# Design notes for an indigenous invertebrate habitat reserve within the proposed Far North Solar Farm, Mackenzie Basin.

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Technical advice, invertebrate ecology

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**Introduction**

Far North Solar Farms (FNSF) are proposing to build a 670hectare solar array in the Mackenzie Basin, Waitaki catchment, South Canterbury (figure 1). The array would be situated between the Ohau and Pukaki Rivers, at the northern of Lake Benmore and some 8.5kms from Twizel township. Currently, the land is being grazed (primarily cattle) and parts of it intensively irrigated. Following an October 2023 site visit between FNSF ('the applicant') and ecologists from Wildlands and Department of Conservation, ideas for an 'indigenous invertebrate reserve' were discussed, as part of the array application. The opportunity to combine a development initiative with an effort to reduce the decline of native invertebrates in the Mackenzie Basin seems worthwhile. Among the rare and threatened invertebrates existing in the Mackenzie Basin, those most at risk of habitat modification include; the Nationally Endangered grasshopper *Sigaus robustus* (was *Brachaspis robustus*, see Trewick *et al*. 2022; 2023), ground wētā, beetles, moths and spiders.

**Ecological context**

The Mackenzie Basin is the largest of several post-glacial intermontane basins on the eastern side of the Southern Alps. These places are high, dry and ecologically isolated from wetter coastal environments. The basins have an extreme climate, controlled primarily by frequent westerlies blowing over the alps (inducing a rain shadow) and, in winter, periods of snow followed by clear skies dropping temperature to as low as -10ºC. Under these conditions, an indigenous biota has adapted, often in isolation with remarkably high proportions of endemic species.

The characteristic Mackenzie Basin landscape with its tall-tussock habitats were substantially modified by the construction of hydroelectric power infrastructure and agricultural intensification (particularly from the 1950s onward). Although rabbits were a notorious problem and an ecological catastrophe during the depression years, it has been the introduction of disturbance-adapted exotic plant species (intentionally or unwittingly) particularly in the late 1950s, that has set the Mackenzie Basin on its present ecological trajectory.

Competition by exotic plant species has resulted in the decline of native vegetation communities, a situation that is generally irreversible. Several exotic plant species are responsible for out-competing indigenous flora, including; pines, lupins, Hawkweed (*hieracium pilosella*) and willows (associated with waterways). Tough, successful weed species are not the only ecological problem in the Mackenzie basin; there is a continuous supply of introduced animals, similarly well-adapted to dry conditions and the introduced plant communities of the basin. Stoats, Hedgehogs, rodents, cats, possums, rabbits, hares and some birds, are serious predators and herbivores of indigenous species, collectively applying pressure on the native Mackenzie Basin biota.

Today, a more insidious ecological change is underway with the rise of large-scale pivot irrigation. High volume, intense watering of the basin represents an abrupt local climatic change within soil horizons and associated organisms. The 'invisible' native invertebrate biota has, arguably, been the most severely hit with the steady conversion of dryland surfaces into intensively irrigated green ryegrass cattle-scapes. In response, a new suite of exotic invertebrates, better suited to the wetter soils, are colonising these modified habitats.

Nevertheless, there several locations throughout the basin that retain much of the pre-european (and earlier) biota, including invertebrates. The braided river systems maintain the Nationally Endangered grasshopper *Sigaus robustus* (was *Brachaspis robustus*), similarly, *Sigaus minutus* a small grasshopper persists in areas such as the Tākapo Scientific Reserve where a viable population of the Data Deficient ground wētā *Hemiandrus* '*furoviarius*' is relatively stable. Rare spiders survive on lightly grazed short-tussock surfaces and several species of large beetle can be found within indigenous communities. Tussock and shrublands also support native moth and butterfly species.

Invertebrates generally have modest real estate needs, therefore establishing invertebrate reserves and strongholds within the Mackenzie basin should not be too difficult and opportunities to do so, not overlooked. Terrestrial invertebrates are not discriminating of landscape values, all they require is appropriate environmental and biotic conditions to persist. To that extent, many invertebrates could be kept within these biodiversity reservoirs.

This summary paper outlines three options (or combinations) for including an invertebrate reserve within a portion of the proposed Far North Solar Farm array, between the Pukaki and Ohau rivers. For a detailed study of changes to indigenous habitats in the Mackenzie Basin Dr Susan Walker of Landcare Research has tracked the shift and her findings have been used in several high-profile hearings available from the Mackenzie District Council (https://www.mackenzie.govt.nz/ the media: https://www.stuff.co.nz/environment/89425177/the-battle-for-the-mackenzie-basin ; https://www.nzgeo.com/stories/how-to-fix-the-mackenzie-basin/) and papers (e.g. Brower *et al*. 2020).

**Site visit**

The proposed solar array site was visited on October 6, 2023. It was immediately apparent that the current surface is ecologically depauperate, particularly for indigenous invertebrates and plants. The surface had been cultivated, over sown, irrigated and has had substantial cattle trampling resulting in few, if any, indigenous organisms persisting in the area.

However, the peripheral surfaces have fared better and maintain remnant surfaces and organisms typical of the less disturbed and some of these, or portions, could be incorporated in an invertebrate reserve. The proposed array area is likely to be the largest in New Zealand, if completed (figure 2) and the opportunity to combine indigenous Mackenzie Basin species and their habitats with the solar array seems viable.

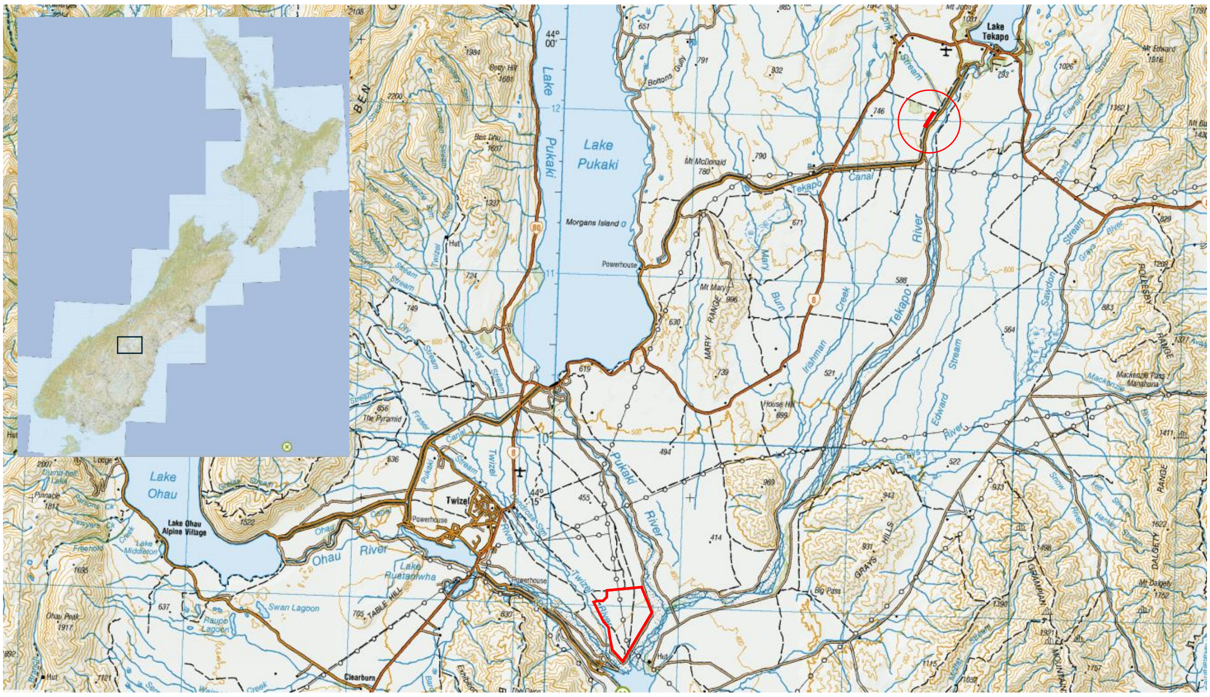


**Figure 1.** Location of proposed Far North Solar Farm solar array (red-coloured irregular polygon), between the Ohau and Pukaki Rivers, immediately north of Lake Benmore, bottom of image. The red circle (upper right) marks the location of the existing *Sigaus robustus* grasshopper reserve (small red oblong).

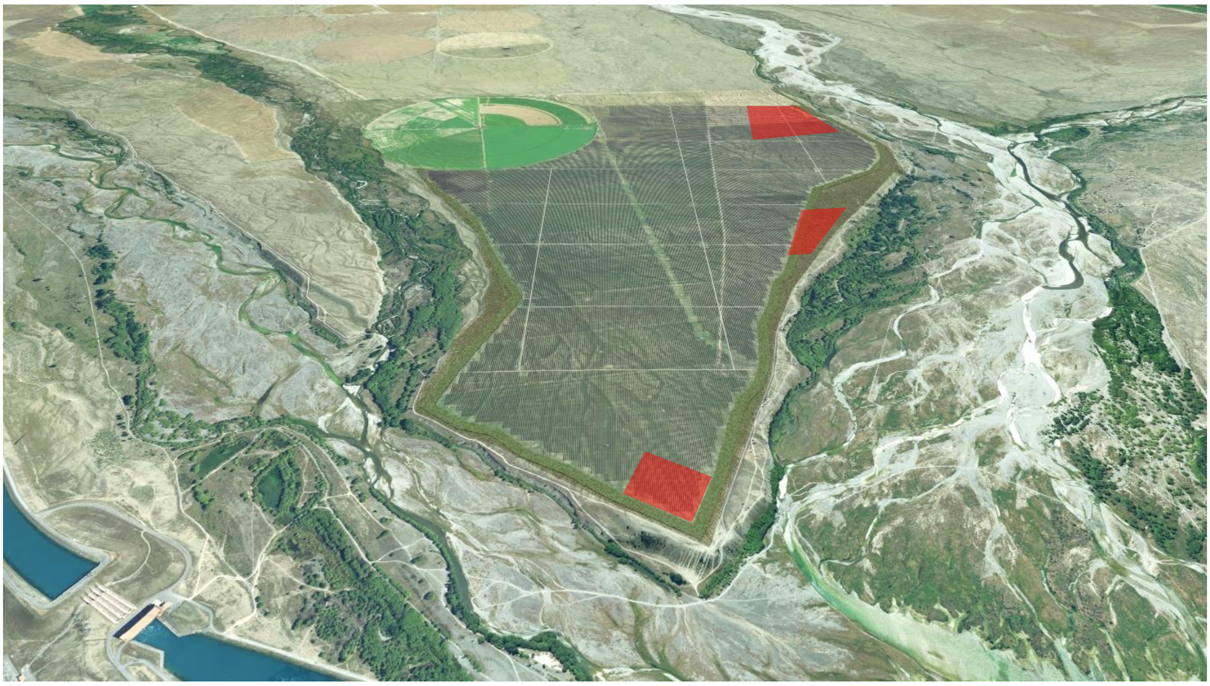

**Figure 2.** Google earth rendered mock-up of the array, view looking north. Potential invertebrate reserves are marked as three red polygons. The green irrigated circle at top right is proposed to remain in-situ, as an agreement between the FNSF and the current landowner.

**Reserve proposals**

Three locations are considered for an invertebrate reserve, or a combination of each. The first area would occupy the northeast corner of the array at about 4.5 ha, with 1ha covered by array panels (figure 3). The balance of the area (3.5ha) would be bare ground available for reserve habitat. The available inter-array strips would then be divided into thirds of differing habitat (figure 4). The ‘thirds reserve’ would comprise:

Strip 1: Semi-bare, stoney ground specifically intended for *Sigaus robustus*. Prostrate herbs and mat forming plants (*Roulia*, *Epilobium* willowherb, *Racomictrium* moss, etc). See Appended mock-up image suggesting panel and gravel arrangement.

Strip 2: Dryland, short sward tussock and mat plants for other grasshopper species (*S. minutus*, *S. australis*), ground weta (*Hemiandrus* ‘*furoviarius*’), moths, butterflies with herbs, *Leucopogon* low-stature shrub species could divide strips two and three. Perhaps manage with limited sheep grazing.

Strip 3: Bands of shrub species bordering a second tussock corridor. Taller tussock, speargrass, prostrate herb species, with a periphery of woody species including *Muehlenbeckia* spp., *Dracophyllum* sp. possibly *Podocarpus nivalis*? No higher than 400mm.

Approximately 25 arrays would fit into 200m (including the four-metre gap between arrays). Each solar array covers about two meters of surface. Total array cover is about 10,000m2 (1 hectare, 2.5 acres), leaving 3.5 hectares for invertebrate habitat. Even if these values are incorrect, the estimate is about available surface for invertebrate habitat.

The benefit of using the north-east corner of the array is three-fold; A) The corner is at an appropriate distance from the present pivot irrigator system – from which there will be considerable over-spray, which is antagonistic to the aim of replicating a semi-arid invertebrate habitat, characteristic of this region of the Mackenzie Basin. B) the corner is accessible by a rough road, allowing for establishing, maintaining and monitoring the reserve. C) That portion of the array is close to the Pukaki River and a potential source population for *Sigaus robustus* grasshopper while simultaneously at an appropriate distance from Lake Benmore (and the potential for predation by birds).


**Figure 3.** Approximate location of a proposed invertebrate reserve No. 1, within the north eastern corner of the planned North Point Solar array. Old river braids are discernible in this part of the landscape and this is a benefit for the reserve as it means the surface is little modified form a pre-human state, and likely to be suitable for dryland invertebrate species.

## Option 2:

This area to the east of the array surface was visited during the October 2023 site inspection. The location is conveniently peripheral to the proposed array and on closer inspection the area appeared highly suitable for *Sigaus robustus* grasshoppers, although none were seen at the time. A shallow outwash gully has down-cut into the Pukaki River bed providing a degree of surface relief and differential shading. This feature could be exploited for varying vegetation types. Currently, the scattered (but sparse) vegetation included Rose hip (*Rosa rubiginosa*), *Melicytus alpinus*, *Roulia australis*, occasional Matagouri (*Discaria toumatou*), short-stature tussock and a considerable number of wilding pines. The pines would need to be eradicated. Nevertheless, minimal effort would be required to prepare the surface for grasshopper occupancy however, erecting a predator fence would be necessary with a perimeter of at least one km, covering an area of 3-4ha (figures 5 & 6).


**Figure 4.** Concept for a triple-tiered invertebrate habitat reserve located in the north eastern corner of the solar farm proposal, Mackenzie Basin. The grasshopper reserve (top 'panel'), will require considerable design detail and substrate manipulation (as stoney ground) to provide the best possible environment for *Sigaus robustus* to survive. A predator fence will also be required, no higher than 1.2 m. The middle panel will have a higher density of vegetation (compared to the grasshopper habitat), primarily short tussock and low-stature herbs. The aim being to encourage local species of moth, butterfly, flies, beetles grasshoppers, weta and spiders. The lower panel will have higher and denser vegetation with the aim of encouraging a rich lepidoptera, orthoptera, beetle and spider fauna. In all cases, the habitats will necessarily be a 'corduroy' system as the arrays will occupy two-thirds of each pair of array rows. Arrays are omitted from the lower panel for simplicity.

Approximately 25 arrays will fit into 200m (including the four metre gap between arrays). Each solar array covers about 2 meters of surface. Total array cover is about 10,000m2 (1 hectare, 2.5 acres), leaving 3.5 hectares for invertebrate habitat. Even if these values are incorrect, the estimate is about available surface for invertebrates and habitat.

**Option 3. South-east corner**. This option has the advantage of being situated well away (diametrically opposite) from the centre pivot irrigator to the north west (Figure 7). It is also well placed to access *Sigaus robustus* habitat for grasshopper recruitment, a potential source-sink situation. An identical or similar habitat configuration to option 1 could be employed here, or a single habitat type. One disadvantage might be the road distance to service the reserve and monitor invertebrates (figure 8).

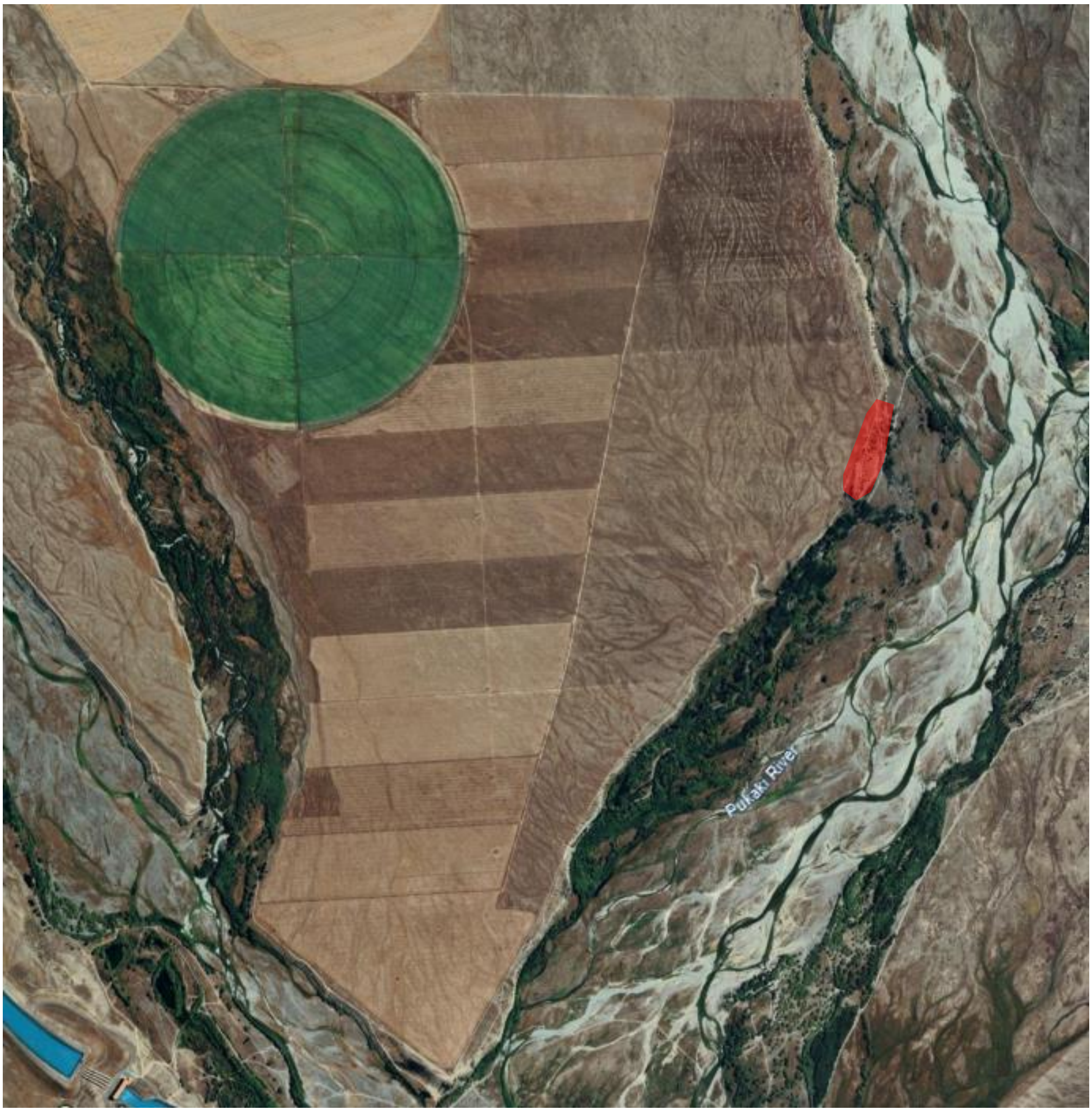


**Figure 5**. Invertebrate reserve area, option two on the eastern flank of the cultivated surface, adjacent to the true right bank of the Pukaki River. Comprising relatively undisturbed gravels and small stones, the area offered appropriate habitat for *Sigaus brachaspis* grasshoppers.

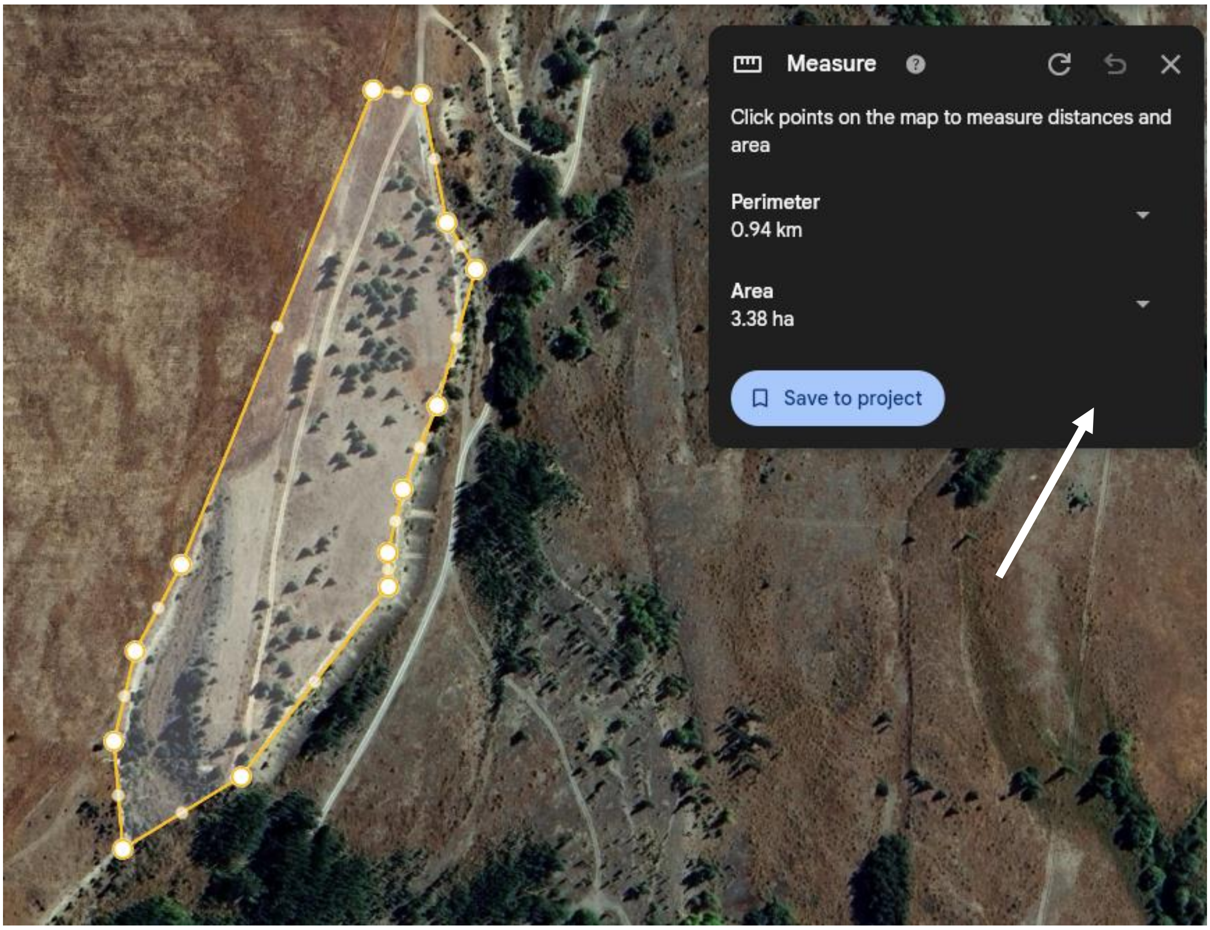


**Figure 6.** Google Earth close-up clip showing rough outline of the second area suitable for a *S. robustus* reserve. The outwash gully can be seen in the lower portion of the enclosed area.

**Figure 7**. Invertebrate reserve option 3: South-east corner, at the confluence of the Pukaki and Ohau rivers.

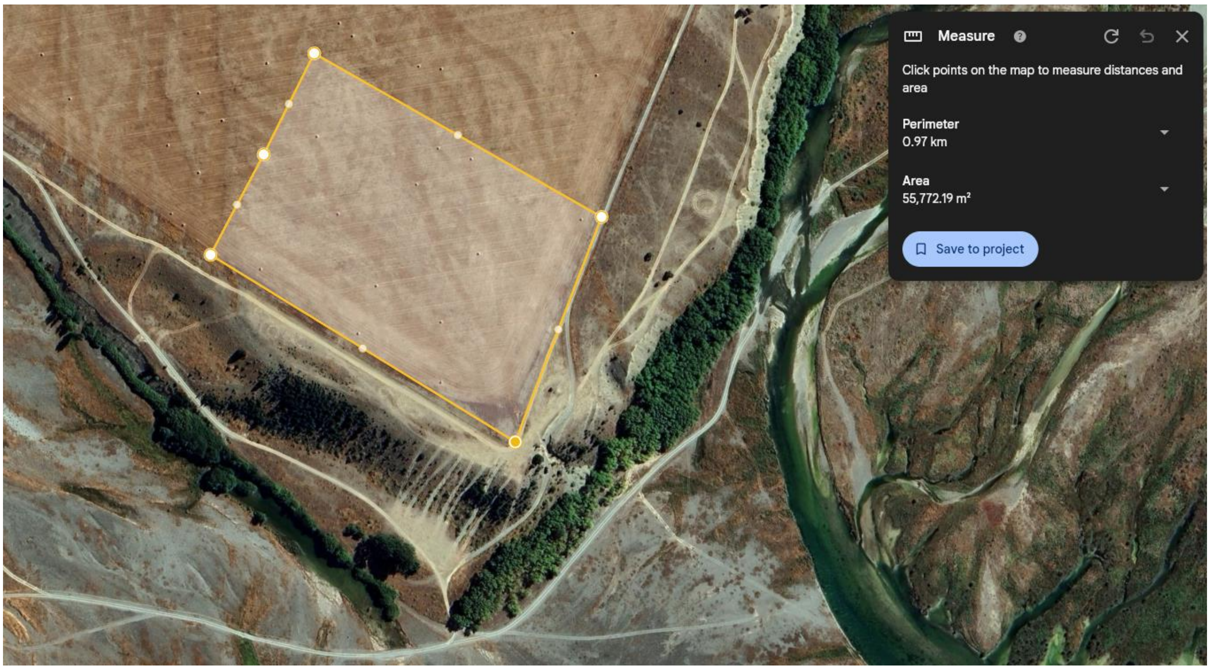


**Figure 8.** Detail of the south-east corner location with reserve overlay.

**The Paterson's Terrace grasshopper reserve.**

Any effort to establish an invertebrate reserve at the proposed NPSF site will need to draw on experience and knowledge acquired from the 0.6hectare Patersons Terrace grasshopper reserve, some 34 kms away near Lake Tekapo/Tākapo. Built in November 2018, the details are: a 1.2m high predator exclusion fence (Central Fencing LTD) using 1.8 m x 150mm diameter, uniformly turned posts (tanalised), 2m spacing. Steel mesh of 1.6mm, welded rather than woven with a 6.3mm aperture – i.e. 4.7mm between wires. A ground skirt, 400mm wide of mesh buried 100mm deep at posts and 160mm deep at outer edge (i.e. a sloping surface). Capping – 1.2m Z600 galvanised steel (0.9mm is ideal). The Patersons terrace fence costs came to $287.00 / metre, approximately $132,020.00 in 2019 (Figures 9 and 10).

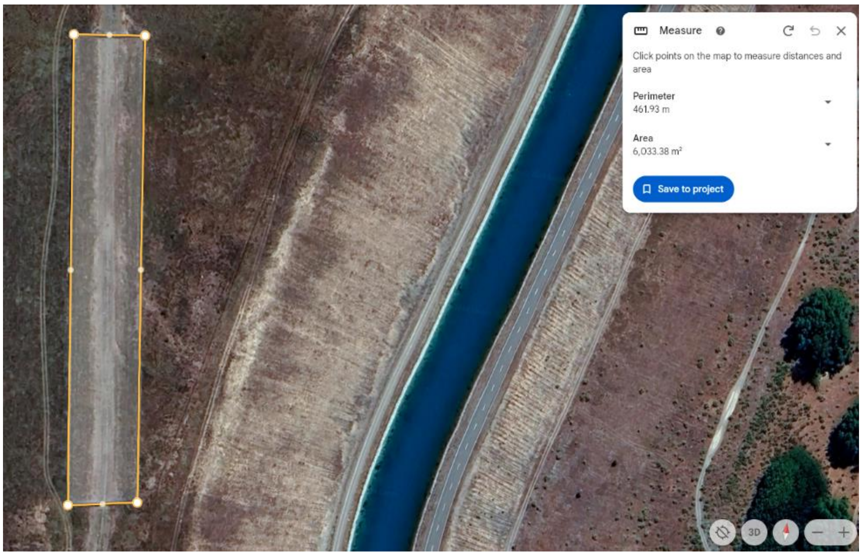


**Figure 9.** Layout of the Patersons Terrace Sigaus robustus grasshopper reserve, near Tekapo/Tākapo.

**Figure 10.** The 0.6ha Patersons Terrace *Sigaus robustus* grasshopper reserve predator-exclusion fence, near the Tākapo River. Photo: Phil Tisch, DOC.

The ability of the Patersons Terrace fence to prevent pest incursions has been successful however birds, specifically Magpies and Starlings are able to fly in and prey on the grasshoppers (and other invertebrates that may be present). This is an ongoing issue and may require either wires to prevent the bird alighting on the fence cap or possibly a more elaborate bird-scarer system (McIver 2020).

**Reserve design considerations**

The design and configuration of an invertebrate reserve will rely heavily on information from the following key studies:

Jennifer Schori (population methods) (Schori 2019 *et al*., Schori *et al*. 2020a, b & c)

Liam McIver 2020 (MSc thesis on Patersons Terrace grasshopper enclosure)

Rebecca Clements 2021 (MSc thesis on grasshopper translocation site selection criteria).

The biotic and abiotic factors associated with population survival of the Robust grasshopper (and other invertebrates) within a reserve, are provided in Table 1. I have listed the ecological criteria of importance, the optimal state (per criterion) and the known and proposed responses to these factors.

**Table 1.** Abiotic and biotic factors associated with the *Sigaus robustus* grasshopper and other native invertebrates, relevant to the construction and monitoring of a reserve.

**Abiotic factors**

| Criterion | Optimal state / System | Action |
|---|---|---|
| Reserve area | At least 0.6hectare for a population density of at least 0.5 hoppers /m $^2$. | Scale reserve accordingly. Hopper density will depend on many variables. Initial season; low with annual increase. |
| Substrate | Semi-spherical local stones (river bed) between 10-100mm diam. | Source from several river bed locations in the basin, or screen existing gravels on site |
| Structures | Predator-proof fencing for robust grasshopper at least. Potentially install artificial cover objects for weta, beetles and spider (cement design) | As per McIver (2020). This will be the most complex and expensive aspect of an invertebrate reserve. Considerable time and thought will be required to devise an optimal predator-exclusion system amongst the solar arrays. Not necessarily a post fence per se. Array pedestals could substitute for fence posts. |
| Environmental | A climate station will be necessary to monitor conditions (at and above ground level) and be solar powered (ironically!) | Researching and costing an appropriate climate station. |
| Climate change | Cool winters necessary for grasshopper egg diapause. Risk of fewer cold nights. | Collect ground temps under arrays and in direct sunlight. Monitor differences (if present). Exploit shaded/open surface differential. Correlate array climate with regional climate. Determine year at which critical threshold reached. Consider alternative (cooler) reserve locations. |

**Biotic factors**

| Criterion | Optimal state | Action |
|---|---|---|
| Source population(s) | Ideally acquire robust grasshoppers from a wild population within the Mackenzie Basin. | Fork Stream and Snowy River fan are candidate sites. Translocation protocols necessary (DOC SOP currently exists in DOC files), determine age cohort, sex ratio, initial numbers, monitoring regime, mating and oviposition success, egg counts, nymph hatching, tracking pop through time. |
| Diet | Provide appropriate plants and density for grasshoppers. *Raoulia*, *Epilobium*, lichens. | Determine ratio of plant : bare surface ratio for hoppers. Translocate plants and/or propagate plants to establish in reserve. |
| Predation | Nil predators. | Remove and exclude all lizards from grasshopper enclosure (s). Exotic bird control systems required - wires on fence capping etc. |

| | | |
|---|---|---|
| Oviposition substrate | Ideal conditions for egg laying and nymph development | Mimic existing grasshopper 'hot spots'. Silty soil, sands, fine stones, sparse vegetation. |
| Inbreeding | Minimal to nil inbreeding risk. | Consider harvesting F2 – 3 progeny and replacing with equivalent number from (ideally) wild populations or Patersons Terrace. Consider periodic genetic tracking of heterozygosity markers. |
| Hybridisation | Crossing between *Sigaus nivalis* and *S. robustus* may occur. | Ensure grasshopper donor population is morphologically *S. robustus*. Periodically screen recipient population (enclosure) for *S. nivalis*. This is a very unlikely risk. |
| Temperatures | Equivalent to wild populations (determine those parameters from wild or Patersons Terrace population) | Monitor invertebrate enclosure for equivalent thermal regime as wild populations |
| Relative humidity | As above | Monitor R/H in the reserve(s). |
| Pre-release survey | Ensure grasshopper enclosure is free of exotic animals including invertebrate predators, including; hymenoptera, White tailed spiders, *Steatoda* spiders (false katipo, *Badumna* sp.). | Tracking tunnels, trail cams, Onduline ACO's for lizards, potentially pheromone traps and pitfall traps (removed after a withholding period). |
| Meso-predation | No predation on grasshopper by Birds or lizards after mammal exclusion | Exclude skinks from the enclosure. Establish tracking tunnels and mammal traps peripheral to the enclosures or open reserves. |

## Conclusion

The prospect of establishing a new reserve, exclusively for native dryland invertebrates, in the Mackenzie Basin is an exciting, but challenging one. Awareness of ecological values has increased in the last few decades and the ability of developers to incorporate conservation concepts into their projects builds on previous engineering and landscape efforts within the Basin. This proposal will be pioneering at all steps and may best be achieved by taking a piecemeal approach, perhaps over several years until fully realised.

The success of the proposal will be the measurable increases of invertebrates within the reserve, to the extent that re-wilding of natural populations is achievable alongside targeted returns of the solar power array. The trial will be a test case in many respects and has the potential to yield knowledge for other arrays in semi-arid environments.

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Appendix. Concept image of small-sized ‘grasshopper gravels’ between solar arrays. Gravels would probably extend under each array and afford some differential thermal properties to the surface.