Simons Pass Ephemeral Wetlands

Survey for significant inherent values in Simons Pass ephemeral wetlands.

Jane Gosden | Technical Advisor, Plant Ecology

Department of Conservation
Te Papa Atawhai

New Zealand Government

Cover: A large ephemeral wetland on Simons Pass Station. *Photo: Jane Gosden, DOC*

DOC - 6101984

Contents

1 Summary

- Wetlands on CC1 'the farm block' have been damaged by farm development (note that farm development in this area was a consented activity).
    - Some native plant values remain in the damaged wetlands.
    - Some of the wetlands on the 'farm block' could recover if given sympathetic treatment.
- The wetland between pivots 12 and 17 that contained a large population of mousetail plants has been irreversibly damaged by farm development.
- The mousetail tarn in CC1 has significant inherent values that require full protection.
    - The mousetail tarn needs to be protected within a buffer area of at least 200 m from developed farmland.
    - The mousetail tarn requires protection as it is the last ephemeral wetland largely undisturbed by recent farm development on the moraines in CC1.
- The ephemeral tarns on CA1 contain significant inherent values.
    - None of the tarns on CA1 visited during the October 2019 site visit had New Zealand mousetail plants present.

2 Ephemeral wetlands

An ephemeral wetland is one where seasonal variation in evaporation and rainfall leads to fluctuations of water between the wetter winter and spring seasons and the dry summer months. The tarns can often dry completely in summer or during droughts. (Johnson & Gerbeaux, 2004). These ephemeral tarns are habitat for many specialised plant species, many of which are threatened (Rogers *et al.*, 2002; Johnson and Rogers, 2003).

Ephemeral wetlands are rare (Williams *et al.*, 2007) and threatened ecosystems (Critically endangered: Holdaway *et al*., 2012). The tarns are located within a landscape of moraine which is also a rare (Williams *et al.*, 2007) and threatened ecosystem (Vulnerable: Holdaway *et al.*, 2012). The moraine sequences on Simons Pass in both CC1 and CA1 contain ephemeral wetlands. Ephemeral wetlands in glacial landscapes are often referred to as kettlehole tarns.

3 Wetlands on the 'farm block'

3.1 Wetlands on CC1 (the 'farm block') have been damaged by farm development.

The tenure review process had identified these wetlands as high value during a visit in January 2019. The Additional Conservation Advice report to Land Information New Zealand (LINZ) noted that the tarns retained "reasonable native species diversity" (DOC, 2019). The tarns were also considered to be suitable habitat for the New Zealand mousetail plant (*Myosurus minimus* subsp. *novae-zelandiae*; Threatened – Nationally Vulnerable).

The wetlands were revisited in October 2019 to assess their value. All wetlands visited on the farm block have been damaged by farm activity. The farm development is a consented activity under Environment Canterbury (ECan), Land Information New Zealand (LINZ) and Mackenzie District Council (MDC) processes. Most tarns no longer resemble the descriptions or photographs from the DOC (2019) Additional Conservation Advice Report.

Ephemeral wetland damaged by overstocking and pugging of the soil profile.

Ephemeral tarn damaged by direct drilling (cropping) and overstocking (pugging of soils).

Green algae growth as a result of increased nutrient inputs into the ephemeral tarn.

Ephemeral wetland (stream channel and tarn) damaged by vehicle tracking.

The ephemeral tarns inside the farm block have been damaged by:

- **Overstocking leading to pugging of the soil profile –** Disturbance of the soils alters the hydrology of the wetland system. Disturbance of the turf plant community provides habitat for invasive weedy plants, and can result in complete removal of the native plant community.
- **Cropping of the land up to the edge of the tarn** – Removal of the plant community by herbicide spray and direct drilling of crops.
- **Increased nutrient inputs and disturbance of the water** – Increase in algae communities as a response to the increased nutrient inputs (fertiliser addition and

faeces from stock). Waterfowl (mallard ducks and Canada geese) have also affected the water quality of tarns in the Simons Pass farm block.

- **Vehicle tracking** – Disturbance to the tarn and break-up of the soil profile resulting in destruction of the hydrology and plant community of the tarn.

3.2 Some native plant values remain in the damaged wetlands.

The damaged wetlands still contain some native plants. These vary between wetlands. Some of the tarns (including some of those pictured above) had lost their native plant cover. At other tarns, plants such as *Crassula sinclairii* and *Limosella lineata* were abundant around the edges of some of the ephemeral tarns. Some *Carex* and *Juncus* species were also present but could not be identified to species because they lacked their reproductive material. Further surveys later in the summer season would likely reveal more surviving native plants.

3.3 Some of the 'farm block' wetlands could recover if given sympathetic treatment.

Despite the damage to the tarns, some will recover to a turf of native plants if given time and sympathetic management. The management actions to enable recovery are:

- Exclude stock.
- No irrigation.
- Prevent nutrient inputs (e.g. runoff, topdressing etc.).
- Fence off the wetlands with a dryland buffer area of at least 200 m from the tarn edge.
- Control weeds.

There is evidence that these ecosystems can recover. In the 1990s DOC created two wetland areas near Twizel. These wetlands were created as habitat for kaki and other wading birds. Both wetlands were created in a predominantly dryland area. The water levels of the ponds are manipulated by raising and lowering boards that control the retention of water in each wetland. Since their creation plants have colonised the wetland margins forming turf communities. Threatened plant species have also been observed colonising these wetlands (Johnson, 2016). That these man-made wetlands have developed an indigenous turf community provides evidence that some of the damaged tarns could recover.

3.4 The mousetail wetland between pivots 12 and 17 has been irreversibly damaged by farm development.

The Department of Conservation understands that this wetland was protected by way of s.18 CPLA consent conditions requiring the Holder to:

- retire it from grazing.
- fence it.
- not irrigate.
- not cultivate.

In February 2019 DOC staff noted that the area was unfenced, showed signs of stock damage, and had surface pooling as a result of irrigation (*pers. comm.* Jacob Dexter, DOC).

3.4.1 New Zealand Mousetail plants are 'spring annuals' that colonise bared ground in ephemeral tarns.

The New Zealand mousetail plant is a 'spring annual' in that it appears in spring and completes its entire life cycle before the start of summer. The mousetail plant is currently ranked as Threatened – Nationally Vulnerable in the New Zealand threat classification system (de Lange *et al.* 2017). The New Zealand Mousetail is known from Lake Manapouri through the eastern South Island to Cape Palliser in the southern North Island (Rogers *et al*. 2002). The population stronghold is Central Otago with Rogers *et al.* (2002) reporting only two known extant populations in the Mackenzie Basin. Both populations were on Maryburn Station, now on public conservation land post tenure review. DOC's bioweb database shows an additional population on the Wolds property. The Simons Pass populations were not known until the tenure review site visits. The population in the now damaged tarn was thought to be one of the largest in the Mackenzie Basin.

Mousetail plants are colonisers of damp bare ground (Johnson and Rogers, 2003). Therefore, the mousetail plant does not cope well with weed invasion as invasive exotic plants outcompete the mousetail plants for bare ground. A study by Rogers *et al.* (2007) found monitored populations disappeared as exotic plant cover increased.

*A New Zealand mousetail plant (*Myosurus minimus *subsp.* novae-zelandiae*) showing developing flower buds and a flower (to right of photograph) beginning to change towards the distinctive fruiting head for which the plant is named.*

3.4.2 The mousetail wetland between pivots 12 and 17 has been irreversibly damaged by farm development.

The mousetail wetland was visited on 30 September 2019. The area had been overturned recently with the soil profile of the ephemeral wetland damaged. The overturned turf will rapidly be colonised by introduced grasses and agricultural weeds.

Views of the New Zealand mousetail site, where the soil has recently been overturned.

One small patch of germinating mousetail plants remains. From a population of several thousand, around 200 plants persist. These plants were in a small area (one by two metres) where the soil had not been overturned.

Germinating New Zealand mousetail plants within a small patch of undisturbed soil.

The scale of the damage and the proximity of the site to ongoing farm intensification (e.g. irrigation, fertiliser and increased stock) mean it is unlikely that this wetland site could recover.

View across the New Zealand mousetail site towards the intensified farm development.

4 Mousetail wetland on CC1

4.1 The Mousetail tarn has significant inherent values that require full protection.

The following significance assessment uses the Department of Conservation guidelines for assessing significant ecological values (Davis *et al.*, 2016).

View from the top of a moraine ridge down onto the Mousetail tarn.

4.1.1 Representativeness: High

Similar tarns exist throughout the moraine sequences on CA1 and previously existed through CC1. The *Limosella lineata* and *Crassula sinclairii* dominated turfs are typical of these ephemeral wetlands. *Carex* species and possibly an *Isolepis* were also present, but their identification was not possible due to lack of reproductive characters on the plants.

The ecological functioning of the wetland has been affected by past stocking and weed invasion but should recover if fully protected as Public Conservation Land.

Limosella lineata *flowering in a Simons Pass ephemeral wetland.*

4.1.2 Diversity and Pattern: Medium/High

The diversity of plants was similar to the large ephemeral tarns in CA1 (Table 1). However, many species typical of kettlehole tarns in the Mackenzie Basin were not found during the October 2019 survey. Visits later in the flowering season are likely to reveal more species as many ephemeral wetland plants are cryptic until flowering (Table 2). Faunal values were not assessed, but the tarn is likely used by wading birds when water is present.

4.1.3 Rarity and Special features: High

Wetlands are a national priority for protection under National Biodiversity Priority Two (MfE and DOC, 2007). The ephemeral tarns on CC1 are a rare (Williams *et al.*, 2007) and threatened ecosystem (Critically endangered: Holdaway *et al.*, 2012). The tarns are located within glacial moraine which is also a rare (Williams *et al.*, 2007) and threatened ecosystem (Vulnerable: Holdaway *et al.*, 2012).

The mousetail tarn in CC1 has one of the largest known populations of Mousetail in the Mackenzie Basin. In October 2019 there were tens of thousands of plants present. A search of 11 tarns inside CA1 found no mousetail populations. Several of these tarns had habitat suitable for mousetail plants. Other threatened species could also be present within this tarn. A survey later in the summer season when more plants are flowering could identify further threatened plants.

Mousetail plants in the CC1 Mousetail Tarn.

4.1.4 Naturalness: Medium

The wetland has been affected by past stocking and weed invasion. This has resulted in some damage (pugging) which has broken up the turf vegetation and allowed the invasion of exotic plants like white clover and browntop (*Agrostis capillaris*). Despite this there are still good areas of native turf vegetation, especially in places where water ponds more frequently. The wetland is also habitat for a large population of the New Zealand mousetail plant.

A closer view of the mousetail wetland. The higher areas of the tarn surface (amongst the rocks) are weedier due to water ponding in this location less often.

4.1.5 Size and Shape, buffering/surrounding landscape and boundaries: High

The wetland is reasonably large (1000 m^2) occupying a shallow depression at the base of a moraine ridge. The surrounding terrain is dominated by grassland (browntop and the native hard tussock (*Festuca novaezelandiae*)). The slopes of the surrounding moraine ridges are regenerating from grassland into woody shrubland with porcupine shrub (*Melicytus alpinus*), pōhuehue (*Muehlenbeckia complexa*), desert broom (*Carmichaelia petriei*), and pātotara

(*Leucopogon fraseri*). Matagouri (*Discaria toumatou*) is also present but has been sprayed with herbicide. Some plants have survived.

The grassland/shrubland and wetland have had increased nutrient inputs from stock presence (urine and faeces) as well as likely oversowing and topdressing. Removing stock and allowing the ecosystems to recover naturally over time will allow the entire areas to recover.

Regenerating shrubland with desert broom (Carmichaelia petriei: *At Risk – Declining*) *on the moraine ridge to the south of the mousetail wetland.*

4.1.6 Long-term Ecological Viability: High

This wetland should be managed in conjunction with the wetlands on CA1. The removal of stock and other farming inputs should allow the recovery of the mousetail tarn. The recovery of the shrubland and natural grasslands on the surrounding moraines will aid in buffering the wetland from the nearby development on CC1. Protection of these regenerating shrublands is essential for the long-term viability of the mousetail tarn.

4.1.7 Fragility and Threat: High

The wetland is threatened by current farm developments, such as the intensification that has occurred in the 'farm block'. Stock (particularly cattle and deer) cause damage to the wetland turf by pugging. This is turn enables the invasion of weedy plants. The threats to the wetland will remain high unless it is protected as public conservation land.

4.1.8 Management Input: Medium

The key management input is to protect this tarn as public conservation land. Removing stock (especially cattle and deer) from the tarn and its surrounding area will enable the recovery of the wetland. Neither *Carex leporina* or *Juncus articulatus* were observed during the October 2019 site visit. These two species are known to threaten kettlehole wetlands. A monitoring regime in this and the CA1 wetlands should allow the early detection of these weeds (or others). Management inputs may be more intensive early on to assist the wetland recovery.

4.2 The mousetail wetland needs to be protected within a buffer area of at least 200 m from developed farmland.

To protect the mousetail wetland from neighbouring farm development an adequate buffer is required. Ideally this buffer would be at least 200 m of undeveloped and unfarmed dryland grassland. At this site, the wetland is afforded additional natural protection by the moraine ridge to the south and east of the wetland. Leaving this moraine ridge undeveloped and allowing it to regenerate into shrublands is important for the long-term protection of the wetland.

5 Wetlands on CA1

5.1 The ephemeral tarns on CA1 contain significant inherent values.

During October 2019 the wetlands on CA1 were visited to record their values and to check for the presence of mousetail plants. Almost all the tarns visited had high values, although several have been damaged through overstocking and weed invasion. The surveys through these tarns were rapid, as the focus was on locating populations of spring annuals such as the New Zealand mousetail and *Ceratocephala pungens*. Further surveys are recommended later in the flowering season to detect more species.

As these tarns are inside CA1 which is already recommended for full protection as public conservation land, significance assessments have not been completed for these tarns. However, most of the individual tarns would have been classed as significant. Furthermore, the network of tarns together are significant ecosystems worthy of protection, as each tarn contains a slightly different suite of native plant species (Table 1).

5.1.1 No mousetail plants were observed in any of the CA1 tarns.

The focus of the October 2019 surveys through the CA1 tarns was to locate more populations of the New Zealand mousetail plant. Despite many several tarns with appropriate habitat no further populations were found inside the CA1 area. Therefore, the importance of protecting the mousetail tarn inside CC1 has increased as it is the largest known population of mousetail remaining on Simons Pass Station. Furthermore, it is likely one of the largest populations in the Mackenzie Basin.

5.1.2 Each of the tarns contain a different suite of ephemeral wetland plants.

The tarns across CA1 each contained a different suite of wetland plants (Table 1). Not every wetland contained all the species found across all the tarns. Therefore, more than one ephemeral tarn must be protected to ensure protection of all threatened species found inside these tarns. The October 2019 site visit and survey was timed to identify spring annual plants. Therefore, other species may be present inside the CA1 tarns that were not observed during the survey (Table 2). Many of the ephemeral tarn plants are cryptic and cannot be accurately identified without their reproductive structures (i.e. flowers and fruits) present. It is likely that these tarns support a greater diversity of plants than that observed during the October 2019 visit.

Ranunculus cheesemanii *(Not Threatened) in an ephemeral wetland on CA1.*

Two threatened plants from ephemeral tarns on Simons Pass CA1 land. Left: Cardamine mutabilis *(Threatened – Nationally Critical) x* Cardamine corymbosa *(Not Threatened)*. *Right:* Myosotis brevis *(Threatened – Nationally Vulnerable).*

Table 1. Comparison of species found on the ephemeral tarns in CA1 and the Mousetail tarn on the land proposed to become freehold (CC1).

Species	Threat Category (de Lange *et al.* 2017).	Mousetail	CA 1 Tarns										
			1	2	3	4	5	6	7	8	9	10	11
Cardamine mutabilis X *Cardamine corymbosa* hybrid	Threatened – Nationally Critical (*C. mutabilis* is Nationally Critical, therefore its hybrid is rare by default).		✓										
Myosotis brevis	Threatened – Nationally Vulnerable						✓						
Myosurus minimus subsp. *novezelandiae*	Threatened – Nationally Vulnerable	✓											
Epilobium angustatum	At Risk – Naturally Uncommon	✓		✓			✓			✓		✓	
Agrostis muscosa	Not Threatened	✓					✓						
Crassula sinclairii	Not Threatened	✓	✓				✓		✓	✓	✓	✓	
Dichondra brevifolia	Not Threatened												✓
Elatine gratioloides	Not Threatened	✓	✓	✓									
Glossostigma elatinoides	Not Threatened	✓											
Geranium brevicaule	Not Threatened		✓										
Hydrocotyle novae-zelandiae var. montana	Not Threatened									✓			
Hydrocotyle hydrophila	Not Threatened								✓				
Limosella liniata	Not Threatened	✓	✓	✓	✓		✓	✓	✓		✓	✓	
Luzula rufa	Not Threatened		✓										
Montia sessiliflora	Not Threatened		✓	✓									
Myriophyllum species	Not Threatened										✓		
Ranunculus cheesemanii	Not Threatened			✓						✓			
Ranunculus glabrifolius	Not Threatened		✓										
Lobelia species	Native	✓	✓				✓		✓	✓	✓		
Carex species	Native	✓	✓				✓	✓	✓	✓			✓
Poa species	Native	✓					✓		✓				
Hypericum species	Native	✓	✓										
Juncus species	Native				✓		✓	✓	✓		✓	✓	
Lachnagrostis species	Native	✓											
Pseudognaphalium	Native	✓	✓	✓	✓		✓		✓	✓			
Agrostis capillaris	Exotic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Anagalis arvense	Exotic	✓											
Anthoxanthum odoratum	Exotic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Aphanes inexpressa	Exotic	✓	✓				✓		✓		✓		
Cerastium fontanum	Exotic	✓					✓				✓		
Cirsium vulgare	Exotic	✓						✓	✓				
Crepis capillaris	Exotic						✓						
Erophila verna	Exotic					✓							
Hypochaeris radicata	Exotic						✓						
Myosotis discolor	Exotic	✓				✓							
Navarretia squarrosa	Exotic	✓											
Oxalis species	Exotic	✓								✓			
Pilosella offinarium	Exotic	✓	✓			✓	✓		✓		✓		
Ranunculus species	Exotic												
Rumex acetosella	Exotic	✓	✓				✓	✓	✓		✓		
Trifolium arvense	Exotic	✓											

Trifolium repens	Exotic	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
Trifolium species	Exotic	✓					✓					✓	
Verbascum thapsus	Exotic	✓											
Veronica verna	Exotic	✓				✓							
Ranunculus species	Exotic								✓				

Table 2. Other ephemeral tarn species that are likely present in the Simons Pass wetlands

Species	Threat Category (de Lange *et al.* 2017).	Notes
Carex berggrenii	At Risk - Declining	Johnson (1991)
Carex diandra	Not Threatened	Johnson (1991)
Carex gaudichaudiana	Not Threatened	Johnson (1991)
Ceratocephala pungens	Threatened – Nationally Critical	Previously observed on Simons Pass
Crassula penduncularis	Threatened – Nationally Critical	Known from the Mackenzie Basin
Deschampsia chapmanii	Not Threatened	Johnson (1991)
Eleocharis acuta	Not Threatened	Johnson (1991)
Eleocharis grascilis	Not Threatened	Johnson (1991)
Eleocharis pusilla	Not Threatened	Johnson (1991)
Galium perpusillum	Not Threatened	Johnson (1991)
Gnaphalium paludosus	Data Deficient	Johnson (1991)
Gnaphalium traversii	Not Threatened	Johnson (1991)
Gonocarpus micranthus	Not Threatened	Johnson (1991)
Hydrocotyle microphylla	Not Threatened	Johnson (1991)
Hypericum pusillum	Not Threatened	Johnson (1991)
Lobelia ionantha	At Risk - Declining	Johnson (1991)
Lobelia perpusilla	Not Threatened	Johnson (1991)
Isolepis basilaris	At Risk - Declining	Johnson (1991)
Juncus pusillus	At Risk – Naturally Uncommon	Johnson (1991)
Leptinella maniototo	At Risk - Relict	Johnson (1991)
Lilaeopsis novae-zelandiae	Not Threatened	Johnson (1991)
Lilaeopsis ruthiana	Not Thretatened	Known from the Mackenzie Basin
Montia angustifolia	At Risk – Naturally Uncommon	Previously observed on Simons Pass
Montia fontana	Not Threatened	Johnson (1991)
Myriophyllum pedunculatum	Not Threatened	Johnson (1991)
Poa lindsayi	Not Threatened	Johnson (1991)
Pseudognaphalium ephemerum	Threatened – Nationally Critical	Known from the Mackenzie Basin
Pseudognaphalium luteoalbum	Not Threatened	Known from the Mackenzie Basin
Ranunculus brevis	Threatened – Nationally endangered.	Johnson (1991)
Veronica lilliputiana	At Risk - Declining	Johnson (1991)

5.2 The wetlands

5.2.1 CA1 Tarn 1

This tarn is the closest to the mousetail tarn on CC1. No mousetail plants were found. A hybrid between *Cardamine mutabilis* and *Cardamine corymbosa* was found here. The tarn was in good condition with some evidence of pugging and weed invasion

5.2.2 CA1 Tarn 2

This tarn was a smaller tarn inside CA1. The plant diversity recorded from the October 2019 survey was low (Table 2), but a more thorough survey later in the season would likely reveal more species. The overall condition of the tarn was good.

5.2.3 CA1 Tarn 3

This tarn was grassier than the others but still had native plant values present.

5.2.4 CA1 Tarn 4

CA1 Tarn 4 was a small tarn with damage from pugging. The soil profile of the wetland has been disturbed and no native plant values were observed. The tarn has been colonised by weedy plants typical of disturbed places.

5.2.5 CA1 Tarn 5

Tarn 5 has a healthy intact turf. One plant of *Myosotis brevis* (Threatened – Nationally Vulnerable) was found. Native *Myosotis* plants are often in small numbers within a site.

5.2.6 CA1 Tarn 6

Tarn 6 was slightly pugged and had evidence of nutrient inputs (faeces) from stock. Nesting pied stilts were present. The tarn was not fully surveyed because of this.

5.2.7 CA1 Tarn 7

Tarn 7 had a mostly intact turf with evidence of past pugging and exotic grasses present. Nesting pied stilts were present so the tarn was not fully surveyed to minimise disturbance to the birds.

5.2.8 CA1 Tarn 8

Tarn 8 has high values with an intact and not pugged turf.

5.2.9 CA1 Tarn 9

Tarn 9 had a highly intact turf with some disturbance by rabbits, cows, and sheep.

5.2.10 CA1 Tarn 10

Tarn 10 had a highly intact turf community.

5.2.11 CA1 Tarn 11

Tarn 11 had evidence of past stock impacts with a high cover of exotic grasses. Some native plant values survived.

6 References

Davis M, Head NJ, Myers SC, Moore SH (2016). Department of Conservation guidelines for assessing significant ecological values. *Science for Conservation 327*. Department of Conservation, Wellington, New Zealand.

De Lange PJ, Rolfe JR, Barkla JW, Courtney SP, Champion PD, Perrie LR, Beadel SM, Ford KA, Breitwieser I, Schönberger I, Hindmarsh-Walls R, Heenan PB, Ladley K. (2017) Conservation status of New Zealand indigenous vascular plants, 2017. *New Zealand Threat Classification Series 22.* Department of Conservation, Wellington, New Zealand.

Department of Conservation (2019) Simons Pass pastoral lease additional conservation advice. *Report to LINZ for Simons Pass tenure review.* Department of Conservation, New Zealand.

Holdaway RJ, Wiser SK, Williams PA (2012). Status assessment of New Zealand's naturally uncommon ecosystems. *Conservation Biology*. 26(4): 619-629.

Johnson PN (1991). Tekapo kettleholes: botanical report. *DSIR Land Resources*. Dunedin, New Zealand.

Johnson P, Rogers G. (2003) Ephemeral wetlands and their turfs in New Zealand. *Science for Conservation 230*. Department of Conservation, Wellington, New Zealand.

Johnson PN, Gerbeaux PJ. (2004) Wetland types in New Zealand. *Department of Conservation*. Wellington, New Zealand.

Johnson PN (2016) Ruataniwha and Waterwheel wetlands: a botanical survey of two man-made wetlands, March 2016. *Botanical report for Project River Recovery*. Department of Conservation, Te Manahuna/Twizel.

MfE, DOC (2007) Protecting our places. Introducing the National priorities for protecting rare and threatened native biodiversity on private land. *Ministry for the Environment and Department of Conservation*, Wellington, New Zealand.

Rogers G, Walker S, Tubbs M, Henderson J. (2002) Ecology and conservation status of three "spring annual" herbs in dryland ecosystems of New Zealand. *New Zealand Journal of Botany.* 40(2): 649-669.

Rogers G, Overton JM, Price R. (2007) Land use effects on "spring annual" herbs in rare non-forest ecosystems of New Zealand. *New Zealand Journal of Botany*. 45(2): 317-327.

Williams PA, Wiser S, Clarkson B, Stanley MC (2007). New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. *New Zealand Journal of Ecology* 31(2): 119-128.