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Project Title:	Landscapes for Life (Stage 2) – An investigation of opportunities for aesthetic improvement and biodiversity enhancement for living roofs in New Zealand.
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Executive Summary

Results from stage 2 of this project have shown that a New Zealand indigenous extensive living roof plant community can provide the basic microhabitat variables required to support lizards with the exception of humidity. Although existing vegetation will provide refuge from predators and modifies temperature and humidity, the designed prosthetic habitat creates humid micro-sites (refuges), allowing a trial translocation of native skinks and ethics approval has now been gained for a trial relocation to occur.

The results of stage 2 have are now providing a solid basis, including comparison of food species from Shakespear and those found on the roof, of the research. Vegetation cover on the roof has significantly increased in the last year (over 70% cover) which provides further enhancement of potential success for the relocation.

Project highlights:

- Collaboration with Auckland Council to gain gut contents to analyse to support food source analysis for the relocation and results confirming food source on roof matches with preferred species being eaten by skink.
- Feedback from International conference which confirmed that a relocation of lizards has occurred in Australia onto a living roof with great success which will support our permit application with DOC.
- A site visit from English living roof expert who has said the living roof at Waitakere is his favourite living roof internationally and is supporting further dissemination of the research at the Green Roof world congress in the Netherlands in September.

Background

Living roofs have been identified as providing significant potential for urban biodiversity within a range of living roof literature.

However, research to date has focused on natural and ad-hoc plant, insect and bird colonisation of living roofs, as opposed to specific opportunities for relocation of endangered species. There has been no research within the New Zealand context on biodiversity opportunity (other than that initiated at the Waitakere City Council living roof in collaboration with Landcare Research). The initial results from this research indicate that this NZ native living roof provides a significant insect diversity which might sustain lizard populations. Internationally, there is a limited resource of habitat biodiversity research on living roofs (particularly those with native plant species (compared with the more common sedum (European origin succulent species) roofs).

Living roofs are potentially ideal sites to establish populations of New Zealand's threatened skink species. This research (2nd stage) led on from a 1st stage which provided quantifiable data showing that a New Zealand native living roof has the required insect and plant structure and diversity to support a lizard population. The second stage research further quantified this information and provided ethics approval and refinement of the prosthetic habitat.

Aims and Objectives

This project seeks to

- Identify the specific habitat requirements of New Zealand lizard species and confirm whether these conditions exist or can be created (using prosthetic habitats) on living roofs.
- Quantify the insect population and vegetation cover that is provided by an existing 500square metre living roof (Waitakere City Council building).
- Develop a range of prototype habitat objects which may assist the creation of optimal habitats for New Zealand lizard species on living roofs.
- Augment existing invertebrate communities on the living roof by releasing NZ native slaters and crickets onto the roof.
- Obtain a permit to undertake the relocation and subsequent monitoring of a small population of copper skinks onto the living roof.
- Continue to quantify the insect population and vegetation cover that is provided by an existing 500square metre living roof.
- Quantify insect population and vegetation cover for a smaller urban indigenous living roof using different installation products to provide comparison of data.

Methodology

The research has quantified the effectiveness of urban skink habitat enhancement methods at existing constructed 'de novo' environments in Auckland and has assessed the potential of living roofs as habitat for local ground-dwelling skink species, initially using the existing bio diverse roof at Waitakere City Council.

Micro-climate data from Stage 1 indicated temperatures under dense vegetation on the living roof are similar to vegetated ground sites at the known lizard habitat of Shakespear.

The living roof currently provides a range of prey species for skink. Seeding of some native insect species such as orthoptera and isopoda and a proactive approach to management and addition of materials to continually increase invertebrate abundance and/or diversity can be undertaken to further increase the level of suitability of the living roof and this has been delayed to occur in autumn and spring 2012.

Stage 2 project methodology involved the continued collection of temperature and humidity data using microloggers located at different vegetative cover sites from Shakespear and the Living roof. This was completed in May 2011. In addition, a prosthetic habitat was monitored to confirm the length of time water stays in the lower chamber (in non-rain events) and measurement of differences in temperature between the habitat layers will be assessed.

Additional data to further strengthen the evidence for a likely successful relocation was initially identified to involve scat analysis from copper and rainbow skinks at Shakespear Regional Park. However collaboration with Auckland Council provided an opportunity to use gut contents analysis instead of scat analysis which is more accurate. Invertebrate sampling to lowest taxonomy possible has been undertaken by an entomology expert (Richard Toft of Entecol) and results have just been received of that analysis.

Vegetation monitoring at the WCC living roof continued throughout Stage 2 and involved three techniques: (1) - Permanent circular vegetation plots (10 in total) in a zone along the centre of the living roof. Plant species in each plot, and x,y dimensions of the *Coprosma acerosa* was noted. (2) - Ten 1m x 1m randomly placed grids with 81 intercept points (and noting what was under each spot) and (3) - photo points.

Progression of Stage 2 aimed as implementing a relocation, however there has been difficulty in getting a confirmed development site for taking the wild skinks from and has thus postponed the relocation to 2012. The relocation will rely on gaining a Wildlife Act Permit from the Department of Conservation (DOC). Identification of a potential development site requiring skink relocation will be required (DOC are more likely to grant a permit if the skinks are coming from a disturbed site where they required relocation). Iwi consultation and involvement will be required and is considered an important contribution to the project at this point in time.

Outcomes/findings

For both pitfall traps and emergence traps, the mean catch of all taxa combined was significantly higher on the green roof than on the adjacent bare roof, with the exception of emergence trap catches in 2007 (Figs. 2a and b). The catch in emergence traps on the green roof was significantly higher in 2008 and 2010, than in 2007, but the catch on the bare roof remained about the same in all years.

For the pitfall traps, the catch on the green roof in 2008 was higher than either 2007 or 2010. The decline in 2010 pitfall trap catches on the green roof (compared to 2008) can largely be explained by much fewer springtails (Fig. 2e) and ants (Fig. 3c). The emergence traps also indicate fewer springtails and ants in 2010 relative to 2008 (Figs. 2f and 3d), but these taxa make up a lower proportion of emergence trap catches than some other taxa, so their decline has less of an effect on the overall emergence trap catch.

Mites make up a higher proportion of emergence trap catches and have shown an upward trend in abundance on the green roof as time goes on (Fig. 2d). In pitfall traps, mite numbers have remained more constant, but with somewhat fewer collected in 2008. Hemiptera catches on the green roof were fairly constant between years in pitfall traps (Fig. 3a), and is dominated by the wheat bug (*Nysius huttoni*). This species is also dominant in emergence trap catches, but the average catch of Hemiptera in emergence traps in 2010 was higher than previous years (Fig. 3b) due to one trap catching 66 individuals of the introduced potato aphid, *Macrosiphum euphorbiae*. While often associated with *Solanum* species, this aphid has a wide host range.

The wheat bug (*N. huttoni*) discussed above is a native species found throughout the country and a significant pest of a variety of crops (Eyles, 1965; Gurr, 1957). It has a very wide host range of plants, including tussocks, *Juncus*, crucifers, clover, *Cassinia*, *Kunzea*, and *Cotula* (Eyles, 1965). It is always found close to the ground surface and prefers hot, dry sites where sunlight strikes the ground (Gurr, 1957), so the well-drained green roof environment is ideal.

Seven species of ant (Formicidae) have been recorded on the green roof, although one of these (*Monomorium fieldi*) has not been recorded since 2007 (Table 1). The only native species present is the ubiquitous *Monomorium antarcticum* complex. The other species are introduced and common to human modified habitats around Auckland. The tyrant ants (*Iridomyrmex* sp.) are particularly prevalent on the green roof. It is an Australian species (the specific identity of the New Zealand populations has yet to be properly diagnosed), and favours hot dry location. They are an aggressive and dominant species where they are established.

Two of the worst ant pest species in New Zealand, the Argentine ant (*Linepithema humile*) and the Darwin's ants (*Doleromyrma darwiniana*) are thankfully absent from the roof garden. Both of these species are widely distributed in Auckland, but the queens do not fly, so it is less likely they will be able to establish on the green roof. However, both are able to spread by a process of "budding off" and there is potential for them to gain access to the roof by crawling up the outside of the building if there are populations around the margins of the building. Their primary mode of long-distance dispersal is by human-mediated transport aboard potted plants and landscaping materials, so vigilance is needed to ensure any material transported up to the roof does not contain a small nest of ants.

Remarkably few beetles were collected on the green roof in any year, and those that were are primarily introduced species common to the surrounding urban environment, such as the Carabid ground beetles *Lecanomerus atriceps* and *Clivina heterogena*, a soldier beetle (*Malthodes pumilis*), and the eleven-spotted ladybird (*Coccinella undecimpunctata*). Introduced species also dominated the fly (Diptera) fauna on the green roof, including the Ephydriids *Hydrellia tritici* and *Scatella nitidithorax*, and the Agromyzid *Cerodontha australis*. In 2007 and 2008, we collected the native crane fly (*Limonia aegrotans*) in emergence traps, but these were not collected in 2010. It is possible they were brought up to the roof as larvae in the soil associated with the plants. In 2008, a native bristle fly

(*Pales* sp.) was collected in a pitfall trap. In 2010, a native Ephydrid, *Parahyadina lacustris*, was collected from 3 emergence traps on the green roof.

A small native cricket (*Bobilla* sp.) was collected from a pitfall trap in 2010, and larger black field crickets (*Teleogryllus commodus*) moved in to concrete lizard refuges that were placed on the roof in 2010. Black field crickets are considered native to New Zealand (also found in Australia), but can be significant pasture pests in some areas during summer months, especially in dry years.

A range of invertebrates utilised the refugia, with the most common being introduced species such as *Steatoda* spiders, a range of slug species, adventives millipedes, and a centipede (probably *Lithobius peregrinus*). Native wolf spiders (Lycosidae) were also found beneath the refugia, and occasionally in pitfall trap samples as well. Ant nests were also present beneath the refugia.

Earthworms arrived with plants on to the roof and were detected beneath the refugia in 2007, but not in 2008. A severe drought in early 2008 killed a number of plants on the green roof and is likely to have had a significant impact on the survival of earthworm populations on the roof. Earthworms were found again on the roof during the spring of 2010 and one was collected in a pitfall trap that year. These may have arrived with new plants that had been brought on to the green roof after 2008.

The last set of invertebrate samples from Nov-Dec 2011 have been sorted to order, and are now just waiting for some more detailed analysis of key orders (e.g. beetles, flies, ants, spiders), which will tie it in nicely with the skink diet analysis that has been completed in 2011 also. Findings of the comparison between gut content and living roof insects is showing that there is already reasonable cross-over between the diet of the skinks and invertebrates on the roof... they even eat baby slugs and snails! Small spiders, ants, flies, and parasitic wasps were all popular diet items with the skinks and were all present on the roof. The gut samples also identified a few extra things we could look to boost on the roof (e.g. millipedes, woodlice, native cockroaches).

Conclusions

Conclusions to date confirm that the proposed trial relocation can proceed with the likelihood of success and now that two possible relocation sites have been identified this work will proceed in 2012 as part of stage 3 of the project.

The green roof clearly support a greater diversity and abundance of invertebrates than areas of bare roof, and many of those collected from the bare roof traps undoubtedly moved from the adjacent green roof or were simply seeking shelter in the traps.

Several groups of invertebrates recorded a decline in abundance between the 2008 and 2010 sampling, particularly ants and springtails. One factor that may have contributed to this was that the 4-weeks sampling period in 2010 started several weeks earlier (early November) than was the case in 2007 and 2008, and I suspect the numbers recorded on the roof in 2010 would have been higher if sampling had started in late November and continued through to the week before Christmas. I would recommend sampling in 2011 reverts to starting in late November.

A range of both native and introduced invertebrates are currently utilising the green roof garden, but it was clear that the majority of species are introduced, and this reflects the typical situation in the highly urbanised areas surrounding the building. A number of the introduced species on the green roof are flightless (such as slugs, centipedes, and millipedes), and were undoubtedly brought to the roof with the plants. This demonstrates the importance of good nursery biosecurity measures to prevent the establishment of unwanted organisms on green roofs.

The high proportion of introduced invertebrates on the Waitakere green roof indicates a difference with European green roofs (e.g. Kadas 2006), which report a significant number of high-value species colonising urban rooftop gardens. New Zealand native invertebrate communities tend to have a higher proportion of poorly mobile species. For example, our

native carabid ground beetles are predominantly flightless. Many of our natives appear poor at utilising urban habitats, whereas introduced species thrive. The native invertebrate communities on green roofs will need additional encouragement, perhaps by forming highly specific habitats for them (e.g. clay banks for native bees) or by directly transferring poorly dispersing natives onto the green roof gardens. With added biosecurity measures to prevent the establishment of common introduced species, there is an opportunity to create native communities on green roofs in urban areas usually dominated by introduced species. For example, on the Waitakere green roof there appears to be no (or very few) woodlice. The European woodlouse (*Porcelio scaber*) is often highly abundant in urban areas of New Zealand, whereas the native species are generally very scarce. It may be possible to bring native slaters on to the green roof and allow them to flourish in an urban "island" situation. The same could work with native ground beetles, which can be released from the pressures of rodent predation on a well maintained roof garden. The key will be to ensure the habitats available on the roof garden match the requirements of the target invertebrates.

Implications

The potential of living roofs to contribute to biodiversity in urban environments is a current topic of interest worldwide. However, the discussion is not supported by much research and none in New Zealand (beyond the existing WCC work).

Currently, there has been no deliberate lizard relocations onto living roofs in New Zealand, neither has this occurred internationally except for a small project at Adelaide zoo in Australia. This potential however, has been discussed. This research will address this gap in information within a specifically New Zealand context and as such, the results of this project will be of interest to living roof researchers, conservation biologists and local authorities and developers involved in projects which impact on lizard populations.

The results of the habitat object trial will be of interest to the above specialists but also potentially the general public in terms of biodiversity improvement in urban environments (backyards). The Department of Conservation have indicated interest in the potential of this research for conservation efforts for skinks.

In addition this project will:

- Improve knowledge on living roof biodiversity, with national and international impact, through existing living and green roof research networks and feedback from the Vancouver conference indicates and interest in this research at an international level.
- Lead to new, healthy native lizard populations in Auckland region. Success leads to expansion of new lizard populations in de novo areas, particularly those in mammal-free, rainbow-skink free habitats (living roofs) and further afield in local parks and backyards.
- Lead to development of habitat objects (commercial potential) for use in lizard relocation projects, but particularly on living roofs.

Stage 1 of this research was just the beginning, and generated a lot of interest from a range of discipline areas. Continuation of the research through stage 2 has further confirmed the above potentials of the research and stage 3 will trial the findings with a relocation which may lead to further opportunities for living roof research in the NZ context. DOC have indicated interest in use of the prosthetic habitats in conservation work (currently being further discussed with them).

Publications and dissemination

- Entry to MFE Green Ribbon Environment Awards. Category of Innovative Solutions for the Environment 2011 (unsuccessful)
- A co-authored paper was accepted for the NZ ecological Society Conference 2011 and presented by Renee.

- Field Workshop: 'living roofs - designing for biodiversity' (TLAs, DoC, consultants, researchers). Being held in November 2011 alongside Dusty Gedge, living roof campaigner from United Kingdom and in association with living roofs Aotearoa.
- Publication of research and project on Living Roofs Aotearoa website. <http://www.livingroofs.org.nz/page/12-research> and <http://www.livingroofs.org.nz/page/36-case-studies>
- Honorable Mention award in inaugural Animal Architecture Awards – International Competition. Poster on research and prosthetic habitats exhibited as part of travelling group exhibition throughout America and project featured on Animal Architecture website. <http://www.animalarchitecture.org/exhibition-opening/>
- Poster accepted for International Conservation Biology World Congress, December 2011.
- Invited to present on living roofs and the research to Auckland University Architecture students in their Expert Seminar Series.

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