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Ecology and conservation of *Alseuosmia quercifolia* (Alseuosmiaceae) in the Waikato region, New Zealand

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Abstract The ecology of *Alseuosmia quercifolia*, a small endemic shrub, was investigated, focussing on its habitat requirements, population dynamics, phenology and reproductive biology, and conservation status. This species occurs most commonly in lowland native forests of the Waikato region of the North Island (north of latitude 38°05′S), but is also found in scattered populations to North Cape. In the Waikato region it typically occupies shady, well-drained, south or south-east facing lower slopes of hills and ranges at altitudes below 400 m. Population structures show considerable variation amongst seven study sites in the Waikato region, with disjunct size classes a reflection of the presence and abundance of introduced browsing mammals. It is a relatively short-lived (less than 50 years), slow-growing species with a fleshy fruit adapted to bird dispersal, but seed dispersal now appears to be primarily by gravity. Flowering occurs early in spring and is synchronous at both individual and population levels, occurring over a 5-week period, with peak flowering during the second and third weeks. While all populations set seed, reproductive output can be negatively affected by persistent browse and by rain during peak flowering. This species is vulnerable because it is highly palatable to introduced mammals and all plants in a population are within browse height. It has relatively narrow habitat specificity, localised distribution, and limited potential to extend its range. We suggest it fulfils the requirements of the category "declining", using the most recent classification of threatened and uncommon plants of New Zealand.

Keywords *Alseuosmia*; *Alseuosmia quercifolia*; Alseuosmiaceae; distribution; ecology; population structure; phenology; reproductive biology; conservation; New Zealand flora

INTRODUCTION

The endemic genus *Alseuosmia*, comprising seven species, was described from specimens collected from Northland forests (Cunningham 1839). Originally placed in Caprifoliaceae, the genus *Alseuosmia* is now included in a small dicotyledonous South Pacific family, Alseuosmiaceae, described by Airy Shaw (1965) and accepted in a revision by van Steenis (1984). Five species in the genus *Alseuosmia* are currently (formally) recognised: *A. banksii*, *A. macrophylla*, *A. pusilla*, *A. quercifolia*, and *A. turneri* (Gardner 1978; Merrett & Clarkson 2000).

Alseuosmia quercifolia (Fig. 1) had previously been known as *A.* ×*quercifolia* (Gardner 1978), *A.* sp. (a) (Eagle 1982), and (by the informal tag name) *A.* sp. "Hakarimata" (Druce 1988) until its specific epithet was reinstated and its general distribution described (Merrett 1997; Merrett & Clarkson 2000). *A. quercifolia* is a small, often overlooked, endemic shrub. It has a slender trunk, is sparingly branched, and is mostly less than 2.5 m tall (Merrett & Clarkson 2000).

Alseuosmia quercifolia is the most common *Alseuosmia* species in lowland, conifer-broadleaved native forest of the Waikato region (Gudex 1955; Allan 1961; Druce 1988). It occurs in scattered populations in native forests north of latitude 38°05′S to North Cape and on Waiheke and Great

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Fig. 1 *Alseuosmia quercifolia* at Claudelands Bush, Hamilton.

Barrier Islands, but is not known from the Coromandel Peninsula or the Bay of Plenty region (Merrett & Clarkson 2000).

This paper describes ecological investigations of *Alseuosmia quercifolia* populations in seven indigenous forests of the Waikato region, carried out to assess habitat requirements, population dynamics, phenology and reproductive biology, and its conservation status.

METHODS

Data collection

Seven native forests in the Waikato region with populations of *Alseuosmia quercifolia* were identified as study sites: Claudelands Bush (aka Jubilee Park), Hamilton; Hakarimata Scenic Reserve; Matahuru Scenic Reserve; Kakepuku Historic Reserve; Maungatautari Mountain Scenic Reserve; Pukemokemoke Bush Reserve; and Te Tapui Scenic Reserve (Fig. 2). At each study site, *A. quercifolia* populations were located and 23 2×2 m plots were established. The exception was Maungatautari Mountain, where 11 plots were established, as only a few individuals were located despite widespread searches on south-east facing slopes. For each plot, habitat was characterised, population structure assessed, browse and herbivory effects noted, vegetation composition and structure recorded, and vascular plant species lists compiled.

All *A. quercifolia* plants taller than 5 cm were measured to the tallest apical shoot. Stem diameter was measured at 5 cm above ground level, and seedlings (less than 5 cm tall) were counted. Browse damage to foliage and stems of *A. quercifolia* plants at the seven study sites was scored by ranking the sampled population, based on the extent of damage noted, into four categories: nil, minimal, moderate, severe. A ranking of severe was given when the entire foliage had been reduced to 2–3 leaves. To establish approximate plant age in relation to height, five moribund plants of varying heights were removed for growth ring analysis. Stems were cut 5 cm from ground level, fine sanded, and stained with Phloroglucinol 5% followed by a drop of 10 *M* HCl to enhance visibility. Growth rings were counted using a binocular microscope.

Flowering pattern and reproductive output were recorded during two flowering seasons from a population subset at Hakarimata and Matahuru Scenic Reserves, and pot-grown plants were used to test aspects of the breeding system. Reproductive output was measured by counting the number of buds and flowers on monitored plants during the flowering season, and then counting developing fruit. Pollinator exclusion trials were conducted to determine whether *A. quercifolia* was able to self-pollinate. A control group of potted plants was placed unobstructed outdoors, near an experimental group that was placed within a shadecloth-covered exclosure to exclude potential pollinators. Flower and bud numbers were counted before starting the experiment. Propagation experiments were conducted in glasshouses at the University of Waikato to establish suitable techniques for population restoration. Replicate numbers of seeds on damp filter paper in petri dishes were placed into various temperature (unheated glasshouse, heated glasshouse, and temperature controlled at 13°C), and light (uncovered and receiving full light, and low light created by a double layer of 50% shadecloth) regimes. Additional seeds were soaked in gibberellic acid (GA_3) at a concentration of 10^{-4} for 24 hours, to test for dormancy, before placing in the various

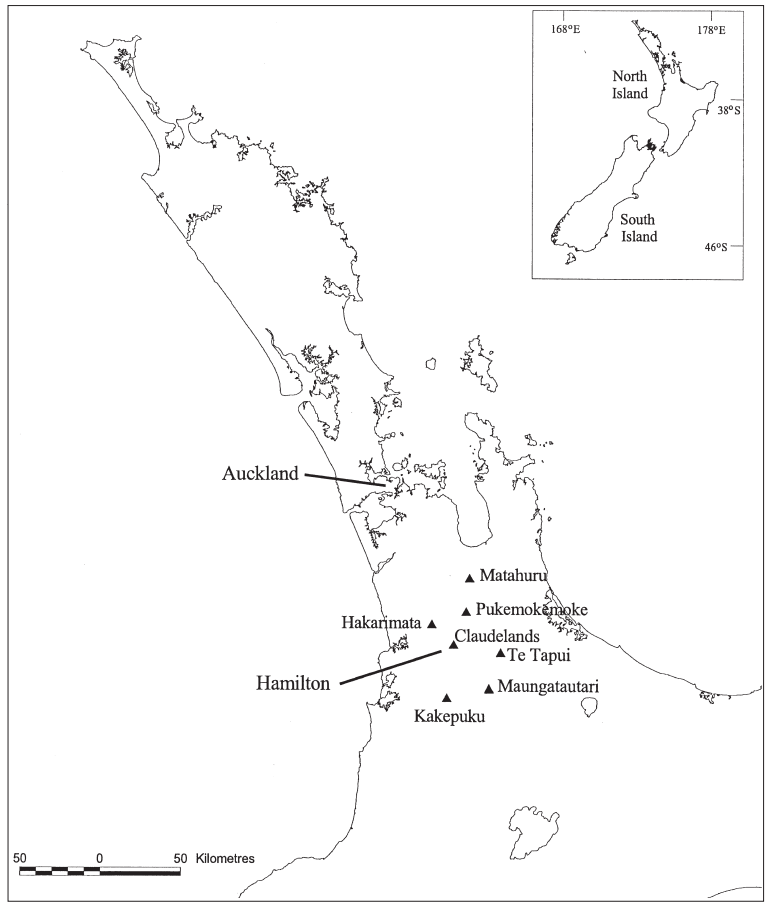

Fig. 2 *Alseuosmia quercifolia* study sites (▲) in the Waikato region.

temperature and light regimes. Tip cuttings were propagated by planting in a rooting medium of 50:50 peat:sand with, and without, rooting hormone, and the trays placed on heated sand under an intermittent mister.

Data analysis

Height and stem diameters of sampled individuals from seven populations were analysed to determine population structure, and the correlation between plant height and stem diameter was calculated. Means and standard deviations were calculated for height classes from each population. Regression analysis was used to determine the relationship between the number of growth rings (age), diameter, and height. These results were used to estimate metapopulation age structure. Vegetation composition relationships were analysed from plot data variables using the unweighted pair-group clustering method that uses arithmetic averages where equal weight is given to objects (flexible UPGMA). The degree of similarity between study sites was measured by Kuczynski's index of dissimilarity (Faith et al. 1987).

RESULTS

Habitat

Alseuosmia quercifolia in the Waikato region occurs most commonly in well-drained, shady habitats, on the less steep, cooler, south or south-east facing lower slopes of hills and ranges, and is only occasionally found in damp gully bottoms. The exception is Claudelands Bush, Hamilton, a 5.2-ha, flat, kahikatea (*Dacrycarpus dacrydioides*)-dominated remnant that supports a healthy, albeit small population. *A. quercifolia* is either absent or rare in other low-lying kahikatea remnants in the Waikato region

Table 1 Summary of study site parameters for seven populations of *Alseuosmia quercifolia* in the Waikato region.

Parameter	Claudelands Bush	Hakarimata Scenic Reserve	Matahuru Scenic Reserve	Kakepuku Historic Reserve	Maungatautari Mountain	Pukemokemoke Bush Reserve	Te Tapui Scenic Reserve
Size of reserve (ha)	5.2	1824	1336	132	2410	60	2382
Number of plots (2 × 2 m)	23	23	23	23	11	23	23
Max. elevation (m a.s.l.)	50	374	535	449	796	166	495
Max. elevation of *A. quercifolia* plots	50	140	240	250	440	60	200
Soil parent material	alluvial sand, silt & gravel	indurated siltstone & sandstone	finely bedded siltstone & sandstone	andesitic & basaltic	andesite-dacite	indurated sandstone	andesite
Mean annual temperature (°C)	13	14	14	14	14	14	14
Mean annual rainfall (mm)	1200	1400	1400	1600	1400	1200	1400
Introduced browsing mammals present	possum	possum pig goat	possum pig goat	possum goat	possum pig goat	possum goat hare	possum pig fallow deer
Browsing level (1996)	nil	moderate	severe	minimal	severe	minimal	severe
Forest cover types	kahikatea-tawa	tawa, rimu-tawa	tawa	rimu-rata, mangeao	rimu-tawa	kauri-hard beech, tanekaha-kanuka, tawa/kohekohe	rimu-tawa

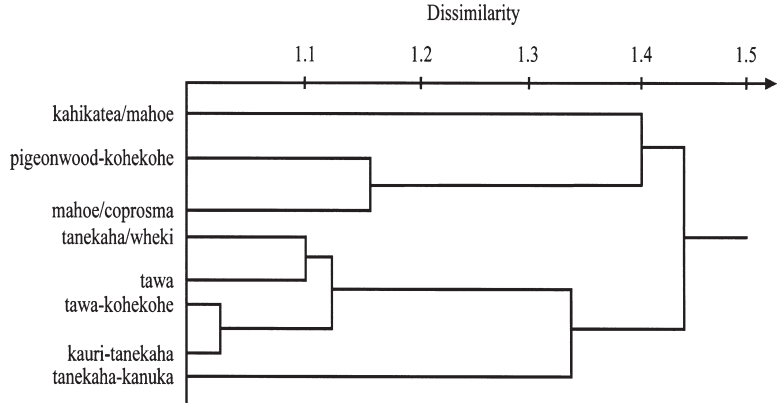

Fig. 3 Dendrogram of similarity amongst eight forest types in the Waikato region where *Alseuosmia quercifolia* occurs.

(Sircombe 1982; B. Burns unpubl. data; M. F. Merrett pers. obs). The size of study sites was variable, ranging from 5.2 ha (Claudelands Bush) to 2410 ha (Maungatautari Mountain) (Table 1). The altitudinal range of the study sites (where *A. quercifolia* occurred) ranged from 50 m at Claudelands Bush to 440 m on Maungatautari Mountain. Herbarium specimens (AK, AKU, WAIK, WELT) indicate that the upper altitudinal limit for the species throughout its range is approximately 450 m. Mean annual temperatures show little variation amongst study sites and range from 13 to 14°C (New Zealand Meteorological Service 1985). Mean annual rainfall varies from 1200 mm at Claudelands Bush to 1600 mm on Kakepuku Mountain (New Zealand Meteorological Service 1985). One or more species of introduced browsing mammals, i.e., brushtail possum (*Trichosurus vulpecula*), feral goat (*Capra hircus*), feral pig (*Sus scrofa*), fallow deer (*Dama dama dama*), and brown hare (*Lepus europaeus occidentalis*), were present at each study site (Department of Conservation 1995).

Vegetation associations

Vascular plants species growing in association with *Alseuosmia quercifolia* are a subset of the floristic assemblage of various conifer-broadleaved forests of the Waikato region. In total, 122 vascular plant species were recorded growing in association with *A. quercifolia*, comprising 38 ferns and fern allies, 7 gymnosperms, and 77 angiosperms (Appendix 1). Only five species occur at all study sites: tawa (*Beilschmiedia tawa*), hangehange (*Geniostoma rupestre*), rewarewa (*Knightia excelsa*), mahoe (*Melicytus ramiflorus*), and supplejack (*Ripogonum scandens*).

Variables recorded from plot data were analysed to establish relationships between forest species composition and structure, and *Alseuosmia quercifolia* presence and abundance. Because of size limitation, the full result of UPGMA clustering (in the form of a 153-line dendrogram) is not shown. A condensed dendrogram shows critical clustering levels amongst and between study sites (Fig. 3). Eight forest types are defined, based on vegetation composition and associated variables. Except for Hakarimata Scenic Reserve, where two forest types were identified, each study site was represented by a single forest type.

Canopy, subcanopy cover, and the presence of a shrub layer and ground cover were variable amongst the study sites. Mean canopy cover ranged from 55% (Hakarimata Scenic Reserve) to 88% (Maungatautari Mountain). Mean subcanopy cover ranged from 19% (Claudelands Bush) to 58% (Te Tapui Scenic Reserve). The variation in canopy and subcanopy cover is largely indicative of forest type. For example, kahikatea-dominated forests (Claudelands Bush) typically have fewer subcanopy species than conifer-broadleaved forests such as Maungatautari Mountain. Mean shrub layer cover ranged from 9% (Maungatautari Mountain) to 74% (Pukemokemoke Bush Reserve). The reduced shrub layer on Maungatautari Mountain is probably a reflection of the effect of long-term browse. Mean ground cover vegetation ranged from 24% (Claudelands Bush) to 61% (Hakarimata Scenic Reserve). The relatively low ground cover in Claudelands Bush was influenced by recent manual removal of wandering Jew (*Tradescantia fluminensis*).

Demography

Populations of *Alseuosmia quercifolia* sampled at the seven study sites showed a range of height class structures (Fig. 4). Of the sampled individuals (n = 1164), 78% were less than 50 cm tall and only 7

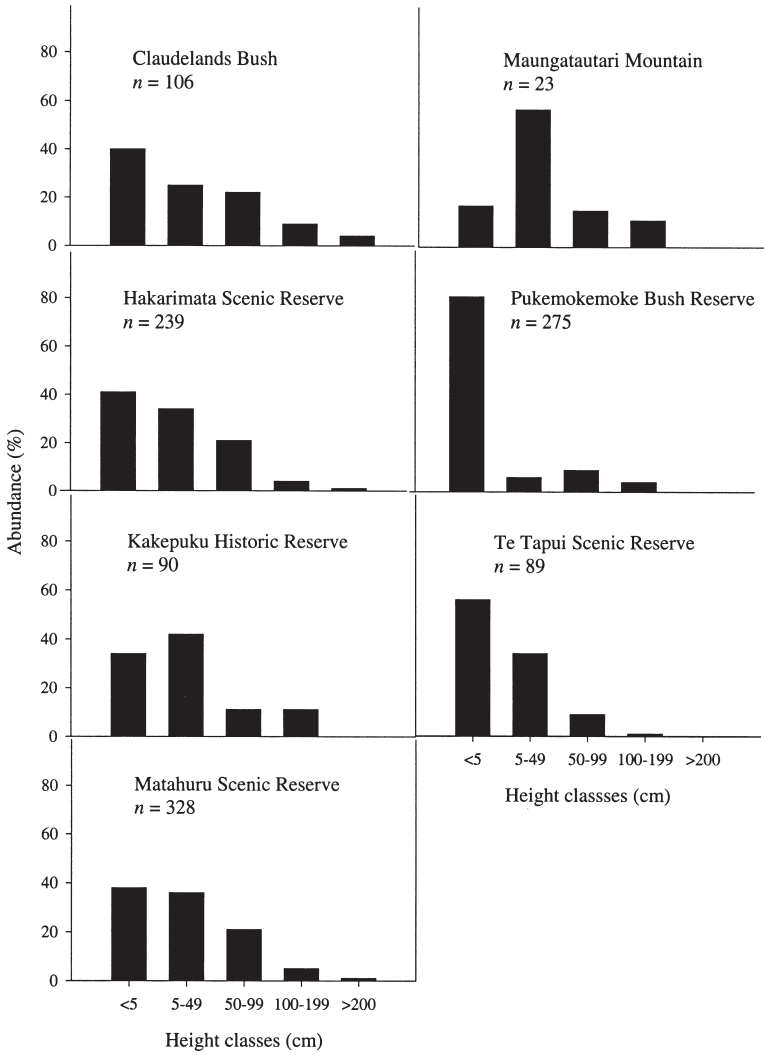

Fig. 4 *Alseuosmia quercifolia* population height class structures from seven sites in the Waikato region.

(0.006%) were more than 2 m tall. All study sites showed recent regeneration (seedlings less than 5 cm tall). However, only four seedlings were found on Maungatautari Mountain, despite widespread searches. Recruitment into the smallest height class (5–49 cm) was evident at all sites. At Pukemokemoke Bush Reserve, however, there was a marked decline, although this site had high seedling frequency (Fig. 4). Te Tapui Scenic Reserve had few individuals in the 50–199 cm size classes, and only three sites, Claudelands Bush, Hakarimata Scenic Reserve, and Matahuru Scenic Reserve, had individuals taller than 2 m. Claudelands Bush, Hakarimata Scenic Reserve, Te Tapui Scenic Reserve, and Matahuru Scenic Reserve showed a reverse-J distribution in population structures, indicating a self-maintaining population (Fig. 4). The atypical height-class structures at Kakepuku Historic Reserve, Maungatautari Mountain, and Pukemokemoke Bush Reserve suggest that some form of disturbance had affected population structure.

Maximum plant height (from the seven populations) ranged from 3.15 m (Claudelands Bush) to 1.2 m at Te Tapui Scenic Reserve (Table 2). Mean plant height ranged from 77.1 cm (Claudelands Bush) to 29.7 cm (Te Tapui Scenic Reserve). Linear regression analysis showed a high correlation between plant height and stem diameter, despite persistent browse at some study sites, e.g., Matahuru Scenic Reserve and Maungatautari Mountain. Mean stem diameter ranged from 6.5 mm (Claudelands Bush) to 3.4 mm (Te Tapui Scenic Reserve) (Table 2).

Table 2 Study sites, sampled area, number and density, maximum and mean height, mean stem diameter, and correlation coefficients of height versus diameter of *Alseuosmia quercifolia* from seven study sites in the Waikato region.

Parameter	Claudelands Bush	Hakarimata Scenic Reserve	Kakepuku Historic Reserve	Matahuru Scenic Reserve	Maungatautari Mountain	Pukemokemoke Bush Reserve	Te Tapui Scenic Reserve
Sampled area (m^2)	92	92	92	92	44	92	92
Total number of stems	106	239	90	328	23	275	89
Stem density of *A. quercifolia* (m^2)	1.2	2.6	1.0	3.7	0.5	2.9	1.0
Maximum height (m)	3.2	2.4	2.1	1.5	1.9	1.6	1.2
Mean height in cm (s.e.)	77.1 (7.49)	46.0 (3.06)	44.3 (5.07)	47.3 (2.58)	49.8 (12.36)	67.9 (4.64)	29.7 (4.6)
Mean stem diameter (mm) (s.e.)	6.5 (0.60)	4.1 (0.17)	3.9 (0.29)	4.5 (0.20)	5.5 (1.66)	6.33 (0.38)	3.4 (0.26)
Correlation coefficient (height versus stem diameter)	0.899	0.914	0.866	0.887	0.847	0.880	0.917

Fig. 5 Severely browsed *Alseuosmia quercifolia* plant in Matahuru Scenic Reserve.

Life-span and growth rate

Plant height, stem diameter, and the number of growth rings counted from five dead *Alseuosmia quercifolia* stems (Table 3), along with the assumption that growth rings are annual, allow a crude estimate of the age structure of the sampled populations. However, because of the small growth ring sample, predictions of age from diameter or height (using regression equations) are indicative only. Stems with diameters greater than 15 mm are more difficult to age because, typically, annual stem increment declines with increasing age. Annual stem diameter increment, based on growth rings, ranged from 0.6 to 0.8 mm yr^{-1} (Table 3). Growth rates calculated from these data suggest that this species is relatively slow growing compared with many other lowland shrubs (Wardle 1991).

We have estimated the oldest individual in the study sample (recorded from Claudelands Bush) to be approximately 38 years old (Table 4). Mean population age structure amongst the seven study sites, based on regression equations, shows the

Claudelands Bush population to have the oldest mean age (11 years). The Te Tapui Scenic Reserve population had the youngest mean age (6.2 years) (Table 4).

Browse, herbivory, and disease

Claudelands Bush had the only unbrowsed population of *A. quercifolia*, despite the presence of the ubiquitous brushtail possum. Matahuru Scenic Reserve, Maungatautari Mountain, and Te Tapui Scenic Reserve were ranked as severely browsed (Fig. 5). At the time of the study, feral goats were present in both Matahuru Scenic Reserve and on Maungatautari Mountain, and fallow deer were present only in Te Tapui Scenic Reserve (Davidson & Nugent 1990; Department of Conservation 1995). Goats were also present on the Hakarimata Range but apparently in relatively low numbers (Department of Conservation 1995). At this site, plants growing alongside an access track had browse damage to stems and foliage, whereas those away from the track were relatively free of browse. Adult *A. quercifolia* plants in Pukemokemoke Bush Reserve showed minimal browse damage. However, low density in the 5–49 cm height class in relation to seedling density suggests high seedling mortality, possibly caused by browsing by hares.

In addition to browse damage, stems of *A. quercifolia* are often damaged by egg-laying cicada (*Melampsalta cingulata*), usually causing death of the stem above the distinctive herringbone-patterned area of damage. Slugs and snails also cause leaf damage, albeit relatively minor, and the common leaf roller/bud borer (*Epalxiphora axenana*) damages leaves while spinning its cocoon.

During visits to several geographically separated populations from November to February 1995–97, many plants were seen to be infected with downy mildew. Leaves subsequently became distorted and discoloured but plants did not die.

Table 3 Number of growth rings, height, stem diameter, and estimated annual stem increment of five stems of moribund *Alseuosmia quercifolia*. The regression equations derived from these data ($n = 5$) are:
age = 0.14 + 0.13 height (cm); $r = 0.99$; $P < 0.001$;
age = 0.71 + 1.6 diameter (mm); $r = 0.99$; $P < 0.001$.

Number of growth rings	Height (cm)	Stem diameter (mm)	Annual stem diameter increment (mm yr^{-1})
21	143.2	13.58	0.65
7	42.2	4.21	0.60
5	39.0	4.15	0.83
5	18.0	3.44	0.69
4	16.8	3.12	0.78

Table 4 Estimated age of oldest individuals and mean age of sampled population based on stem diameter of *Alseuosmia quercifoli*a from seven study sites in the Waikato region.

Study site	Maximum stem diameter (mm)	Estimated age of oldest individual (years)	Mean stem diameter (mm)	Estimated mean population age (years)
Claudelands Bush	23.8	38.8	6.5	11.1
Hakarimata Scenic Reserve	16.4	26.9	4.1	7.3
Kakepuku Historic reserve	10.4	17.3	3.9	6.9
Matahuru Scenic Reserve	21.5	35.1	4.5	7.9
Maungatautari Mountain	9.9	16.5	5.5	7.1
Pukemokemoke Bush Reserve	13.8	22.8	6.3	10.8
Te Tapui Scenic Reserve	7.1	11.9	3.4	6.2

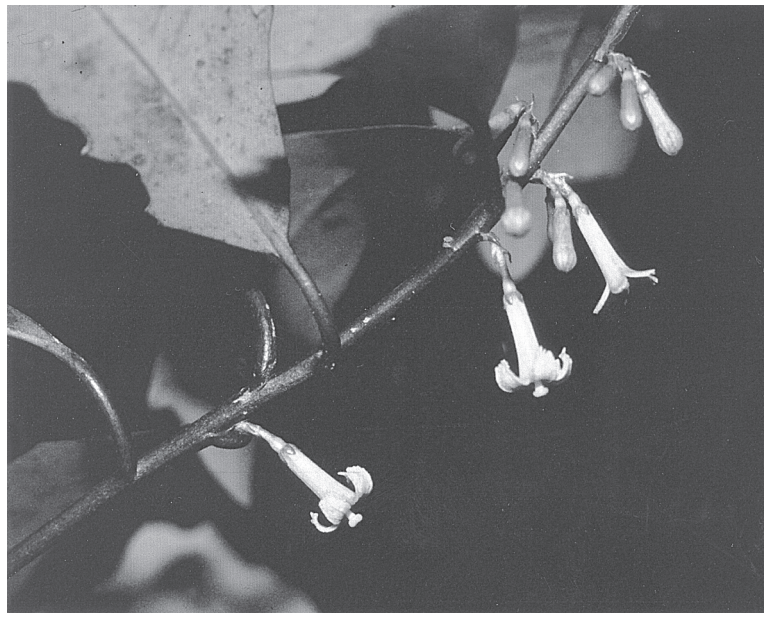

Fig. 6 *Alseuosmia quercifolia* flowers, Hakarimata Scenic Reserve, September 1996.

Phenology and reproductive biology

Alseuosmia quercifolia flowering is initiated in spring, associated with an increase in temperature during late August and early September. Although flower bud development usually occurs from mid to late winter (Jun–Aug), occasional flowers may be present at any time of the year. Flowering may vary from year to year, depending on seasonal variation in air temperatures. For example, in 1995, peak flowering at Hakarimata Scenic Reserve was 20 September, whereas in 1996 it was 4 October. *A. quercifolia* flowers (Fig. 6) are bisexual, nectar-bearing, and highly fragrant, both diurnally and nocturnally. Flower colour is variable, ranging from creamy green, pink, pale dusky pink, to dark dusky pink. At the bud stage of flower development, the anthers sit close to the style and are positioned directly below the stigma. As the bud matures and the lobes open, the style elongates and becomes exserted, concomitant with anther dehiscence. Flowers appear to be dichogamous, with the stigma becoming receptive shortly after anther dehiscence. The initial, slightly sticky, translucent, stigmatic surface changes to viscid and milky-coloured with receptivity and age.

The longevity of individual flowers, recorded from monitored individuals, ranged from 2 to 9 days (mean = 5). Flowering was synchronous, both at individual and population levels during two seasons of monitoring. Population flowering lasted five weeks, with the majority of plants in full bloom during the second and third weeks of each season.

Successful pollination was measured by the number of fruit set. In 1995, 25 monitored plants produced 131 fruit from 698 flowers, an 18.8% rate of fruit set. In 1996, 23 of the same individuals (two had died) produced 393 fruit from 824 flowers, a 47.7% rate of fruit set which was significantly higher than the previous year. Analysis of weather patterns during the 1995 flowering season suggests that persistent rainfall during peak flowering may have depressed fruit set. For the university-located control group (1305 flowers), pollination success was 41%, whereas the experimental (isolated) group (1958 flowers) had a success rate of only 1%.

The fleshy fruit (berry) begins ripening from late summer (February) through to May. Ripe fruit are round to oblong and a reddish purple colour. Ripe fruit persisting on stems and clusters of seedlings beneath parent plants suggest that some fruit dispersal is by gravity. Historically, native frugivorous birds such as kakapo (*Strigops habroptilus*), kokako (*Callaeas cinerea*), kereru (*Hemiphaga novaeseelandiae*), and moa species would probably have been natural seed dispersers when these species were more widespread and abundant or extant (Atkinson & Millener 1990). Introduced exotic frugivores such as blackbirds (*Turdus merula*) may feed on *A. quercifolia* fruit, but this has not been recorded, nor were systematic observations conducted during this study.

The number of seeds per fruit varied from 1 to 17, with a mean of 6 (Merrett 1997). Mean fruit length was 5.9 mm (Merrett 1997; Merrett & Clarkson 2000), mean fresh fruit weight was 0.19 g, and mean dry seed mass was 3 mg (n = 80). Dry seed mass is comparable with *Coprosma rhamnoides* (2.7 mg) and *Nothofagus solandri* (3.4 mg) (Wardle 1991).

The pollination vector of *Alesuosmia quercifolia* has not yet been systematically identified. *Alseuosmia* flower architecture and a lack of observed diurnal insect visitation suggest nocturnal pollination. *Alseuosmia* floral characters such as perfume, fringed lobes, and horizontal or pendulous blossoms are indicative of moth floral syndromes (Faegri & van der Pijl 1979; Wyatt 1983). A single moth was captured at dusk while in the process of nectar feeding from *A. quercifolia* flowers, and has since been identified as *Epyaxa rosearia*, a common and widespread species in New Zealand (R. Toft pers. comm.). Pollen collected from the base of the proboscis was identified under microscopic examination as that of *Alseuosmia*. No other pollen type was present. Bird pollination concomitant with nectar feeding may have occurred in earlier times. For example, nectar feeding of *A. macrophylla* by stitchbird (*Notiomystis cincta*) has been reported from Little Barrier Island (Angehr 1986), and bellbirds have been observed nectar feeding on *A. macrophylla* flowers on the Mamaku Plateau and on *A. turneri* flowers in Ohinetonga Scenic Reserve, Owhango, central North Island (M. F. Merrett pers. obs.). However, the stitchbird is no longer present on mainland New Zealand, and bellbirds are rare or absent in lowland forests in the Waikato region.

New season's vegetative growth normally begins immediately after flowering. In cases when stem and/or foliage damage had occurred, plant energy was directed into vegetative growth at the expense of reproductive output. For example, monitored flowering plants during 1995 that subsequently suffered vegetative damage did not produce flowers the following season. *A. quercifolia* stems have the ability to produce adventitious roots when they come in contact with the ground.

Seed germination is indicated first by splitting of the seedcoat, followed by radicle emergence. Seed germination occurs in spring with the appearance of two cotyledons, followed by seedling leaves with distinctive white venation and red petioles. The most successful seed germination rate was 65% for GA_3-soaked seeds under low light at a controlled temperature of 13°C. Propagation by tip cuttings, with or without rooting hormone, was 100% successful. Root development of cuttings was initiated 5–8 weeks after planting.

DISCUSSION

Habitat

Alseuosmia quercifolia is present in most lowland conifer-broadleaved forests of the Waikato region, in varying degrees of abundance, but is less common in kahikatea remnants. Its habitat preferences in the Waikato region are apparently those sites that receive more than 1100 mm of rainfall annually, are free draining, on cooler, south-facing slopes, and less likely to experience excessive soil moisture deficit. *A. quercifolia* mainly occurs within a relatively narrow east to south-east aspect range (excluding Claudelands Bush), indicating an intolerance of overly dry or excessively wet soil conditions.

Most threatened species have a restricted geographic range and narrow habitat requirements and, in a review of recovery plans for 85 endangered plant species, 95.9% were classified as having narrow ecological requirements (Schemske et al. 1994). For example, compared with *Pittosporum obcordatum* (Clarkson & Clarkson 1994), *A. quercifolia*'s habitat requirements are not particularly narrow, but its latitudinal range is more restricted. *Melicytus drucei*, however, has both narrow habitat requirements and a restricted geographical range (Molloy & Clarkson 1996). Before forest clearance for agricultural development in the Waikato region, *A. quercifolia* was presumably more widespread. For example, the area of potential habitat in lowland native forest in Waikato region was contained within 184 947 ha, but is now reduced to only 6.3% of its former extent (Leathwick et al. 1995). This reduction in lowland habitat is probably the most significant factor leading to its current restricted status.

The presence of *A. quercifolia* in Claudelands Bush is unusual and interesting, because this species is absent from most kahikatea remnants in the region. Gudex (1955), Boase (1985), and Whaley et al. (1997) suggested that the drainage regime put in place to protect surrounding suburban development was one of the factors responsible for changes in plant species composition there: losses of species characteristic of damp habitats, e.g., ferns and understory shrubs such as *Coprosma propinqua* and *C. tenuicaulis*, and increases of those more commonly found in drier, free-draining habitats, e.g.,

mahoe and adventive species such as Jersusalem cherry (*Solanum pseudocapsicum*) and privet (*Ligustrum sinense, L. lucidum*). The earliest record of *A. quercifolia* from Claudelands Bush was by Gudex (1955) who classified it as "rare", but, unfortunately, the number of individuals present at that time was not recorded. Over 100 individuals were counted there at the time of this study, and considering that this is a small (5.2 ha) remnant, it is possible the population has increased in abundance in the last 50 years. This may have been a consequence of the improved drainage regime and protection from browsing animals. Thus, altered site characteristics may have been beneficial for this species.

Demography

Atypical size-class distributions at three of the seven study sites suggest that some form of disturbance has affected population structure. For relatively short-lived taxa, continual recruitment is important to ensure long-term population viability. In most of the populations studied, *A. quercifolia* was reproductively viable and, without disturbance, would be self-sustaining. However, because *A. quercifolia* is highly palatable, plant height, reproductive output, and, ultimately, lifespan were affected at sites where browse effects were severe. Recruitment failure at some sites, because of low numbers in juvenile size-classes, was particularly evident at Pukemokemoke Bush Reserve. This can probably be attributed to grazing by hares of ground cover vegetation, including seedlings of palatable species.

Possum do not appear to be implicated in browsing of this species. For example, Claudelands Bush was the only site with a reasonable representation of individuals in each size class, and the entire adult population there was the best example of healthy, unbrowsed individuals encountered. The only herbivore present was possum, and although the devastation caused to many native canopy species (Cowan 1990; Brockie 1992) and some threatened shrub species (Molloy & Clarkson 1996) by possum has been established, low growing species, including seedlings and saplings of preferred species, are often not affected. In the Hakarimata Range, severe browse damage of kohekohe (*Dysoxylum spectabile*) canopy foliage is widespread, but saplings and subcanopy foliage are largely untouched.

Because of the current decline of native bird dispersers in these forests, the ability of *A. quercifolia* to extend its range is severely restricted and it is now almost totally reliant on dispersal by gravity. Persistent browse also affects reproductive output, foliar growth taking precedence over flower bud initiation. Propagation by tip cuttings was highly successful and although not necessarily the best option for genetic variation would, in a restoration programme, be a useful rescue method where a population had been reduced to a few non-reproducing individuals.

The seven populations in this study are not at risk from land development because they each have some form of legal protection. Unfortunately, protection from development does not protect species from human-induced factors such as alien herbivores. Active management in the form of control of goats, hares, and deer would help ensure the long-term survival of this species. The largest population of *A. quercifolia* in the Waikato region is in the Hakarimata Scenic Reserve. Relatively low numbers of goats at this site have had minimal effect on population dynamics. However, in a more recent visit (May 2000) to monitored, known groups of plants, it was noticed that many previously unbrowsed individuals had lost their apical shoot, which is typical of goat browse. The population at Matahuru Scenic Reserve is estimated to be the second largest, but is systematically being decimated by goats and there is a lack of any control measures. The small population (22) on Maungatautari Mountain is also at risk. These individuals may be at their altitudinal limit here, and are possibly a relict of a larger population that was present on the now deforested lower slopes. The effect of goats on many native species was severe at this site; tree bark was damaged, there were few seedlings or saplings of any species, and the sparse ground cover comprised non-palatable species only.

Conservation

Alseuosmia quercifolia does not currently appear in checklists of nationally threatened plants (de Lange et al. 1999), but the results of this study have enabled an assessment of its conservation status. This species has a relatively short life span, is slow-growing, and, in some years, reproductive output is low. The populations at all sites in this study are currently reproductively viable but, in the longer term, this will depend on the level of browsing, particularly by goats. Most individuals of *A. quercifolia* are less than 2 m tall, placing whole populations within browse height. We recommend that *A. quercifolia* be categorised as "declining" under the most recent classification of threatened and uncommon plants of New Zealand (de Lange et al. 1999).

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REFERENCES

Airy Shaw, H. K. 1965: Diagnoses of new families, new names, etc., for the seventh edition of Willis's 'Dictionary'. *Kew Bulletin 18*: 249–273.

Allan, H. H. 1961: Flora of New Zealand. Vol. I. Wellington, Government Printer.

Angehr, G. R. 1986: Ecology of honey eaters on Little Barrier Island: a preliminary survey. *In*: Wright, A. E.; Beever, R. E. *ed*. The offshore islands of northern New Zealand. Wellington, Department of Lands and Survey.

Atkinson, I. A. E.; Millener, P. R. 1990: An ornithological glimpse into New Zealand's pre-human past. *Acta XX Congressus Internationalis Ornithologici 1*: 129–188.

Boase, M. R. 1985: The flora and vegetation of Jubilee Park (Claudelands Bush). *Rotorua Botanical Society Newsletter 4*: 10–19.

Brockie, R. 1992: A living New Zealand forest. Auckland, David Bateman.

Clarkson, B. D.; Clarkson, B. R. 1994: Ecology of an elusive endemic shrub, *Pittosporum obcordatum* Raoul. *New Zealand Journal of Botany 32*: 155–168.

Cowan, P. E. 1990: Brushtail possum. *In*: King, C. M. *ed*. The handbook of New Zealand mammals. Oxford, Oxford University Press.

Cunningham, A. 1839: Florae Insularam Novae Zelandiae Precursor; Specimen of the botany of the Islands of New Zealand. *Alseuosmia. Annals of Natural History II*: 209–210.

Davidson, M. M.; Nugent, G. 1990: Fallow deer. *In*: King, C. M. *ed*. The handbook of New Zealand mammals. Oxford, Oxford University Press.

de Lange, P. J.; Heenan, P. B.; Given, D. R.; Norton, D. A.; Ogle, C. C.; Johnson, P. N.; Cameron, E. K. 1999: Threatened and uncommon plants of New Zealand. *New Zealand Journal of Botany 37*: 603–628.

Department of Conservation 1995: Recreational hunting system. Unpublished newsletter held at the Department of Conservation, Hamilton, New Zealand.

Druce, A. P. 1988: Indigenous higher plants of New Zealand (May revision). Unpublished checklist held at Landcare Research, Lincoln, New Zealand.

Eagle, A. 1982: Eagle's trees and shrubs of New Zealand. 2nd series. Auckland, Collins.

Faegri, K.; van der Pijl, L. 1979: The principles of pollination ecology. 3rd ed. Oxford, Pergamon Press.

Faith, D. P.; Minchin, P. R.; Belbin, L. 1987: Compositional dissimilarity as a robust measure of ecological distance. *Vegetatio 69*: 57–68.

Gardner, R. O. 1978: The species of *Alseuosmia* (Alseuosmiaceae). *New Zealand Journal of Botany 16*: 271–277.

Gudex, M. C. 1955: The native flora of Claudelands Bush. *Transactions of the Royal Society of New Zealand 83*: 310–319.

Leathwick, J. L.; Clarkson, B. D.; Whaley, P. T. 1995: Vegetation of the Waikato region: current and historical perspectives. Unpublished Landcare Research contract report LC9596/022 prepared for Environment Waikato, Hamilton, New Zealand.

Merrett, M. F. 1997: *Alseuosmia quercifolia* A.Cunn.: taxonomy, ecology and conservation, reproductive biology and propagation. Unpublished MSc thesis, The University of Waikato, Hamilton, New Zealand.

Merrett, M. F.; Clarkson, B. D. 2000: Re-instatement of *Alseuosmia quercifolia* (Alseuosmiaceae) from New Zealand. *New Zealand Journal of Botany 38*: 153–164.

Molloy, B. P. J.; Clarkson B. D. 1996: A new, rare species of *Melicytus* (Violaceae) from New Zealand. *New Zealand Journal of Botany 34*: 431–440.

New Zealand Meteorological Service 1985: Annual rainfall climatic map. Part 6. Wellington, Ministry of Transport.

Schemske, D. W.; Husband, B. C.; Ruckelshaus, M. H.; Goodwillie, C.; Parker, I. M.; Bishop, J. G. 1994: Evaluating approaches to the conservation of rare and endangered plants. *Ecology 75*: 584–606.

Sircombe, L. 1982: Whewells Bush Reserve. Unpublished report held at The University of Waikato, Hamilton, New Zealand.

van Steenis, C. G. G. J. 1984: A synopsis of Alseuosmiaceae in New Zealand, New Caledonia, Australia, and New Guinea. *Blumea 29*: 387–394.

Wardle, P. 1991: Vegetation of New Zealand. Cambridge, Cambridge University Press.

Whaley, P. T.; Clarkson, B. D.; Smale, M. C. 1997: Claudelands Bush: ecology of an urban kahikatea (*Dacrycarpus dacrydioides*) forest remnant in Hamilton, New Zealand. *Tane 36*: 131–155.

Wyatt, R. 1983: Pollination and breeding systems. *In*: Real, L. *ed*. Pollination biology. London, Academic Press.

Appendix 1 Study sites and plant species growing in association with *Alseuosmia quercifolia* in the Waikato region. *, adventive species; +, present

Species	Claude-lands Bush	Hakarimata Scenic Reserve	Kakepuku Historic Reserve	Matahuru Scenic Reserve	Maunga-tautari Mountain	Puke-mokemoke Bush Reserve	Te Tapui Scenic Reserve
Ferns & fern allies							
Adiantum fulvum			+				
Asplenium bulbiferum	+	+	+		+		
A. flaccidum				+		+	+
A. oblongifolium		+	+	+	+	+	
A. polyodon	+	+		+	+	+	+
Blechnum chambersii		+	+				
B. discolor				+	+		+
B. filiforme	+	+	+		+	+	+
B. fraseri				+			
B. novae-zelandiae		+		+			
Cyathea dealbata	+	+	+	+		+	+
C. medullaris	+						
Dicksonia squarrosa	+	+		+	+		+
Diplazium australe	+						
Doodia australis						+	
Hymenophyllum demissum		+	+			+	+
H. flexuosum			+				
H. sanguinolentum		+		+			
Lastreopsis glabella	+						
L. hispida							+
Leptopteris hymenophylloides			+	+			
Lycopodium deuterodensum		+					
L. volubile		+		+			
Lygodium articulatum		+		+		+	+
Microsorum pustulatum			+	+	+	+	+
M. scandens	+		+			+	+
Pneumatopteris pennigera		+					
Polystichum richardii			+				
Pteridium esculentum		+		+		+	
Pteris macilenta							+
Pyrrosia eleagnifolia	+					+	
*Selaginella kraussiana**	+						
Sticherus cunninghamii		+					
Tmesipteris elongata		+		+			
T. tannensis							+
Trichomanes elongatum		+					
T. reniforme		+		+		+	
T. venosum							+
Gymnosperms							
Agathis australis		+				+	
Dacrycarpus dacrydioides	+					+	
Dacrydium cupressinum	+	+		+		+	

(continued over page)

Appendix 1 *(continued)*

Species	Claude-lands Bush	Hakarimata Scenic Reserve	Kakepuku Historic Reserve	Matahuru Scenic Reserve	Maunga-tautari Mountain	Puke-mokemoke Bush Reserve	Te Tapui Scenic Reserve
Phyllocladus trichomanoides		+		+			
Podocarpus hallii		+					
P. totara		+		+		+	
Prumnopitys ferruginea				+	+	+	
Flowering plants – dicotyledons							
Alectryon excelsus	+				+	+	
Alseuosmia macrophylla					+		
A. quercifolia	+	+	+	+	+	+	+
Beilschmiedia tawa	+	+	+	+	+	+	+
*Berberis glaucocarpa**	+						
Brachyglottis repanda		+		+		+	
Carpodetus serratus	+						
Clematis paniculata			+				
Coprosma arborea						+	+
C. grandifolia			+	+	+	+	
C. lucida			+		+		
C. rhamnoides						+	
C. robusta				+			
C. spathulata					+		
C. tenuicaulis	+						
Corynocarpus laevigatus						+	
Cyathodes juniperina						+	
Dysoxylum spectabile		+		+			+
Elaeocarpus dentatus				+			
Elatostema rugosum		+					
Geniostoma rupestre	+	+	+	+	+	+	+
Hebe stricta		+					
*Hedera helix**	+						
Hedycarya arborea		+	+	+	+	+	+
Knightia excelsa	+	+	+	+	+	+	+
Kunzea ericoides var. *ericoides*			+				+
Laurelia novae-zelandiae	+	+	+		+		+
Leptospermum scoparium		+					
Leucopogon fasciculatus		+		+		+	
*Ligustrum lucidum**	+						
*L. sinense**	+						
Litsea calicaris		+	+	+	+	+	+
Macropiper excelsum		+	+		+	+	+
Melicope simplex						+	
Melicytus ramiflorus	+	+	+	+	+	+	+
Metrosideros diffusa		+		+		+	
M. fulgens		+		+	+		+
M. perforata		+		+	+	+	+
Mida salicifolia		+				+	
Muehlenbeckia australis	+						
Myrsine australis	+	+	+	+		+	
Nertera depressa		+					
Nothofagus truncata						+	
Olearia rani		+		+		+	
Parsonsia heterophylla	+				+	+	+
Passiflora tetrandra	+						
Pittosporum eugenioides						+	

(continued)

Appendix 1 *(continued)*

Species	Claude-lands Bush	Hakarimata Scenic Reserve	Kakepuku Historic Reserve	Matahuru Scenic Reserve	Maunga-tautari Mountain	Puke-mokemoke Bush Reserve	Te Tapui Scenic Reserve
Pseudopanax crassifolius		+		+		+	+
Rhabdothamnus solandri		+					
Rubus cissoides		+					
Schefflera digitata		+	+				
Solanum sp.*	+						
Streblus heterophyllus	+						
Weinmannia racemosa		+					
Flowering plants – monocotyledons							
Astelia banksii				+			
A. solandri		+		+			
A. trinervia		+				+	
Carex sp.	+						
Collospermum hastatum				+			+
Cordyline banksii				+			
Dianella nigra		+		+		+	
Drymoanthus adversus		+		+			
Earina autumnalis			+				
Freycinetia banksii	+	+	+	+			+
Gahnia pauciflora				+		+	
Microlaena avenacea	+	+	+	+	+		+
M. stipoides		+					
Oplismenus imbecillis		+				+	+
Rhopalostylis sapida			+	+	+		+
Ripogonum scandens	+	+	+	+	+	+	+
Rytidosperma sp.		+					
Schoenus tendo		+					
*Tradescantia fluminensis**	+						
Uncinia sp.						+	
U. uncinata		+	+	+	+	+	+
U. zotovii				+			
Winika cunninghamii				+			