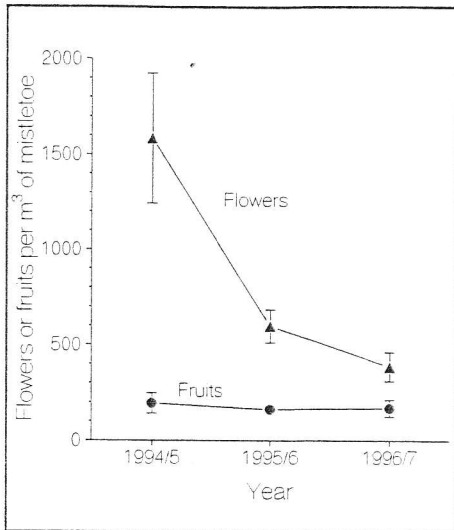


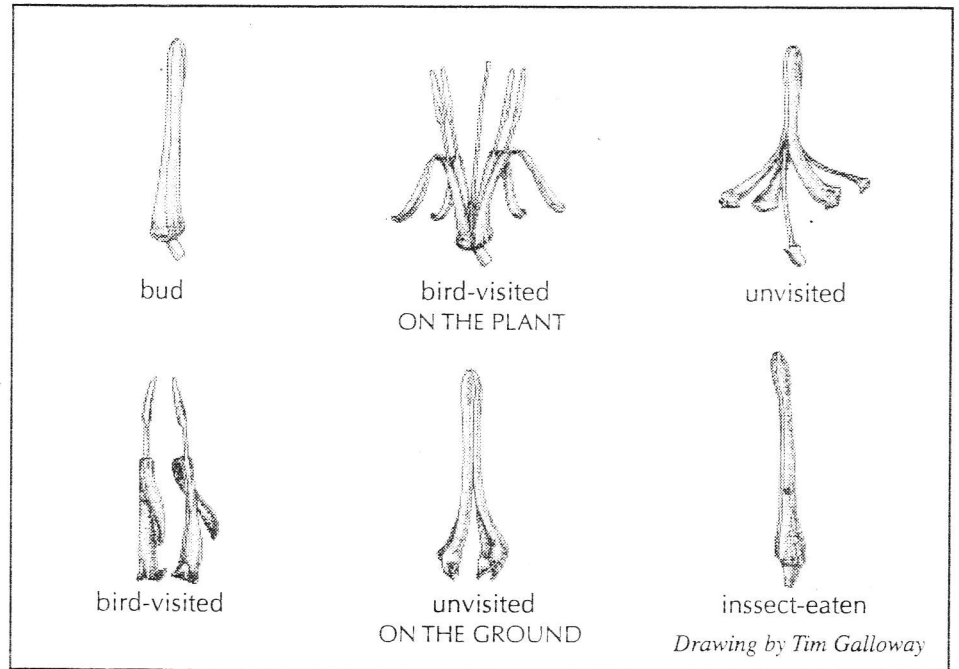
Figure 6. Flower and fruit production per volum of mistletoe foliage of *P. tetrapetala* at Craigieburn over four seasons.



each mistletoe, a branch containing around 100 buds or flowers is selected and marked. The buds or flowers are classified into unripe buds, ripe buds, open flowers, unvisited flowers, already abscised or aborted. The presence of the caterpillar *Zelleria* is also noted. At the same time, approximately 200 flower petals directly beneath a mistletoe are gathered and similarly classified (Figure 7). The ratio of visited to unvisited plus ripe unopened flowers on the plant indicates the rate of flower opening by birds or bees. Several months later, the fruit-set on the marked branch is recorded (Figure 8), and compared to a sample of hand-pollinated flowers.

Visitation rates for the 1997-98 season are presented in Figure 9a. Visitation rates clearly differ throughout New Zealand, with high visitation occurring at Wakefield, while Lake Ohau, the Temple and Kaweka sites showed a serious lack of pollinators. High rates of visitation at Craigieburn were probably mostly due to bees rather than birds. Fruit set also varied across the country and, in general, correlated with visitation rates (Figure 9b). Only the sites with high visitation rates set much fruit.

Figure 7. Different Classes of *Peraxilla* petals.



Bellbird densities at Craigieburn

Declining bellbird numbers have been attributed by some to competition for food particularly for honeydew in South Island black and mountain beech forests. Honeydew is a very important food source for native birds and bees. However, the arrival of common wasps in the 1980's meant that many native species were outcompeted for honeydew access, especially during late

summer. Bellbirds were a particular concern.

David Murphy of the University of Canterbury studied bellbird density and diet at Craigieburn in 1997-98 for his Masters of Science thesis. He found that bellbird density was highest in March and declined throughout the winter, reaching a minimum in October. Invertebrates and honeydew were the biggest portions of bellbird diets,

Figure 8. Fruit-set in *P. tetrapetala*. The sample on the left was not pollinated and did not set fruit



although they largely foraged on mistletoes during flowering and fruiting seasons. It was also discovered that bellbirds spent approximately the same amount of time each day searching for food during all months of the year. Therefore, no evidence was found for food shortage during any particular month.

Thus, neither a lack of food over certain months, nor alternative food sources during mistletoe flowering periods appear to be controlling bellbird densities. Instead, low numbers of bellbirds at Craigieburn are probably caused by predators, particularly stoats. Therefore, new strategies must be implemented to conserve mistletoes. This should include a reduction or elimination of predators of mistletoe pollinators.

Implications of pollen limitation

Pollination failure of *P. tetrapetala* was first unwittingly recorded in 1882 by Field, a road constructor and natural historian. He described a condition for

almost all *P. tetrapetala* flowers he observed near Raetihi, (Central North Island), which we now recognise as unvisited. These flowers clearly were not being visited by birds. At the time, bellbird and tui numbers were at an all-time low throughout the North Island probably because of the rapidly expanding ship rat populations. It did not take long before *P. tetrapetala* became largely absent in this area.⁵

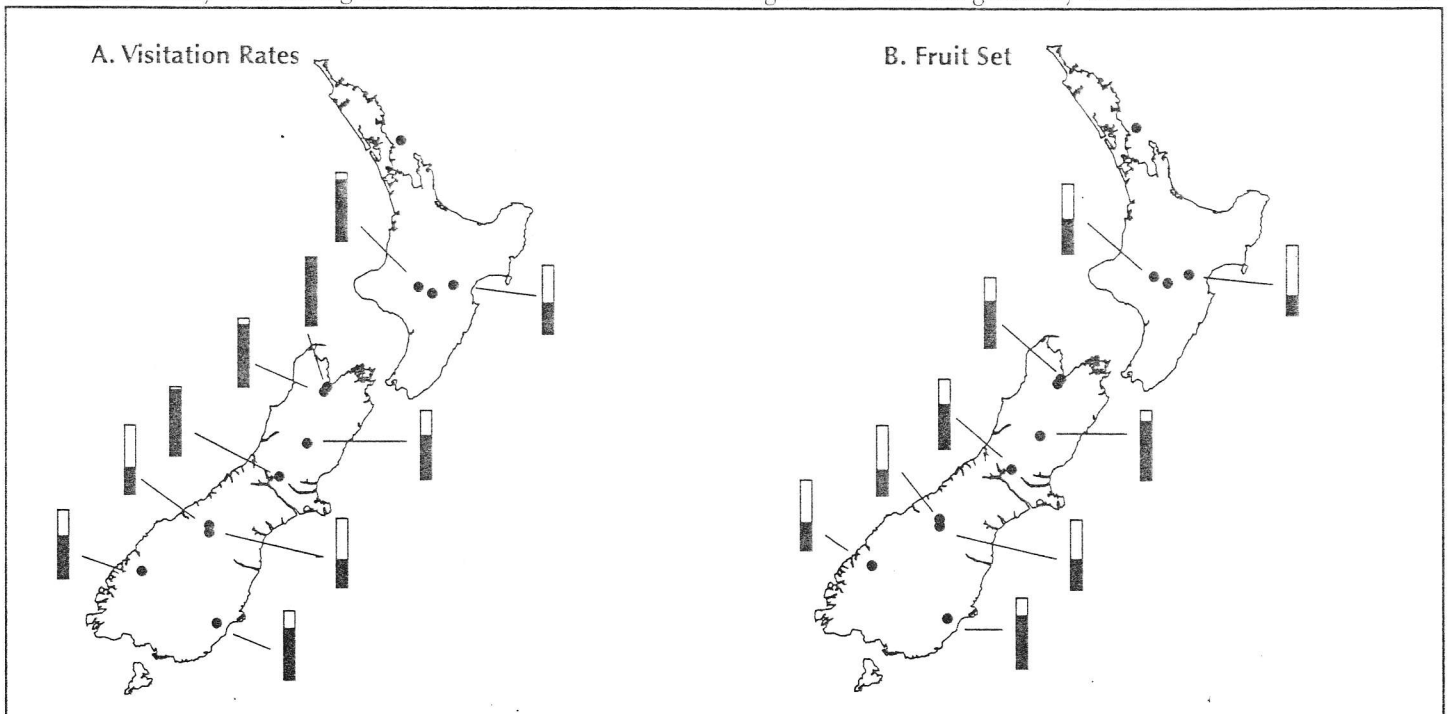
Some plants may be able to compensate for losing pollinating animals by relying on self-pollination. However, *P. tetrapetala* can not fully depend on this, as experiments have shown it ripens less than one-fifth of the flowers into fruits if the flowers are bagged.¹² Although native bees may also assist *P. tetrapetala* pollination and fruit-set, they are still not as efficient as tui and bellbirds. Additionally, they can not regularly open buds of *P. colensoi*. In low flowering years, reduced densities of honeyeaters may adequately cope with pollination, which could explain the persistence of mistletoes in areas with few tui and bellbirds. However,

they do not manage to pollinate many mistletoes during high flowering years, and thus, proportionately fewer fruits are produced.

In predator-free areas such as offshore islands, honeyeaters are much more abundant and can visit flowers of many different plants very frequently. Before introduced predators were released in New Zealand, honeyeater numbers were probably sufficient to pollinate *Peraxilla* spp. more often than at present. Therefore, fruit-set would have been high and mistletoe populations more easily maintained.

All of these results suggest that the decline of some mistletoe populations may be partly due to the breakdown in mutualisms, as well as forest clearance and possum herbivory. They also indicate ways to increase mistletoe numbers. If honeyeater predation is reduced through trapping or poisoning stoats, we may be able to increase bellbird and tui populations. Hopefully, this will allow more successful mistletoe pollination, and thus enhance mistletoe populations.

Figure 9a and 9b. Visitation rates for all mistletoe study sites during the 1997-98 season are shown in figure 9a. Visitation was quite low at Lake Ohau, the Temple and in the Kawekas. This signifies a lack of pollinators in these areas. Fruit-set for all mistletoe study sites during the 1997-98 season are shown in figure 9b. Fruit-set generally correlated with visitation rates.



Dispersal

Biotic and abiotic factors are important to the dispersal, germination and establishment of both Peraxilla spp. and A. flavida. Birds must find and eat mistletoe fruits and deposit seeds on other suitable host trees. Also, establishment sites must include sufficient lighting conditions, as establishment rates are much higher in light environments than in heavy shade.¹⁴ However, continued decline in bird densities may render the dispersal of mistletoe fruits inadequate in the future.

Dispersal quantity and quality

New Zealand mistletoes are fleshy (Figure 10), and contain a single seed coated in a sticky viscin layer.⁴ They are dependent on bird dispersal, primarily by endemic tui and bellbirds, and to some extent, the native silvereye (*Zosterops lateralis*). The seeds will not germinate unless the fruit wall is removed by passage through the gut of a bird. Introduced birds, such as blackbirds, rarely eat *Peraxilla* and *A. flavida* fruits, and so are numerically unimportant to their dispersal.

Recent work on dispersal by the team at Craigieburn suggests that the resident bellbirds are able to disperse most of the fruit produced. In 1996, only 3.1% of *P. tetrapetala* fruits were not eaten by dispersers, and in 1997, 1.5% *A. flavida* fruits and 4.1% of *P. tetrapetala* fruits were not eaten.

Dispersal quality must also be considered along with the quantity of seed dispersal. Dispersed seeds must land in germinable condition in a safe site.⁴ The behaviour of bellbirds and tui make them well suited to fruit dispersal. Honeyeaters tend to eat a few fruits each visit, and with gut passage of 30-60 minutes, most mistletoe seeds

Figure 10. *P. colensoi* fruits, Wakefield



will be deposited at a distance from the parent. Also, tui and bellbirds tend to perch in high branches, which increases the chance of defecated seeds falling on other suitable host branches.

Establishment and growth

Generally, the establishment of new seedlings of New Zealand mistletoes is quite slow compared to tropical species.⁴ *P. tetrapetala* and *A. flavida* may be 6 to 8 years old before they first begin flowering. High mortality in the first few months of the mistletoe lifecycle (between germination and establishment) adds to the uncertainty of establishment. Ladley and Kelly (1996) found that only 15% of germinated *P. colensoi* seeds survived the first 12 months.⁴

Are New Zealand mistletoes dispersal limited?

Tui and bellbirds can pollinate and disperse *Peraxilla* spp. and *A. flavida*. Therefore, a breakdown in pollination mutualisms could also signal changes in dispersal mutualisms - if bird densities are low for pollination, they will probably also be low for dispersal. However, a critical difference is the

relative duration of the flowering period compared to the fruiting period. The flowering season is normally very short, (2 to 3 weeks), while fruiting can last for several months during the autumn and winter, depending on each mistletoes species. (*A. flavida* fruit ripens between April and June, while *P. colensoi* fruit matures from April to September, and *P. tetrapetala* from May to November).⁴ For example, flower ripening rates for *P. tetrapetala* at Craigieburn were generally 116-574 flowers m⁻³ per week, while fruit ripening rates were around 15-22 m⁻³ fruits per week. Therefore, in abundant flowering seasons at sites with few honeyeaters, birds will be unable to efficiently pollinate so many flowers in such a short time. In contrast, a longer fruiting period allows small numbers of tui and bellbirds to adequately disperse most mistletoe fruits. Currently, then, beech mistletoes are more likely pollen-limited rather than dispersal-limited. However, in the long-term, declining honeyeater densities could threaten mistletoe regeneration at some sites through both parts of the reproductive cycle.

Fragmentation effects on beech mistletoes

Habitat clearance has clearly been detrimental to the preservation of native mistletoe species, although the repercussions of fragmentation are not as straightforward as previously thought. Recent research suggests that the habitat fragmentation per se that has accompanied the clearance of Canterbury beech forest may not actually be a threat to mistletoe persistence. Investigation into these effects need to be studied, though, as other factors, such as disturbance, can cause further complications.

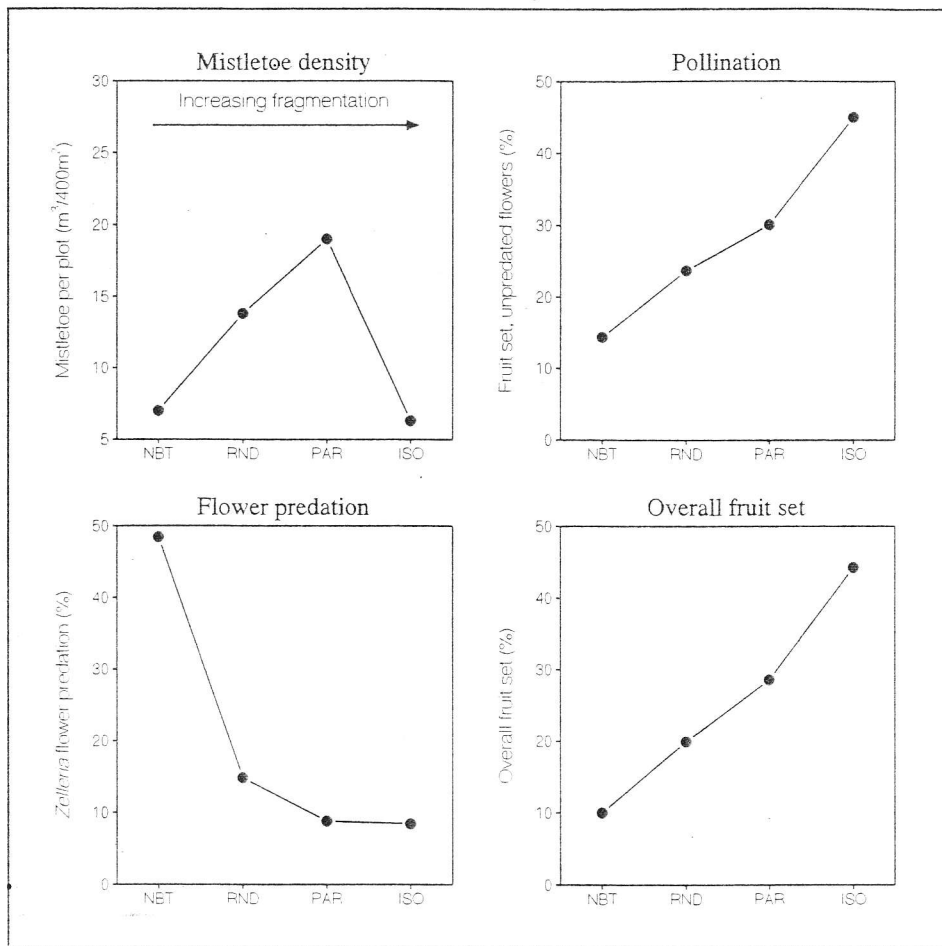
Fragmentation can significantly alter ecosystem processes, including water, nutrient and energy cycling within a remnant patch.²² Plants in small populations may be inhibited by fragmentation due to increased vulnerability to biological invasions, catastrophic events, (severe weather, fire, etc.), grazing and timber harvesting. However, the main factors controlling New Zealand mistletoe distribution in beech forests are light levels and bird behaviour. In disturbed forest and on forest edges, light levels are higher and bird activity may be greater. Therefore, mistletoes may thrive in fragmented landscapes due to changing disturbance patterns over time and space.

For example, beech mistletoes frequently can be found in patchy and even isolated populations. In the South Island, *A. flavida* and *P. tetrapetala* commonly increase in density along forested edges of highways, access roads, and tracks that dissect continuous areas of mountain/black beech forest. *P. colensoi* also has similar distributions

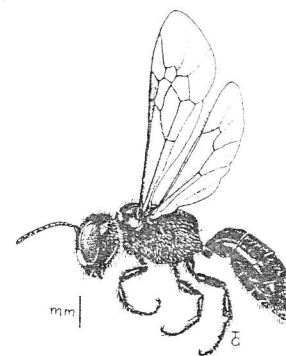
in patchy, but long-standing, silver beech forest remnants.¹⁵

The effects of fragmentation on *P. tetrapetala* was monitored by the team over the 1997-98 season at the Lake Ohau/Temple area of the South Island (Figure 11). Mistletoe density and reproduction was measured in sites of increasing fragmentation. Percentage flower predation by *Zelleria* was also measured. Overall, fruit-set was highest in the most isolated plants, as they were pollinated more often and were the least predated and mistletoe density was highest in the partly fragmented sites. However, Norton et al. (1995) discovered that fragmentation effects on Western Australian mistletoes can be complex.²² They believe that distribution patterns and scales of patchiness in the pre-fragmented landscape must be reconstructed to accurately predict mistletoe response to fragmentation. Certainly, young host

Figure 11. Fragmentation effects on *P. tetrapetala* at Lake Ohau/the Temple, 1997-98



trees must be present in order to keep host and mistletoe populations healthy. Disturbance factors in these areas can also confound fragmentation effects. For instance, grazing can compact the soil and change water availability to both the host species and mistletoes. The full consequences of fragmentation on the distribution of New Zealand mistletoes therefore requires more work.



Hylaeus agilis – one of the native bees that have been observed opening *P. tetrapetala* buds (see page 6).

Drawing by Tim Galloway

Conservation of New Zealand Mistletoes

*The conservation of New Zealand's unique mistletoes will depend on correctly identifying the agents of decline in each of the remaining localities. We have seen that, although undoubtedly significant in some areas, possums may not be the only threat. Pollen limitation may threaten the persistence of some of the best remaining *Peraxilla* populations. Continuing research over the next six years will hopefully provide us with more information and ways to protect our mistletoes, as they are such valuable species to New Zealand.*

Why conserve New Zealand mistletoes?

Loss and severe decline in most North Island *Peraxilla* sites has occurred for some time, primarily due to possums, habitat loss and honeyeater predation by introduced animals.³ Varying mistletoe densities in the South Island in part reflect tui and bellbird populations. Therefore, conservation of mistletoes and honeyeaters are inherently linked. If bird populations are not maintained or increased, beech mistletoes, especially *P. tetrapetala* and *P. colensoi*, may be at risk.

Learning behaviour in birds should also not be ignored. For instance, a solution to enhance North Island *Peraxilla* populations has involved tree banding. Although flowering increased in some of these locations due to declines in possum browsing, in the first season many flowers still did not open. This suggests that honeyeaters in the area may take some time to re-learn how to open these flowers.¹¹

Overall, then, *Peraxilla* spp. and *A. flavida* may be seriously threatened in some places. The beech mistletoes are highly specialised and depend on native birds, and to some extent, native bees, for efficient pollination,³ and loss of

these mutualistic interactions may have detrimental consequences for entire ecosystems.

Ecosystem management

At the ecosystem level, current mistletoe densities may mirror the combined effects of forest fragmentation and composition, possum densities and herbivory levels, as well as honeyeater numbers. Therefore, mistletoes may be used to indicate the ecological health of an area.

Short-term solutions, such as tree-banding of particular host-trees, and individual mistletoe plant caging to prevent possum predation, are no longer viable. These techniques are expensive over large areas and in the long-term.¹ Instead, preventative methods which address an ecosystem approach to mistletoe conservation is probably the most efficient way to incorporate both the direct and indirect causes of current mistletoe populations.¹

For example, both the direct effects of possum herbivory on mistletoe decline, as well as the indirect influence of predators on pollinating and dispersing species, have to be understood in relation to each other. Presently, integrated pest management may be the best solution to enhance both mistletoe populations and ecosystem condition. Reintroduction of mistletoes into former ranges could also be implemented if the factors that controlled pre-human distributions in New Zealand are also considered.¹

Where do we go from here?

With the continuing assistance from the Public Good Science Fund, investigations into the ecology and conservation of New Zealand mistletoes are continuing. Two new experiments are planned for the Craigieburn *P.*

tetrapetala site - first trapping for honeyeater predators (mainly stoats), to see if bellbird numbers and, subsequently, mistletoe pollination, increase. The other experiment involves enhancing fruit-set, which will allow the number of fruits/number of seedlings relationship to be fully explored.

Bird densities at each site during the mistletoe flowering period will be quantified using a line-transect or point-centred method. Preliminary trials of the bird-line transect began during the summer of 1997-98, and the technique will now be refined and implemented. It will then become possible to see how bird densities change over time and how bird numbers affect mistletoe pollination on a broad scale.

It is also crucial to understand how other plants with mutualistic dispersal mechanisms are important to forest ecosystems. Therefore, regeneration of other native New Zealand plants will be studied and compared to mistletoes to find if they are pollination or dispersal limited. For example, investigations will continue from a recent thesis on the reproductive ecology of *Fuschia excorticata* by Kate McNutt (Massey University).

Obviously, much more work remains to be carried out on New Zealand's Loranthaceous mistletoes so we can better understand and conserve these invaluable species for generations to come.

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