# HABITAT CHARACTERISTICS, POPULATION STRUCTURE AND REGENERATION STRATEGY OF THE ENDANGERED SMALL TREE *PITTOSPORUM PATULUM*

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## INTRODUCTION

*Pittosporum patulum* is a small, uncommon, enigmatic tree endemic to New Zealand's South Island. Currently, *P. patulum* is distributed from northwest Nelson and inland Marlborough in the north to the head of Lake Hawea in the south (Townsend 1999). Except in northwest Nelson, all occurrences are to the east of the main divide. However, the distribution is not continuous with major discontinuities between northwest Nelson/Marlborough and north Canterbury, and between north Canterbury and south Canterbury/Otago. Where it is present, *P. patulum* is commonly found in association with mid-to-high altitude beech forest where it is present either under the canopy, on rocky bluffs, or in nearby scrub.

*Pittosporum patulum* grows to a maximum height of c. 6 m but is most frequently observed as tall slender seedlings or saplings. The foliage of *P. patulum* is heteroblastic; juvenile leaves are very dark green, coarsely toothed, leathery, linear and often lobed in shape, and 2-5 cm long, while adult leaves are linear-oblong with entire to crenate margins, and 4-7 cm long (Allan 1961; Eagle 1982; Wilson and Galloway 1993; Poole and Adams 1994). *P. patulum* exhibits strong apical dominance, resulting in long slender seedlings and adults with straight trunks and limited lateral branching.

It is likely that in pre-human times *P. patulum* was naturally uncommon but locally abundant, occurring at scattered sites primarily east of the South Island main ranges. However, its present conservation status of "Endangered" (de Lange et al. 1999) reflects its much more restricted distribution today, which has been largely attributable to browse by introduced herbivores and habitat destruction (Townsend 1999). Heavy browse of adult plants has meant that *P. patulum* populations at many sites comprise mainly seedlings and small saplings. The apparent absence of mature trees at these sites is likely to become a serious concern if current trends of low seedling growth and infrequent recruitment continue. Reflecting the current status of this species, the Department of Conservation has published a recovery plan for *P. patulum* (Townsend 1999) that outlines management actions that are needed to improve the status of this species.

The present study investigates several aspects of the ecology of *Pittosporum patulum* as a basis for enhancing its conservation. Specifically this paper addresses the following questions:

1. What are the characteristics of the vegetation and environment associated with *P. patulum* populations? A description of preferred *P. patulum* habitat might highlight likely areas in which to search for additional populations. Additionally, a description

of the range in *P. patulum* habitat may help identify representative areas for conservation, which is an established goal for the conservation of this species (Townsend 1999).

2. What is the population structure of *Pittosporum patulum* at sites throughout the South Island? Initial observations indicate an absence of mature trees at a number of sites where seedlings and saplings are present. Evidence of cohort establishment and the presence of recent regeneration may provide insights into the regeneration ecology of this species.

3. Are populations of *P. patulum* situated in areas that have experienced significant disturbance? If this is found to be true it would indicate that disturbance is required in order for *P. patulum* to regenerate successfully.

## STUDY SITES

*Pittosporum patulum* populations were studied at six sites, five in Nelson/Marlborough and one in Canterbury (Table 1).

**St Arnaud (populations 1–4)**: Four sub-populations containing a total of 54 specimens were sampled within the boundaries of the Rotoiti Mainland Island, Nelson Lakes National Park in mountain beech (*Nothofagus solandri*) and mixed red-silver beech (*N. fusca-N. menziesii*) forest.

**Tophouse (population 5)**: This site contained only one specimen (an adult) and was adjacent to the main road below Tophouse, approximately 5 km north of St. Arnaud village. The site is situated in a small roadside red-silver beech forest remnant.

**Lee's Creek (populations 6, 7)**: This site is situated in the Wairau Valley, inland Marlborough where *P. patulum* occurs in mountain beech forest. Two sub-populations containing a total of 67 plants were sampled approximately 3 km up the creek from the Wairau River. The Department of Conservation uses this site for *P. patulum* monitoring.

**Cobb Valley (populations 8–10)**: Three groups of *P. patulum* were sampled adjacent to the Cobb River, Kahurangi National Park. The site is mountain beech forest located on gentle slopes and slightly raised humps where the valley sides meet frost flats. Some sub-adults (saplings with some adult foliage at the very top) were present. Thirty-five individuals were sampled. This is also a Department of Conservation monitoring site.

**Mt. Patriarch (population 11)**: The site was above the Chalice-Patriarch road, Richmond Forest Park, in a tongue of mountain beech forest extending down from the ridge-top. The beech forest was surrounded by regenerating scrub, presumably initiated by a fire (burnt stumps present). *Pittosporum patulum* was also present as seedlings and emergent saplings in this adjacent scrub. The total number of individuals sampled was 35. This site is also used by the Department of Conservation for *P. patulum* monitoring.

**South Temple Stream (populations 12, 13)**: This site was in the upper reaches of the South Temple Stream, near Lake Ohau, Twizel. Numerous emergent adults were present in subalpine scrub dominated by mountain celery pine (*Phyllocladus alpinus*), inaka (*Dracophyllum longifolium*), and bog pine (*Halocarpus bidwillii*). Populations were located on slopes originating from slip debris, and river flats; seedlings and saplings were also numerous in the adjacent mountain beech forest. A total of 54 individuals were sampled at this site in two groups.

## METHODS

### Field methods

Each population was defined as an obvious isolated cluster of *P. patulum* individuals. If the spatial distribution was more continuous, as was the case at the South Temple Stream site, a sample comprising 40–50 individuals was arbitrarily chosen to represent the population. The area of the population (the 'site') was defined as a circle or oblong that encompassed the sampled individuals within a boundary that was at least five metres away from individuals at the extremities of the cluster.

The vegetation at each site was sampled using the reconnaissance (recce) plot method of Allen and McLennan (1983). Within each recce plot the cover abundance of the vegetation was assessed in up to four tiers and site factors such as altitude, aspect, slope and drainage recorded. The cover abundance of each vascular plant species was recorded as a cover score relating to a percentage cover interval.

The height of all *P. patulum* individuals within each population was measured. While it is recognised that height is not always the best indicator of age, as height growth can be suppressed by hebivory and low light levels, it is the most sensible measure when dealing with small seedlings and narrow stemmed saplings on which it is impractical to measure diameter. Furthermore, the use of diameter is similarly affected by herbivory and low light levels. The threatened classification of this species precluded direct ageing through stem sections, while stems were too small for coring.

The diameter at breast height (1.4 m) of all canopy trees that occurred within the population site, as well as those that were not rooted within the site but whose canopies extended over the site, were measured.

### Analysis

The plant communities present at each site occur as a result of a combination of different ecological factors. Therefore, comparison of plant communities present at the different sites is analogous to comparing broad ecological conditions. Vegetation composition at each site was compared using detrended correspondence analysis (DCA) to identify dominant floristic compositional gradients independent of other factors. It does this by providing an indirect ordination of the sites by species data matrix. This data matrix is formed by multiplying each species mid-point canopy cover by $\log_{10}$(tier height+1), and then summing across tiers. This gives a scaled matrix consisting of the overall relative abundance of each species at each site. Default options were used in the analyses which were undertaken using the program CANOCO (ter Braak 1987).

Temperature data was estimated by using multivariate regression equations derived by Norton (1985). The equations predict temperature as a function of three variables: latitude, altitude and distance from the nearest coast. Rainfall data was extrapolated from annual rainfall diagrams (N.Z. Meteorological Service 1985).

Height-class versus percentage frequency histograms of *P. patulum* individuals were plotted for each population in order to observe the population structure at each site. Diameter-class versus percentage frequency histograms of canopy trees were plotted for each site in order to observe the size distributions and the presence, if any, of even-aged tree cohorts.

## RESULTS

### Habitat characteristics

All of the populations sampled except one were located within beech forest, the exception being a subalpine shrubland site directly adjacent to beech forest (South Temple Stream). Populations occurred on a wide range of landforms including steep avalanche or slip prone areas, moderately sloped colluvial fans, stable mid-slope areas, river flats and streamside terraces.

The average slope of sites was 22° (range was 2–42°; Table 1). The altitudinal range of the populations was 640–1300 m above sea level, which closely follows the probable distributional limits of 600–1400 m above sea level for *P. patulum* as postulated by Eagle (1982). Only one site (Tophouse) had a southerly aspect, while aspects for all other sites ranged from west to northeast. Mean annual temperature ranged from 6.0–9.3 °C and mean annual rainfall from 1200–2400 mm (Table 1).

Analysis of the associated vegetation showed that eleven of the thirteen populations were very similar floristically as they were clustered close together in the ordination diagram (Fig. 1). All of these sites occur in mountain beech forest. Populations 4 (St Arnaud) and 12 (South Temple Stream) were very different from the others. Population 4 occurred at a site dominated by red and silver beech while population 12 was located in subalpine scrub.

### Population structure

Analysis of the height-class distributions of the 13 populations was limited as many of the populations sampled had too few specimens to obtain a robust pattern of height distribution (Fig. 2). Nonetheless it is clear that most populations lacked adult individuals. Of the northern South Island sites, only population 5 (Tophouse) had a genuine adult specimen but there were no other plants of the species present there. Sub-adults were present in populations 2 (St Arnaud), 10 (Cobb Valley) and 11 (Mt Patriarch), and population 1 (St Arnaud) contained a specimen that was probably an adult before it was browsed to such an extent that only juvenile epicormic shoots persisted. Population 12 (South Temple Stream) was the only one to have adult plants common.

Small seedlings (<250mm) were present at low abundance in populations 1, 2, 3 (all St Arnaud) and 11 (Mt Patriarch), and were abundant in population 7 (Lee's Creek) on the edge of the creek bank. It is likely that most of the small seedlings in population 7 represent recent regeneration because they showed no obvious signs of height suppression by herbivory. Furthermore, small, shallow rooted seedlings would be unlikely to persist for any great length of time at such a site, as floods would soon remove them. The small seedlings at the other sites probably include some recent regeneration as well. However, old seedlings that have been suppressed by herbivory are also likely to be present.

### Site Disturbance

Indicators of past disturbance were present at all sites. Many of the higher altitude sites were located on exposed, sharp spurs that were likely to be disturbed frequently by wind and snow storms as well as land slides. In the lower altitude sites, disturbance was evident as old windfall gaps and flood damage. *Pittosporum patulum* was also observed to regenerate in scrubland induced either by fire or by avalanche.

The diameter-class distributions of canopy beech trees showed a high abundance of small trees for most sites. It might be argued that these small diameters are a result of the harsh climate at high altitudes. However, the presence of a few large trees up to 60 cm dbh at most sites suggests that the dominance of small stems may be more of a result of past disturbance rather than an environmental suppression of growth. Indeed, the size-class distributions of canopy trees associated with all populations, excepting population 13 (South Temple Stream) and those that had no canopy trees present, hint at the presence of cohorts of small beech stems that probably established after a disturbance event. This was exhibited well at population 5 (Tophouse) which was surrounded by small canopy trees whilst being situated at a relatively low altitude. However, this pattern is not reflected in the canopy trees associated with population 13 (South Temple Stream) as they were extremely large considering the altitude of the site. Their large size was probably a result of establishment in a high light environment on the forest edge.

## DISCUSSION

### Limitations

This study involved the sampling of only a limited number of populations. The populations sampled were chosen for several reasons. Ease of access was an important consideration due to restrictions in time available for data collection. Also, large populations were preferentially chosen in order to obtain more robust site and population information. The overall completeness of the study could have been improved by sampling further subalpine scrub populations, some of the Canterbury populations and some populations in the North Temple Stream which contained adults within beech forest (Head 1998). However, the populations sampled did encompass a broad spectrum of habitats; populations were sampled at known upper and lower altitudinal limits, and also over a wide range in slope and exposure. As a result the data obtained are representative of the habitat and distributional range of *P. patulum* and results are indicative of the ecological requirements of this species.

### Habitat characteristics

At a national level, *P. patulum* occupies a very limited habitat range, being primarily restricted to mid-to-high altitude beech forest and associated subalpine scrub on north-facing, sunny sites to the east of the main divide. However, within this restricted habitat distribution *P. patulum* is found on a wide range of landforms and within several vegetation types. The results presented here suggest that *P. patulum* occurs in three main vegetation types: subalpine scrub, short-to-medium height mountain beech forest and tall mixed red-silver beech forest. A cluster of floristically similar sites represented the mountain beech vegetation type and was the dominant vegetation type for the sites studied here. Their similarity was due to the overwhelming dominance of mountain beech in what is a low diversity forest type (Ogden et al. 1996; Dawson 1988). Although these sites were very similar floristically, they varied widely in topography. This wide range of sites included steep, high-altitude slopes, stable, mid-altitude slopes, mid-altitude riparian terraces and rolling, lower altitude hill slopes.

**Population structure**

*Beech forest sites*

When found in beech forest, the population structure of *P. patulum* is dominated by seedlings and saplings with sub-adults and adults being rare or absent. The apparent absence of adult plants, but the presence of populations of seedlings in certain areas, could be explained by several hypotheses:

1.There may be adult plants present in high light areas such as bluffs or slip edges that remain undiscovered and provide a continual seed source for regeneration.

2. Seedlings may have persisted while associated adults have perished due to browse pressure. This scenario would result in patches of seedlings and saplings around the site where the adult or adults once occurred.

3. A seed bank may have been present before the introduction of possums and ungulates. Herbivory may have removed adult plants but continued regeneration could have occurred from the seed bank.

The most likely scenario is a combination of seedling and sapling persistence and continued regeneration from the seed bank. Sites of regeneration are likely to be centred on areas once occupied by adults. Larger saplings probably represent seedlings that established when the adult was present, and smaller seedlings probably represent, to some extent, recent regeneration from seed that has persisted in the soil. This hypothesis is supported by observations from most of the populations sampled in beech forest, as there is a near continuous range from small seedlings to tall saplings present at these sites. The overall population structure for most sites indicates that there is a lower abundance of recent regeneration than would be expected when the abundance of larger size-classes are considered. This could be explained by declining seed availability as a result of very low adult abundance and an exhaustion of the seed bank. However, the long-term viability of the seed in the soil needs to be critically assessed.

*Subalpine scrub site*

The population structure present at South Temple Stream is quite different to that observed in the northern beech forest populations. There are many large adults and a good distribution of smaller saplings and seedlings. The presence of many adults is not definitive proof that this habitat type is superior to the forested sites. Indeed, the presence of adults here may simply be a reflection of past herbivore densities. The forest in the Temple Stream catchment is somewhat geographically isolated from other forest. Surrounding mountains separates it from neighbouring valleys, as does bordering farmland on lower slopes and river flats of the Ohau Valley. This geographic isolation coupled with previous possum control work in the Temple Stream catchment (D. Massam pers. comm. 1999) is likely to have meant that, overall, past herbivore densities have been low. The high abundance of browse-susceptible mistletoes (*Peraxilla tetrapetela* and *Alepis flavida*) in the Temple Stream area probably reflects these lower herbivore densities. The use of mistletoes as an indicator of herbivore densities is backed up by observations made by Head (1998) and others on an inspection of North Temple populations. They found that where adult *P. patulum* specimens were present numerous healthy mistletoes were also present. Conversely, in areas where dead or heavily browsed *P. patulum* adults were found, mistletoes were also observed to be heavily browsed or dead.

It does seem, however, that the subalpine scrub offers a more stable site for *P. patulum* persistence and regeneration. This is backed up by the observation that populations seem to be more evenly distributed at these sites, which is probably a reflection of sustained regeneration. The patchy nature of forest populations is probably attributable to irregular regeneration at predominantly ephemeral sites.

**Site disturbance**

It is evident that disturbance has played a significant role in the establishment of all of the populations studied. Establishment of *P. patulum* appears to occur after a wide range of disturbances that affect beech forest. Frequent, small-scale disturbances induced regeneration in riparian populations at Lee's Creek (populations 6, 7) and high altitude populations at St Arnaud (populations 1–3), while regeneration occurred in large-scale disturbance subalpine scrub on slip sites at population 12 (South Temple Stream) and fire-induced scrub adjacent to population 11 (Mt Patriarch).

From observations of *P. patulum* populations it appears that adults and sub-adults are only present in open areas such as in large tree fall gaps, in regenerating scrub, or on the edge of slips and roadsides. Creation of these high light areas is obviously a trigger for *P. patulum* to increase growth, produce adult foliage, and become reproductively mature. A requirement for high light may not be as crucial for seed germination and seedling establishment, as recent regeneration was observed in relatively shady areas. The structure of the South Temple Stream population (12) suggests that *P. patulum* can regenerate successfully without recent disturbance providing it can maintain itself in a high light environment, such as scrub, bluffs, and river banks.

These observations lead to the hypothesis that localised *P. patulum* densities fluctuate markedly over time in response to disturbance events. It is possible that, historically, *P. patulum*'s strategy was to persist at low abundances in beech forest, using sites created by small-scale disturbance as refugia, only to increase in abundance in response to large-scale disturbances that open up large areas for relatively long periods of time.

**Conservation implications**

The lack of adult *P. patulum* plants in northern populations is likely to become a serious concern in future if current saplings and sub-adults do not grow into adult trees. Preliminary findings from current monitoring operations being undertaken by the Department of Conservation suggest that herbivory is preventing recruitment into larger size-classes. If current trends of little or no height growth of seedlings and saplings continue, herbivore control operations will be required to ensure recruitment into adult size-classes in order to provide an on-going seed source for continued regeneration. The desired option identified for the conservation of this species is to provide this herbivore control at a range of representative sites (Townsend 1999).

As a result of this study, several recommendations can be made on selection criteria for representative sites for more intensive management (e.g., herbivore control):

1. Representative management sites should include: subalpine scrubland populations; steep, high-altitude mountain beech forest populations; mid-altitude mountain beech forest populations; riparian mountain beech forest populations; and lower-altitude populations such as those in disturbed tall red-silver beech forest. Protection of these sites will protect almost all aspects of the habitat range of *P. patulum* and will also encapsulate the diversity of disturbance regimes operating on these habitats.

2. Representative management sites should encompass all genetic provenances, with protected sites in all three land districts (Nelson, Marlborough and Canterbury). Provincial discontinuities and the patchy nature of *P. patulum* populations may have resulted in isolated populations that have evolved unique traits, so protection of this genetic variability should be considered as important as protecting general abundance.

3. Representative management sites should be large. This study has shown that disturbance is necessary for successful regeneration. As disturbance is a stochastic process, sites need to be large enough to ensure that disturbance will occur in them on a regular basis. This implies that lower-altitude and more stable protected areas will need to be larger than higher-altitude, more highly disturbed sites.

The short-term goal for the protection of *P. patulum* should be to encourage the establishment of adults in populations in which they are absent. Along with herbivore control, it may be necessary to manipulate the site environment in order to encourage the growth and maturation of saplings. This will speed up the regeneration process and is likely to result in a more healthy and stable population in the longer-term.

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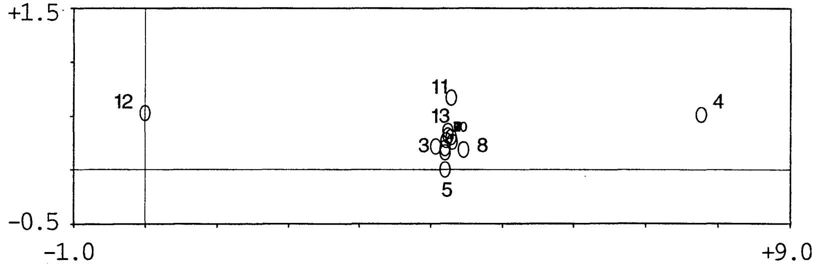
**Table 1**. Study sites details.

| Population location | Pop. | Map sheet 260 series | Grid reference | Number of plants | Altitude (m) | Slope (deg.) | Aspect (deg.) | Temperature ( °C ) Mean | Max | Min | Annual rainfall (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **St. Arnaud** | 1 | N29 | 985309 | 26 | 1300 | 42 | 278 | 6.0 | 12.1 | -2.4 | 1200-1600 |
| | 2 | N29 | 002322 | 10 | 1200 | 38 | 310 | 6.5 | 12.1 | -2.4 | 1200-1600 |
| | 3 | N29 | 003327 | 10 | 1200 | 30 | 320 | 6.5 | 12.1 | -2.4 | 1200-1600 |
| | 4 | N29 | 994325 | 8 | 920 | 18 | 290 | 7.9 | 14.4 | -1.3 | 1200-1600 |
| **Tophouse** | 5 | N29 | 015385 | 1 | 640 | 11 | 235 | 9.3 | 16.3 | -0.4 | 1200-1600 |
| **Lee's creek** | 6 | N30 | 058160 | 22 | 850 | 4 | 280 | 8.3 | 14.7 | -1.2 | 1200-1600 |
| | 7 | N30 | 056160 | 45 | 850 | 2 | 270 | 8.3 | 14.7 | -1.2 | 1200-1600 |
| **Cobb valley** | 8 | M27 | 763094 | 10 | 830 | 41 | 40 | 8.7 | 16.3 | 0.3 | 1600-2400 |
| | 9 | M27 | 763094 | 20 | 830 | 15 | 40 | 8.7 | 16.3 | 0.3 | 1600-2400 |
| | 10 | M27 | 763094 | 5 | 830 | 20 | 40 | 8.7 | 16.3 | 0.3 | 1600-2400 |
| **Mt. Patriarch** | 11 | O28 | 375590 | 35 | 1240 | 15 | 300 | 6.3 | 13.7 | -1.1 | 1200-1600 |
| **South Temple** | 12 | G38 | 494722 | 46 | 920 | 20 | 35 | 6.8 | 13.6 | -2.6 | 1600-2400 |
| **Stream** | 13 | G38 | 494720 | 9 | 980 | 25 | 65 | 6.5 | 13.3 | -2.7 | 1600-2400 |

**Fig. 1.** Ordination diagram showing the floristic relationships of the study sites. Sites that occur close together in the ordination diagram are floristically similar while those that are more widely separated are less similar.




Juvenile and adult foliage of *Pittosporum patulum*. (del. Emily S. Harris based on an illustration by Audrey Eagle).

**Fig 2.** *Pittosporum patulum* height histograms for the study sites. Height classes are 1 (0-0.25 m), 2 (0.25-0.5 m), 3 (0.5-0.75 m), 4 (0.75-1m), etc.