2000 New Zealand Science and Technology Postdoctoral Fellowship

The evolution of indigenous grasses and their response to environmental change

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After leaving school in the far north and enjoying several years as an itinerant cyclist picking fruit, cutting scrub, and doing other farm work both in New Zealand and in Britain, I returned home to more of the same but soon began thinking I didn't really want to be living a low-skilled, itinerant lifestyle when I was 40. So I enrolled at the University of Otago in 1992 (at that time there were only two universities in the South Island, which I had grown to love, and one of them was in Christchurch which was too flat for my liking, so that left Otago), developed a fondness for botany, and ended up with an honours degree in that subject at the end of 1995. The easiest option after the frenetic year that was honours was to do a PhD so I did one of those too, still at the Department of Botany, and arrived at the end of it four years later having studied the comparative ecology of rare and common native snow tussocks (*Chionochloa* spp.) and bidibids (*Acaena* spp.) and having done some superlative tramping trips in the mountains of Otago and Fiordland.

Not really having a plan, I did a few consultancy contracts, one of which was to write up my PhD data into scientific papers, kindly funded by Bill Lee at Landcare Research, who had been one of my PhD supervisors. I applied for a job with Landcare Research in Auckland, and was relieved when I didn't get it, for big city living was not really my thing. However, with Bill's help I had also applied for a 3-year FRST Science and Technology Postdoctoral Fellowship and to my surprise and relief I was awarded it in late 2000 and began it in 2001.

My postdoctoral fellowship was hosted by Landcare Research in Dunedin and it involved extending my work on tussocks to include all the species of two genera – snow tussocks and the short tussock genus *Festuca*. Bill Lee was my mentor, and I collaborated with Dr David Orlovich at my old Otago University Botany Department for other aspects of the work. As well as funding from the Foundation for Research, Science and Technology, the Miss E.L. Hellaby Indigenous Grasslands Research Trust also provided funding which helped to employ summer students to assist with my projects, and contributed to other research consumables.

A PhD is just training, I found. I was now much more efficient as a researcher and the first year of my fellowship saw me travelling the country collecting the grasses that would occupy my scientific attention for the next two. I started on Stewart Island and finished in the far north, where a species of 'snow tussock', *Chionochloa bromoides*, happened to live on coastal rocks. Then I had to propagate my grasses in sufficient numbers to enable adequate replication in a range of ambitious experiments I had planned. Just keeping all these tussock plants alive and happy was a major undertaking... I usually needed about 40 plants of each species and subspecies, each of which I would subdivide further for experimental material. Forty multiplied by the 44 taxa I collected left me with about 1760 plants to look after.

I designed and set up two large-scale experiments with the help of summer students. One of these experiments looked at the ability of my tussock grasses to compete against cocksfoot, at high and low fertility levels. This experiment had over 1400 experimental units each of PB5 (approximately two litres) size, arranged in eight randomised blocks that required periodic re-randomisation. The other experiment had the tussocks growing alone in big 45 litre bags, again at two fertility levels, with the intent being to examine their whole-plant allocation into roots, stems, leaves, and flowering material. This would require washing out the roots of over 600 tussock plants, outdoors, in midwinter, on the Taieri Plain where my experimental setup was located. These are probably some of the largest experiments that have ever been undertaken with tussock grasses (Figure 1).

Another experiment involved a 'tussock cafeteria' in which my grass taxa were offered to farmed deer and sheep, a tame goat, and feral rabbits and hares. Unfortunately the rabbits and hares grazed my tussocks so hard there were no differences between them. The tussock responses to a single tame goat were deemed unfit for further generalisation by the editor of a journal to which we have recently submitted a revised paper on the herbivory results, leaving only the sheep and deer (Lloyd *et al.* submitted).

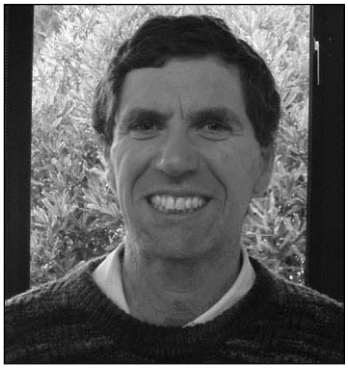

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Figure 1: **Chionochloa *and* Festuca *tussocks growing in 45 litre bags (centre), which were later washed out to measure whole-plant allocation of biomass, and in competition with cocksfoot (crates on margins) to assess competitive ability.***

The two big experiments ran for almost two years before I harvested them, and I used the spare time to write up some of my PhD research, resulting in two additions (Lloyd *et al.* 2002a,b) to my small publication list.

I also accompanied Bill on annual extramural expeditions to Takahe Valley in Fiordland to measure tussock demography by counting their tillers (growth units). Takahe Valley is an awesome place, with towering limestone bluffs, red tussock valley floor and lake, and alpine head basin reached by a minor scrub bash. Also of interest was the fact that the valley was home to no less than eight species of *Chionochloa*, including one of New Zealand's rarest tussocks, *Chionochloa spiralis*, which grew under the limestone bluffs. Counting tussock tillers was tedious but we were encouraged by contributions of Minties from Bill. They were particularly necessary the time we had to kick the snow off the red tussock transect in the valley floor in order to count the tussock tillers. It is impossible to do with gloved fingers. These field trips were associated with some other improvised experiments as well as a survey of the weeds occurring outside the hut. These were later written up and published, in addition to another PhD paper (Lloyd *et al.* 2003a,b; 2006).

New skills were one of the five criteria against which my postdoctoral fellowship application had been assessed, so it also included an objective of obtaining a molecular-based phylogeny (or family tree) of my two tussock genera, so that the traits of these tussock grasses could be related to their evolutionary history. During my undergraduate days I had been renowned as a lab klutz, and making a blunder was briefly known in the Botany Department as 'doing a Kelvin'. So it was very easy to demonstrate that the molecular-based phylogeny would enable the postdoctoral fellow to learn a new skill! I was very lucky to have the support of David, as I learned how to extract, purify, amplify, sequence, and analyse DNA. I have to say I never really developed an intuitive feel for this molecular work – it was more like following recipes, and when something went wrong I was seldom able to diagnose the cause. My *Festuca* tussocks happily gave up their DNA, and sequencing them proved relatively easy. The converse was true for the snow tussocks – the only two sequences I got were of fungal and red algal contaminants! This was very disappointing, and I tried without success to obtain *Chionochloa* sequences for the remainder of my post-doc.

Luckily the *Festuca* tussocks provided an interesting story, with two independent origins for the New Zealand species (Figure 2), the two groups of species also being separated by chromosome number and size. I presented this information at a five-yearly international conference on grasses and monocots (Lloyd *et al.* 2003c), and my presentation was later published as a paper in the proceedings of the conference some four years after I had given it (Lloyd *et al.* 2007). At the conference I found that grass taxonomists were a very friendly and collegial bunch, and didn't mind talking to an ecologist with a very limited feel for plant systematics. Funnily enough I helped to describe a new species of snow tussock a little later, but you can read about how this happened below.

We had also thrown some *Austrofestuca littoralis* (sand tussock) into our molecular analyses for good measure, and found it was more closely related to *Poa* than *Festuca*. Australian sequences provided by Dan Murphy in Melbourne saw us writing a paper in which we clarified the generic position of Australian and New Zealand *Austrofestuca* (Hunter *et al.* 2004), and reinstated two genera that had previously been included in *Austrofestuca*.

Another objective of my fellowship was to map the distributions of my tussock subjects, and I tackled this with vigour, finding that tramping trips to remote mountain areas were an excellent way to gather new distribution data. The other way was to visit the herbaria held in various museums and universities throughout the country. The curators of these herbaria soon got to know of my PhD experience with bidibids, and generally dragged out their unidentified specimens for me to try my hand on. Trawling through herbarium specimens was an interesting task, as was estimating the locations of collections with vague location information. The late Tony Druce was a pioneer with respect to including map references on his herbarium specimens, but very few others did so. I got to scope out some choice tramping destinations as I pored over the hardcopy topographic maps. These days it is much easier, with readily available digital maps and the ability to electronically search for place names and convert old map coordinates to the 7-figure coordinates that were required for my GIS analyses. A map is never finished, and I have still not published any analyses relating to the vast amount of data collected! One day….

I met some delightful, helpful, and very knowledgeable characters during my postdoctoral fellowship, including Henry Connor, with whom I enjoyed much hand-written correspondence. At first requiring Bill to translate Henry's writing, I soon learned to understand it myself. After starting his career as a rather perceptive ecologist, Henry had become fixated by grass breeding systems and grass taxonomy, and had published the most recent revisions of both of my study genera, as well as co-writing the long awaited grass Flora, compiling taxonomic advances in native grass systematics into a long-awaited single volume (Edgar & Connor 2000).

My tramping experiences and snow tussock research combined happily to discover that an unusual snow tussock growing on Mt Burns had a wider distribution in that part of eastern Fiordland. Returning from a trip with my future wife to the 'Electric Mountains' above Lake Monowai, I wrote to Henry and boldly informed him that I found several more populations of this tussock and I thought it was a new species. Henry quickly responded. 'Go back and collect some then – ten specimens will do'... So a month later I found companions for a second expedition to the area and returned with the required specimens, which I sent off to Henry. He replied that, 'I am prepared to describe *Chionochloa modesta* (or some other epithet) on the basis of more than Mt Burns and Titiroa'...

Much correspondence ensued between Henry and me in early and middle 2003. He duly found some consistent morphological differences from all other known snow tussock species, while I provided distribution data and advice on recognition and habitats. We turned this information into the description of a new species of snow tussock endemic to eastern Fiordland (Connor & Lloyd 2004).

Henry's process for choosing a name was an interesting one. 'The first thing one must do is find a suitable specific name', he wrote to me on 16 July. He was against having species names in the same genus that had the same initial letter. Henry must have been disgusted with the taxonomists that previously described species of *Chionochloa*, in which the letter 'a' accounts for three species (*C. acicularis*, *C. antarctica*, *C. australis*) and the letter 'c' several more (*C. cheesemanii*, *C. conspicua*, *C. crassiuscula*). Worse still is the subtle difference between *Chionochloa flavicans* and *C. flavescens*.

So when it came to our new species, names that began with the letters a, b, c, d, f, h, j, l, m, o, p, r, s, t, and v were out. Furthermore, the letter k does not occur in Latin, and u, q, w, x, y, and z were deemed unsuitable by Henry... This left g, i, and n to choose from. Henry devoted three hours to the task, and came up with the following options:

galbana – yellowish
galbinea – yellowish
gelida – reference to icy cold places
gilva – pale yellow
inertans – not wandering far
nivea – of or from snow
nivifera – covered with snow
nutifera – cloudcapped, for the mountains
nupena – new, recently found

Of these Henry preferred galbana, nivifera, and gelida in that order. I didn't like galbana or gelida, but nivifera was almost sibilant and perhaps reminiscent of wind through the tussock. Besides that, it was an accurate description of our new tussock species' habitat, as our newly described *Chionochloa nivifera* was frequently found in habitats in which snow lies late.

Another person who became interested in my research was Polly Stupples, who was writing an article on tussocks. When she learned of my tussock studies through a mutual acquaintance I invited her on a tussock collecting trip to provide material for her story, which was later published in *New Zealand Geographic* magazine (Stupples 2003).

My substantial collection of grasses also provided an opportunity for others to work on them, and Ray Marx, a keen geology student, ground specimens of each one up to extract phytoliths, which are aqueous silica deposits laid down within the leaf cells. These deposits occur in a range of shapes and sizes, and these different phytolith morphologies had been formally classified according to international standards. Ray's work was duly written up and published (Marx *et al.* 2004).

So after three years of postdoctoral fellowship I had established a good publishing record, and had been well received by the international community of grass researchers. There weren't too many of us in this category and I was keen to carry on working as a scientist and explore this niche more deeply. My fellowship had given me a wide range of skills, particularly with respect to experimental design and grass identification, and I had become a much more efficient researcher.

The only trouble was that Landcare Research didn't have a job for me at the end of the fellowship. This was a fairly common phenomenon for FRST-funded postdoctoral fellowships at this time, with host institutions rarely having any sort of process to help you progress your career. Postdoctoral fellows were taken on as permanent staff in some cases, but generally on an ad-hoc basis. I understand that there has been some resolution of this problem in more recent years, and longer term funding has also helped to reduce uncertainty over the longevity of research programmes. The outstanding work of young scientists is also recognised professionally by awards of the 'best young researcher' type. These changes are definitely heading in the right direction. I don't know what systems are available elsewhere in the world, but if we want to make science an attractive career option, we have to provide pathways so that young scientists can forge such careers.

At the end of my fellowship I was lucky enough to get a job as an ecological consultant, working for a company who rented space in the same building. In effect I moved two doors down the corridor, which I was very happy about as the staff from the different organisation in our building were a friendly, humorous and supportive bunch.

I noticed several differences as a consultant. Firstly, you get thanked a lot for doing your job, something which rarely happens as a scientist. This is because as a consultant, you are performing expert services for clients, and they greatly appreciate your assistance. Ecological consultants are also at the cutting edge of resource management decision-making, and before long I found myself influencing the outcomes of weighty Environment Court cases.

Some of the scientific papers I appreciate the most are those that describe basic ecological patterns and processes at defined

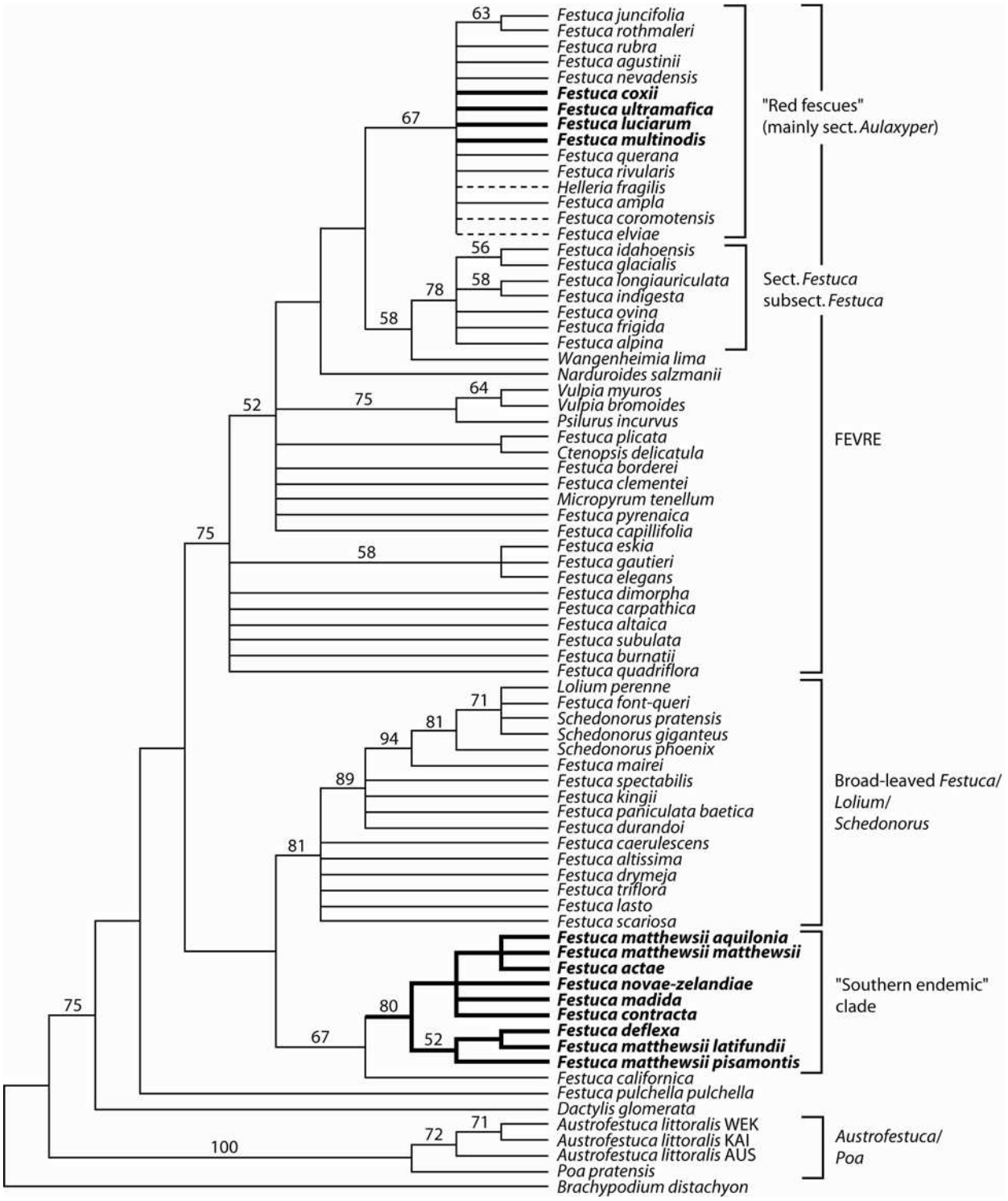

Figure 2. Estimated family tree of* Festuca *and related genera, showing endemic New Zealand species (bold type) in two distinct groups with independent evolutionary history. Numbers on the diagram are bootstrap values, which illustrate the strength of support for each branch of the tree: the higher the number, the greater the confidence that the branch actually exists.

locations. These descriptive papers have become a bit of a rarity these days. I also found I was a much poorer botanist than I had thought I was. A major difference between science and consultancy work is that in science you examine the things you are interested in, whereas in consultancy you examine things that your client is interested in. This results in a considerable broadening of botanical expertise. As an ecological consultant, you also need to have well-rounded skills. A botanist has to be able to identify birds as well as plants. But the key skill is understanding ecological processes, and being able to work out the factors that drive vegetation and habitat differences. This is essential to understanding the effects of development activities on ecosystems. I have found that I am a good ecologist, and I am sure my scientific training has a lot to do with this. As an ecological consultant I enjoy a lot of variety in my work, but balancing the requirements of multiple short deadlines takes some getting used to, as does balancing job budgets!

I have been an ecological consultant for five years now, but I have remained an Honorary Research Associate at Landcare Research, and continue to work away at publishing the large amount of unpublished data that was left at the end of my fellow-

ship. I struggle to find the time to write up this material, but have successfully farmed my data out to collaborators who have had the time to do so. One of the most successful collaborations has been with Peter Linder's group of grass researchers, chief among them Michael Pirie, a courteous and friendly Englishman who, with the aid of my tussock samples, achieved a well-resolved family tree of *Chionochloa* (Pirie *et al.* 2008 and other papers in review). This has been especially pleasing, given my repeated frustrations trying to sequence *Chionochloa* DNA during my postdoctoral fellowship. It turned out that *Chionochloa* DNA is plagued with 'pseudogenes' and had I used different primers this might have been avoided.

I have data for a range of small papers that might be published one day, but what would be really nice would be to get those two big experiments written up and published.

References

Connor, H.E.; Lloyd, K.M. 2004. Species novae graminum Novae Zelandiae II. *Chionochloa nivifera* (Danthonieae: Danthonioideae). *New Zealand Journal of Botany 42:* 531–536.

Edgar, E.; Connor, H.E. 2000. *Flora of New Zealand. Volume 5, Grasses.* Manaaki Whenua Press, Lincoln.

Hunter, A.M.; Orlovich, D.A.; Lloyd, K.M.; Lee, W.G.; Murphy, D.J. 2004. The generic position of *Austrofestuca littoralis* and the reinstatement of *Hookerochloa* and *Festucella* (Poaceae) based on evidence from nuclear (ITS) and chloroplast (*trn*L-*trn*F) DNA sequences. *New Zealand Journal of Botany 42:* 253–262.

Lloyd, K.M.; Lee, W.G.; Wilson, J.B. 2002a. Competitive abilities of rare and common plants: comparisons using *Acaena* (Rosaceae) and *Chionochloa* (Poaceae) from New Zealand. *Conservation Biology 16:* 975–985.

Lloyd, K.M.; Lee, W.G.; Wilson, J.B. 2002b. Growth and reproduction of New Zealand *Acaena* (Rosaceae) species in relation to rarity and commonness. *New Zealand Journal of Ecology 26:* 149–160.

Lloyd, K.M.; Lee, W.G.; Fenner, M.; Loughnan, A.E. 2003a. Vegetation change after artificial disturbance in an alpine *Chionochloa pallens* grassland in New Zealand. *New Zealand Journal of Ecology 27:* 31–36.

Lloyd, K.M.; Wilson, J.B.; Lee, W.G. 2003b. Correlates of geographic range size in New Zealand *Chionochloa* (Poaceae) species. *Journal of Biogeography 30*: 1751–1761.

Lloyd, K.M.; Hunter, A.; Draffin, S.; Orlovich, D.A.; Lee, W.G. 2003c. Phylogeny and ecology of New Zealand *Festuca* species. Third International Conference on the Comparative Biology of the Monocotyledons and the Fourth International Symposium on Grass Systematics and Evolution, 31 March- 4 April 2003. Ontario Convention Centre, Ontario, California, USA.

Lloyd, K.M.; Lee, W.G.; Walker, S. 2006. Takahe Valley Hut: a focal point for weed invasion in an isolated area of Fiordland National Park, New Zealand. *New Zealand Journal of Ecology 30:* 371–375.

Lloyd, K.M.; Hunter, A.M.; Orlovich, D.A.; Draffin, S.J.; Stewart, A.; Lee, W.G. 2007. Phylogeny and biogeography of endemic *Festuca* (Poaceae) from New Zealand based on nuclear (ITS) and chloroplast (*trn*L–*trn*F) nucleotide sequences. *Aliso 23*: 406–419.

Lloyd, K.M.; Pollock, M.L.; Mason, N.W.H.; Lee, W.G. (submitted). Leaf trait-palatability relationships differ between ungulate species: evidence from cafeteria experiments using naïve tussock grasses. Submitted to the *New Zealand Journal of Ecology*.

Pirie, M.D.; Humphreys, A.M.; Galley, C.; Barker, N.P.; Verboom, A; Orlovich, D.; Draffin, S.J.; Lloyd, K.M.; Baeza, M.; Negritto, M.; Ruiz, E.; Sanchez H.C.; Reimer, E.; Linder P. 2008. A novel supermatrix approach improves the resolution of phylogenetic relationships in a comprehensive sample of danthonioid grasses. *Molecular Phylogenetics and Evolution 48*: 1106–1119.

Marx, R.; Lee, D.E.; Lloyd, K.M.; Lee, W.G. 2004. Phytolith morphology and biogenic silica concentrations and abundance in leaves of *Chionochloa* (Danthonieae) and *Festuca* (Poaeae) in New Zealand. *New Zealand Journal of Botany 42:* 677–691.

Stupples P. 2003. Fields of gold. *New Zealand Geographic 66*: 22–48.