Lucy Cranwell Lecture 2005 – Biosystematics – more than providing a name

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"Discovery and description"

New Zealand has a rich history of botanical discovery and description of its flora, with the first voyages made by Captain Cook including naturalists such as Daniel Solander, Joseph Banks, Johann Forster, and Georg Forster. Plants collected by these naturalists formed the backbone of the early floras of New Zealand, including *Florulae Insularum Australium Prodromus* by G. Forster (Forster 1786) and the *Handbook of the New Zealand flora* by J. D. Hooker (Hooker 1864; Hooker, 1867). The more recent New Zealand flora's have relied much more extensively on plant collections and research by botanists resident in New Zealand, including T. Kirk (*The students' flora of New Zealand and the outlying islands*), T. F. Cheeseman (*Manual of the New Zealand flora*), and the authors of the five volume *Flora of New Zealand* series published between 1961 and 2000 (Allan 1961; Moore & Edgar 1970; Healy & Edgar 1980; Webb et al. 1988; Edgar & Connor 2000). These floras provide a wealth of information that is used, for example, by students, farmers, and gardeners for understanding New Zealand's biodiversity.

The flora treatments provide the latest information up to the time they are published, but subsequent field work, plant collections, and detailed study of character variation and plant distributions frequently provides new insights into relationships among plants. Therefore, taxonomic research on many groups of New Zealand plants is an ongoing process, and for some groups, such as the herbaceous *Myosotis*, *Craspedia*, and *Cardamine*, there is not a comprehensive, modern, and thorough taxonomic revision. The "discovery and description" of the New Zealand flora is very much incomplete, and although over 2000 indigenous New Zealand plants have been named it is estimated that about another 15% (c. 300) have yet to be formally named and described. Some of these unnamed species have been given informal "tag names", but these have not been the subject of careful and rigorous scientific study which is required before a new species should be named.

Since the early 1990's there has been a renaissance in flowering plant taxonomy, and from this time over 156 new species, subspecies, and varieties of New Zealand plants have been named. Much of this recent research has been on grasses, threatened species, and species-rich genera which lacked a modern taxonomic treatment. Although many of the new species have been previously known by tag names, a number are completely new discoveries that have been made by careful and detailed observation. From my research (and that of my collaborators) these include species such as *Sophora godleyi* (Heenan et al. 2001), *Uncinia perplexa* (Heenan & de Lange 2001), *Arthropodium bifurcatum* (Heenan et al. 2004), *Myrsine umbricola* (Heenan & de Lange 2004), *Olearia adenocarpa* (Heenan & Molloy 2005), and *Pseudowintera insperata* (Heenan & de Lange 2006).

During the course of undertaking taxonomic research many biological attributes of the plant group (e.g., genus or species) being studied are often investigated in detail. Such attributes include, for example, leaf and wood anatomy, breeding system, phenology, hybridisation, and DNA variation. This information is usually an essential and critical part of the taxonomic decision making process, but it is also very valuable for understanding other aspects of the group, such as conservation biology and evolutionary processes. Two examples are now discussed whereby general taxonomic information is utilised for the conservation of *Olearia adenocarpa* and in the development of *Pachycladon* as a model plant for understanding evolutionary processes.

Olearia adenocarpa: conservation

An unnamed *Olearia* from the Canterbury plains was first recognised as potentially distinct in August 2002. This was subsequently named as *O. adenocarpa*, and a conservation assessment recommended it be listed as Nationally Critical (Heenan & Molloy 2004). Over 600 plants are known of this species but the majority of these are severely browsed by cattle, sheep, hares, and rabbits. The paper describing this *Olearia* included information of relevance to its conservation biology, including plant growth habit, age (growth rings), height, stem number, wood anatomy, and phenology. Furthermore, detailed description of its habitats and distribution was presented, and issues and opportunities for conservation management presented.

At the time of its discovery, only 11 mature plants of *O. adenocarpa* were considered to be capable of sexual reproduction and therefore research on its breeding system was considered to be critically important to its long term survival. This research has been undertaken, and the species has been shown to have a mixed breeding system that includes self-compatible and self-incompatible plants (Heenan et al. 2005). The self-compatible plants most probably occurred by the loss of self-incompatibility. The progeny of self-compatible plants have been shown to suffer from inbreeding depression, as about 25% of the progeny of selfed self-compatible plants were runts. Since *O. adenocarpa* is probably naturally self-incompatible, populations comprising large numbers of plants (at least 50 individuals) are required to ensure successful outcrossing.

Two areas comprising about 36 hectares and including about 250 plants of *O. adenocarpa* have been fenced with stock and rabbit/hare proof fencing. Since the fence was completed in August 2004, plants have had two growing seasons and their recovery has been very successful. New shoots have emerged from at and below ground level, and plants that were once severely browsed to only a 2–3 cm high are now 30–50 cm high.

Replanting inside the fenced areas with one-year-old nursery raised plants of *O. adenocarpa* has been undertaken in August 2004 and July 2005 by the Canterbury Botanical Society. This has only been partially successful, with about 10% of the plants surviving. To address this problem research is planned on the suitability of different potting mixes for nursery raised plants, particularly in regard to plant growth and establishment after being planted out. Further research is also planned on the ecophysiology of *O. adenocarpa*, including water stress, photosynthesis, and respiration. This research is part of a collaborative project involving Lincoln High School year 13 students, Landcare Research, and Lincoln University.

***Pachycladon*: developing a New Zealand model for understanding plant species and adaptive radiations**

Generic and species relationships in the Brassicaceae have traditionally been based on morphological characters that are now known to exhibit considerable convergent evolution and homoplasy. Therefore, to further understand relationships of the New Zealand species we began in 1998 a study using nrDNA ITS sequence data. All genera and most Brassicaceae species from New Zealand were sequenced (Mitchell & Heenan 2000). The outcome of this phylogenetic research and subsequent reappraisal of generic boundaries is that New Zealand now has 5 genera and only about 30 species that belong to the family Brassicaceae. *Cardamine* (including *Iti*; Heenan 2002), *Lepidium*, and *Rorippa* are cosmopolitan genera with mostly endemic NZ species. *Notothlapsi* is a New Zealand endemic alpine genus with two species, and *Pachycladon* occurs in New Zealand and Tasmania. On the basis of the phylogenetic research and a reassessment of morphological characters, *Pachycladon* was recircumscribed to include the genera *Cheesemania* and *Ischnocarpus*, and now comprises 8 endemic South Island species, with an additional species in Tasmania (Heenan et al. 2002).

An intriguing aspect of the phylogenetic research is that *Pachycladon* is related to *Arabidopsis thaliana* (Mitchell & Heenan 2000; Heenan et al. 2002), the model plant for much current genetic and molecular research. The monophyly of the *Pachycladon* complex and its relationship to *Arabidopsis* has subsequently been confirmed by the analysis of additional molecular markers, including *rbc*L, *gap*C, *FRIGIDA*, and *trn*L-*trn*F (McBreen & Heenan, submitted). Based on the close relationship between *Pachycladon* and *Arabidopsis*, *Pachycladon* is considered to have the potential to be a model genus for gaining a deeper understanding of species and adaptive radiations in New Zealand. In particular, the *Arabidopsis* genetic and molecular resources are likely to be well-suited to being used in *Pachycladon*.

Species of *Pachycladon* comprise several distinct morphological characters and distributional attributes that also make *Pachycladon* a suitable candidate to study the genetic and molecular basis of species and adaptive radiations. These characters include, for example, three leaf types: heteroblastic, serrated, and lobed; growth habit: polycarpic or monocarpic; fruit: laterally compressed and the seeds uniserate, biseriate, or terete; winged or not winged. The monocarpic species can take several years to flower in the wild and grow as rosettes until doing so. Under ideal conditions, such as provided in cultivation, the polycarpic species can flower only a few months after being grown from seed – they are long day plants.

Pachycladon species mainly grow on shaded south facing rock bluffs, but they grow in soils derived from different parent material rock types (Heenan & Mitchell 2003). There are three groups of *Pachycladon* with different distributional and substrate preferences. These include species that are restricted to either schist (e.g. *P. novae-zelandiae*) or greywacke (e.g. *P. enysii*), and others that are generalists (e.g. *P. cheesemanii*), occurring on a wide range of substrates such as schist, greywacke, marble, limestone, and basalt.

In addition to the taxonomic, phylogenetic, and biogeographic research that has been published on *Pachycladon*, there are several other studies on the biology of the genus and these further highlight its usefulness as a model genus. Seed anatomy and morphology has been described by Garnock-Jones (1991a). A feature of this study is the similarity of the seeds among the different species, with the main differences being that the embryos of some species have accumbent or incumbent radicles and some species have a distinctive apical wing. The breeding systems are notable for the occurrence in *P. exilis* of meiotic parthenogenesis and endo-replication (matromorphy), and this mostly occurs when that species is crossed with other species of *Pachycladon* (R. Bicknell & P. Heenan, unpublished data). During the matromorphy study we also successfully transformed *P. exilis* by the insertion of the Green Fluorescent Protein (GFP) and kanomycin genes. Gynodioecy is also known to occur in two species, *P. stellata* and *P. wallii* (Garnock-Jones 1991b; Heenan & Garnock-Jones 1999). Embryology has been examined for one species, *P. exilis*, and this follows a sequence of events very similar to that of *Arabidopsis* (Luo et al. 2003). One significant difference from

Arabidopsis is an unusual delay of seven days after anthesis until the first division of the endosperm nuclei. Amplified Fragment Length Polymorphism (AFLP) data for most species of *Pachycladon* indicate that greater genetic variation was found among populations and within species than within populations (Mitchell & Heenan 2002). Because of this variation, AFLP methods are therefore suited to a range of studies involving genetic variation, and in particular for implementing fingerprinting and mapping populations. Artificial interspecific F1, and some F2, hybrids have also been generated between species previously assigned to the genera *Cheesemania*, *Ischnocarpus*, and *Pachycladon* (Heenan 1999).

In addition to the features outlined above, other attributes of *Pachycladon* are their short-lived evergreen perennial growth habit, they are relatively easy to cultivate, some (e.g. *P. exilis*) can produce up to 20,000 seeds in one flowering, the species show little sequence divergence, and are considered to have evolved in the last 1.0–3.5 million years (Heenan et al. 2002).

Although comprising only 8 endemic New Zealand species, with this number being at the lower end of the range for the number of species occurring in a radiation, *Pachycladon* is an ideal candidate to study species and adaptive radiations. In particular, the biological attributes of *Pachycladon* combined with the molecular and genetic resources of *Arabidopsis* provide a unique opportunity to examine the genetic and molecular basis of the evolution of morphological characters and to test biogeographic hypotheses in a New Zealand setting. In regard to the genetic basis of adaptive radiation, research, for example on *Arabidopsis thaliana*, has shown that variation in only a few genes is sufficient for producing a range of morphologies, but it is not known whether this is a common feature of radiations. We intend to test the hypothesis that a few genes are responsible for morphologically and ecologically important variation in *Pachycladon*. Secondly, ecological theory holds that diversifying selection is the cause of adaptive radiations. We will test the hypothesis that diversifying selection has shaped the distribution of genotypes responsible for morphological and ecological differences of large phenotypic effect.

In regard to biogeographic hypotheses' two main themes emerge. It is now generally accepted that virtually the entire New Zealand flora has originated from long-distance dispersal (Pole 1994), and in the case of *Pachycladon* the closest relatives are *Transberingia* and *Crucihimalaya* (Heenan et al. 2002). Comparative research of morphological, molecular, and genetic data for these three genera could test the hypothesis that immigration selection, the non-random selection for particular biological traits, has been important in the establishment and radiation of *Pachycladon* in New Zealand, and its subsequent dispersal to Tasmania. In New Zealand the geological and climatic history has been dominated in recent geological times by two phenomena. Firstly, the uplift of the Southern Alps of the South Island during the Pliocene and, secondly, by Pleistocene glaciation. Both of these events have had a major impact on the evolution and distribution of the indigenous New Zealand flora. For example, centres of endemism in southern and northern South Island have been considered to be either glacial refugia or tectonically stable areas. Species of *Pachycladon* occur in these regions and have distribution patterns that are typical of other species radiations in New Zealand, and are therefore suited to testing these hypotheses.

New Zealand also has a very diverse geology, including sedimentary schist, greywacke, and limestone rocks, andesitic and basaltic volcanics, and ultramafics; many of the adaptive radiations in New Zealand have utilised the diversity of habitats that are available on these different parent materials. *Pachycladon* species occupy specific habitats on some of the different parent materials; some species of *Pachycladon* are habitat generalists and others specialists. We can test whether environmental factors are important drivers for speciation and if they are imposing selection.

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Field trip: Wairoa Dam and the Hunua Falls. 22/04/06

Joshua Salter & Mike Wilcox

Steve and Benjamin McCraith were the leaders for a gaggle of 22 of us on the April field trip to the Hunuas.

Participants: Enid Asquith, Paul Asquith, Robin Asquith, Duncan Benzie, Jan Butcher, Brian Cumber, Frances Duff, Gael Donaghy, Raewyn Faloon, Peter Hutton, Graeme Jane, Mei Nee Lee, Elaine Marshall, Benjamin McCraith (leader 2), Steve McCraith (leader 1), Carol McSweeney, Garry McSweeney, John Millett, Josh Salter (recorder 1), Heather Stone, Alison Wesley, Mike Wilcox (recorder 2), Tony Williams, Maureen Young.

To Wairoa Dam via Suspension Bridge Tk and Cossey-Wairoa Tk, Joshua Salter.

After rendezvousing at Hunua township, we set off at a good clip for the Wairoa Dam. Here we left the vehicles, walking back along Otau Road to the bridge at the start of the track. Although it doesn't appear on my 1978 map (NZMS 260 S12), the suspension bridge looked well weathered (the sign advised a maximum of 3 persons at a time, so we dared not gather in the middle to admire the Wairoa River below). The bridge crosses high enough for a close view of the canopy of a large *Elaeocarpus dentatus* (not in flower or fruit at this time).

Suspension Bridge Track ascends to the ridge-line west of Otau Road, running north until it meets the long-distance Cossey-Wairoa Track. In this part of the Hunua Ranges, the "reverting scrubland" of 30 years ago (Barton 1972) has given way to low regenerating mixed podocarp forest. After an initially steep gradient, noticed by at least some of us, the track eases to a gentler climb. Elaine Marshall spotted a small seedling of mangeao (*Litsea calicaris*) barely 75 mm tall, and higher up was a maire (*Mida salicifolia*) about 2m tall. Without Mike Wilcox's sign on the path, it would have been easily missed. Indeed, its slender stems and widely spaced dark leaves were hard to see even when I was staring straight at it. The high-gloss surface of the leaves and their irregular arrangement clearly distinguished it from a young *Nestegis*, whose leaves are, reassuringly, always opposite (Gardner 1997). Close to where the ridge levelled off, an elevated platform gave views out across farmland to the west and south, and into the Wairoa Valley to the north-east. Here, emergent rewarewa (*Knightia excelsa*) were the most obvious feature of the regenerating forest (Fig. 1). Further along the ridge was a male *Astelia solandri*, perched at waist height, presenting a lax panicle of maroon flowers for our delectation. Not far from this we saw *Cordyline pumilio* growing close to young trunkless *C. banksii*, the latter distinguishable by the reddish midrib and angled secondary veins in its leaves.

Several heaps of gravel were encountered along the track. Although no weeds were evident on the heaps, a single patch of *Selaginella kraussiana* was seen not far from one of them. Another notable weed was the invasive grass, *Miscanthus nepalensis*, lining a more open section of the track along the ridge. The most worrying weed was Himalayan honeysuckle