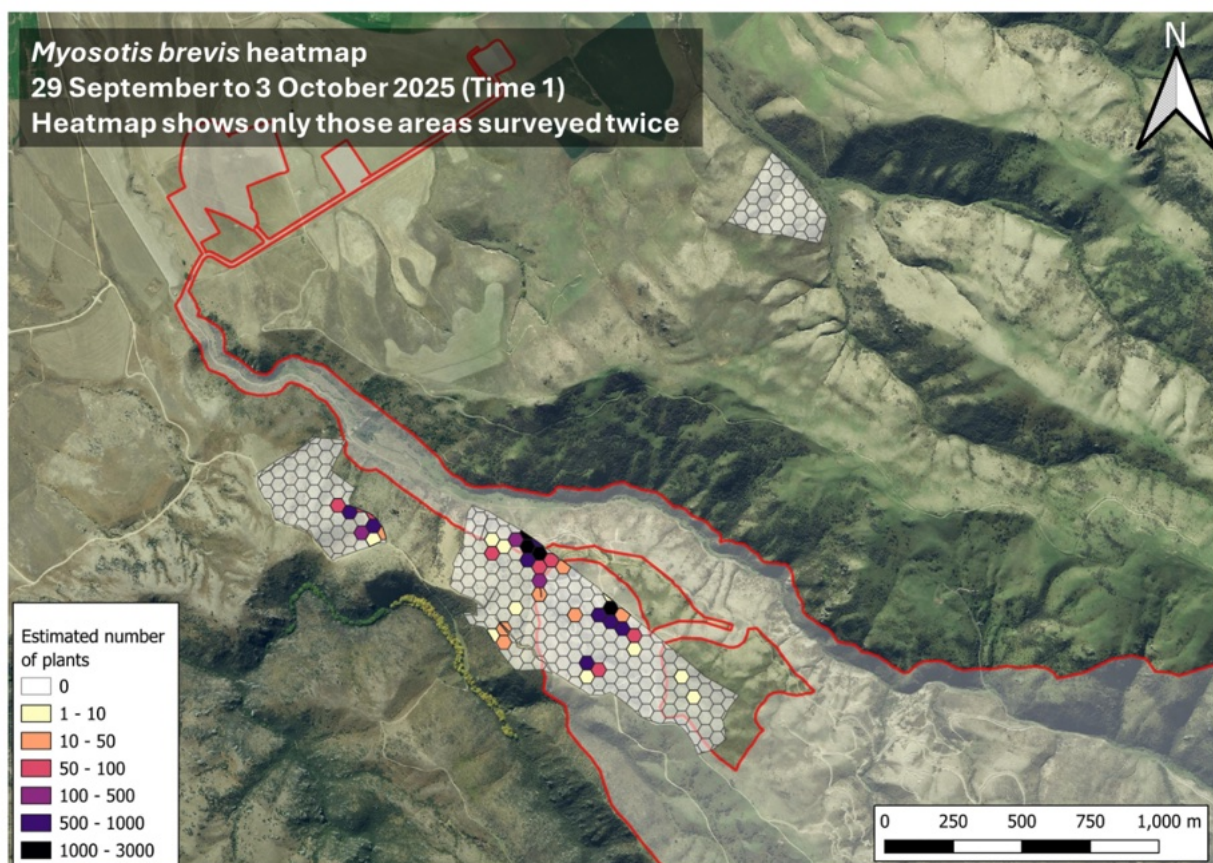


Figure 8. Hexagonal heatmaps of estimated numbers of *M. brevis* plants recorded in the first survey (upper image) and second survey (lower image) within the areas surveyed twice on Bendigo. The red line shows the DDF. Each hexagon has a short diagonal distance of 50 m and an area of about 0.217 hectares.

5.3 *Myosurus minimus* subsp. *novae-zelandiae*

Habitats of *M. minimus* subsp. *novae-zelandiae* were characteristically open ridge crests, shallow seasonally damp hollows on spurs and crests (including among emerging weed cover), and bare or slightly mossy ground beneath and on the sheltered and shaded aspects of shrubs in kānuka and other mixed woodland sites. It was also found scattered among *Raoulia* cushions in places.

M. minimus subsp. *novae-zelandiae* was much more prevalent in the second survey than the first (Tables 2 & 3). In the first survey (470 hectares) 68 plants per hectare were estimated on average; while 306 plants were estimated to occur per hectare in the second survey (427 hectares) (Table 3). The highest concentration of plants was recorded in the Bendigo DDF (169 and 663 plants estimated per hectare on average in the first and second surveys respectively).

Figure 9 shows hexagonal heatmaps mapping the estimated numbers of *M. minimus* subsp. *novae-zelandiae* plants within areas sampled in the first and second survey periods (with the heatmap for the second period showing only the eastern areas sampled in the second survey). Note that the legend scale (i.e. differentiating the colours on the heatmap) is different from those for *C. pungens* and *M. brevis*, to reflect the higher maximum densities of *M. minimus* subsp. *novae-zelandiae* plants. Heatmaps for the second period again exclude the highest and most southern areas sampled in the second sampling period where no spring annuals were found.

Figure 10 shows the point locations recorded of *M. minimus* subsp. *novae-zelandiae* in areas surveyed twice (i.e. in both survey periods) using the same method. Figure 11 shows hexagonal heatmaps mapping the estimated numbers of this plant for each survey period within those areas that were sampled twice.

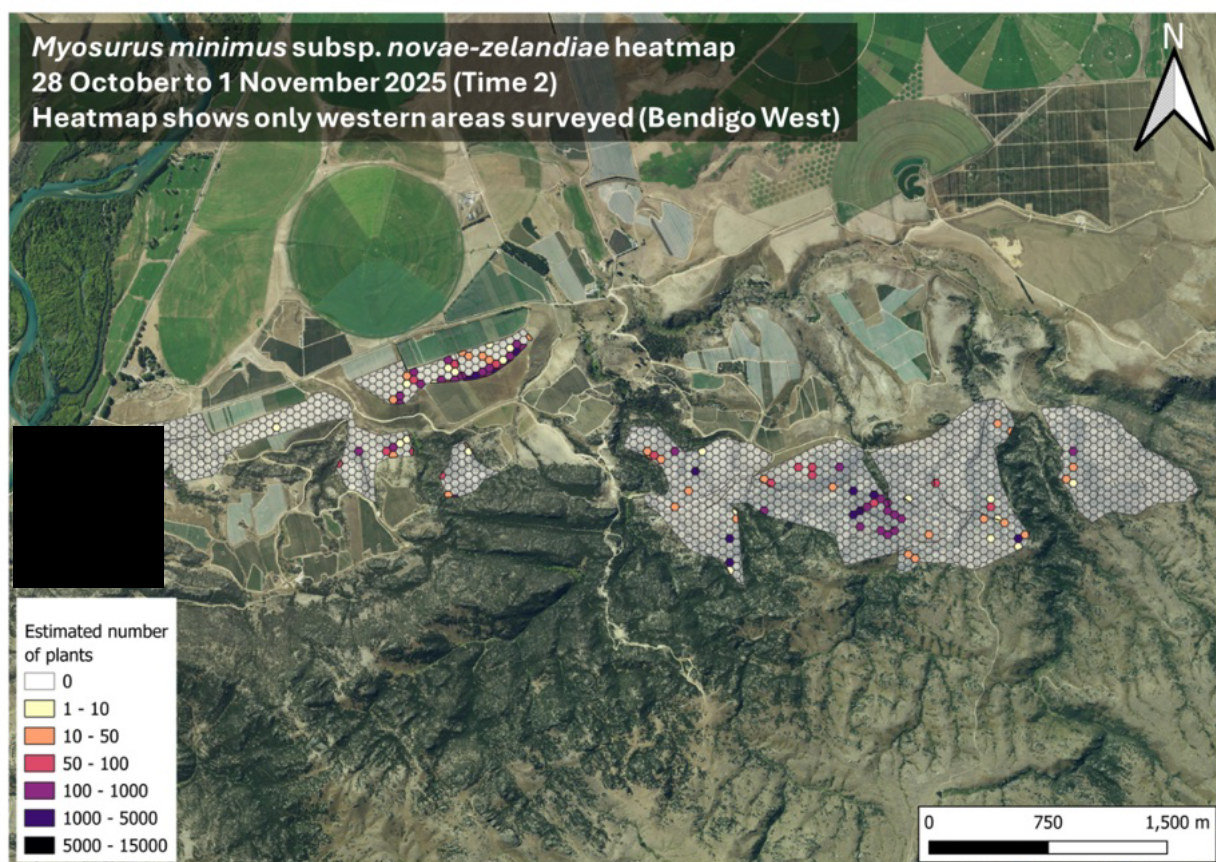
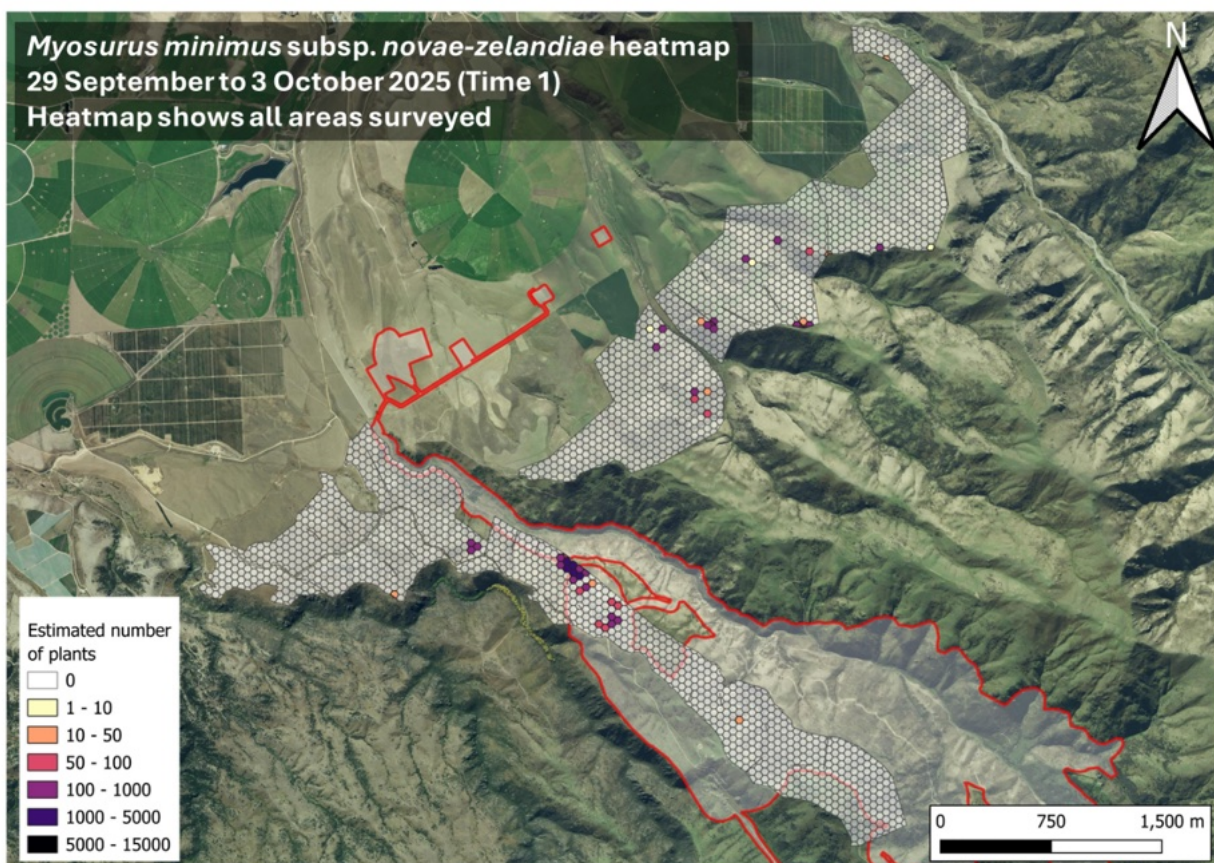


Figure 9. Hexagonal heatmaps of estimated numbers of *M. minimus* subsp. *novae-zelandiae* plants recorded in the first survey (upper image) and the western portion of the second survey (lower image) (Bendigo West). The red line shows the DDF. Each hexagon has a short diagonal distance of 50 m and an area of about 0.217 hectares.

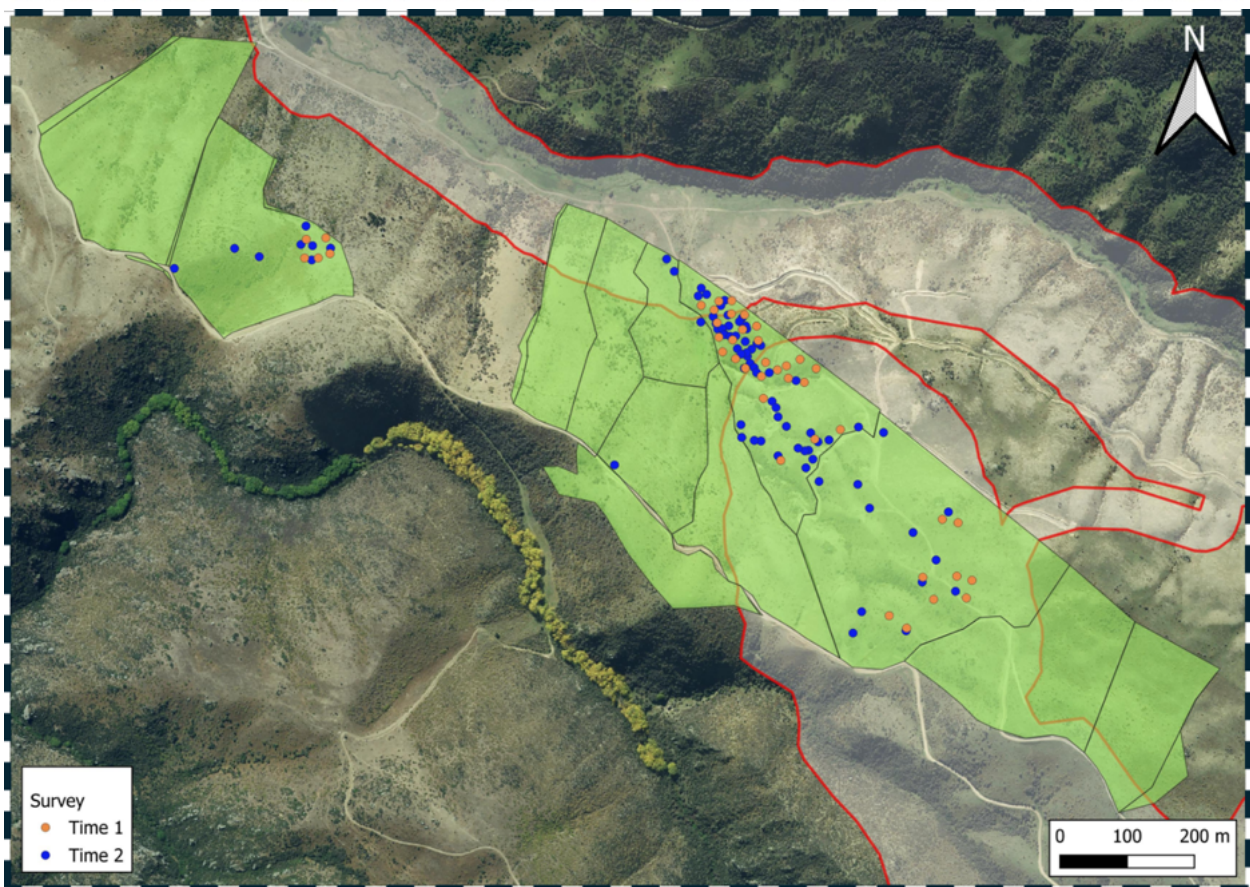
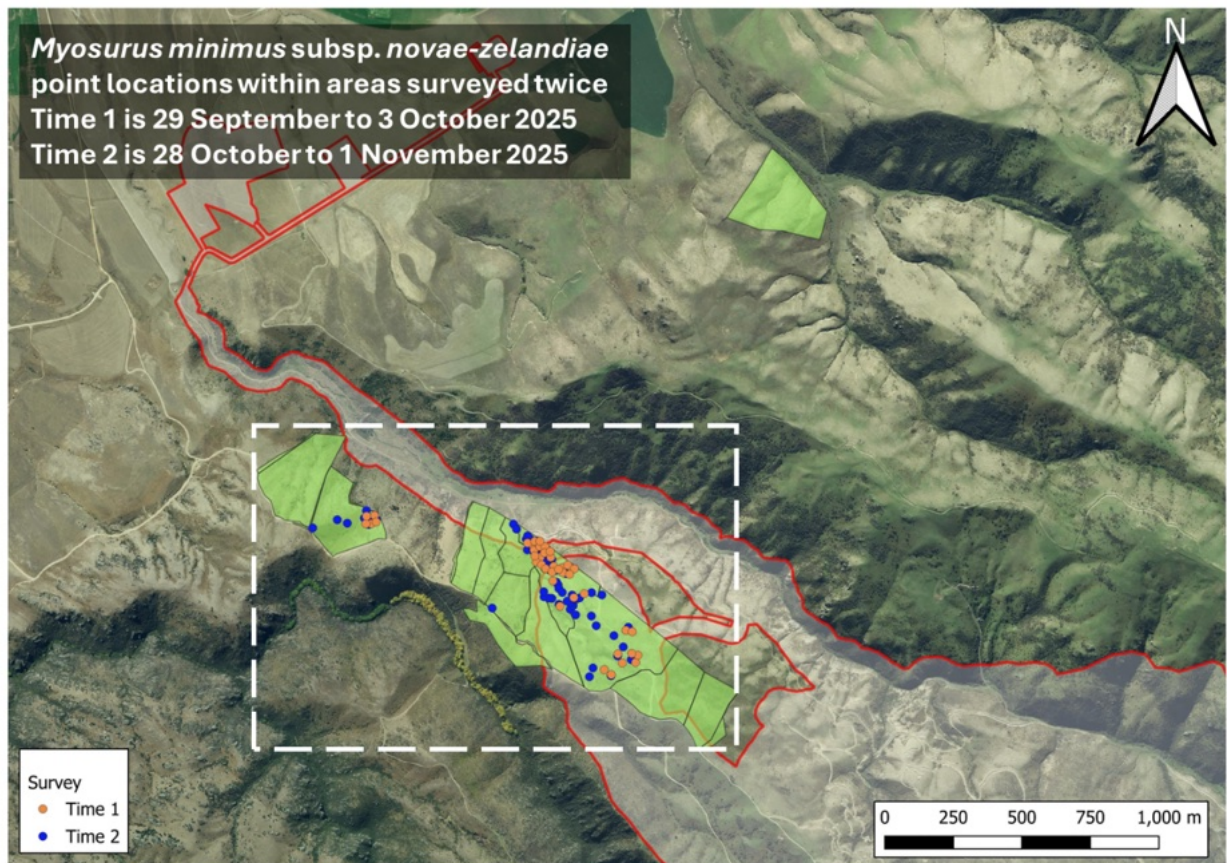


Figure 10. Point locations of *M. minimus* subsp. *novae-zelandiae* recorded in the first and second surveys. The lower image zooms in to better show point locations within the areas surveyed twice on Bendigo. The red line shows the DDF.

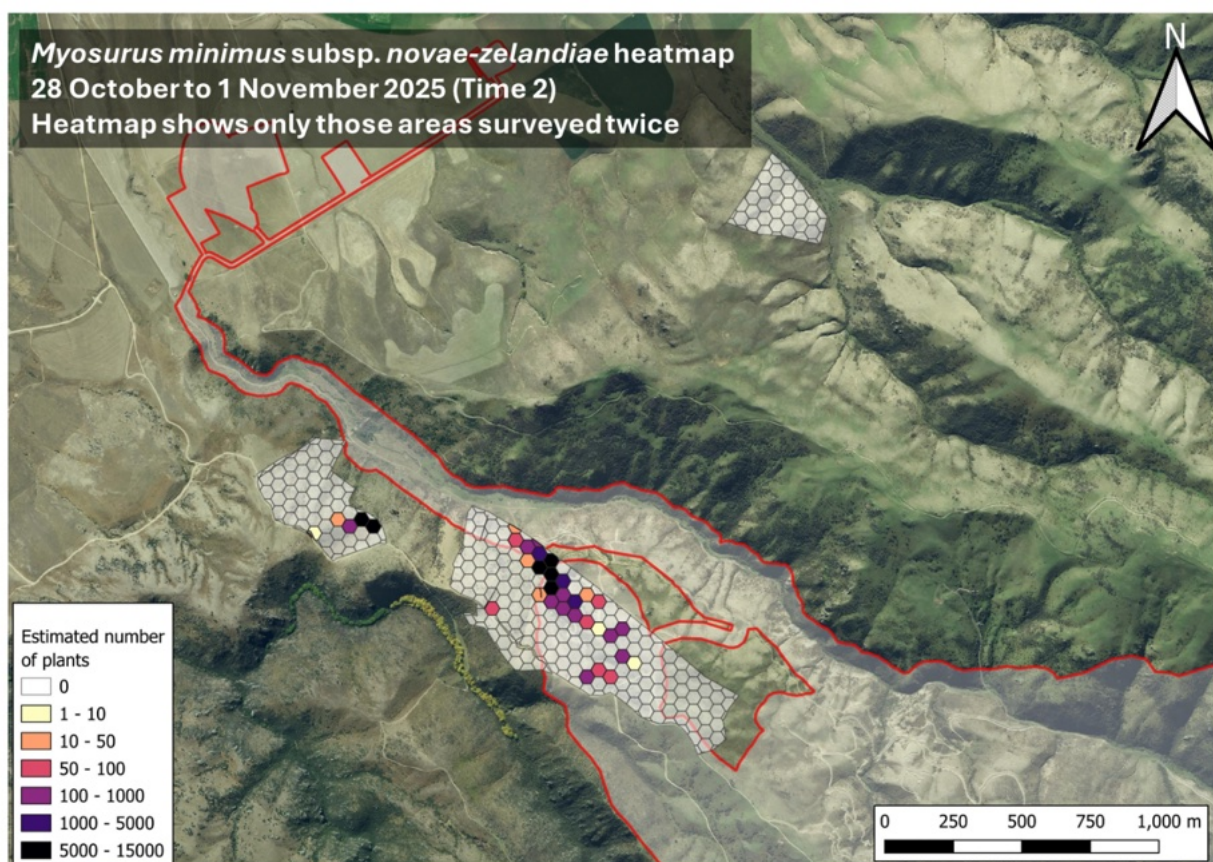
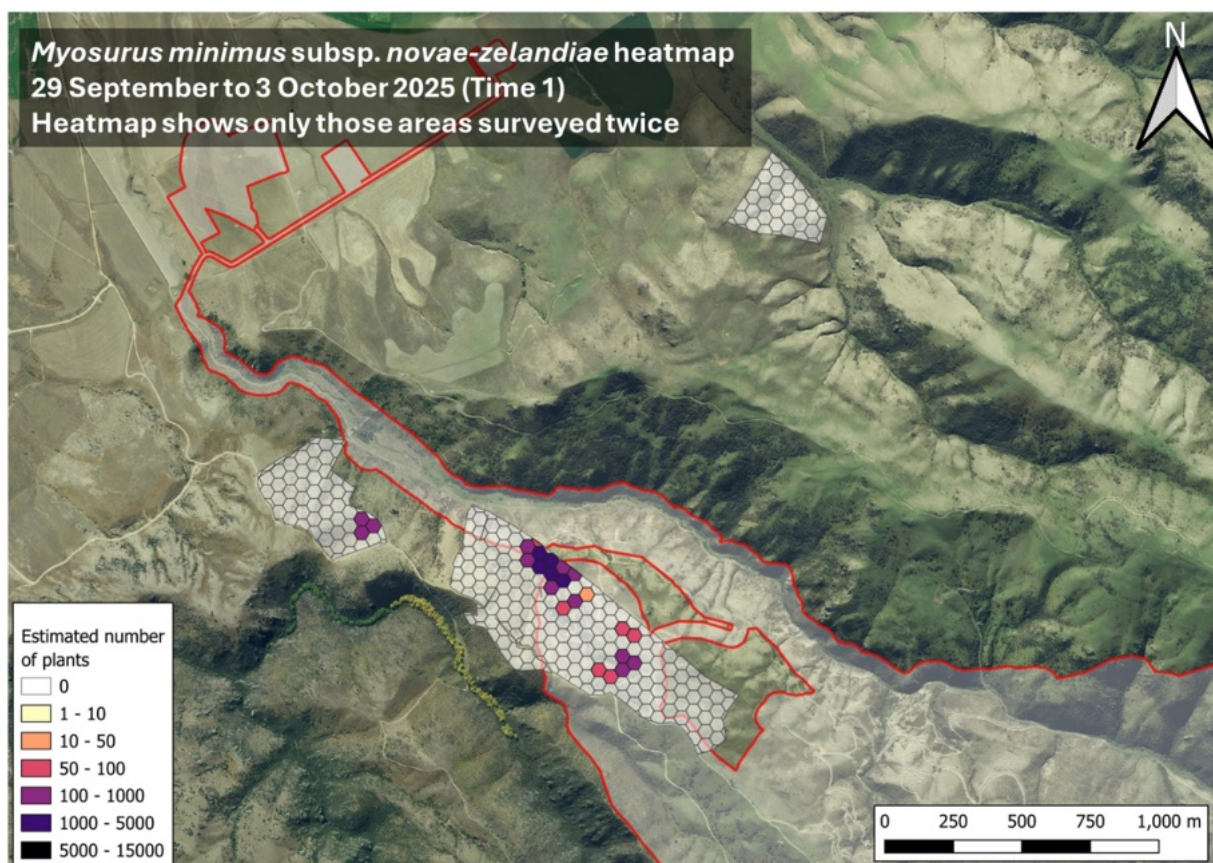


Figure 11. Hexagonal heatmaps of estimated numbers of *M. minimus* subsp. *novae-zelandiae* plants recorded in the first survey (upper image) and second survey (lower image) within the areas surveyed twice on Bendigo. The red line shows the DDF. Each hexagon has a short diagonal distance of 50 m and an area of about 0.217 hectares.

5.4 *Myosotis antarctica* subsp. *antarctica*

Figure 12 shows the blocks in which *M. antarctica* subsp. *antarctica* was recorded in each survey period. The point locations of this species that were recorded by RMA Ecology (Milner et al. 2025) are also shown on this map. *M. antarctica* subsp. *antarctica* was recorded twice in 7 of the 13 blocks that were surveyed twice (and was found in the same blocks both times).

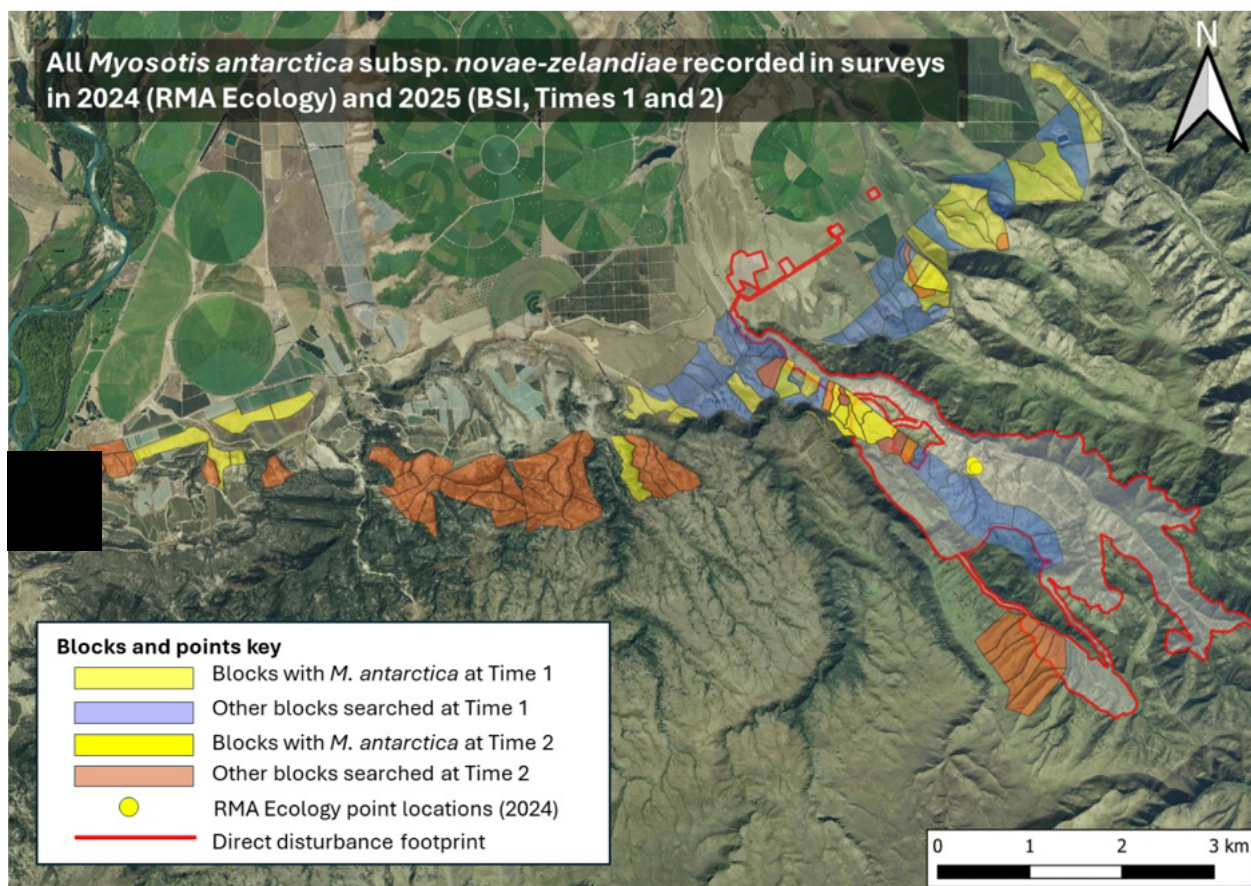


Figure 12. Blocks containing *M. antarctica* subsp. *antarctica* plants (shaded yellow) in the two surveys by BSI in 2025. Point locations recorded by RMA Ecology in 2024 are shown as yellow circles.

5.5 RMA Ecology results

Milner et al. (2025) (RMA Ecology) recorded the presence of all four targeted spring annual plant species across their ecological survey area in November 2024, and the point locations they recorded for each species are reproduced in this report in Appendix 1. Due to lambing, the BSI surveys in 2025 were unable to search many areas on Ardgour in which Milner et al. found spring annuals (the RMA Ecology survey took place in mid-November, after lambing).

6 Discussion

6.1 Presentation of location data

Unlike perennial plant species, which grow in the same location for multiple years, spring annual herbs can emerge across new and different locations where and when conditions are suitable in different years. To avoid any impression that locations are durable, this report does not make any attempt to delimit sites, patches or subpopulations of any species across the BSI survey areas.

The identification of a site or patch for a spring annual is problematic because of the plant's biology. Plants germinate from the seedbank, have a short growing season and set seed, which is then blown or moved around by other means. It is not known how much seed is in the seedbanks, where seedbanks are, how long seed can remain viable in the seedbank, nor how those attributes vary among the different species and different environments. However, it is evident from the point data collected and mapped in the two successive BSI surveys that the locations of plants change across the spring growing season within a single year, and it is foreseeable that locations are also likely to vary among different years. Sites with spring annuals therefore need to be identified over multiple years.

No conclusions can be reached on differences in the distributions and numbers of the species in different years by comparing the RMA Ecology results with the BSI surveys, even across the areas sampled by both surveys, because the methods and survey timings were different. The RMA Ecology survey in 2024 provided information about spring annuals while having much broader goals and was undertaken later in spring than the BSI surveys. The BSI surveys in 2025 were undertaken earlier in spring and focused solely on better understanding the distributions and estimating the numbers of spring annuals.

Tracking distributional changes and trends in the numbers of the spring annuals in future will depend on similar targeted surveys, using similar methods by similarly experienced observers.

6.2 *Ceratocephala pungens*

6.2.1 Distribution and numbers

C. pungens was estimated to have the lowest numbers of the three spring annuals in the 2025 survey. A rough estimate of nearly 12,000 plants found in the first BSI survey included scattered individual plants and clusters of up to hundreds of plants. *C. pungens* was located by BSI near all the locations recorded by Milner et al. (2025) where the two surveys overlapped. *C. pungens* was also found in many more locations within the part of the DDF sampled than those recorded by Milner et al. (see Appendix 1, Maps A1 & A2) in both BSI sampling periods. The heatmaps (Figure 3) show that the recorded locations extended across many northwest- to northeast-facing slopes above Shepherds Creek (inside and outside of the DDF). The habitat of *C. pungens* also included newly disturbed soils on both sides of a recently upgraded road at higher elevations within the DDF.

Notably, many of the *C. pungens* point locations recorded in the second survey were distant (i.e. >20 m) from those recorded in the same blocks in the first survey. Many of the new and different locations in the second survey therefore probably represent different (i.e. additional) groups of plants. This indicates that the extent of the potential habitat is greater than the point locations (see Figure 4 inset, and discussion under section 7.2.2, 'Ecology and species biology', below).

The number of *C. pungens* plants present within the DDF area in 2025 is likely to be greater than that recorded over the two 2025 BSI surveys, because the search area excluded adjacent areas of the DDF north of the boundary fence between Bendigo and Ardgour, where Milner et al. (2025) marked three groups of *C. pungens* in November 2024 (see Appendix 1, Map A2).

The 2025 survey on Ardgour outside the DDF extends the previously known range of *C. pungens*, because Milner et al. (2025) did not record the species anywhere on Ardgour outside the DDF in November 2024 (Appendix 1, Map A2).

The searches of Bendigo West during the second BSI survey in late October 2025 (Bendigo Reserve and vineyards area, lower Map in Figure 3) recorded *C. pungens* at just three points over 3 days of searching with a team of six (see Appendix 1, Map A1, and digital Appendix). The numbers of *C. pungens* plants at each of these points were one, three, and ten plants (Appendix 2).

To provide context for the BSI findings additional information was sought. DOC was asked for information on recent surveys and present locations of *C. pungens*. They provided this information as a table of sites and estimated numbers. In addition, a botanical report (Wells & Lloyd 2024⁴) was downloaded, which describes a search for spring annuals in December 2024 at the site of a proposed housing subdivision on private land in the Bendigo area, an area partly covered in the second BSI survey.

The results of the BSI survey of Bendigo West were similar to those from a partially overlapping survey by DOC at Bendigo, west of old Welshtown, which was undertaken 3 weeks earlier by experienced observers (R. Ewans, DOC, pers. comm. December 2025). In the DOC search no plants were found at or near points recorded in DOC's bioweb from previous years. However, DOC did record a single location (with about 20 individual *C. pungens* plants) from 'on Bendigo covenant near PCL'. The DOC survey supports the data from the BSI survey in indicating that *C. pungens* is very rare to the west of the DDF on Bendigo at present.

Wells and Lloyd (2024) reported several *C. pungens* plants at a housing subdivision in Bendigo West in mid-December 2024; the second BSI survey (late October 2025) found one *C. pungens* plant in the vicinity. The Wells and Lloyd report is unusual because December is the latest time in the spring that *C. pungens* has ever been recorded. BSI asked for photographs of the plants reported by Wells and Lloyd to check that the identification was correct and to observe the growth stage. That request was turned down, and therefore BSI cannot confirm the report.

The DOC table shows that the only other population of *C. pungens* which numbers in the thousands of plants is at the Bannockburn Sluicings Historic Reserve. The second-largest population is at a site on road reserve beside Conroys Road, which was estimated to have 700 plants in 2024. All other populations listed were either smaller or thought to be no longer extant. DOC's collated data therefore emphasise the significance of the *C. pungens* population on Bendigo and Ardgour Stations. This context suggests that the *C. pungens* population on Bendigo and Ardgour Stations make up a substantial proportion of all plants known to occur today.

6.2.2 Ecology and species biology

Phenology

By the time of the first BSI survey (late September to early October) many *C. pungens* plants were already bearing seed. This shows that *C. pungens* had clearly emerged in some places much earlier in the spring of 2025 than in the first BSI survey. This is consistent with the species description in de Lange et al. (2010), which notes that the species may emerge in July (although local observations suggest that emergence as early as July is very rare).

In the second BSI survey, in late October, *C. pungens* plants in some of the patches targeted for revisiting had disappeared, died back, or become browned off or faded. Some plants within the DDF were difficult to find amongst exotic grass swards that had become established since the first survey, and it is possible that the sowing of grass seed as rehabilitation for roading disturbance may have contributed to that outcome.

⁴ This report is presently on the council website as [230179 Minute 6 of the Commissioner.pdf](#) under Minutes and responses for [RC230179 TKO Properties Limited - Under Appeal - Central Otago District Council](#).

However, many of the *C. pungens* plants found in blocks searched for a second time were in different locations from those recorded in the first survey. Slight differences in location might be expected simply because GPS points were recorded only when a new individual was found more than 20 m from the last. However, two patterns suggest that a proportion of the points recorded by BSI in late October represented new plants that had emerged and grown in the month since the previous BSI survey 4 weeks earlier.

- First, some new point locations were identified along paths that had been searched in the previous survey without recording any plants in the vicinity and are therefore new and additional records. Figure 13 shows, as an example, a group of points representing about 180 *C. pungens* plants recorded in the second survey in an area that was traversed by tracks in both surveys. It is unlikely that such high numbers of non-senescent plants would have been missed in the first survey had they been present.
- Second, the plant material collected by BSI at locations that had previously supported high numbers of plants suggests that *C. pungens* had emerged, flowered and died back across an extended period this spring. Collected specimens included plants with completely senescent leaf material and dried-off (dark brown) achenes (seed capsules), while another specimen dissected was still flowering, with stamens and possibly also petals still visible.

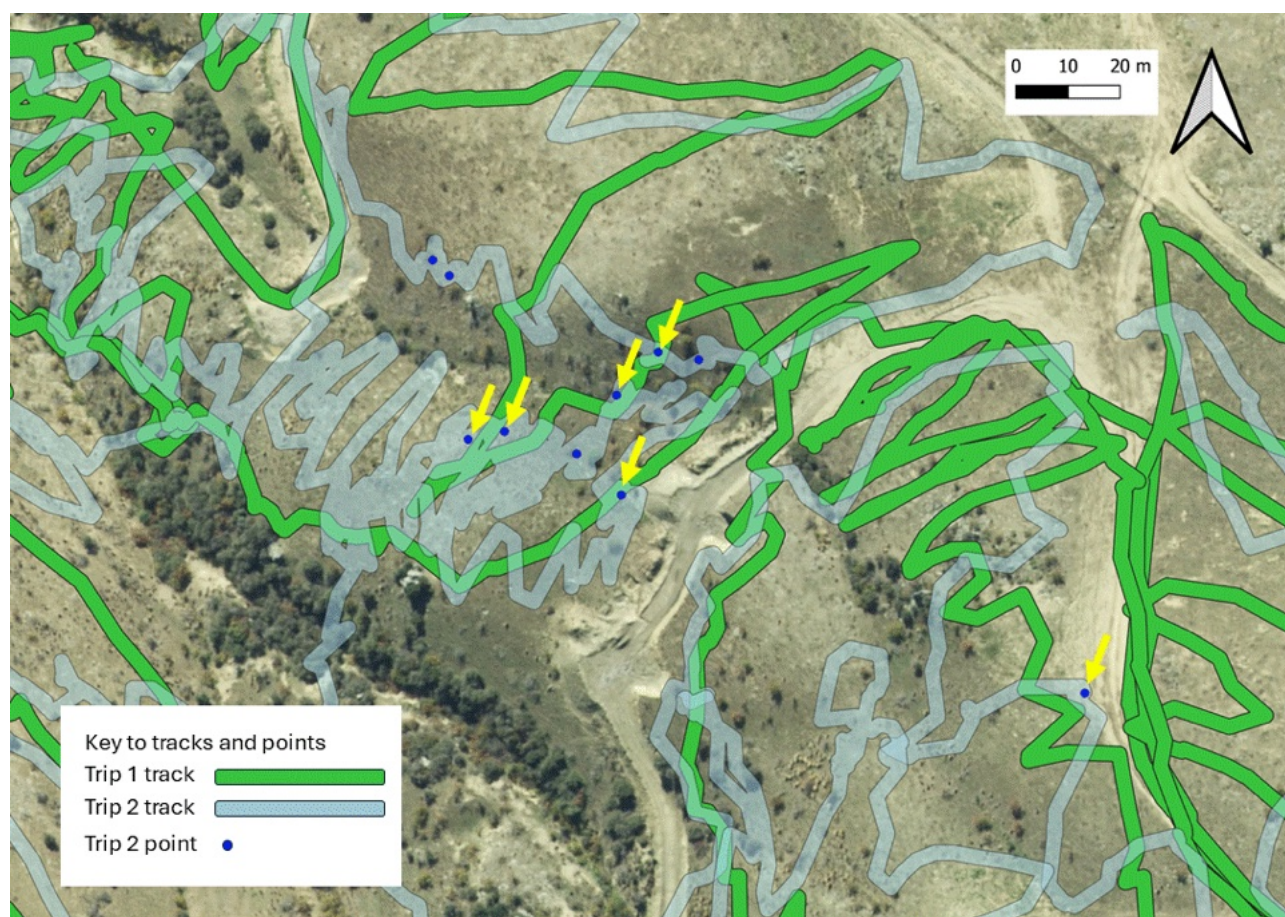


Figure 13. Example of point records of *C. pungens* plants recorded in Trip 2 (28 October 2025) but not in Trip 1. About 180 individual plants were estimated to have been present within the area in the image in Trip 2, and none in Trip 1. Yellow arrows indicate groups of plants that were either covered by or within 0.5 m of a track in both surveys.

Overall, results from areas twice surveyed by BSI suggest there is a turnover of *C. pungens* plants across the habitat throughout spring. In other words, it appears that germination and emergence do not occur all at once but are extended across the spring growing season if conditions remain favourable. The life of an individual *C. pungens* plant may be short (a few weeks), but while some plants are dying back others are germinating and emerging, either nearby and within the same

location, or elsewhere. This process may continue over a few months. Turnover throughout a protracted growing season has important implications for the survey effort required to confirm the absence of the species and its habitat, because absence in one single survey period does not necessarily indicate absence either earlier or later in the spring.

Total counts of *C. pungens* in the areas searched by BSI for a second time were smaller than those in the first survey, using the same methods. Therefore, the results suggest that the main flush of *C. pungens* germination and emergence in the resurveyed area was in early spring, with comparatively fewer plants appearing later. However, it is not known whether this is a typical pattern in every year, or at every site. That year (2025) and the previous year (2024) were both 'wetter than normal' across much of Central Otago (but not eastern Otago). Anecdotal data from across Central Otago suggest that the species may be absent or undetected at some sites in some years and then reappear again.

It is possible that in some places new *C. pungens* plants may appear later into the spring than BSI was able to sample (i.e. they may emerge as late as November, and possibly December). That would be consistent with the presence of hundreds of plants in the DDF on Bendigo and Ardgour in the 3rd week of November in 2024 (Milner et al. 2025), which is 3 weeks later than the period of the second (late October) survey in 2025.

Dispersal

As the heatmaps show, many groups of small numbers of plants were found (shown as pale yellow or orange hexagons), which were often several hundred metres from the nearest larger group numbering many hundreds of plants (shown as darker hexagons on the heatmaps).

Dissections of collected material showed that each *C. pungens* plant bears one or more short-stalked flowers. Most plants collected during the field trip had one to two flower heads, and the largest plant had nine. Each flower produced a compact seedhead with 9 to 44 seeds. A single stem connected the plant to a fine root system with roots of 25 to at least 45 mm in length. Outlying groups of live plants often contained relatively low numbers of plants (often <50), and plants in these small, outlying groups were often arrayed in compact or trailing patterns. Those patterns might indicate that either a single plant or a single seedhead had been dispersed to the location, and that many of the achenes within those seedheads (or the single seedhead) had germinated locally to form the small patch.

If there is dispersal across appreciable distances, then it is possible that *C. pungens* plants on Ardgour and Bendigo are parts of an interconnected metapopulation, and that patches operate as a moving set of sources and sinks for propagules across the landscape. However, at this stage those observations are anecdotal and speculative.

Because so little is known about the biology of *C. pungens*, further work – including monitoring of individual plants – will be needed to build an understanding of its phenology (longevity and seasonal turnover patterns, interannual variation, and dispersal).

6.3 *Myosotis brevis*

Plants of *M. brevis* were recorded on Bendigo (inside and outside the DDF) and on Ardgour in the first survey, and across many of the additional areas to the west of the DDF on Bendigo Historic Reserve and on undeveloped land among the vineyards in the second BSI survey. Numerous patches on Bendigo and Bendigo West were estimated to have 500 to 3,000 individuals, but patches on Ardgour were smaller. Plants were recorded in kānuka woodlands (often on the less exposed aspects of kānuka shrubs as well as in cushionfield and on sparsely-vegetated ridge crests).

More than 59,000 plants were estimated to have been found in the second survey, although densities in re-surveyed areas were less than half those in the first survey. The general distribution of *M. brevis* plants across the resampled blocks was relatively similar in both surveys (Figures 7 & 8), although somewhat narrower in the second survey (Figure 7). However a proportion of the

plants located in the second survey are probably different plants and additional to those in the first survey.

Heatmaps (Figure 6) show that observations within the DDF were centred within the lower and central part of the Shepherds Creek valley. Milner et al. (2025) recorded numerous points for *M. brevis* in the DDF in November 2024 within areas north of the boundary fence between Bendigo and Ardgour that could not be surveyed in 2025 (Appendix 1, Map A4), indicating more locations on the Ardgour parts of the DDF than on the Bendigo parts of the DDF in 2024. However, Milner et al. note that *M. brevis* was not always correctly distinguished from the different *Myosotis* species (*M. antarctica* subsp. *antarctica*) in the field in 2024, and therefore not all of the yellow points shown in Map A4 of Appendix 1 may actually be *M. brevis*.

M. brevis plants were comparatively few and sparse on the blocks searched on Ardgour in the BSI surveys (Figure 6; Appendix 1, Map A3; Appendix 2).⁵ In 2024 Milner et al. recorded some patches of *M. brevis* at higher elevations on Ardgour that were unable to be accessed by BSI in 2025.⁶ *M. brevis* plants were numerous in many of the Bendigo West areas surveyed by BSI in late October 2025.

In sum, the data show that *M. brevis* within the DDF makes an important contribution to total numbers of the plant within the general Bendigo–Ardgour area. It is not possible to assess that contribution fully without surveying the areas on Ardgour that were closed for lambing.

6.4 *Myosurus minimus* subsp. *novae-zelandiae*

Plants of *M. minimus* subsp. *novae-zelandiae* were recorded on Bendigo Station (inside and outside the DDF) and on Ardgour in the first BSI survey, and across many of the additional areas of Bendigo West covered in the second survey (Figure 9; Appendix 1, Map A5). More than 130,000 plants were estimated to have been encountered in the second survey. Patches were estimated to have from <10 to 3,000 individuals. Plants were recorded in kānuka woodlands, cushionfield, and also in shallow depressions on or near ridge crests that are underlain by rock and hold ephemeral water in the spring.

Heatmaps (Figure 9) show that observations of *M. minimus* subsp. *novae-zelandiae* within the DDF had a narrower distribution across the DDF than either *C. pungens* or *M. brevis*, being mainly found in a few patches of many hundreds to thousands of individuals (see Appendix 2). Numbers of this plant in the DDF were estimated to be about four times higher in the second survey than in the first survey across the blocks that BSI resampled (Figure 11).

Milner et al. (2025) recorded several patches of *M. minimus* subsp. *novae-zelandiae* plants in the areas on Ardgour within the DDF (i.e. east of the Bendigo–Ardgour boundary fence) in November 2024 (Appendix 1, Map A6). These areas were unable to be searched by BSI in 2025 due to access constraints during lambing.

M. minimus subsp. *novae-zelandiae* plants were much less common in the blocks north of Shepherds Creek on Ardgour than in the DDF on Bendigo (Figure 9; Appendix 1, Map A5). In the blocks searched on Ardgour in the first BSI survey, plants were confined to a few localised shallow depressions on spurs and high points, and the concentration was low (17 plants per hectare). Milner et al. (2025) recorded only one location for *M. minimus* subsp. *novae-zelandiae* on Ardgour outside the DDF (Appendix 1, Map A6).

M. minimus subsp. *novae-zelandiae* plants were also present in many of the surveyed areas of Bendigo West in late October 2025 (Figure 9; Appendix 1, Map A5) but at about one third of the

⁵ *M. brevis* numbers on Ardgour may in fact be lower than this, because distinguishing *M. brevis* plants from *M. antarctica* subsp. *antarctica* in the field was difficult in the first survey, when plants of both species were very small and the flower characteristics indistinct. While we are confident in most of our identifications, we have collected material that would enable some to be checked using genetic analysis. Most of these collections were of plants from Ardgour, which are likely to have been *M. antarctica* subsp. *antarctica* misidentified as *M. brevis*.

⁶ As noted earlier in this discussion, Milner et al. (2025) noted that *M. brevis* was not always correctly distinguished from the different *Myosotis* species (*M. antarctica* subsp. *antarctica*) in the field in 2024.

concentration (196 plants per hectare) of that on Bendigo Station (inside and outside the DDF, 663 and 570 plants per hectare, respectively).

Overall, the data suggest that *M. minimus* subsp. *novae-zelandiae* is generally rarer on the parts of Ardgour that were surveyed by the BSI than in the wider Bendigo area.

There is limited information on the present distribution and numbers of *M. minimus* subsp. *novae-zelandiae* outside the areas surveyed by BSI in 2025. The species is considered extinct in the North Island and now confined to parts of the eastern South Island. Although the species was ranked Nationally Critical in 2010, its threat status was progressively downgraded to At Risk – Declining over the next four assessments as new populations have been found in the eastern South Island.

6.5 Threats

The BSI was not asked to provide an assessment of weed threats to spring annual habitats and cushionfield communities. However, at least two highly drought-tolerant perennial herb species observed in the BSI surveys could prove an impediment to the maintenance and restoration of spring annual populations.

- *Sedum acre* (stonecrop) is a succulent weed that is a threat to spring annuals, because it can form dense, smothering mats in similarly seasonally dry habitats in the presence of rabbits. It is not present (to BSI's knowledge) in the DDF. It is present on Ardgour outside the DDF (although not seen within the areas of Ardgour searched in 2025, it was noted to be present on directly adjacent land that was closed for lambing). *Sedum acre* is also present west of the DDF on Bendigo. It is very easily transferred between sites by machinery and poses a threat to the spring annual populations within the DDF and on those parts of Ardgour outside the DDF that now support spring annuals.
- *Erodium moschatum* (musky storksbill) was very abundant in dry, rabbit-prone environments on Ardgour where spring annuals might otherwise have been present. It is either not present or rare within the DDF on Bendigo Station. Little is known about its potential to spread and threaten spring annual plants within the DDF.

There may be other drought-tolerant herbaceous weeds that could become an important threat to spring annual habitats in future. Some examples include Australian sheep's burr (*Acaena agnipila*), vipers bugloss (*Echium vulgare*), and *Eschscholzia californica* (California poppy).

7 Conclusions

The two BSI surveys of potential habitat for spring annual species in the Bendigo and Ardgour areas in 2025 targeted four spring annual species: *Ceratocephala pungens*, *Myosotis brevis*, *Myosurus minimus* subsp. *novae-zelandiae*, and *Myosotis antarctica* subsp. *antarctica*. The first three species were often found co-occurring. However *M. brevis* and *M. minimus* subsp. *novae-zelandiae* occupied a wider range of habitats and were found considerably more often and generally in larger numbers than *C. pungens*.

The following conclusions are drawn:

Ceratocephala pungens

- Plants were recorded across the survey area: inside and outside the DDF on Bendigo Station, on areas of Ardgour that were able to be searched (outside the DDF), and in the Bendigo West area, mainly between 300 m and 800 m in elevation, but occasionally lower or higher. Plants were found on sparsely vegetated silty soils in hollows and just off the tops of ridges but also on lower slopes and often in disturbed soils.
- Many more points were recorded and estimated on the surveyed areas of Bendigo Station and Ardgour than in the Bendigo West survey area, where *C. pungens* was very rare.

- Resurvey (i.e. survey repeated early and then later in spring) indicated that *C. pungens* is likely to have sequential germination. In 2025 the main flush was early in spring and fewer plants germinated towards the end of spring.

Myosotis brevis

- Plants were recorded across the survey area: within and outside the DDF on Bendigo Station, on areas of Ardgour that were able to be searched (outside the DDF), and in the Bendigo West area, between 200 m and 700 m of elevation.
- More points were recorded and higher numbers of plants were estimated on Bendigo Station and in the Bendigo West areas than on Ardgour.
- Plants were recorded in kānuka woodlands and cushionfield, most often in sparsely vegetated patches with thin silty soils.
- Resurvey (i.e. survey repeated early and then later in spring) indicated that, in 2025, most plants appeared in early spring (although some may have emerged later) and that some continued to grow and set seed throughout the spring season.

M. minimus subsp. *novae-zelandiae*

- Plants were recorded across the survey area: within and outside the DDF on Bendigo Station, on areas of Ardgour that were able to be searched (outside the DDF), and in the Bendigo West area, between 200 m and 700 m of elevation.
- More points were recorded and higher numbers of plants were estimated to occur on Bendigo Station and in the Bendigo West area than on Ardgour outside the DDF.
- *M. minimus* subsp. *novae-zelandiae* was recorded in kānuka woodlands, cushionfield, and in bare shallow soils in hollows on the tops, or just off the tops, of ridges.
- Resurvey (i.e. survey repeated early and then later in spring) indicated that in 2025 many more individuals of this species appeared later in spring.

M. antarctica subsp. *antarctica*

- Plants were recorded between 200 m and 700 m of elevation: within and outside the DDF on Bendigo Station, on the parts of Ardgour outside the DDF that were searched, and in the Bendigo West survey area.

8 Recommendations

The following recommendations are made for future work:

- Surveys for *C. pungens* should be carried out between early August and mid-October. To accurately estimate population size, multiple surveys are required within a single year.
- Surveys for *M. brevis* and *M. minimus* subsp. *novae-zelandiae* should be carried out between mid-September and mid-November.
- Areas recommended for the next survey for spring annuals are mapped in Appendix 2. The search area for the surveys should include north and northwest facing slopes and ridge tops with bare silty soils or sparse vegetation cover, e.g. kānuka woodlands and cushionfield habitats.
- Access to all parts of the DDF is needed across this full survey period.
- Research into the biology of *C. pungens* is most pressing as it is the most threatened species. Further work over the next decade is needed to better understand species phenology (timing of emergence, flowering, seeding, and dieback), the variation in the timing of these stages from year to year and among habitats, as well as seed viability, seed dispersal and natural fluctuations in plant numbers from year to year. Studies of the characteristics of suitable microhabitats and the potential role of soil disturbance will also assist in the recovery of the species. That research requires good numbers of plants to be present and should therefore focus on the habitat within the DDF. Habitat on Ardgour outside the DDF alone may not provide sufficient numbers.

- It is very important that *Sedum acre* (stonecrop) is not inadvertently moved into the habitats of spring annuals that are presently not invaded by it. There is a particular risk of movement by vehicles or machinery transferring propagules and seed. *Erodium moschatum* (musky storksbill) is another potentially serious threat, although it is not currently widely distributed within the DDF. Other herbaceous weeds also potential pose a threat to spring annual habitats in future.

It is further recommended that:

- any plants of stonecrop and musky storksbill found within the DDF be removed and destroyed
- stonecrop distribution on Ardour be assessed as soon as possible
- a monitoring and containment plan is developed and implemented for stonecrop on both properties
- there is a targeted assessment of other herbaceous weeds that could potentially threaten spring annual habitats in future, and monitoring of those weeds is commenced, and appropriate management undertaken.

9 Acknowledgements

The authors acknowledge and thank [REDACTED] and [REDACTED] (MGL) for assistance in the field, and thank MGL site and office staff for facilitating our work. We thank [REDACTED], [REDACTED], and [REDACTED] for field sampling, and [REDACTED] and [REDACTED] for generously sharing their experience of these species and their habitats. We thank RMA Ecology, especially [REDACTED], for access to and discussions on 2024 survey information. We thank [REDACTED] and other contributors to the Department of Conservation's Species on the Brink programme for sharing information on other known *Ceratocephala pungens* populations. [REDACTED] (BSI) and [REDACTED] kindly reviewed the report and made helpful comments and suggestions. We thank [REDACTED] for editing and [REDACTED] for formatting the report.

10 Declaration on the use of generative AI / AI-assisted technologies

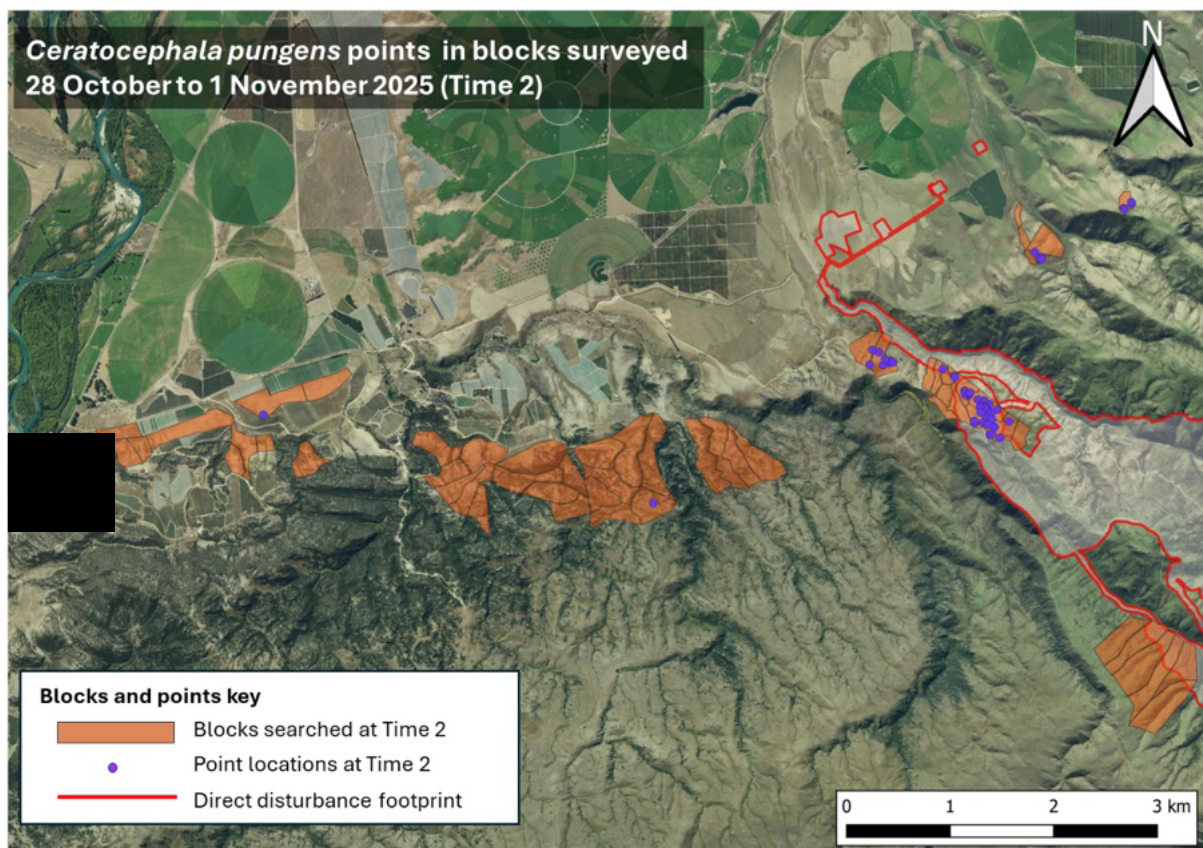
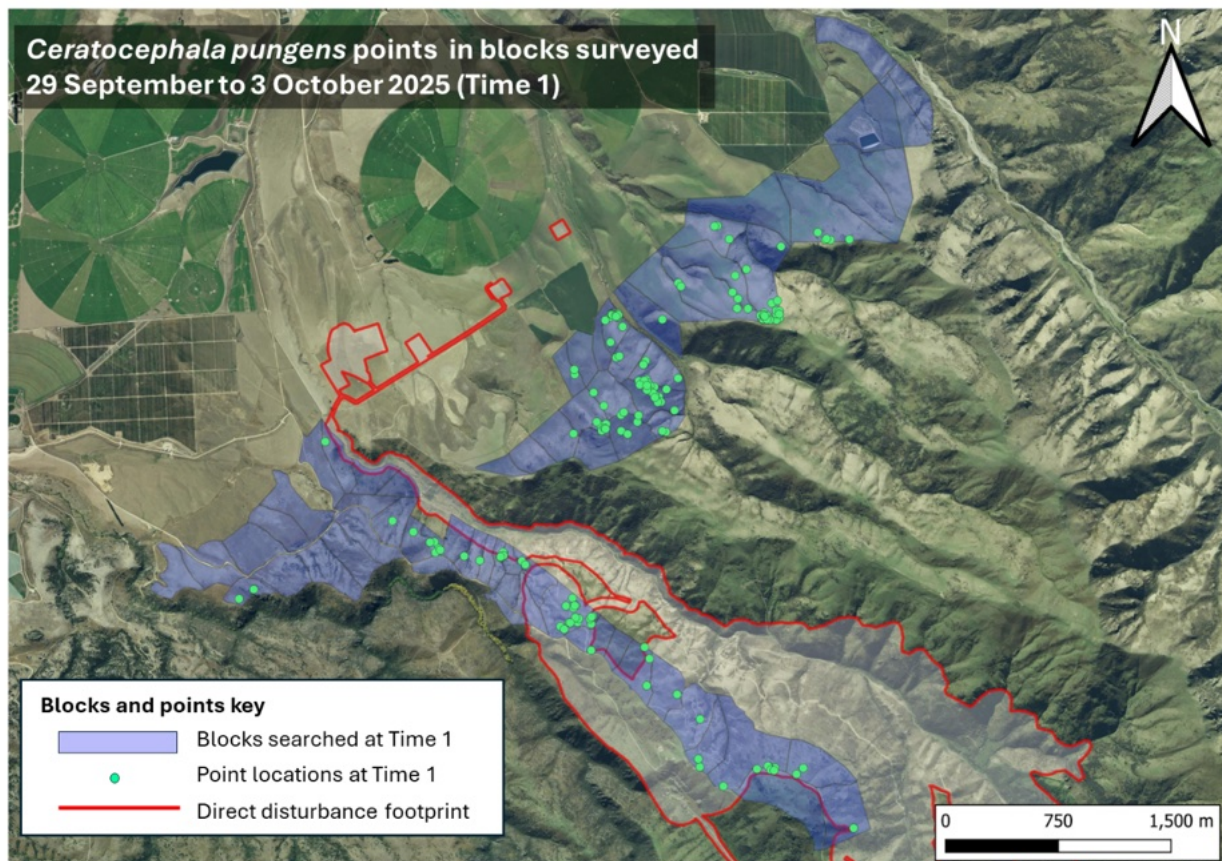
No AI-assisted technologies were used in this research.

11 References

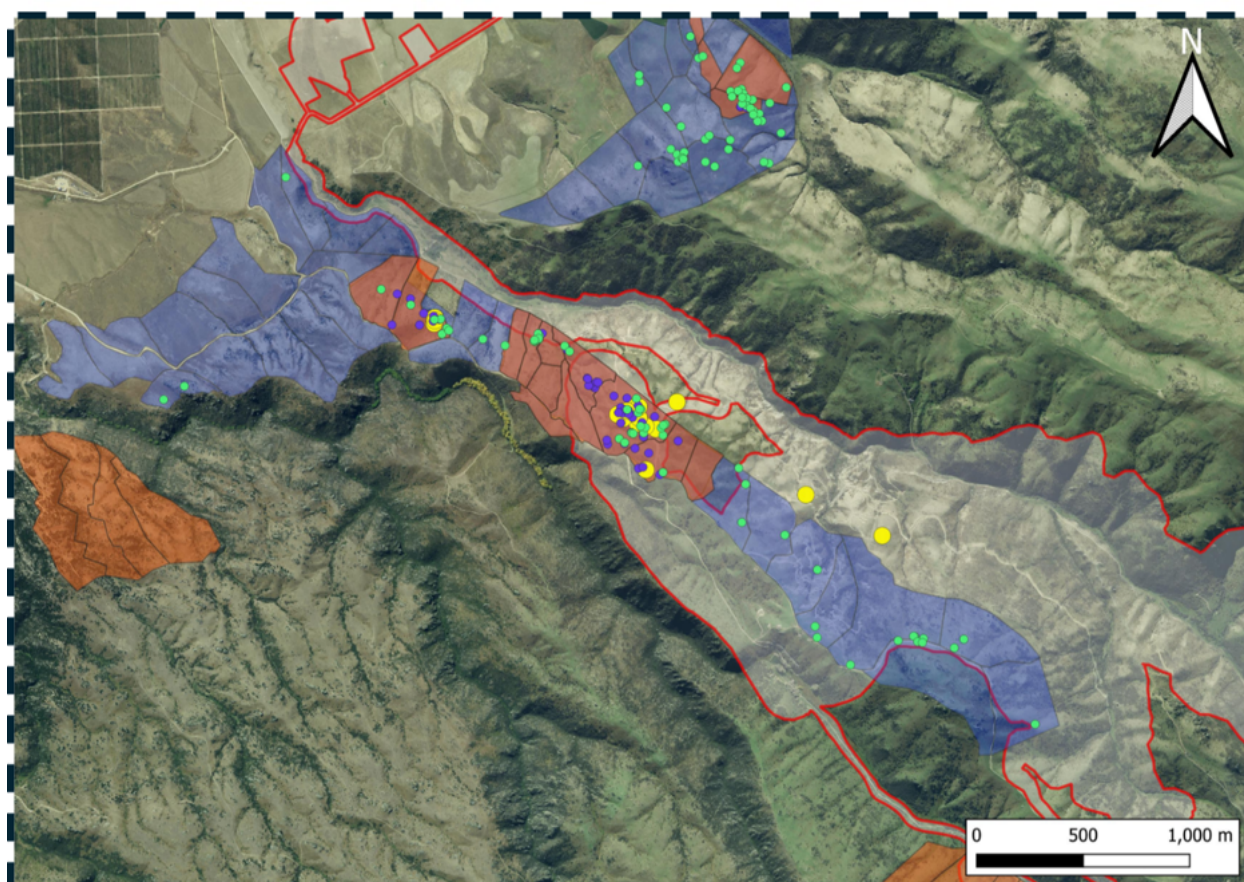
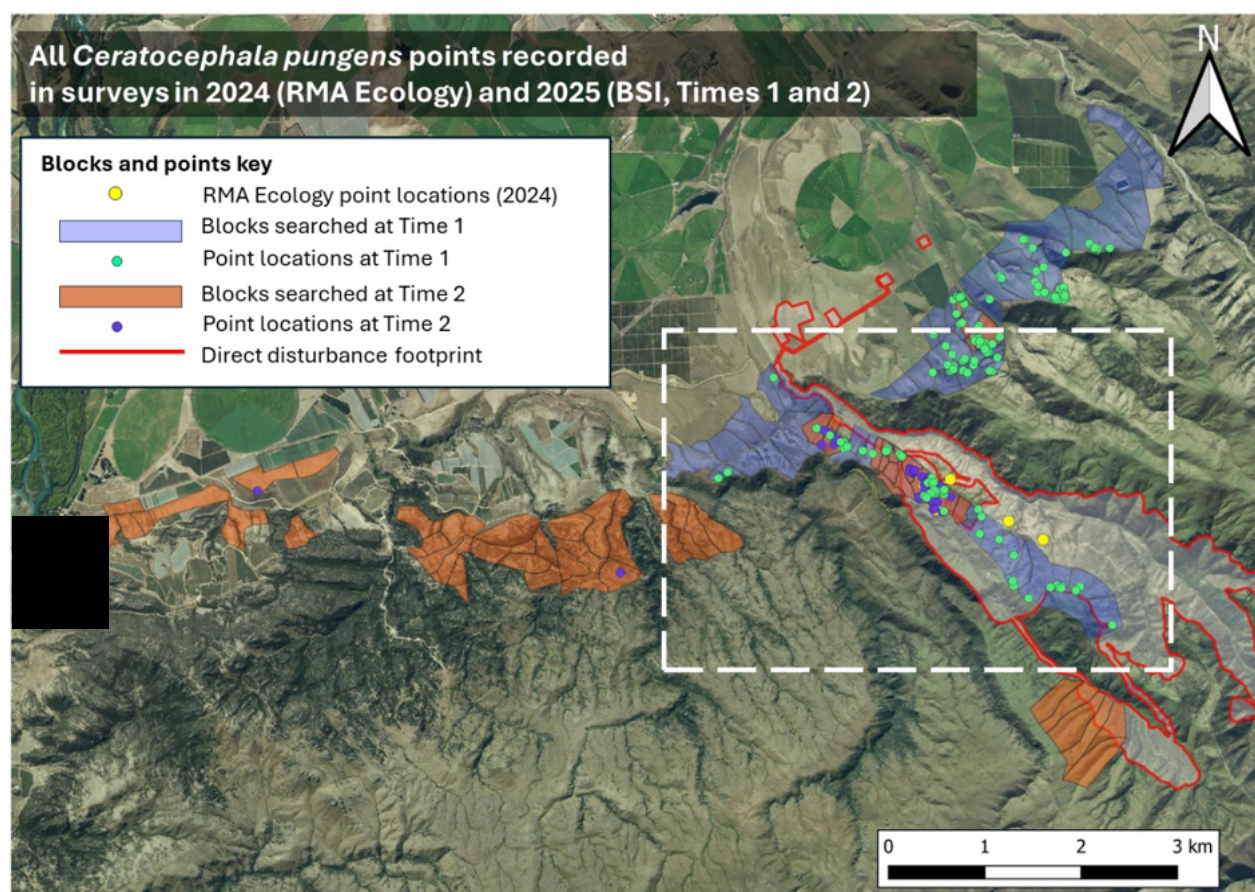
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in the matter of RC230179, an application for a 33-lot subdivision at Rocky Point on Tarras-Cromwell Road (SH8) by TKO Properties Limited.

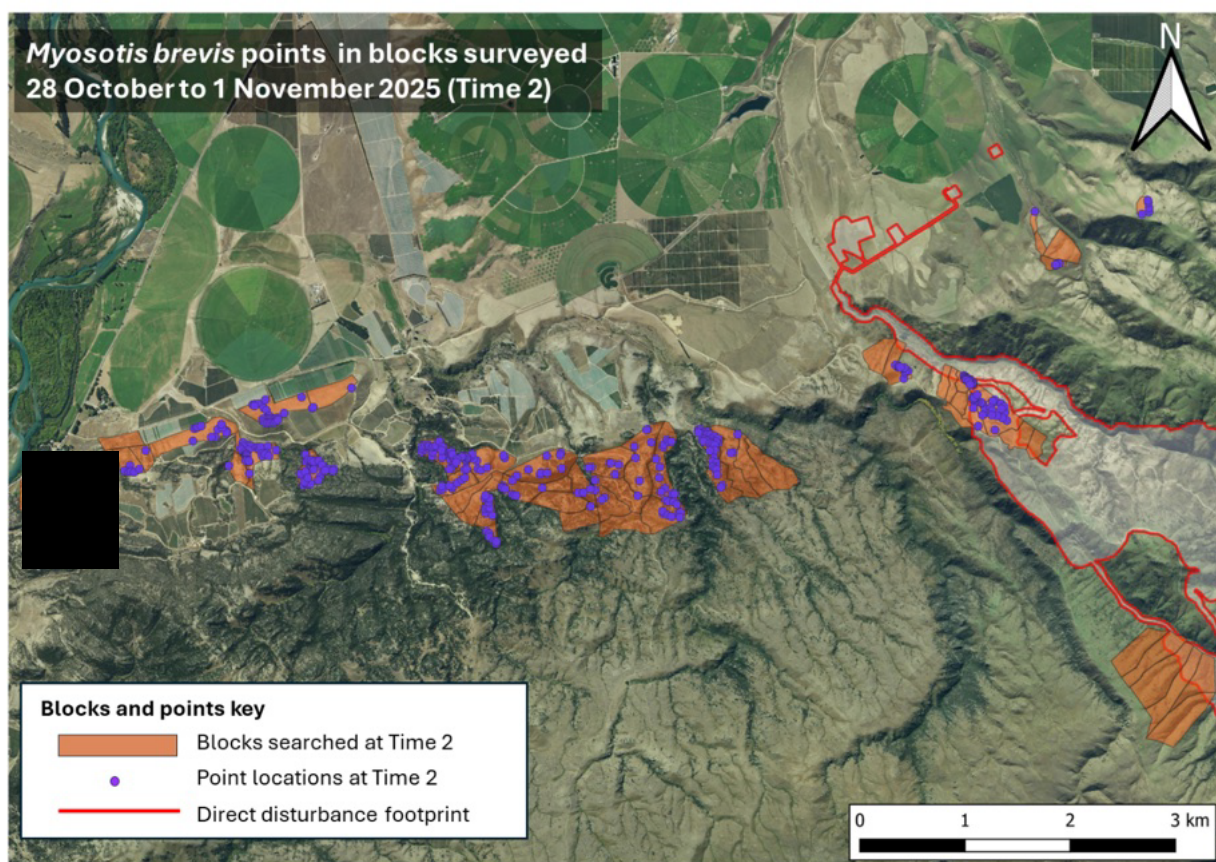
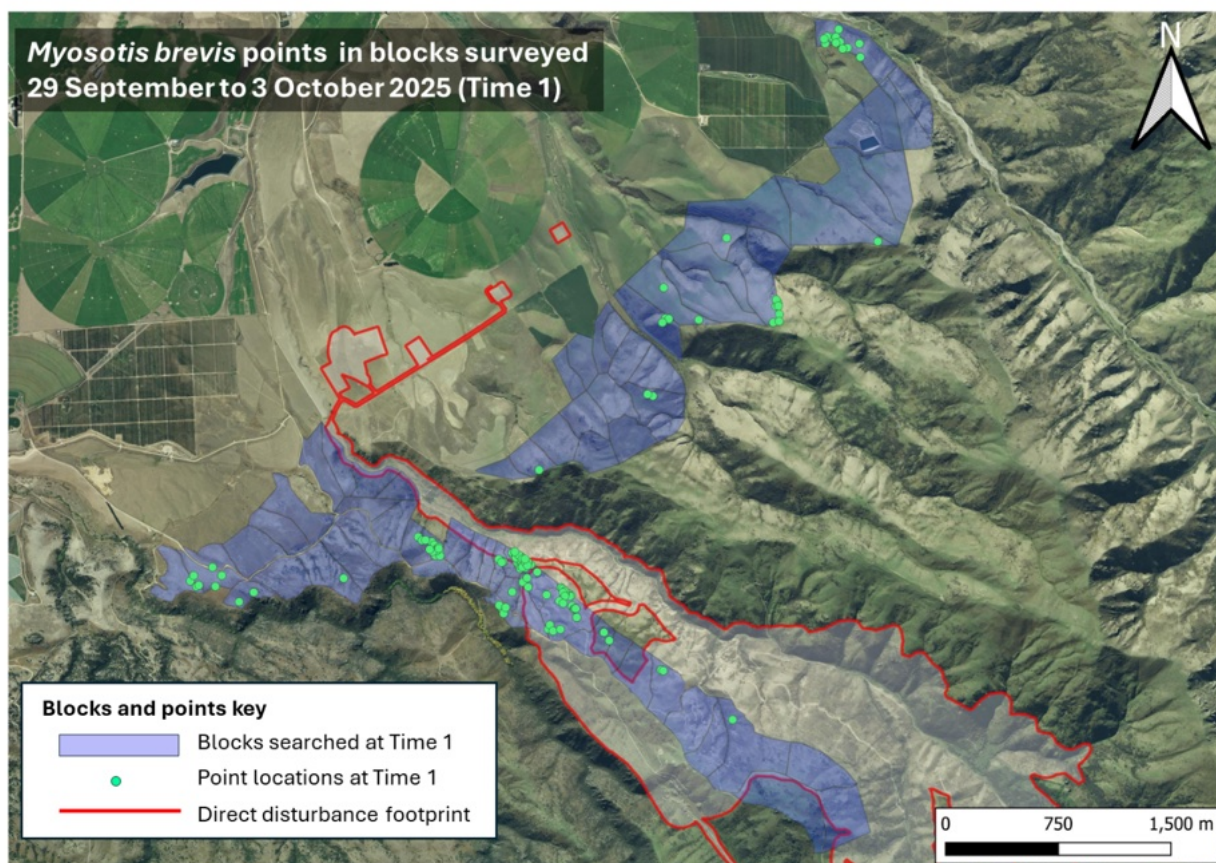
Appendix 1 – Maps of point locations



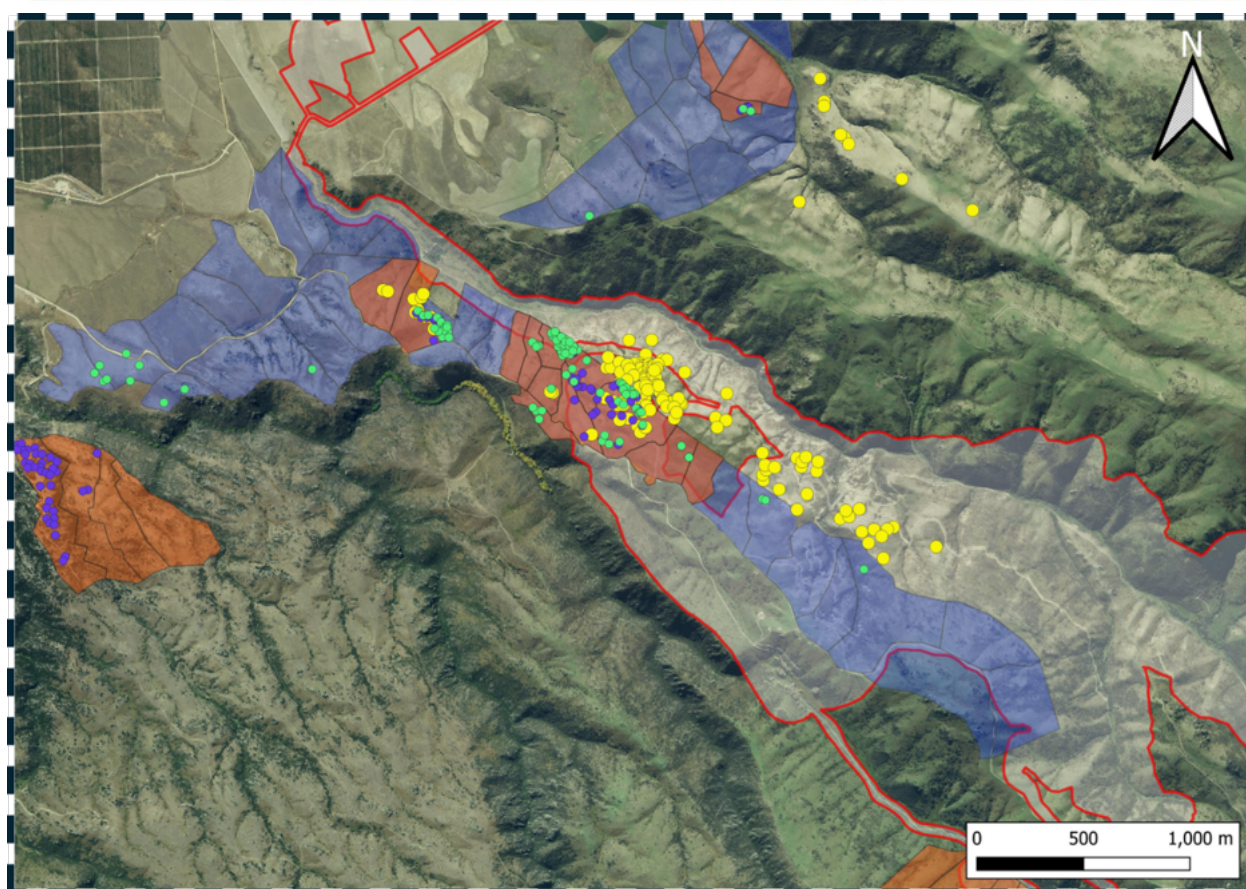
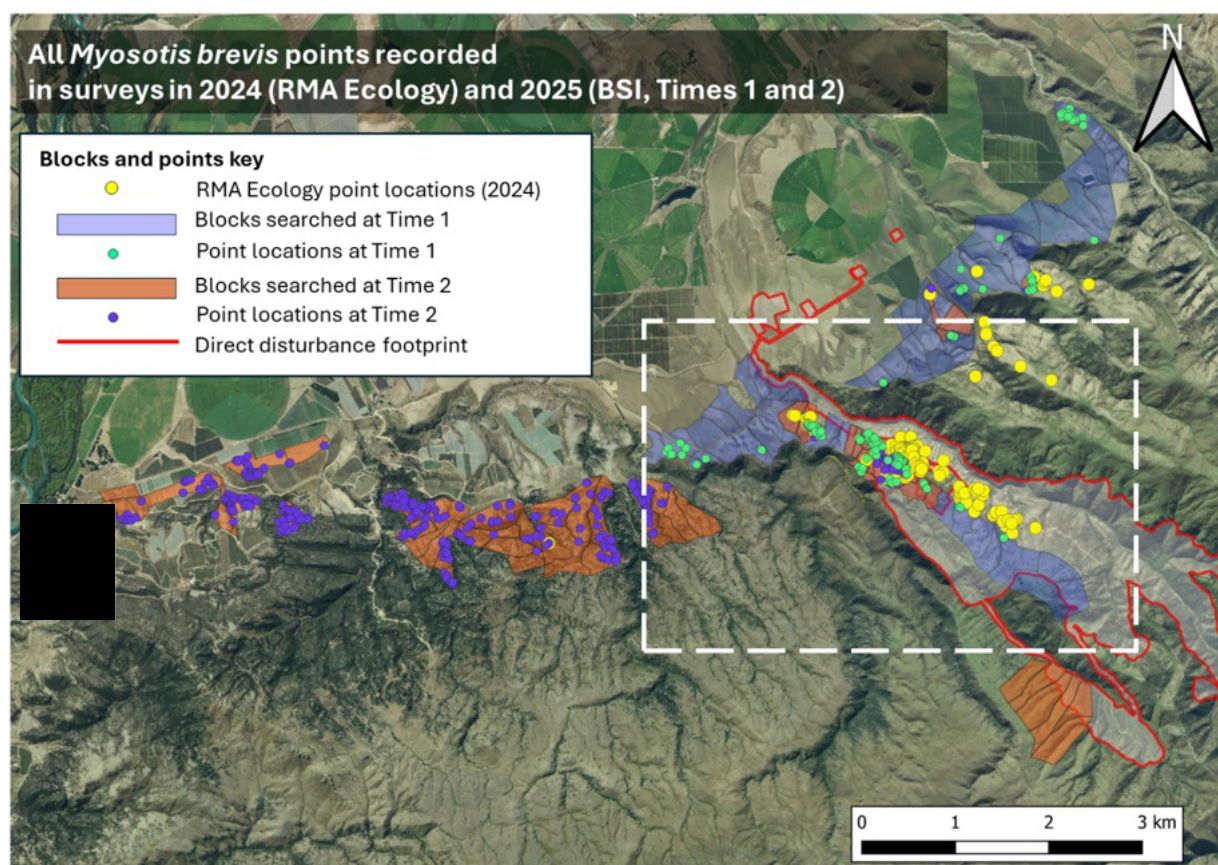
Map A1. All point locations of *C. pungens* recorded in 2025. The upper map shows the first survey period (Time 1) and the lower map shows the second survey period (Time 2). Note that the maps are shown at different spatial scales. The red line shows the DDF.



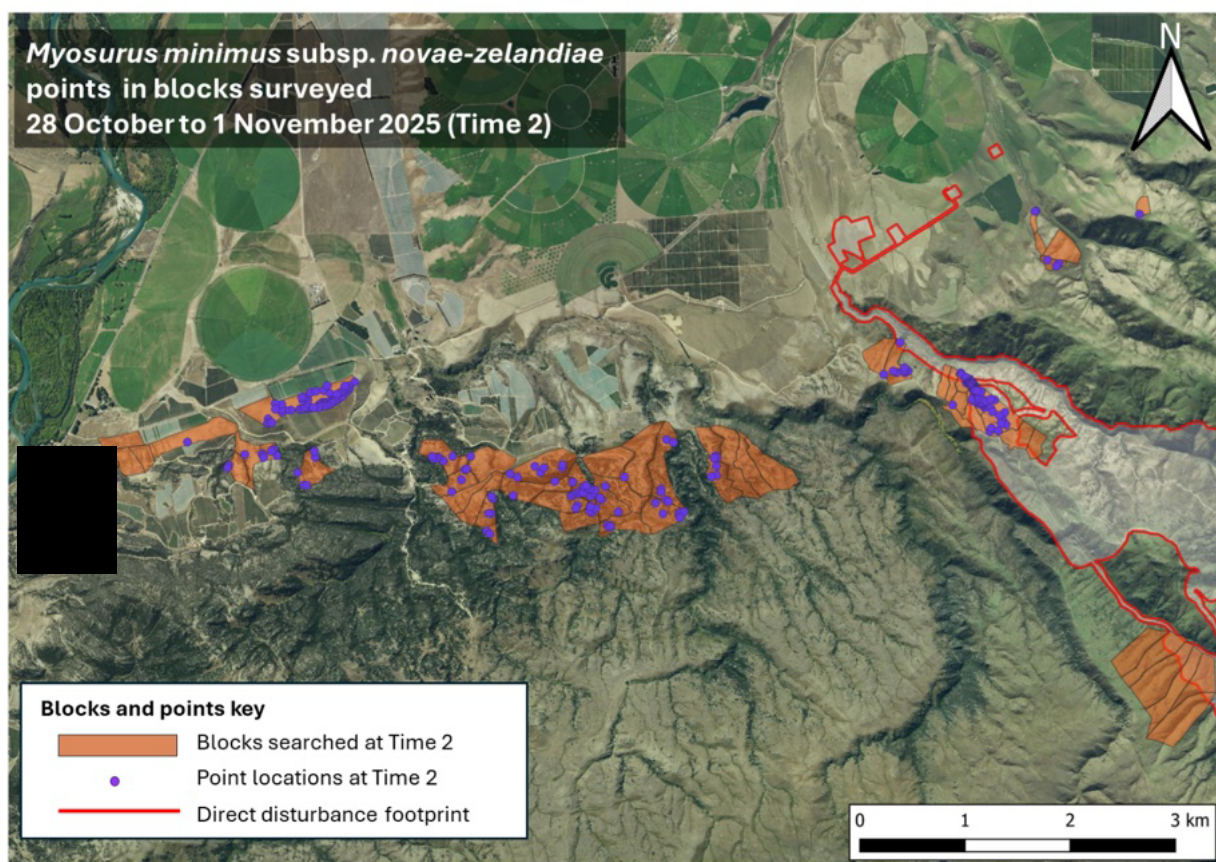
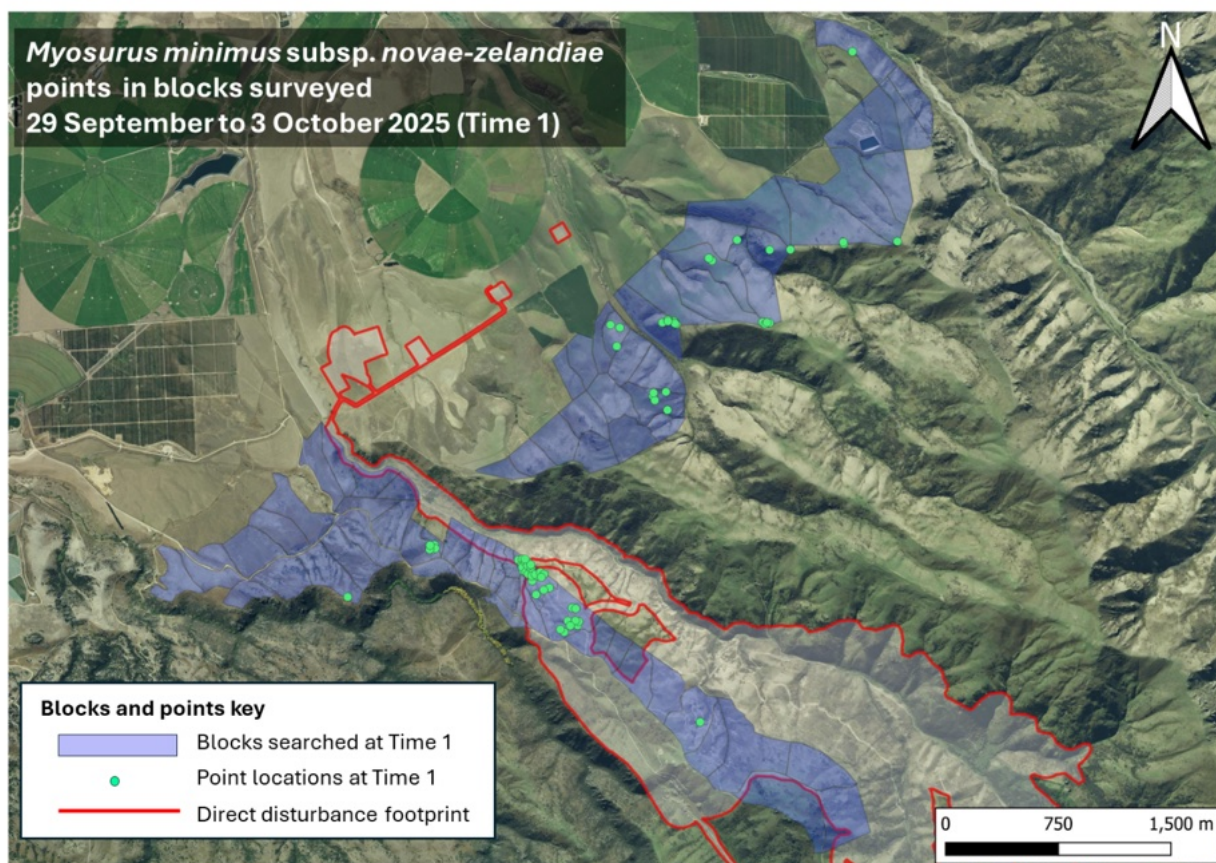
Map A2. All point locations of *C. pungens* recorded by RMA Ecology in 2024 and by BSI in 2025. The lower image is a zoomed-in portion of the upper image to better compare the numbers and positions of point locations recorded in the two different years across the DDF. The red line shows the DDF.



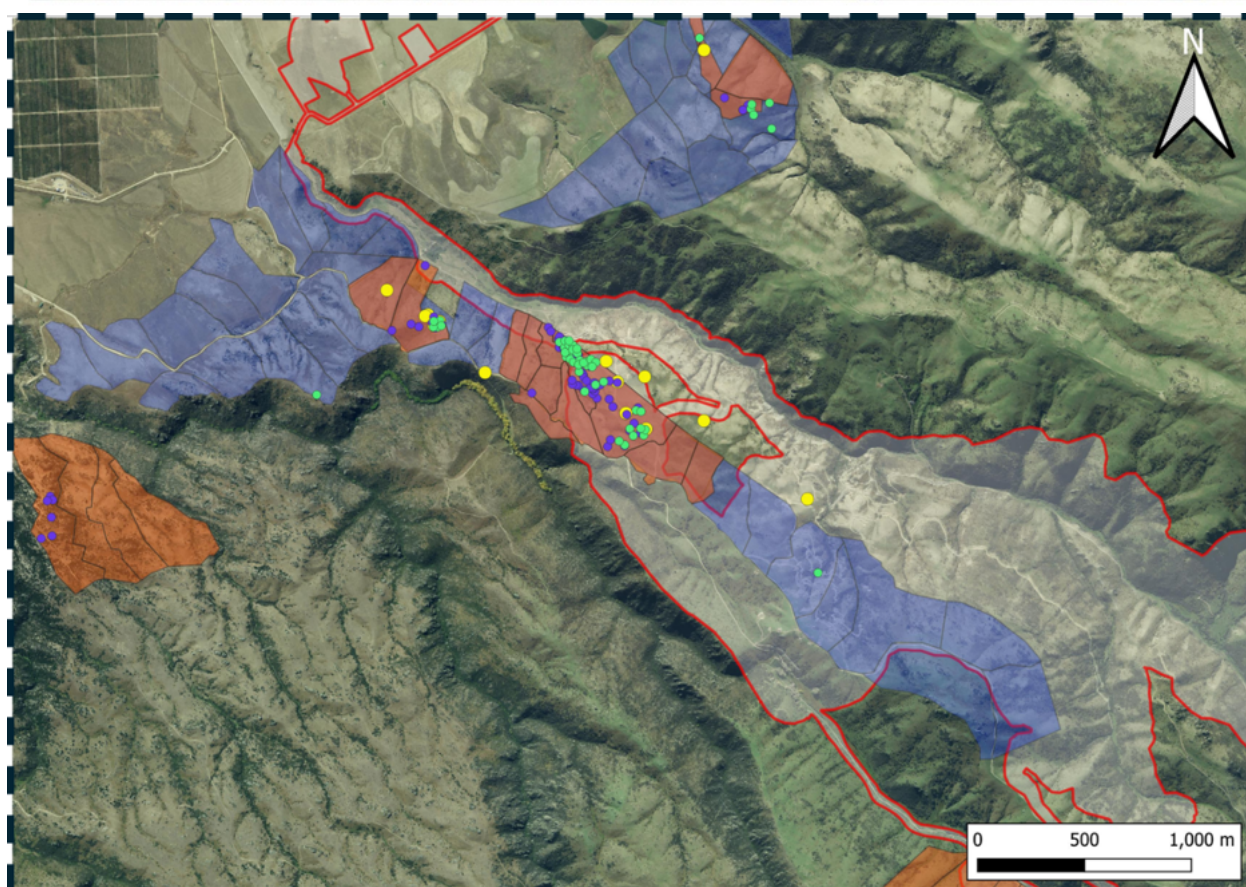
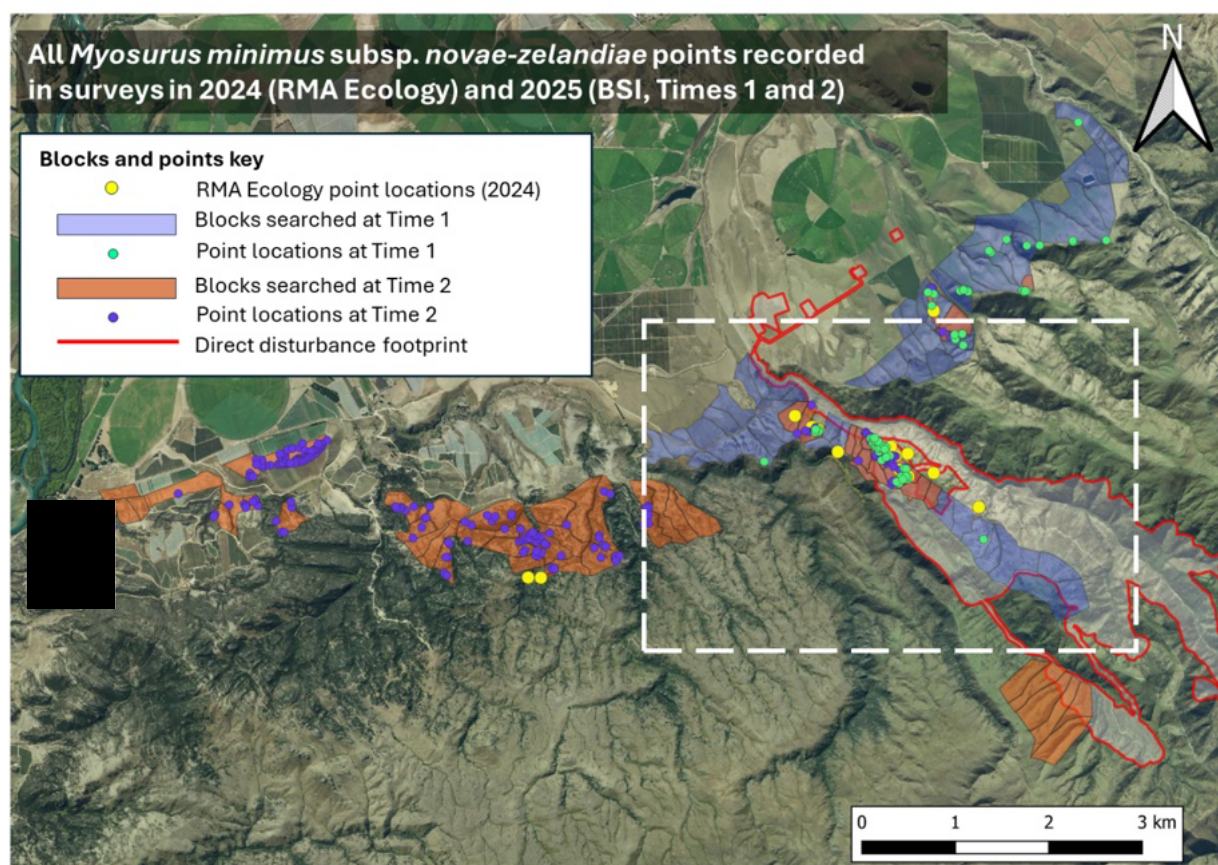
Map A3. All point locations of *M. brevis* recorded in 2025. The upper image shows the first survey period (Time 1) and the lower image shows the second survey period (Time 2). Note that the maps are shown at different spatial scales. The red line shows the DDF.



Map A4. All point locations of *M. brevis* recorded by RMA Ecology in 2024 and by BSI in 2025. The lower image is a zoomed-in portion of the upper image to better compare numbers and positions of point locations recorded in the two different years across the DDF. The red line shows the DDF.

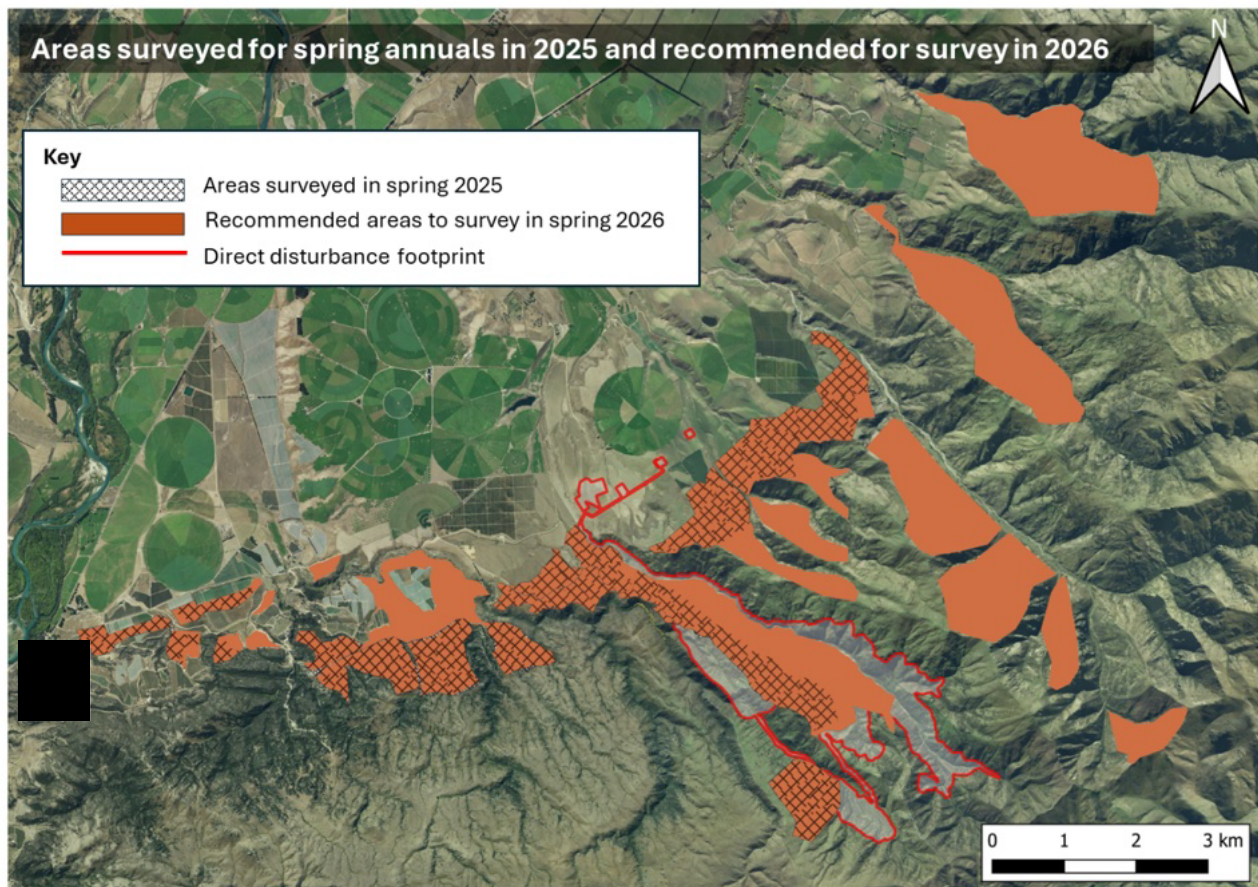


Map A5. All point locations of *M. minimus* subsp. *novae-zelandiae* recorded in 2025. The upper image shows the first survey period (Time 1) and the lower image shows the second survey period (Time 2). Note that the maps are shown at different spatial scales. The red line shows the DDF.



Map A6. All point locations of *M. minimus* subsp. *novae-zelandiae* recorded by RMA Ecology in 2024 and by BSI in 2025. The lower image is a zoomed-in portion of the upper image to better compare numbers and positions of point locations recorded in the two different years across the DDF. The red line shows the DDF.

Appendix 2 – Recommended spring annual survey areas -



Map A7. The recommended survey areas (brown polygons) for the next spring annual herb survey. The recommendations are based on habitats that have similar cover to those where these species were found in the RMA Ecology and BSI surveys.