THE AUTECOLOGY OF *LONICERA JAPONICA* IN A RESTORATION CONTEXT

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ABSTRACT

This thesis concerns the autecology of *Lonicera japonica* in relation to ecological restoration in Hamilton. It addresses three groups of questions, relating to *L. japonica*'s place in the plant community, its reproduction and spread, and its impacts on other plants.

*L. japonica'*s role in the plant communities of natural areas and restoration sites and its variation with environmental factors were studied quantitatively through vegetation measurement and soil analyses at plots established at a naturally regenerating site in Hamilton. Its role under varying disturbance regimes and physical conditions was studied qualitatively and semi-quantitatively at eight other locations. A simple model relating stem diameter to age was developed to assess the age and demography of *L. japonica* populations.

L. japonica's potential to spread was assessed through trials to establish seed and fragment viability, examination of climatic records, and the identification from the literature of potential vectors.

Impacts of *L. japonica* on other species were assessed first through a consideration of the frequency at which plants of differing characteristics are invaded, and second by characterising its impacts upon those plants.

The thesis concludes with recommendations for further research and for the management of the plant in restoration areas.

Through the field work it was found that *L. japonica* is more widely dispersed both within and across natural areas and restoration sites in Hamilton than had been detected from initial site visits, to the extent that it was difficult to detect patterns and relationships at the chosen scale of investigation. It exhibits a tolerance for low pH and wet conditions greater than found in studies overseas, and neither those factors nor soil fertility are likely to limit its spread in restoration and natural areas in New Zealand. However at light levels found

beneath typical native canopy cover the plant's vigour is greatly reduced, and this offers the most promising avenues for control.

L. japonica disperses readily *via* stem fragments incorporating nodes and sets plentiful fertile seed. Though the viability of that seed is short, propagation by this means is possible in Hamilton and may become significant in relation to future restoration work.

In good light conditions *L. japonica* forms dense mats that smother vegetation of low stature and prevent natural succession in canopy gaps, as well as compromising the health of restored areas. In locations with mature canopy *L. japonica* may survive over lengthy periods on the ground, with restricted vigour, or in canopy-entering clumps that have grown with the host; either form will expand rapidly if light conditions improve. However because of their growth form and trunk texture even mature tree ferns may be killed by *L. japonica.*

Novel elements that have emerged from this study are the plant's tolerance of a wider range of environmental conditions in New Zealand than reported overseas, its potential to spread by seed in local conditions, and an emerging synergistic relationship with another invasive liane, *Ipomoea indica.* The latter two issues are worthy of further study.

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CHAPTER 1 – INTRODUCTION

This thesis presents a study of the autecology and synecology of *L. japonica* in relation to ecological restoration in Hamilton. It considers the plant's reproduction, spread, direct impacts on other plants and its place in the vegetation community in relation to its environmental requirements and interactions with other plants. It then offers suggestions for future study and recommendations for management. These matters were first explored through a literature survey, which identified areas where field work and trials were required to test the applicability in Hamilton of study results from other environments.

1.1 GENERAL

1.1.1 Botany

L. japonica Thunb. is of the order Dipsacales, family Caprifoliaceae, the honeysuckles. Its common name is Japanese Honeysuckle. It is a twining climbing or trailing perennial that can climb into the canopy or form dense ground cover. The green, herbaceous, pubescent stems quickly become densely tangled during growth, mature to reddish-brown, become woody and non-pubescent, and eventually develop a shredded, peeling bark (Kartesz, 2008).

The flowers, berries and seeds are described as follows:

"Flowers are in axillary pairs, fragrant, with peduncles 0.5–2.5 cm long that are densely hairy. The bracteoles and calyx lobes are very small and fringed with long hairs. The corolla is 2.0–4.5 cm long, usually white but becoming yellow after anthesis, and flushed with pink on the reverse surface. The entire corolla is 2.0–5.0 cm long and the corolla tube 1.0–3.0 cm. The lower protruding lip is two-lobed and the upper one four-lobed. The stamens and style are approximately equal in length to the corolla. The stamens are attached to the corolla tube and the style to a small inferior ovary. The sessile berries, 4.0–7.0 cm in diameter, are hard and green when immature and black when ripe. The 2 or 3 seeds are approx. 0.2 cm in diameter, ovate to oblong, with a flat to concave inner surface and with three ridges on the back" (Williams and Timmins, 1998).

There is one New Zealand genus in the family, *Alseuosmia* A. Cunn., 1839. Cunningham described eight species. Though the precise number is uncertain (Allan, 1982), all are erect or spreading shrubs; there are no lianes.

1.1.2 Vegetative Spread

L. japonica produces numerous runners, whose length can exceed 15 m. The runners develop roots at nodes in contact with soil. If runners are severed between rooted nodes, each portion develops into a separate plant (Nuzzo, 1997). One purpose of this study is to assess the proportion of severed nodes likely to develop into plants when the severance occurs before roots are established.

1.1.3 Sexual Reproduction

In its native range *L. japonica* sets abundant fruit and produces large quantities of viable seed (Williams and Timmins, 1998; Schierenbeck, 2004). However Williams and Timmins suggest (loc cit) that seedling production in New Zealand is extremely rare, and that apparent seedlings are usually detached stem segments that have developed into plants.

1.1.4 Range

L. japonica is a liane of Asian origin from the family Caprifoliaceae, the honeysuckles. The first specimens were taken to Kew from China in 1806 by William Kerr. It has subsequently naturalised in portions of North America, Mediterranean and Central Europe, southern Britain, North Africa, South Africa, Australia, New Zealand, the Philippine Islands, the Hawaiian and other Pacific Islands, and Central and South America (Schierenbeck, 2004). It has been identified as invasive in all these locations except Africa, where there is insufficient information to make a determination.

1.1.5 Ecological Impacts

Schierenbeck identified a need for research into *L. japonica*'s ecological impacts in a wider range of regions (it has been extensively studied in the South Eastern United States but much less elsewhere), an exploration of its potential to disrupt successional processes, and a better understanding of the role of stratification in seed fertility(Schierenbeck, 2004). Schierenbeck's remarks set the context for this thesis but with an emphasis on ecological restoration rather than on un-mediated processes.

The impact of *L. japonica* is evident at many natural areas and ecological restoration sites in Hamilton where, in terms of the model of invasiveness set out by Henderson et al, it is both invasive and transformational (Henderson, Dawson et al., 2006). At the edges of areas with full bush cover it forms scrambling mats up to 1 m. in depth, excluding most other vegetation. It is capable of covering and killing low canopy. In areas with denser cover it can engulf the crown of some species, killing individual specimens. It can survive in low light conditions at an immature stage, expanding rapidly when canopy gaps open.

1.2 RESEARCH QUESTIONS

Despite its wide distribution, *L. japonica*'s invasiveness and impacts vary greatly. The objective of this thesis is develop an understanding of the way the plant's autecology and synecology condition its impact on natural and restoration areas in Hamilton. In addressing this objective, a consideration of the relevant literature and field visits to a range of sites led to the following research questions:

- What is the role of *L. japonica* in the vegetative communities of Hamilton natural areas and restoration sites, and how does it vary with environmental factors? This question also led to a number of hypotheses about *L. japonica* in relation to vegetative composition; their testing is described.
- What are the implications of *L. japonica*'s reproductive biology for Hamilton's natural areas and restoration sites? How does it spread now and how could it spread in the future?
- What direct impacts does *L. japonica* have on restoration species and selected exotic species common at restoration sites? What general implications can be drawn from those specific impacts?

1.3 THESIS STRUCTURE

The results of investigations into the above questions are presented in five chapters:

Chapter 1 – Introduction

This chapter sets the context for the thesis, presents an overall literature survey, identifies the research questions and describes the thesis structure.

Chapter 2 – *Lonicera japonica* in the Plant Community

This chapter surveys the literature on the autecology and traits of *L. japonica*. It then considers its place in the plant community as an expression of these traits, based on quantitative field work at one site and primarily qualitative work at eight other sites in Hamilton. Hypotheses about the role of *L. japonica* in the plant community are tested in relation to the qualitative field work.

Chapter 3 – Age Estimation from Stem Size

This chapter describes the development of a method to estimate plant age from field measurements of stem diameter, subsequently used in the fieldwork.

Chapter 4 – Reproduction and Propagule Spread

This chapter surveys the literature on the reproduction of *L. japonica* then presents results of the following:

- an assessment of light conditions necessary for *L. japonica* to flower in Hamilton
- a trial of the proportion of stem segments that set shoots
- germination trials from seed gathered from Hamilton sites.

Chapter 5 – Direct plant impacts of *L. japonica*

This chapter considers the direct impacts of *L. japonica* on other plants through:

- an analysis of the propensity of plants to host *L. japonica* at the primary study site
- a categorisation of those impacts
- the drawing of general conclusions about the aspects of plant life form that affect the impacts *L. japonica* has upon them

Chapter 6 – Conclusions and Recommendations

This chapter summarises the study's conclusions, highlights further information needs and produces recommendations for management of *L. japonica* in a restoration context.

1.2 STUDY SITES – TOTARA PARK

1.2.1 Background

The quantitative work for this study was carried out at Totara Park, Hamilton. Originally a sand quarry, Totara Park (vicinity 175 15 02 E, 37 44 48 S) is now reserve land owned and administered by Hamilton City Council (HCC) subject to the Reserves Act 1977 and is classified under that Act for the purpose of recreation. Its management policies and objectives are set out in the Neighbourhood and Amenity Parks Management Plan.

The park's name reflects previous ownership by the Taupo Totara Timber Company (TTT) rather than current or past vegetation. Though records are unclear, it appears that TTT continued a sand quarrying operation while developing surrounding land in its ownership for housing between 1969 and 1970. Hamilton City Council acquired the bulk of the former quarry site after it ceased operation in 1970.

1.2.2 Physical Description and Study Area

Following conclusion of the quarrying operations the site was left in the form of a wide U shaped valley sloping to the East, denuded of topsoil. At some point after 1970 the lower portion was filled and topsoil was placed to create a neighbourhood park. The park is drained by one stormwater pipe at its Eastern end whose invert is only slightly lower than the ground level of the study area at that point. In combination with the filling to create the neighbourhood park, this has established a high water table across the study area.

The park's total area is 3.76 ha. comprising 0.84 ha. in grass (the neighbourhood park referred to above) with the remainder in regenerating wetland vegetation and in slopes transitional between the larger vegetation in the floor of the park and the surrounding residential properties.

A relatively topographically uniform study area of c. 1.23 ha was selected from within the regenerating area so as to reduce the influence of topography as a confounding variable. It is defined by the boundary of the grassed area to the East and the 25 m. contour round the other three sides of the park. The elevation of the study area ranges from 23 m above sea level next to the grassed area to 25 m at the West end, while the enclosing banks to the West, North and South are 7-8 m high. Mean slope East-West is c. 1:80 or approximately 0.7 degrees. From the North and South to the low point in the centre of the park the mean slope is approximately 1:30 or about 2 degrees, though much of the elevation change North-South occurs close to the study area boundaries.

The study site is traversed by overland flow paths connecting stormwater pipes that enter the park from the West and North with the continuation of the stormwater system to the East. In addition to this poorly defined water course, areas within the study site are seasonally inundated and there are also depressions of a few metres radius and up to c. 1 m deep that are frequently flooded.

When quarrying ceased the site was left as worked over tephra deposits, so that, in effect, the process of the return of vegetation was a primary succession, albeit accelerated by enrichment from stormwater inputs, garden waste disposal from adjoining sites and the ingress of colluvium from the surrounding banks. The impact of these factors has been enhanced by the relatively small size of the site. The soil is heavily organic and seems to have been formed primarily from decaying vegetation from the initial colonising plants and subsequently from leaves of the canopy dominant, the deciduous tree *Salix cinerea*.

1.3 QUALITATIVE STUDY SITES

1.3.1 Selection Criteria

These sites were chosen to cover a range of restoration and maintenance regimes in order to characterise the role of *L. japonica* in different settings. The selection was confined to gullies and the river bank because of the number and importance of this type of site in Hamilton.

The variables considered were:

- Aspect (slope, orientation)
- Drainage
- Canopy type and % cover
- Disturbance regime
- Site Shape/edge characteristics
- Prevalence of *L. japonica*

Age/Size Structure of *L. japonica*

L. japonica relationships with other site vegetation

Relatively uniform sites were selected within the locations described in Table 1 so as to be capable of consistent characterisation across their area.

1.3.2 Site List

Site Name	Code	Disturbance Regime
Riverbank, Pine Beach	RPB	20+yr old restoration planting, maintained
Riverbank, Fairfield Esplanade	RFE	No planting, no maintenance
Gully behind Porritt – Snell to Crosby	GPO	No planting, no maintenance
Mangaiti Gully, Huntingdon to Hukanui Rd	GMGT	5-10 yr old restoration planting, some maintenance
Tauhara Park (Kirikiriroa Gully), Wairere Bridge	GTA	10 yr old amenity planting, some maintenance
Waitawhiriwhiri Gully between Ulster St and Seddon Rd	GWA	3 yr old restoration planting, no maintenance
Riverbank, Mangakotukutuku Gully confluence	RMA	No planting, no maintenance
Mangakotukutuku Gully, Sandford Park	GMA	30 yr old restoration planting, some maintenance

Table 1 –Totara Park and study sites in Gullies (G) and on the banks of the Waikato River (R)

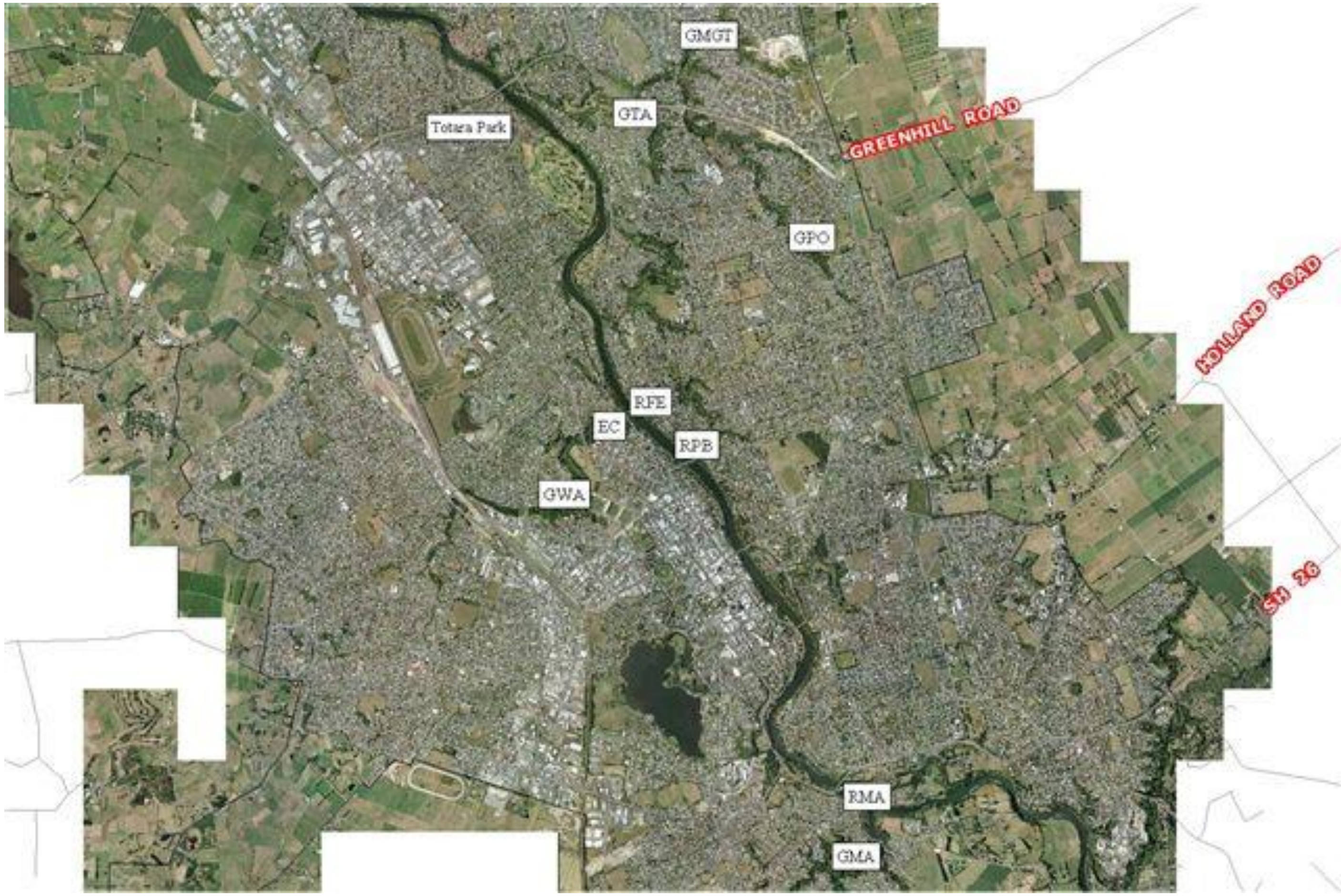

Figure 1 - Site locations

CHAPTER 2 – *LONICERA JAPONICA* IN THE PLANT COMMUNITY

2.1 INTRODUCTION

L. japonica is important in two contexts in Hamilton; first, as an invader of natural areas, and second as a component of the city's many highly modified sites, where the issue is its role in succession, whether mediated by human intervention and restoration efforts or not. This study's central assumption is that *L. japonica*'s role in the plant community is the result of the interaction of its means of dispersal, its environmental requirements and its interactions with other plants.

This chapter examines the assumption by describing *L. japonica*'s prevalence, forms and patterns in relation to other vegetation and environmental factors, quantitatively at one site (Totara Park) and qualitatively across Hamilton at sites selected to reflect a range of disturbance regimes and varying intensities of restoration effort (Table 1). On the basis of previous studies, it is hypothesised that at Totara Park, an un-managed site, there will be an inverse relationship between quantity of large, canopy entering *L. japonica* and species diversity, a positive relationship between the deciduous canopy and quantity of *L. japonica* and an inverse relationship between the distance from the edge of the densely vegetated portion of the park and the quantity of *L. japonica.* Qualitatively, it is expected that *L. japonica* will be most prevalent on disturbed sites with low quantities of evergreen canopy (using available light and canopy cover estimate as a joint measure) and low or non-existent maintenance regimes.

2.2 GENERAL BACKGROUND

2.2.1 Competitive Mechanisms

An important determinant of *L. japonica's* importance in natural and restoration sites is its competitive success. Plants compete through a variety of mechanisms. They may reduce the availability of sites for the establishment of competitors, they may exhibit allelopathy, and they may compete for edaphic resources and light (Crawley, 1997). They may also cause physical damage to other plants, the outcome of which may be community-level changes. *L. japonica* exhibits all these characteristics. Meiners et al. have noted a clear relationship between increasing cover by an invasive species and the magnitude of its effects, from which they inferred that cover dominance is more important than presence in determining invasive impact(Meiners, Pickett et al., 2001). In favourable conditions *L. japonica* can form dense ground or canopy cover. Thus it has the potential to have significant impacts in a restoration context.

2.2.2 Traits of successful invaders

In the restoration context, Funk et al. suggested introducing species having similar traits to potential invaders and with a broad range of traits to fill potentially niches capable of being invaded(Funk, Cleland et al., 2008). The obverse of this suggestion is that a successful invader will have traits distinct from those of its native competitors and will also have wide environmental tolerance, possibly manifested through phenotypic plasticity, to enable it to take advantage of any vacant or under filled niches. It has been noted that "vines are commonly found both in deep shade and in full sun and thus may possess a broad intra-specific physiological plasticity… vine physiological adaptability to low light environments may be coupled to the ability to compete for sunlight and related to the climbing mechanism" (Carter and Teramura, 1988). *L. japonica* may appear as scrambling ground cover, a twining liane on a single or multiple hosts or as a dense mass covering plants. It is able to occupy these multiple roles by virtue of its phenotypic plasticity (Rejmanek, 2000). This plasticity also equips the plant well to exploit broken or mixed environments characteristic of disturbed areas.

2.2.3 Morphology

Lianes are long-stemmed, rooted woody vines that climb or twine around other plants. They are structural parasites that, after a juvenile scrambling phase, use plants or trees for support to reach well-lit areas. In doing so they may become twisted together to form a hanging network of vegetation. Lianes generally differ from trees and woody plants phenologically, anatomically and allometrically, in ways that make them highly competitive with trees, shrubs and in some instances, ground covers. Their use of other plants for support enables a higher proportion of resources to be devoted to extension growth, ensuring that a liane that reaches the canopy can stay there as the host plant grows. Similarly, lianes can support a greater leaf area per stem diameter than a tree since less stem diameter is devoted to support structures (Putz, 1984; Putz, 1984; Putz and Chai, 1987; Putz, 1990).

2.3 *L. JAPONICA* BACKGROUND

2.3.1 Plant community impacts and potential spread

Williams and Timmins summarise the likely effects of *L. japonica* on North American vegetation communities as follows: in deciduous forests, the vines may cause the collapse of the understorey shrub layer and occasionally small canopy trees, preventing the establishment of new shrub populations, leading to a simplified forest structure and lower floristic diversity. Open habitats such as low shrublands may be completely smothered. They suggest that effects in New Zealand are similar, with the most vulnerable areas being open scrub, shrublands, woodlands, and the margins of forests, particularly where these occupy moist alluvial or colluvial sites and wetland and riparian margins. After a survey of regional prevalence, they concluded that *L. japonica* occupies only a fraction of the areas suitable for it, and that it will continue to spread over wide areas of New Zealand (Williams and Timmins, 1998).

2.3.2 Allellopathy

Skulman et al. found that *L. japonica* leaf tissue added to soil at a rate of 2 gm 100 gm^{-1} reduced the mean height of loblolly and shortleaf pine (Skulman, Mattice et al., 2004). This study was carried out in North America, where *L. japonica* is commonly deciduous; in Hamilton it is evergreen so leaf fall is gradual. Consequently levels of *L. japonica's* potential allelopathic agents may not reach harmful levels. This is a question worthy of further study.

2.3.3 Light Requirements

Baars and Kelly compared the light requirements of *Clematis vitalba*, *L. japonica*, and *Passiflora mollissima* (introduced vine species) with two common native vine species (*Muehlenbeckia australis* and *Parsonsia heterophylla*) (Baars and Kelly, 1996). They grew plants under irradiance levels corresponding to 40%, 7%, 3.5%, and 2% of available sunlight (expressed as relative irradiance (% RI)). Though *P. heterophylla* had the lowest light compensation point of the species studied, *L. japonica* had a higher growth rate and responded rapidly to increased light levels. *L. japonica*'s light compensation point was found to be c.0.9% RI, a result consistent with that reported by number of other workers(Sasek and Strain, 1990; Schierenbeck and Marshall, 1993; Robertson, Robertson et al., 1994). Slezak (1976), (in (NatureServe, 2008)) divided honeysuckle-infested plots into density and vigour classes and found that vigour (measured by the number of vegetative runners) was adversely affected by shading of less than 3% of full sunlight, but density was unaffected. Though according to Little & Somes 1967, in (Williams and Timmins, 1998) initial growth rates are slow, established plants have the ability to grow rapidly into high light regions of the canopy. From the above it can be concluded that an infestation of *L. japonica* can survive in low light conditions at relatively low biomass but will respond strongly to a changed light regime.

2.3.4 Phenology

L. japonica is usually evergreen in New Zealand conditions, but exotic canopy dominants in restorations areas are frequently deciduous. This can be expected to give *L. japonica* a competitive advantage in terms of reaching and growing over the canopy, additional to the advantages arising from the liane form (Carter and Teramura, 1988).

2.3.5 Morphology

In comparing aspects of the morphology of *L. japonica* and *Lonicera sempervirens* (a congener indigenous to the United States) a number of workers have found that *L. japonica* shows shorter inter-node distances when climbing than trailing, thus concentrating leaves in more favourable photosynthetic conditions (Schweitzer and Larson, 1999; Larson, 2000). Conversely the longer trailing internodes enable the plant to cover a greater area in search of climbing supports and suitable rooting sites. When climbing *L. japonica* produces fewer but longer lateral shoots than when trailing, optimising its climbing abilities without diverting excessive resources from the central shoot. Prostrate shoots of *L. japonica* displayed reduced circumnutation in comparison with climbing shoots, again optimising climbing ability.

2.3.6 Soil and nutrient requirements

L. japonica's nutrient requirements have not been extensively studied. Segelquist et al. investigated the response of *L. japonica* to fertilisation in order to assess the viability of increasing the plant's productivity as deer browse. Their study employed three levels of nitrogen application and two each of phosphorus and potassium(Segelquist and Rogers, 1975). Total vegetation production responded significantly to the application of 175 kg N/ha but there was no significant increment over that level from the application of 300 kg N/ha. Thus *L. japonica* growth will not be limited by N on any soil with N in excess of 175 kg/ha. There were no significant effects with applications of P and K nor were there significant interactions. *L. japonica* prefers well-drained forest soils of pH 6.1 to 7.9 but has been found invasive in areas where the soil pH values are 4.0 and 8.0 (Schierenbeck, 2004). Typically wetland sites in Hamilton have pH levels lower than Schierenbeck's suggested optimum range. A lack of soil organic matter and low mineral composition do not appear to have a major effect on *L. japonica* (Caiazza and Quinn, 1980; Schierenbeck, 2004). It has been inferred from its typical associations in New Zealand that *L. japonica* should be characterised as early secondary vegetation on moist, fertile sites (Williams and Timmins, 1998).

2.3.7 Tolerance of wet conditions

Brush et al. correlated the distribution of 15 different forest associations with substrate and water availability (Brush, Lenk et al., 1980). An analysis of indicator species in these associations showed that liana species, including *L. japonica*, reached their highest incidence in floodplains, bottomlands and adjacent substrates, suggesting a high tolerance for wet environments. *L. japonica* is considered to be a lower-end facultative wetland indicator (USFWS, 1988, 1993). Thus it usually occurs in wetlands and is occasionally found in non-wetlands but not, in the USA at least, in poorly drained, permanently saturated soils. It will thrive in sandy soils as long as there is available moisture. The evidence on tolerance of wet conditions is inconclusive and this study addresses the question in Hamilton.

2.4 METHOD

2.4.1 Introduction

The aim of this research was to survey *L. japonica* in relation to vegetative composition, quantitatively at Totara Park and qualitatively at a range of sites elsewhere in Hamilton.

2.4.2 Plot Location and Measurement – Totara Park

A 10 X 10 m grid was superimposed on a map of Totara Park using Hamilton City Council's GIS system. Each cell in the grid falling wholly within the study area was assigned a number and twelve were selected using Microsoft Excel's pseudo-random number generator (See Figure 2 - Plot Locations).

The plot measurement technique employed was adapted from that described by (Allen, 2003) for forests but substituting transect measures of groundcover for the understory plots he recommends. The plot size was reduced from Allen's recommended 20 x 20 recognising that the vegetation on this site is of much lesser stature than that of the indigenous forest for which the technique was developed. Also the site itself is small and somewhat irregular, so that too large a plot size would lead to the exclusion of substantial parts of the study area. Plots were located using a GPS and then tagged at the North West corner and marked out with nylon cord. Diameter of all stems greater than 1.5 m in height was recorded. This departure from standard practice was because of the frequent growth habit of the canopy dominant on this site, *Salix cinerea*. Often mature specimens of this species fall but send up multiple stems from the fallen trunk, which may constitute the canopy even when of quite small diameter. For example on one fallen trunk in Totara Park there were 17 stems with total diameter 71 cm, average size 4.2 cm and none larger than 9 cm; this fallen tree dominated the light well it had opened up in falling.

There were difficulties in quantifying *L. japonica* and assessing its influence on vegetative composition. As noted above *L. japonica* demonstrates considerable phenological plasticity (Rejmanek, 2000). In maturity its form may range from liana to a self-supporting scrambling mass. Between these two extremes it may be a vine inhabiting the sub-canopy or supported by a single tree fern or immature tree. Similarly juvenile plants may occur as the early stages of any of these forms or as lengthy stems hidden in leaf litter. Seedlings and ramets can be counted collectively but not readily distinguished at the plot level since positive discrimination of ramets from seedlings would require that each be carefully removed and inspected. The essence of the methodological problem is that methods to characterise vegetation across the whole plot are not suitable for measuring *L. japonica*. The adopted solution was to carry out three measures for each plot – canopy/sub-canopy, a diagonal transect of ground cover, and a count and classification of all *L. japonica* specimens. Where appropriate, plant ages were estimated using the method reported in Chapter 3 – Age Estimation from Stem Size. Specimen data sheets appear as Appendix 1.

Figure 2 - Plot Locations

Measurement of *L. japonica* presented some difficulties and imprecision in quantifying it is a weakness in method for this study. It is possible to measure diameters where a plant is in the canopy and its stems are free, or the plant comprises a single isolated stem. This cannot be done for large scrambling masses. The method adopted was to categorise each plant or ramet of *L. japonica* by size (small, medium, large, very large) and degree of maturity, (seedling/ramet, juvenile, mature). Where a plant was climbing on one or more hosts, the species were recorded. Where a plant was 2m diameter or greater in diameter either scrambling or in the canopy, it was classified as “very large”, a 0.5-2 m plant was classified as “large” less than 0.5 m with multiple shoots was classified as medium, while any plant with a single shoot was classified “small”. For the purposes of analysis, a score was assigned to each category based on an estimate of the area covered by plants falling into each class:

Size	Index 1	Index 2
Small	1	
Medium	5	
Large	40	40
Very Large	60	60

Table 2 - *L. japonica* weightings employed for analysis

An index for presence of *L. japonica* in each plot was then calculated as the product of the above weightings and the number of plants falling into that size class.

2.4.2 Soil Samples

Soil samples were collected from each plot at Totara Park. The samples were taken from five locations 2 m apart on the North West/South East diagonal within each plot. So far as possible given root masses and the extremely fluid nature of the soil on some plots a sample of approx. 10 cm depth by 2 cm diameter was taken at each sampling location; these were accumulated into a single sample for each plot. The samples were analysed by Hill Laboratories; a sample plot result sheet and explanation of sampling protocols are attached as Appendix 2 – Soil Analyses. The results are summarised in Appendix 4 – Plot Environmental .

2.4.3 Qualitative sites

As described on p.6 eight sites was selected to characterise *L. japonica* in a range of restoration settings with different maintenance regimes. A qualitative assessment of each site was carried out with a more detailed assessment of a smaller area within each site. The information recorded was location, aspect, slope, drainage, soil type, canopy type and percentage cover, disturbance/maintenance regime, site shape/edge characteristics, prevalence of *L. japonica* and its relationship to other site vegetation, and light at flowering point of mature plants. A partial census of *L. japonica* was then carried out through lengths of two gully systems adjoining two of the above sites, with contrasting maintenance and light regimes. The method was to count all substantial growths of *L. japonica* visible from the walkway as a general assessment of its prevalence at each site. Impact of the infestation was assessed on a scale 1-10, where 1 represents presence only and 10 was death of the host.

2.4.4 Analysis

Results were aggregated into tabular form. Associations between variables were tested using Pearson's Product Moment Correlation Coefficient for interval data and Spearman's Rank Order Correlation Coefficient for associations involving the *L. japonica* index, which is arguably an ordinal measure given the methodological difficulties discussed above. In order to detect patterns between variables across plots, cluster analysis was carried out. The method was Euclidean distance, complete linkage. Data entry and initial manipulation was carried out using Microsoft Excel (Microsoft, 2007) and statistical analyses were carried out with Statistica (Statsoft, 2008).

2.5 RESULTS -TOTARA PARK

2.5.1 Species Prevalence

Canopy composition of the twelve plots combined is shown in Table 3. *Salix cinerea* is the canopy dominant by a substantial margin, with roughly equal contributions from *Cordyline australis*, *Dicksonia squarrosa* and *Dacrycarpus dacrydioides*. The relative success of the latter three species probably relates to their growth form and hence their ability to compete with the canopy dominant for light. *C. australis* and *D. squarrosa* have a crown/trunk structure and *D. dacridioides* being tall and slender. Numerically *Coprosma robusta* is well represented but the specimens are not large (average diameter 3.6 cm). They are typically found growing adventitiously in light wells opened up by the fall of *S. cinerea*, a common feature of the site, and can be regarded as temporary occupants of the canopy.

Species	Count	%	Sum of Diameters	%
Betula sp.	1	*0.3*	6	*0.1*
Coprosma robusta	41	*11.1*	147	*1.7*
Cordyline australis	15	*4.1*	161	*6.2*
Dacrycarpus dacrydioides	11	*3.0*	166	*9.7*
Dicksonia squarrosa	19	*5.1*	260	*9.8*
Fatsia japonica	1	*0.3*	3	*0.0*
Geniostoma rupestre	1	*0.3*	2	*0.0*
Melicytus ramiflorus	15	*4.1*	49	*0.6*
Pittosporum eugenioides	1	*0.3*	2	*0.0*
Pittosporum tenuifolium	1	*0.3*	4	*0.0*
Pseudopanax lessonii x crassifolius	4	*1.1*	13	*0.1*
Salix cinerea	257	*69.6*	2152	*71.5*
Schefflera digitata	2	*0.5*	11	*0.2*
Total	369		**2975**	

Table 3 - Canopy - Species and Size

Sub-canopy composition (Table 4) presents a different picture. *S. cinerea* remains the most common species numerically, followed closely by *Coprosma robusta,* but falls to second place behind *Dicksonia squarrosa* in size. This reflects the tree-fern growth form of *D. squarrosa* – it has a relatively large trunk at low (sub-canopy) heights, while *S. cinerea* exhibits radial growth, and diameter and height are in proportion.

Species	Count	%	Sum of Diameters	%
Coprosma robusta	69	*19.7*	156	*3.1*
Cordyline australis	32	*9.1*	209	*11.2*
Dacrycarpus dacrydioides	4	*1.1*	8	*0.1*
Dicksonia fibrosa	1	*0.3*	17	*2.1*
Dicksonia squarrosa	56	*16.0*	656	*57.9*
Fatsia japonica	1	*0.3*	2	*0.0*
Geniostoma rupestre	9	*2.6*	22	*0.5*
Gunnera tinctoria	10	*2.8*	51	*1.8*
Ligustrum sinensis	16	*4.6*	31	*0.5*
Melicytus ramiflorus	19	*5.4*	51	*2.3*
Pittosporum tenuifolium	2	*0.6*	5	*0.1*
Pseudopanax crassifolius	1	*0.3*	5	*0.1*
Pseudopanax lessonii x crassifolius	5	*1.4*	18	*0.7*
Salix cinerea	70	*19.9*	337	*17.4*
Schefflera digitata	56	*16.0*	119	*2.1*
Total	351		**1685**	

Table 4 - Sub-canopy - Species and Size

Of the 363 *L. japonica* plants counted in plots at Totara Park, 4.7% were seedlings, 48.5% juveniles, and 46.8% mature, flowering plants(Table 5). The juvenile plants are for the most part under the canopy, as they do not flower in low light (see p. 54).

Life Stage	n in plots	%	n/ha
Seedlings	17	4.7%	142
Juvenile	176	48.5%	1467
Mature	170	46.8%	1417
Total	363	100.0%	3025

Table 5 - Prevalence of *L. japonica* at Totara Park

It is possible that this table over-states numbers of plants at the site, because of the difficulties of confirming that a particular plant is in fact a separate entity. With that caution, there appear to be c. 1400 separate flowering *L. japonica* plants per hectare at Totara Park and the same number of juveniles.

2.5.2 Soil analysis

The soil at Totara Park is highly organic and very fertile. It has a low weight/volume ratio and high levels of all key nutrients except phosphorus, which at a mean plot value of 18.3 mg/L is at the low end of the desirable range for optimal plant growth (McLaren and Cameron, 2002). However growth is unlikely to be limited by phosphorus at this level in organic soils, which have low to very low phosphate retention capacity (McLaren et al. op. cit.). Despite the soil's high Cation Exchange Capacity (CEC) the levels of other nutrients are such that they too are unlikely to limit plant growth. The water table is very shallow, at a mean depth across the plots of only 11.4 cm. This is likely to be an important environmental factor determining plant community composition.

Cluster	Water Table (mm)	pH	P (mg/L)	K (me/100gm)	VW (g/ml)	N (kg/ha)	CEC (me/100gm)	Dist.
Av.	114	5.7	18.3	2.5	.3	341	96	38.3

Table 6 – Average environmental variables, all plots

To explore relationships between main soil and environmental variables a correlation matrix across plots was calculated (Table 7). Increasing depth of water table was significantly associated with increasing acidity and decreasing levels of phosphorus, potassium and calcium; relationships between other nutrients reflect this fundamental association. Similarly soil volume weight was negatively associated with levels of all nutrients, though oddly, the relationship between volume weight and water table is not strong though it is in the expected direction. A partial explanation may lie in the difficulty of taking a sample of an extremely wet soil that accurately reflects its water content, i.e. water loss before a sample can be bagged is inevitable unless special techniques are used. At Totara Park the water table is relatively uniform across the study area but surface level rises towards the edges of the park. The character of the soil varies accordingly; further from the water courses pH is lower and levels of all nutrients except nitrogen are less. From the work of Segelquist and Rogers (op. cit.) and from results reported by Schierenbeck (see p. 12) the range of nutrient levels is unlikely to have affected the vigour of *L. japonica*, though pH is low relative to the plant's reported range (Schierenbeck, 2004). The site's fertility and high water table was reflected in *S. cinerea*'s canopy dominance.

	pH	P (mg/L)	K (me/100gm)	Ca (me/100 gm)	Mg (me/100 gm)	Na (me/100 gm)	VW (g/ml)	N (kg/ha)	CEC
Water Table	-0.8576	-0.5269	-0.7291	-0.5827	0.1375	-0.3037	0.3437	0.0535	0.0667
pH		0.4153	0.7001	0.7434	0.0019	0.3018	-0.4495	-0.0504	0.1383
P (mg/L)			0.7268	0.3347	0.1873	0.6403	-0.4701	-0.0540	0.2735
K (me/100gm)				0.4920	-0.0492	0.5836	-0.7698	-0.3704	0.1691
Ca (me/100 gm)					0.5602	0.2071	-0.4068	-0.4699	0.6584
Mg (me/100 gm)						0.0338	-0.1338	-0.5308	0.8918
Na (me/100 gm)							-0.5300	0.0037	0.1337
VW (g/ml)								0.5585	-0.4475
N (kg/ha)									-0.6435

Table 7 – Pearson's correlation coefficient matrix between main soil variables

(highlighted cells significant at $p<0.10$)

VW = Soil Volume Weight   CEC = Cation Exchange Capacity

2.5.3 Edge Effects

Though the site is relatively small there is still the possibility of edge effects. To investigate these the shortest distance was measured from the centre of each plot to an edge of the vegetated area of the park, using Hamilton City Council's GIS system. The average edge distance is 38 m. One plot was at the edge of the park's grassed area and two are c. 20 m from that edge. Plot 7 is close to housing but is separated by large scale vegetation and a steep bank (see Table 8 and Figure 2). There is a wide distribution of edge distances among the plots relative to the size of the park.

Plot	Edge Distance
7	28
19	49
36	44
40	34
41	43
42	52
51	57
52	60
69	42
87	21
90	21
96	9
Minimum	**9**
Maximum	**60**
Average	**38.3**

Table 8 - Edge Distances

2.5.4 Plant Community Associations

In analysing the plant community numbers of each species were insufficient to allow investigation at the species level or at the growth form level for ground cover. Accordingly species and ground cover type were classified, as follows:

Ground Cover

Native groundcover (62% *Carex secta*, *baumea* sp., *Blechnum novae-zelandiae*., remainder various seedlings, notably *D. dacridioides; L. japonica* was excluded to avoid auto-correlation)

Exotic groundcover (67% *Zantedeschia aethiopica*, 18% *S. cinerea* seedlings; various lianes and seedlings)

Water

Bare ground

Leaf litter

Canopy

Deciduous canopy

C. australis canopy

Evergreen canopy

Tree Fern canopy

Deciduous subcanopy

Evergreen subcanopy

Tree Fern subcanopy

% Canopy cover

Canopy mean height

A correlation matrix showing relationships between the above variables was calculated (see Table 9). Two significant associations with plot prevalence of *L. japonica* emerged. There was a positive correlation (.6449) with bare ground and a negative correlation (-.5715) with ground cover of leaf litter. Leaf litter was itself positively associated with the presence of tree ferns (because tree fern litter is very slow to decompose, while *S. cinerea* leaf litter had decomposed by the time sampling was undertaken in spring and summer). Bare ground was positively associated with canopy height (.4988) and negatively associated with *C. australis* canopy (-.6307).

	Native ground cover	Exotic ground cover	Water	Bare ground	Leaf litter	% Canopy cover	Canopy mean height	Decid. canopy	C. austral. canopy	Evergr. canopy	Tree Fern canopy	Decid. Sub canopy	Evergr. Sub canopy	Tree Fern sub canopy	C. austral. Sub canopy
LJ Index	-0.0358	0.2174	-0.1486	0.6449	-0.5715	-0.0250	0.1172	0.3948	-0.1585	0.0283	-0.3455	-0.4349	0.3357	-0.2758	-0.1240
Native groundcover		-0.0920	-0.1986	-0.3129	-0.2863	0.3550	0.4152	0.1472	0.0916	0.2809	0.2435	-0.2245	0.2028	-0.1222	0.4773
Exotic groundcover			0.4384	-0.1762	-0.4928	-0.7042	-0.4138	0.5228	0.4147	-0.1708	-0.5197	0.3762	0.4305	-0.4206	0.2962
Water				-0.3754	-0.1680	-0.3558	-0.1847	0.0152	0.5673	-0.2269	-0.2049	0.0428	-0.2323	-0.2197	0.0792
Bare ground					-0.3676	-0.0535	0.4988	-0.1110	-0.6307	0.1630	-0.2046	-0.2912	0.1466	-0.1006	-0.1939
Leaf litter						0.2427	-0.2982	-0.4068	0.0482	0.0097	0.5767	0.3842	-0.4811	0.7035	-0.2968
% Canopy cover							0.2226	0.0793	0.0473	-0.1025	0.4862	-0.4876	-0.1232	0.4259	-0.2881
Canopy mean height								-0.3747	-0.4861	0.4721	0.3360	-0.2161	0.0757	0.0439	0.2439
Deciduous canopy									0.5369	-0.6482	-0.4008	-0.1807	0.2933	-0.0052	0.3131
C. australis canopy										-0.4835	-0.0812	-0.0160	-0.2308	0.0788	0.1204
Evergreen canopy											0.4269	0.1994	0.3487	-0.2637	-0.1192
Tree Fern canopy												0.3439	0.0406	0.6152	-0.1981
Deciduous subcanopy													0.2618	0.3049	0.0669
Evergreen subcanopy														-0.3375	0.0588
Tree Fern subcanopy															-0.0192

Table 9 - Spearman's rank order correlation coefficient matrix for vegetation variables

Highlighted values significant at $p < 0.10$ (*L. japonica* excluded from ground cover)

2.5.5 Species Diversity and prevalence of *L. japonica* in the canopy

It was hypothesised that there would be an inverse relationship between quantity of large, canopy entering *L. japonica* and species diversity. A correlation matrix was calculated between large, canopy entering *L. japonica* (Index 2, Table 2) and number of species by category.

	L. japonica in canopy
Native Ground Cover & Presence	-0.2135
Native canopy/Sub Canopy	0.5672
Total Native Species	0.2343
Exotic Ground Cover and Presence	0.1437
Exotic Canopy and Sub-canopy	0.2967
Total Exotic Species	0.2686
Total All Species	0.3781

Table 10 – Spearman's rank order correlation coefficients between presence of *L. japonica* and species numbers

Highlighted cell significant at p <.1 level.

There was a weak positive correlation (significant at the 10% level) between quantity of *L. japonica* and number of native canopy and sub canopy species. Further, though no other correlation is statistically significant, all except that between quantity of *L. japonica* in the canopy and native ground cover species number were weakly positive. This may have occurred because there was greater sub-canopy diversity under deciduous canopy, because competition for light was less severe, but the plot sample size was too small to support analysis of this question. In any event, the data contradicted the hypothesis.

2.5.6 Deciduous canopy and quantity of *L. japonica*

It had been hypothesised that there would be a positive relationship between amount of deciduous canopy (measured by total stem diameter of *S. cinerea*/plot) and *L. japonica*, represented by Indices 1 and 2, Table 2. There was a non-significant positive relationship between quantity of deciduous canopy and *L. japonica* (Table 11). The evidence does not support the hypothesis.

	L. japonica	
	All plants	Plants in canopy only
Deciduous Canopy	0.3916	0.2993

Table 11 – Spearman's Rank Order correlation coefficients between deciduous canopy and presence of *L. japonica*

no significant correlation at p <0.1

2.5.7 *L. japonica* Edge Effect

It was hypothesised that *L. japonica* would be more prevalent at the edges of the park than in its interior. This was tested through the calculation of correlation coefficients between edge distance (Table 8) and quantity of *L. japonica* (Indices 1 and 2, Table 2). The results shown in Table 12 do not support this relationship, suggesting rather that *L. japonica* was to be found throughout the site.

	Edge distance
All *L. japonica* plants	-0.1786
L. japonica in canopy	-0.1182

Table 12 – Spearman's Rank Order correlation between distance from edge and *L. japonica* numbers

no significant correlation at the p<.1 level

2.5.8 Environmental and species prevalence patterns across plots

In an attempt to detect patterns between environmental and species prevalence data , cluster analysis of plot environmental values was carried out. The pattern of vegetation associated with each cluster was then analysed. The environmental variables subjected to cluster analysis were depth of water table, pH, phosphorus (milligrams/litre), potassium (milliequivalents/100gm), weight/volume ratio of dried, ground soil (grams/millilitre), available nitrogen (kilograms/hectare), cation exchange capacity (milliequivalents/100gm) and distance (shortest distance from plot centre to edge of vegetated area of park). The plots resolved into five clusters, as follows:

Cluster	A	B	C	D	E
Plots	7, 96	19	36, 42	41,51,52,69, 87	40,90

Table 13 – Plot Cluster Membership

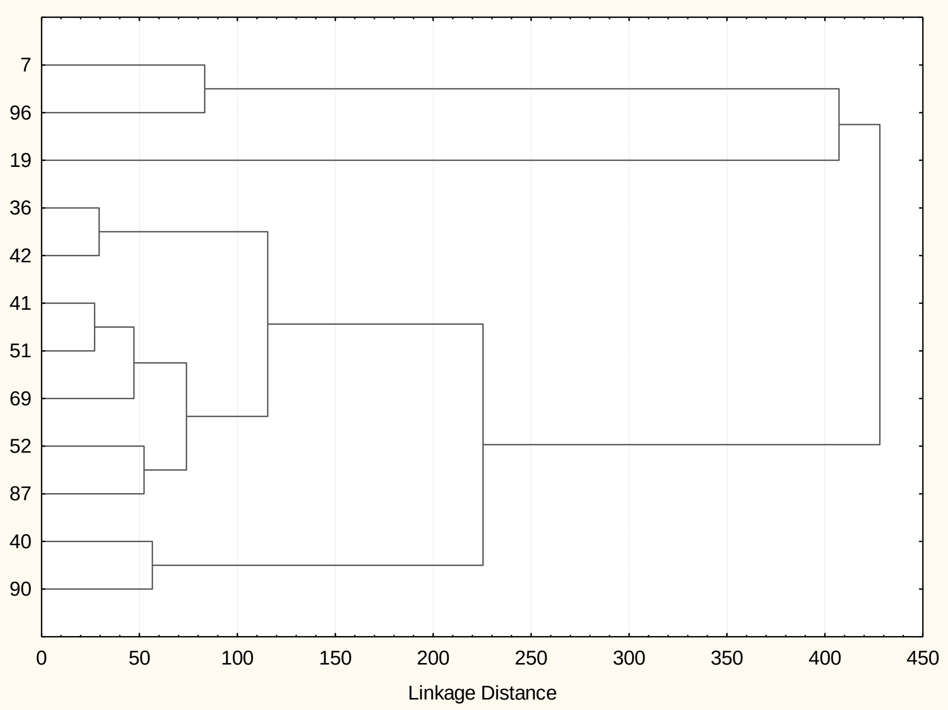

Figure 3 - Cluster Tree Diagram, Complete Linkage, Euclidean Distances

The clusters resolved at short linkage distances, demonstrating coherence within clusters on the variables employed (Figure 3). This coherence appears to reflect the location of the clustered plots in relation to the stormwater flow paths through the park which in turn is closely associated with depth of water table. Plots 42 and 19 are apparently anomalous, but on the basis of water table depth reflect localised high spots. Means were computed for each cluster on all environmental and vegetation composition variables (Table 14). The clusters formed around a gradient of increasing depth of water table, which was in turn associated with increasing acidity and decreasing phosphorus and potassium.

Figure 4 - Cluster membership, showing relationship to drainage channels

A B C D E

	Cluster					
Variable	D	C	E	A	B	Mean
Water Table	17.0	110.0	130.0	205.0	400.0	172.4
pH	5.9	5.9	5.7	5.6	5.2	5.6
P (mg/L)	20.8	17.5	18.5	15.5	13.0	17.1
K (me/100gm)	3.0	2.7	2.5	1.5	1.5	2.2
VW (g/ml)	0.3	0.2	0.3	0.4	0.3	0.3
N (kg/ha)	339	307	200	580	227	330.4
CEC (me/100gm)	93	102	106	84	101	97.1
Distance	44.6	48.0	27.5	18.5	49.0	37.5
L. japonica Index	383.2	415.5	250.0	404.5	383.0	367.2
Native Ground Cover	18%	9%	20%	27%	4%	0.2
Exotic Ground Cover	39%	21%	33%	42%	16%	0.3
Water	7%	0%	0%	0%	0%	0.0
Bare Ground	28%	45%	7%	32%	80%	0.4
Leaf Litter	7%	26%	40%	0%	0%	0.1

	Cluster					
Variable	D	C	E	A	B	Mean
% Canopy Cover	52.0	40.0	77.5	35.0	60.0	52.9
Deciduous Canopy	239.8	111.1	225.3	161.1	82.2	163.9
Cordyline Australis Canopy	18.3	7.4	27.5	3.1	0.0	11.2
Evergreen Canopy	5.9	54.0	23.4	101.4	69.6	50.9
Tree Fern Canopy	0.0	7.0	66.5	40.6	31.9	29.2
Deciduous Sub-canopy	19.5	15.1	34.1	58.9	19.6	29.4
Evergreen Sub-canopy	39.6	11.0	42.1	98.8	40.9	46.5
Tree Fern Sub-canopy	55.8	29.1	119.1	19.0	60.4	56.7
Cordyline Australis Sub-canopy	28.6	13.2	0.0	26.6	0.0	13.7

Table 14 - Cluster means of environmental and vegetation variables

Note: *L. japonica* index is Index 1 as described in Table 2; ground cover variables are the % of points on a diagonal transect across the plot falling into the stated category; % canopy cover is an estimate of cover over the plot; the canopy and sub-canopy variables are the sum of diameters of plants of that category in the plot.

A correlation matrix was computed to indicate relationships between the mean cluster values for *L. japonica* and the other variables (see Table 15).

Environmental and vegetation class variables by cluster	LJ Index total
pH	0.1111
P (mg/L)	-0.0251
K (me/100gm)	-0.2642
VW (g/ml)	-0.1861
N (kg/ha)	0.1668
CEC (me/100gm)	0.5452
Distance	-0.5677
LJ Index total	0.3439
Native Ground Cover	-0.2457
Exotic Ground Cover	-0.1326
Water	0.1331
Bare Ground	0.5858

Environmental and vegetation class variables by cluster	LJ Index total
Leaf Litter	-0.7067
% Canopy Cover	-0.8994
Deciduous Canopy	-0.5374
Cordyline Australis Canopy	-0.8031
Evergreen Canopy	0.4779
Tree Fern Canopy	-0.7572
Deciduous Sub-canopy	-0.0930
Evergreen Sub-canopy	0.0642
Tree Fern Sub-canopy	-0.9565
Cordyline Australis Sub-canopy	0.5617

Table 15 – Pearson's Correlation between *L. japonica* index and the other clustered variables.

Highlighted cells significant at the $p < 0.1$ level.

There was a significant negative correlation between quantity of *L. japonica* and percentage canopy cover and between *L. japonica* and quantity of tree ferns in the sub canopy. These results should be interpreted with caution, given that there are only five clusters. However, less *L. japonica* under dense canopy is an expected result, and tree fern sub canopy is itself strongly associated (.9827) with percentage canopy cover.

2.6 RESULTS – QUALITATIVE SITES

2.6.1 Introduction

This section comprises a study of the role of *L. japonica* in the plant community at eight natural and restoration sites in Hamilton (for locations see Figure 1). Results are summarised in Table 16 and fully described in Appendix 6 – Qualitative Sites. The sites reflect two broad disturbance categories; minimal intervention since original clearing/farming (sites RFE, GMGT, GPO, RMA and the lower half of the Tauhara Park gully site) and clearance and restoration planting (RPB, GMA, GWA and the upper half of Tauhara). The variables are all direct measurements except "Cover/Height Score" which is the product of canopy mean height and % cover. The first disturbance category is further distinguished by the quantity of canopy. The presence of large canopy species at the Porritt gully site has resulted in the co-existence of predominantly *S. cinerea* canopy and large stemmed *L. japonica* plants with foliage in the canopy. At the Mangaiti gully, Tauhara lower part and the Fairfield Esplanade sites, where there is little or no canopy, *L.*

japonica or *I. indica* form large scrambling mats that are the dominant vegetation over large parts of the sites. Isolated trees or shrubs within the sites support large growths of *L. japonica.* The river bank at the Mangakotukutuku confluence is an intermediate case. The lower canopy specimens (up to 5 m) are close to being over-whelmed by *L. japonica* , while the larger trees (up to 10 m) support quite large growths of *L. japonica* but appear healthy.

The second disturbance category sites have been cleared and planted with restoration species at varying times up to c. 30 years ago. Pine Beach has had a limited range of relatively short lived native species planted on the slopes (*M. ramiflorus, P. eugenioides, C. medullaris*- the latter possibly self –sown) with some exotics at the river edge (*A. glutinosa, S. cinerea*). At Mangakotukutuku Gully a similar range of natives has been planted amongst a number of exotic species, including *P. radiata*, *Cupressus sp.*and *R. pseudoacacia.* In both cases the understorey is very limited and *L. japonica* runners traverse the site; less so at Pine Beach as there appears to have been recent clearing of ground cover. On both these sites there are numbers of mature, canopy reaching *L. japonica* plants, often with thick (to 24 mm) stems. The Waitawhiriwhiri site was completely cleared in 2006 and planted with a fuller range of restoration species. However *I. indica* has returned to the site very rapidly and has smothered a number of the restoration plants. *L. japonica* is present but much less prevalent than the *I. indica*. It occurs on a number of shrubs and small trees but not to the extent of threatening their health at present.

The sites show a pattern detectable across a number of variables. Sites with a lower canopy/height score are more likely to have large cohesive areas of *L. japonica,* either as scrambling mats or overlying low canopy species. At sites with a higher score *L. japonica* is usually less continuous and may attain considerable age, more or less in balance with its hosts.

Site Code	Location type	aspect	slope	drainage	soil type	canopy species	Canopy cover	Mean Canopy Height	Cover/ Height Score	Disturbance	site characteristics	*Lonicera japonica* presence
RFE	Riverbank	210 ^{o}	1:20, 1:5	good	W	None	0%	-	0	No maintenance, no planting	Lower river terrace	Lower part of site is 10 m wide scrambling mat, covering stumps and dead shrubs. Est age 6 years.
GTA	Gully bottom	240^{o}	1:12	good	Anth/V	PIE, ALG, COA	10%	2 m	0.2	Half planted and irregular mtce, half neither	Gully floor and slope created as part of bridge construction	Large scrambling mats on lower part of site, planted specimens on upper portion invaded by *L. japonica* in various degrees. Est. age 2-3 years max.
GWA	Gully slope	260^{o}	1:3	Good	Anth	PON, LSC, DAC, PIT, PIE, PHT, COPR, KUE	20%	2.5-3m PON to 20 m at edge of plot	0.55	Clearance & restoration planting, 2006. Minimal maintenance since	Section of east bank of steep sided c. 20 m. deep gully.	Sparse through site, usually with IPI. Flowering on restoration species at age of approx. 3 years
GMGT	Gully bottom	270^{o}	1:20	poor	V	SAC, SAF	20%	3 m	0.6	No mtce, no planting	Section of gully floor	Large tangle on SAF, stems to GAM & CARS, with IPI in scrambling heaps. Oldest stems est. 14 years
GPO	Gully	315 ^{o}	Flat	poor	V	SAC,	40%	7.5 m	3	Canopy removal at	Section of back	Mature stems on canopy

Site Code	Location type	aspect	slope	drainage	soil type	canopy species	Canopy cover	Mean Canopy Height	Cover/ Height Score	Disturbance	site characteristics	*Lonicera japonica* presence
	bottom					CYM				w. of site, some weed control in body of site	swamp	trees, many stems scrambling across site. Est. age oldest stems 16 years.
RMA	Riverbank	60°	1:10, 1:2	Good	Anth Kk	EUC, LIS, COPR, SAC	75%	5-10 m	5.625	Heavily modified with civic works, c. 30 years BP. No planting or maintenance since	Artificial terrace then slope to river	TRF merges into scrambling mat of *L. japonica* which climbs into the canopy of a number of trees. 3 x 5 m cover of an LIS supported by many stems, oldest c. 11 years
GMA	Gully slope	100°	1:2	Good	Kk	PIE, DIF, CYM, CUP, PIR, ROP, MER	75%	20 m+	16.5	Restoration planting c. 1980. Minor pest plant mtce since, mostly at edges	Section of gully slope. Former back swamp at foot has been filled.	Eight large canopy reaching *L. japonica* on MER, CYM, ROP. Estimated ages range from 6-18 years. Many runners at ground level under canopy.
RPB	Riverbank	210 °	1:4, 1:3	good	Kk	MER, CYM, PIE, ALG	90%	20 m	18	30 yr old rest. Planting. Ground cover removed - herbicide	Section of river scarp	Four large mature *L. japonica* on MER. Eight major stems –oldest stem c. 14 years Only one Mahoe seriously affected.

Table 16 - *L. japonica* at sites of varying topography and disturbance regime

Site code: RPB - Riverbank, Pine Beach, RFE - Riverbank, Fairfield Esplanade, GPO - Gully behind Porritt, GMGT - Mangaiti Gully, GTA - Tauhara Park, GWA - Waitawhiriwhiri Gully, RMA - Riverbank, Mangakotukutuku Gully confluence, GMA Mangakotukutuku Gully

Soil key: V – Tamahana soils, alluvium and organic debris; Anth. – Anthropic, various origins; KK – Soils of terrace scarps and gully sides, related to yellow brown loams, from rhyolitic alluvium (Hinuera formation), mainly Kirikiriroa series; W - Waikato loamy sand - yellow-brown pumice soils from rhyolitic alluvium (Taupo Pumice Alluvium) Waikato series

Species key: PIE - *Pittosporum eugenioides* ALG - *Alnus glutinosa* COA - *Cordyline australis* SAF - *Salix fragilis* SAC -*Salix cinerea*
GAM *Glyceria maxima* CARS - *Carex secta* IPI - *Ipomoea indica* CYM – *Cyathea medullaris* MER - *Melicyctus ramiflorus*
PON – *Populus nigra* LSC - *L. scoparium* DAC - *D. dacridioides* PIT - *P. tenuifolium* PHT - *Phormium tenax*
COPR - *C. robusta* KUE - *Kunzea ericoides* TRF - *Tradescantia fluminensis* DIF - *Dicksonia fibrosa* CUP - *Cupressus sp* PIR - *Pinus radiata* ROP - *Robinia pseudoacacia* LIS – *Ligustrum sinensis*

2.6.2 PARTIAL CENSUS RESULTS

Two sites were assessed: Mangaiti Gully, from the eastern Keswick Crescent access to Hukanui Rd, and the Waitawhiriwhiri Gully from Ulster to Victoria Streets.

2.6.3 Mangaiti Gully (for route see Figure 5)

The 700 m section of Mangaiti Gully described here falls into two sections. The upper section is un-maintained and has had no restoration planting. The canopy is predominantly *S. cinerea* and various tree fern species. At about 350 m from the eastern end of the walkway there is a transition to a more open section with more broken canopy; restoration planting starts at about 500 m and continues through successive stages of maturity to Hukanui Rd. From about 600 m there are sections with near canopy closure.

There are 33 substantial *L. japonica* plants visible from the path. In the section with denser canopy cover and no maintenance regime scrambling *L. japonica* is almost omnipresent. In the planted and occasionally maintained section, where the canopy is less dense it is much less prevalent, being replaced by *Ipomoea indica*. In the more intensively maintained restoration are with developing canopy it is very sparse.

size	host	Comment	Host impact 1-10
MM	COPR		3
MM	COPR		7
SJ	Scram		0
MM	CARS	with IPI	4
LM	Unknown dead		10
VLM	SAC		8
LM	LIS		8
LM	SAC	(fallen branch) with IPI	6
LM	SAC	Lower reaches, with IPI	4
MJ	DIC/Scram		1
MM	SAC	Lower reaches	5

size	host	Comment	Host impact 1-10
MM	LIS	Overtopped	7
MM	DIC	Reaching canopy	3
MJ	SAC	Under canopy	1
LM	SAF	Covers large parts of lower canopy	6
LM	SAC/COA	Fallen SAC, covers one upright, heavy on young COA(1 m)	6
LJ	SAC	Widespread under canopy	3
MJ	SAC	Under canopy	2
MJ	SAC	Under canopy	2
MJ	CYM	Confined to trunk	2
LM	SAF	Over lower reaches with Ip	6
MM	LIS	Sparse	4
MM	LIS	With IPI – largely covers	8
MJ	SAC	In lower reaches	3
LM	SAC	With IPI	7
LM	SAC	With IPI	8
MM	UEU, PIE	Major impact on PIE	8
VLM	UEU, CYM,	Long bank of *L. japonica*	8
MM	SAC	Lower reaches	5
LM	Scram with IPI	Possibly plants under	-

size	host	Comment	Host impact 1-10
LM	COA, Scram with IPI	Part of dense mat.	5
MM	COPR	In upper reaches	6

Table 17 - Mangaiti Gully Partial *L. japonica* Census Results

Size/Maturity code: S – Small M – Medium L - Large VL – Very Large;
J – Juvenile M - Mature
Species key: COA - *Cordyline australis* SAF - *Salix fragilis* SAC -*Salix cinerea*
CARS - *Carex secta* IPI - *Ipomoea indica* CYM – *Cyathea medullaris*
PIE - *P.eugenioides* COPR - *C. robusta* DIC - *Dicksonia squarrosa*
UEU – *Ulex europeus* LIS – *Ligustrum sinensis*

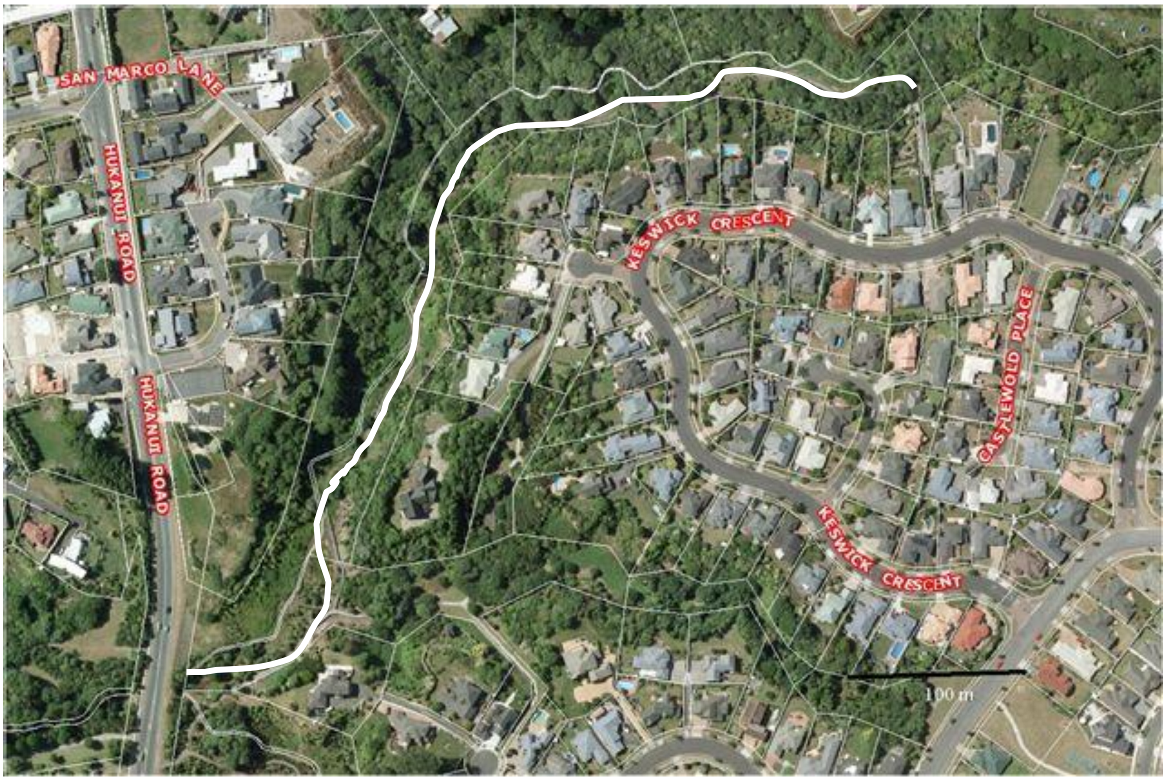

Figure 5 - Mangaiti Gully - route of partial *L. japonica* census

2.6.4 Waitawhiriwhiri Gully (for route see Figure 6)

The section of Waitawhiriwhiri Gully that was inspected runs from Victoria to Ulster Street. It is approximately 575 m long.

Figure 6 - Aerial photograph of Waitawhiriwhiri Gully through Edgecumbe Park, showing route of *L. japonica* census

Size	**Host**	**Comment**	**Host impact 1-10**
MM	Juvenile KAH	Host overwhelmed	9
MM	ROP	Over lower trunk only, in combination with IPI	2
JS	Scram	With TRF	0
MM	LIS	Some control	6
MM	Scram	Some control	-
*VLM	ROP	Some stems cut but still viable.	4
VLM	EU Sp.	Some stems cut but still viable – hanging free	4
LM	COA, ROP	COA crown still clear	7

Table 18 - Waitawhiriwhiri Gully Partial *L. japonica* Census Results

Size/Maturity code: S – Small M – Medium L - Large VL – Very Large;
J – Juvenile M - Mature
Species key: COA - *Cordyline australis* IPI - *Ipomoea indica*
EU sp.- *Eucalyptus sp.* DAC - *D. dacridioides* TRF - *Tradescantia fluminensis*
ROP - *Robinia pseudoacacia* LIS – *Ligustrum sinensis*

*This plant reached to 20+m. and had 13 major stems, ranging from 11 to 36 mm diameter. This suggests that the oldest stem is c. 25 year old. Light beneath the canopy was c.0.7% available PAR (probably an underestimate allowing for diurnal variation) and there was no foliage in the sub-canopy or groundcover portions of these plants – see Plate 1, suggesting that they had grown with the canopy specimens and before the current density of canopy cover was achieved.

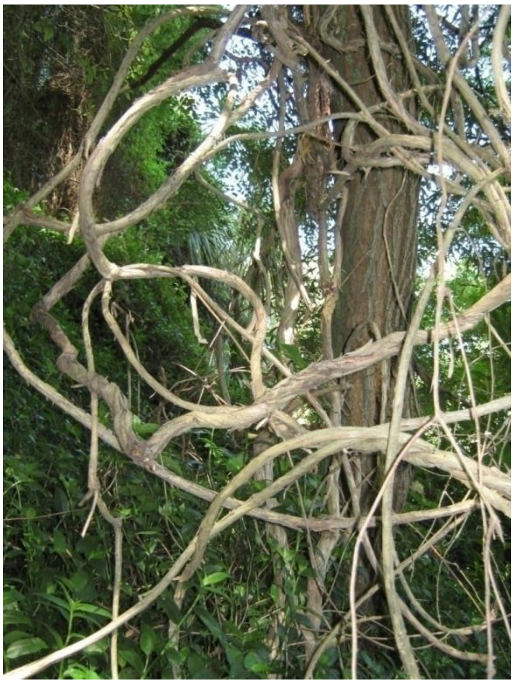

Plate 1 – *L. japonica* stems on *Robinia pseudoacacia* in Waitawhiriwhiri Gully, Edgecumbe Park.

As with the Mangaiti Gully, there was a clear distinction between open areas and those with greater canopy cover. In the former, *L. japonica* was vigorous and invasive, and appeared to have killed some restoration plants. In the latter it reached the canopy but did not appear to have covered the crown of any large tree.

2.7 DISCUSSION

2.7.1 Vegetation Community – Totara Park

It was hypothesised that at Totara Park there would be an inverse relationship between the quantity of *L. japonica* within each plot, and in particular the largest *L. japonica* plants, and diversity of indigenous species and species generally within the plot. No such relationships were detected, either in terms of species numbers or relative dominance. Nor was any other systematic relationship detected between *L. japonica* and either environmental factors or the plant community, apart from the relationship with canopy density which emerged from the cluster analysis (see Table 15). Possible reasons for this apparent lack of a pattern include the following:

a) *L. japonica*'s distribution over the site

L. japonica occurred in every plot. The weighted index ranged from 70 to 887 and the actual number of plants from 13 to 52. The distribution is narrower than the range would suggest (mean and medians 29.5 and 30.25 and 362 and 370) and with the exception of two outlying values *L. japonica* is much more widely dispersed through the site than had been detected on initial visits to design the vegetation survey. Thus there is less possibility of detectable effects or patterns that might be associated with a more uneven distribution.

b) Chosen plot size

Plots were 10 m x 10 m. Few scrambling thickets of *L. japonica* were more than 2-3 m. at their longest dimension, and with the exception of a few light wells the larger plants were in the canopy. Thus the plant's impact tended to average out within plots. Much stronger effects would have been detected with a smaller plot size, though purposive sampling might have been required to ensure a good representation of *L. japonica* in its various forms and on various species of interest.

c) Definition of the study area.

To avoid confounding variables of slope, aspect, drainage and soil type, the study area was confined to the flat area of Totara Park. Consequently edges were under-represented in the plot sample yet the plant (and other vines) is most evident at the edges of the vegetated area.

2.7.2 Soil and moisture requirements and tolerance

The literature presents an unclear picture of *L. japonica*'s soil and moisture requirements. It has been observed in the United States that *L. japonica* prefers well-drained forest soils of pH 6.1 to 7.9 (Schierenbeck, 2004), and it has been inferred from its typical associations in New Zealand that *L. japonica* could be characterised as early secondary vegetation on moist, fertile sites (Williams and Timmins, 1998). The mean pH at Totara Park was 5.7 and the water table ranges from surface to a maximum of 40 cm. *L. japonica* is found all across the site except in standing water. At the qualitative sites it was found on a range of soil types ranging from those similar to that of Totara Park (heavily organic, low pH, poorly drained to saturated) through to well drained sandy loams on steep sites. Thus in Hamilton *L. japonica* appears tolerant of greater acidity and wetter sites than indicated by North American studies.

There is a lack of published information about *L. japonica*'s nutrient requirements. Its response to application of various nutrients has been studied. *L. japonica* showed little growth increment at a nitrogen application of 300 kg/ha over an application of 175 kg/ha, and no significant direct or interactive effects to applications of phosphorus or potassium (Segelquist and Rogers, 1975). Unfortunately only nutrient application rates were recorded rather than initial soil values, so all that can be inferred is that levels of the latter nutrient were above the growth requirements of *L. japonica.* In any event the mean nitrogen figure at Totara Park is 341 kg/ha so it is unlikely to be a growth limiting factor for *L. japonica* in this locality.

2.7.3 Light Requirements

The literature on light requirements is more consistent, with a number of studies indicating a light compensation point of c.0.9% RI. Slezak (1976) found that vigour (measured by the number of vegetative runners) was adversely affected by available light of less than 3% of full sunlight, but density was unaffected. In the present study light measurements were undertaken to establish the plant's flowering requirements (Table 23). Of the 34 light measures of juvenile plants or seedlings, 11 were below the light compensation point noted above and 21 were below the point at which Slezak (1976) noted vigour being lessened. It is evident that though low light conditions may prevent *L. japonica* flowering or reduce the plant's vigour, they are no impediment to it spreading through a site and climbing into better light and/or being present to take advantage of changes in light conditions, either through tree fall opening light wells or through clearance associated with restoration efforts.

2.7.4 Vegetative community – qualitative sites

The qualitative sites surveyed fell into two general disturbance regimes – no disturbance since farming or original clearance, and clearance and restoration planting, with or without subsequent maintenance. The character and prevalence of *L. japonica* growing at each varied according to the character of the resulting canopy. Sites undisturbed since farming or original clearance are typified by either exotic canopy or weedy species characteristic of open gully bottoms (e.g. *Glyceria maxima, Persicaria persicaria, P. hydropiper*).

The character of restoration sites depends on their age and the degree of maintenance that has been undertaken. If the sites have been released and maintained for 10-15 years plus, dense evergreen canopy is usually established. Such canopy, > 5m in height, is associated with older *L. japonica* in the canopy, typically older plants with large stems hanging free from the plant's foliage mass. There are likely to be runners among the ground cover but they will be of low vigour. Younger and/or un-maintained restoration sites are likely to be characterised by plants that are heavily colonised by *L. japonica* or other lianes such as *I. indica*.

Undisturbed sites with dense deciduous canopy are associated with older *L. japonica* plants in the canopy with twining or free hanging stems depending on the size of the host trunk. Growth in the sub-canopy and amongst ground cover may be more vigorous than under ever-green canopy. *Salix sp*., particularly *S. cinerea*, are prone to windfall and re-growth from the fallen trunk. If *L. japonica* is present it will take advantage of the resultant light well and may form dense mats. Where canopy species are less prevalent or absent *L. japonica* or another liane (typically *I. indica* in Hamilton) will form scrambling mats which may cover large areas.

CHAPTER 3 – AGE ESTIMATION FROM STEM SIZE

3.1 INTRODUCTION

3.1.1 Background

This section describes the development of a tool to estimate *L. japonica* age from diameter measurement. It has been noted that annual rings are prominent in *L. japonica* stem sections (Williams and Timmins, 1998). If a relationship between diameter and number of rings can be inferred, this will provide a method to impute age to *L. japonica* plants on the basis of a field measure of diameter. It would also enable the demography and history of *L. japonica* populations to be estimated.

Number of growth rings and diameters have been reported for a small number of stems harvested at different sites in New Zealand (Williams and Timmins, 1998). Their results are as follows:

Location	Diameter (cm)	No. of Rings
Motueka	1.1	3
Cobb Valley	1.2	3
Motueka	1.8	4
Rotorua	1.8	7
Cobb Valley	2.2	4
Morere Springs	2.3	10
Cobb Valley	3.3	5

Table 19 - Diameter and growth rings (Williams and Timmins, 1998)

These measurements fall into two groups, those taken at sites in the north of the South Island, and the North Island measures. The latter have roughly twice the number of rings at a given diameter. This suggests that while there is a relationship between diameter and number of annual rings, it needs to be calibrated for local conditions. There appears to be no international data on the *L. japonica* diameter/growth ring relationship (literature search and K. Schierenbeck, p. comm.).

3.2 METHOD

Forty-six stem sections were gathered from *L. japonica* plants at three (of the eight study sites in Hamilton, each being taken close to the base. The sections were digitally photographed and the rings were counted both with a hand glass and from enlargements of the photographs. Additionally, sections were prepared from eight stems and rings were counted beneath a binocular microscope at magnifications of up to 50X. This count was taken without knowledge of the initial count. The binocular count was substituted for the original value where different. Using vernier callipers, diameters were measured outside the bark when the stems were freshly cut. This approach was adopted to give comparability with field measurements. A linear regression was then carried out with Statistica (Statsoft, 2008) using diameter as the predictor variable and number of rings as the dependent variable.

3.3 RESULTS

Table 20 sets out measured diameters, rings counted with a hand glass and from digital photography and the original count where a check microscopic count has been carried out. Plate 2 shows a representative group of stems, some showing clear cut rings and others less so. The stems in Plate 2 have diameters and counted growth rings as follows:

Stem #	Diameter (mm)	Growth Rings
2	19.8	14
4	8.3	6
5	13.9	9
11	11.4	8

The rings do not show at all clearly on stem 4; it was examined microscopically but they remained rather indistinct. About one third of stems fell into this category.

Stem 2 Stem 4

Stem 5 Stem 11

Plate 2 - Cross Sections of *L. japonica* stems showing growth rings

Stem	Diam (mm)	Rings – photograph count	Original count	Estimate value (mm)	Difference (estimate – count)
1	15.0	8		11	3
2	19.8	14	14	14	0
3	10.5	7	6	8	1
4	8.3	6	5	6	0
5	13.9	9		10	1
6	14.2	8		10	2
8	14.6	10		11	1
9	15.8	12		11	-1
10	22.5	15		16	1
11	11.4	8		8	0
12	15.0	10		11	1
13	21.8	17		16	-1
14	12.9	13		9	-4
15	8.2	7		6	-1
16	10.3	9		7	-2

Stem	Diam (mm)	Rings – photograph count	Original count	Estimate value (mm)	Difference (estimate – count)
17	11.4	8		8	0
18	14.4	13		10	-3
19	15.0	7		11	4
20	13.0	9		9	0
21	17.3	15		12	-3
22	12.5	10		9	-1
23	20.5	14		15	1
24	14.0	14		10	-4
25	17.5	16	16	13	-3
26	18.5	13		13	0
28	18.0	14		13	-1
29	11.9	11		9	-2
30	19.5	18		14	-4
31	12.8	9		9	0
32	10.3	9		7	-2
33	19.5	10		14	4
34	13.5	10		10	0
35	14.5	15		10	-5
36	8.0	7		6	-1
38	13.0	12		9	-3
39	12.3	9		9	0
40	14.5	13		10	-3
41	9.5	7		7	0
42	8.0	8		6	-2
43	15.0	8	6	11	3
44	7.0	3	2	5	2
45	13.8	9	8	10	1
46	7.0	2	1	5	3
Average	13.9	10.4		10.0	1.68

Table 20 - Diameter and growth rings and model results - Hamilton 2008/9

	Multiple - R	Multiple - R²	Adjusted - R²	SS - Model	df - Model	MS - Model	SS - Residual	df - Residual	MS - Residual	F	p
Rings	0.8004	0.6406	0.6318	340.84	1	340.84	191.20	41	4.6634	73.1	0.0

Table 21 – Test of diameter/rings model (Rings=.7190*Diameter)

	Rings - Param.	Rings - Std.Err	Rings - t	Rings - p	-95.00% - Cnf.Lmt	+95.00% - Cnf.Lmt
Intercept	0.4032	1.2117	0.3328	0.7410	-2.0439	2.8502
Diameter	0.7190	0.0841	8.5491	0.0000	0.5492	0.8888

Table 22 - Diameter/Rings model parameters

A linear regression of rings on diameter produced the model R =0.7190*D, where R = rings and D=diameter. Table 20 compares actual values with those produced by this model. When the lower confidence ring counts were eliminated from the analysis the model did not change materially, noting that age estimates are in whole years (alternative model R=.7932*D).

3.4 DISCUSSION

Not all stems presented clear growth rings, and there was usually difficulty picking up the first one or two outside the pith where present, even microscopically. Therefore there are varying degrees of confidence in the ring counts on which this model is based. However since only the inner rings are usually hard to distinguish, the likely percentage error in age estimate will decline as the plant ages. Further, since the history of younger restoration sites and natural areas is better recorded or more accessible to recall, age estimation by this method is least important where it is likely to be least accurate.

It is concluded that despite its weaknesses this model is an acceptable tool for the purpose, and will give reasonable estimates of age of *L. japonica* from stem diameter measures. Accordingly it was employed to calculate the age estimates used in Chapters 2 and 5 to gain an understanding of the populations structure of long-established *L. japonica* on various host species.

CHAPTER 4 – REPRODUCTION AND PROPAGULE SPREAD

4.1 INTRODUCTION

L. japonica's invasive potential arises from the interaction of a number of factors, including its ability to propagate vegetatively and from seed and the existence of means of dispersing propagules. According to published studies (Haywood, 1994; Williams and Karl, 1996; Williams, Karl et al., 2000; Larson, 2002; Fowler and Larson, 2004) at least some of these factors vary widely through the plant's range, suggesting the need for local or regional study.

4.2 LITERATURE SURVEY

4.2.1 Vegetative Reproduction

It has been found that adventitious roots occurred frequently in the normal growing shoot, and were generally to be found at the node, in a median or lateral position just below the insertion of a leaf, but could be at any part of the internode (Sandison, 1934). They were commonest in the lower regions of the plant. He also noted root production from the ends of cut stems bearing foliage, and demonstrated that *L. japonica* grows readily from cuttings. This is the usual method of propagation where the plant is deliberately cultivated (Nuzzo, 1997). It seems likely therefore that it will be easily spread by fragments in garden waste or spread in the course of maintenance operations.

4.2.2 Sexual Reproduction

Flowering

A study of *L. japonica* in New Zealand reported variable flowering and fruit production at Nelson, Cobb Valley, and Wellington City(Williams and Timmins, 1998). Plants flowered at all three sites but set fruit only in Wellington. There, fruit per stem ranged from 4-15.

Fruit Set

Studies in the Eastern United States of America suggested that *L. japonica* decreases flowering activity as light decreases; in 8% of full light no flowers are produced (Thomas, 1980; Blair, 1992; Robertson, Robertson et al., 1994). However these studies were focused primarily on biomass and chlorophyll production in relation to light. The flower set results were incidental and there is a need for further New Zealand data.

Seed Viability

L. japonica's propensity to produce viable seed has been variously reported. (Larson, 2002) found that in Arkansas 17.4% of naturally pollinated flowers set fruit, by comparison with 78.7% of hand pollinated flowers. The researchers concluded that seed set was limited by available pollinators; as an invasive plant *L. japonica* had lost the services of its specialised pollinators.

Pollination

The *L. japonica* flower is adapted for pollination by hawk moths (*Sphingidae*) and their congeners (Miyake and Yahara, 1998), but bees also pollinate the species in its native range. *L. japonica* is pollinated by insects and hummingbirds in the USA. Insects involved include Hymenoptera (*Apis mellifera*, *Bombus spp*., and hornets), Lepidoptera (a hawk moth), and Diptera (syrphid flies) (Williams and Timmins, 1998). All these groups are present in New Zealand (Clunie, 2004). Thus pollinators are available and the issue for this study is whether *L. japonica* sets sufficient seed for spread by this means to be significant in Hamilton.

Seed Dispersal

Dispersal of seeds by small mammals and birds has been studied in New Zealand (Williams and Karl, 1996; Williams, Karl et al., 2000). The fruit of *L. japonica* is black and black or black/purple is a common fruit colour for New Zealand indigenous species (Williams and Karl, 1996) and its average fruit size (c. 5 mm) is close to the average for 21 indigenous species recorded by those researchers (5.7 mm, excluding *Solanum aviculare* which is larger by a factor of 10 then other fruit in their sample). *L. japonica* was fed to mammals and formed a part of the natural diet of birds; intact seed was recovered from the faeces of both (particularly possums) albeit in small numbers.

Unpublished data from a seed rain and seed bank experiment in Hamilton (Overdyck, 2008) showed *L. japonica* being present in vegetation at 7/14 sites sampled. Only one seedling germinated from 56 soil seed bank samples (4 samples each at 14 urban sites); this was at a site with *L. japonica* in the vegetation (Mangaiti Gully). Overdyck concluded there was no permanent seedbank. Four seedlings germinated from seed rain collected in the period April-July at four separate sites: Ranfurly Park, Tauhara Park, Yendell Park and Wairere

Drive. *L. japonica* was present in the vegetation at each site and dispersal may have been solely by gravity.

Seed Germination and Banking

Varying rates are reported for seed germination. An early study reported 63% germination after no stratification treatment, following storage at 4–16°C (Leatherman, 1955). Schierenbeck states that fresh seeds require stratification at 5-8°C for 60 days, and that germination begins at temperatures of approximately 10°C but is greatest from 18-25°C (Schierenbeck, 2004). Under dry storage, day conditions of 25°C and 15°C nights for 6 months, seeds retain a viability of 47% (Hidayati et al., 2000). After three years, Japanese honeysuckle has a seed viability of 1 to 3% and thus relies on dispersal just before or following disturbance (Shelton et al., 2002). Other studies confirm these trends (Haywood, 1994; Fowler and Larson, 2004). *L. japonica* seed has reasonable fertility in its first season but fertility declines rapidly thereafter.

Seedling Survival

Seedling survival with adequate moisture is 60% in 2% full sun and 100% at 3% full sun (Baars and Kelly, 1996). Reported field results are considerably lower – e.g. c. 14% survival in a forest interior (light level not known) (Fowler and Larson, 2004).

4.3 FIELDWORK AND TRIALS

4.3.1 Viability of Stems

Materials

Techno Plas 90 mm plastic injection moulded Petri dishes, Whatman 9 cm filter paper circles, magnifying glass, min-max thermometer, glasshouse, segments of *L. japonica* stem c. 5-8 cm in length, with and without nodes.

Method

The purpose of this trial was to test viability of stems with and without nodes. A sample size calculation (Statsoft, 2008) indicated that 86 of each category were required to test the hypothesis that the actual proportion of viable stems was within 2% of the assumed 90% rate with a 90% probability. Thirty-six petri dishes were prepared with triple layers of filter paper in each. Five stem segments were placed in each petri dish, giving a total of ninety with and ninety without nodes. Leaf nodes were distinguishable from root nodes and the stems were oriented accordingly. The petri dishes were inspected approximately every other day for a period of 58 days, by which time no further shoots were developing; at each inspection the number of leaf and root shoots was counted and the Min-Max temperatures were recorded.

Results

At the end of 58 days 65 of 90 stems with nodes (72%) had produced one or more shoots and one stem without a node had produced a root. The rate of shoot production over time is illustrated in Figure 7 and Figure 8. Through the period the highest temperature (controlled by the glass house's ventilation system) was 30^0C and the lowest was 16^0C. The mean diurnal range was 8.8^0C. Stems without nodes produced only one root, this appeared after 24 days.

Plate 3 - Shoots (leaves and roots) on stem segments with nodes

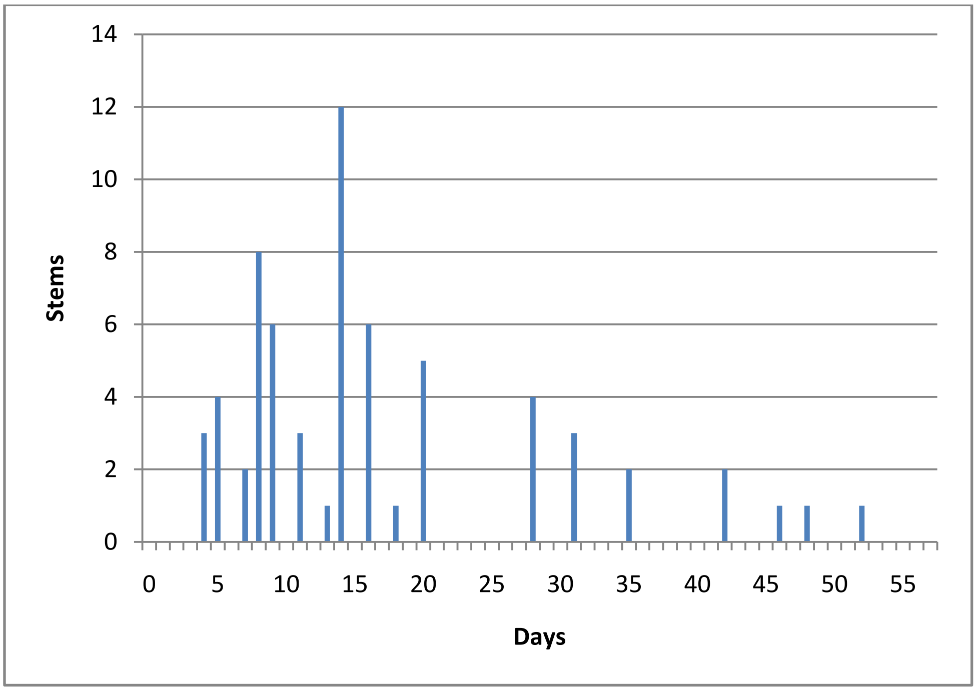

Figure 7 –Numbers of stems producing a first shoot over the course of the trial

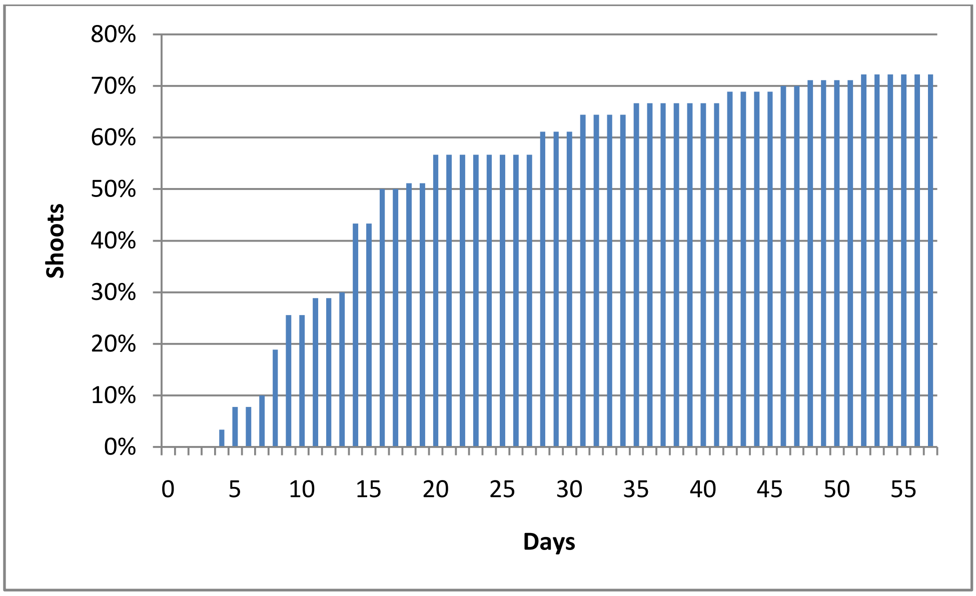

Figure 8 –Cumulative percentage of stems with shoots

Discussion

From Figure 8 –Cumulative percentage of stems with shoots it can be seen that 57% of the stems had produced a shoot by 21 days. This is 78% of the total that would eventually do so. The final percentage, 72% can be regarded as a low estimate of the proportion of stem fragments likely to set shoots in favourable conditions the wild since the sections used were quite short, had only one node, and were subject to high temperature and humidity in the glasshouse setting which led to some problems with fungus growth. This may have compromised the viability of some stems.

Growth of only one root from a stem section without a node was perhaps unexpected given the work of Sandison. He described the presence of pre-formed adventitious roots at a range of locations on stems (though principally at nodes) and also observed the growth of roots at cut ends of stems in the course of propagation of *L. japonica* from cuttings (Sandison, 1934). The latter was not fully tested in the current study since the roots observed by Sandison grew on cuttings with leaves at the other end. However no roots from cut ends were observed in the current trial. The distribution of shoot production over time approximates to a sigmoid curve, reflecting a normal distribution with a long tail. In evolutionary terms this would appear to be a good tactic since it would prolong the period over which stem segments could strike, making at least some stems more likely to encounter favourable conditions for growth.

4.3.2 Light Conditions for Flowering

Materials and Method

This part of the study entailed a field assessment of the light levels associated with plants at different stages of maturity. The method was to measure photo-synthetically available radiation (PAR) at the growing point of specimens of *L. japonica*, categorised as juvenile (non-flowering) or mature (flowering or showing evidence of having done so). Measurements were taken at all plots at the principal study site and at the secondary sites. The light levels were measured in µmol s-1 m-2 and are reported as percentages of available light. The light meter employed was a LI 250A produced by LI-COR Environmental, using a Quantum sensor.

Each measurement at a plant was matched with a full light measurement taken under, so far as possible, the same sky conditions. This presented some difficulties at Totara Park where the full light comparison measurements were taken in full sun but in light wells and may be slightly lower than a measurement taken in the open. A similar issue arose at one of the riverbank sites (RMA, riverbank confluence with the Mangakotukutuku) where three of the four lowest light levels for a mature plant were found; the site slopes to the East and because of the configuration of the canopy relative light measures taken in the afternoon are probably an under-estimate.

Results

Fifty-four light measures were carried out in summer 2008/9 – see Table 23.

	Juvenile	Mature
Average	3.4%	58.8%
Median	1.9%	58.3%
Minimum	0.2%	5.5%
Maximum	16.6%	100.0%
N.	34	20

Table 23 - Percentage available PAR, juvenile and mature *L. japonica*

Average percentage available light for mature plants was 58.8%, and for juveniles 3.4%.

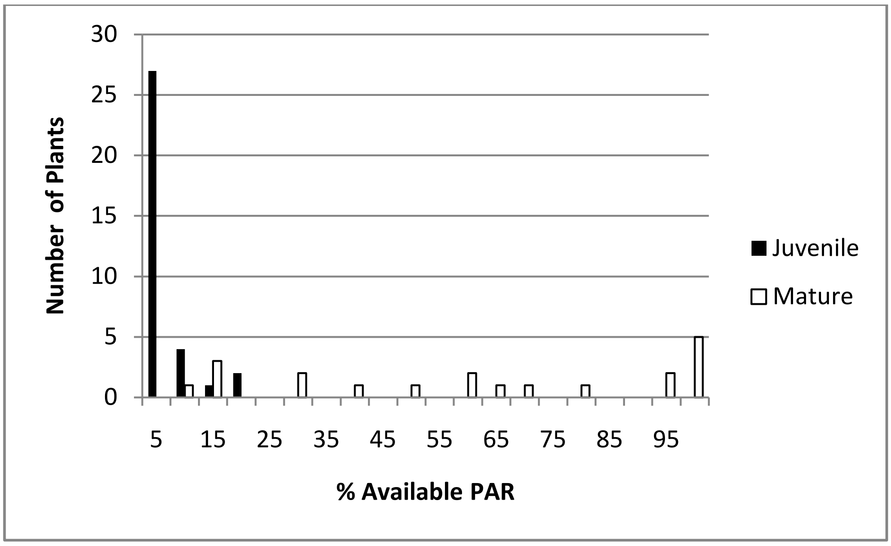

Figure 9 - Available PAR at mature and juvenile *L. japonica*

Discussion

As noted above, studies in the Eastern United States of America suggest that *L. japonica* decreases flowering activity as light decreases; in 8% of full light no flowers are produced (Thomas, 1980; Blair, 1992; Robertson, Robertson et al., 1994). The results above present some anomalies arising from the vagaries of measuring light under a broken canopy. These anomalies would probably disappear if light measurements were taken over the course of a day. However it can still be concluded that there is a low probability of *L. japonica* flowering in Hamilton if available light is under 10%.

4.3.3 Seed Germination

Materials

Techno Plas 90 mm plastic injection moulded Petri dishes, Whatman 9 cm filter paper circles, magnifying glass, min-max thermometer, glasshouse, refrigerator, *L. japonica* fruit.

Method

Two trials were carried out – one for seed gathered in the season before attempted germination, and the other for seed gathered in the same season as attempted germination. It was anticipated that the germination rate for aged seed would be very low. However a conservative assumption of a germination rate of 15% was employed for the calculation of the desired sample size. It was calculated that a sample size of 216 was required to test the hypothesis that the actual proportion of viable seed was within 2% of the assumed 15% germination rate with a 90% probability.

For the first trial, fruit was gathered from three Hamilton locations on the 9th and 15th of April 2007. It was stored at 2-4°C until November 2007. The fruit was then rehydrated to enable recovery and cleaning of the seed. The mean number of seeds per fruit was 8.3, minimum 3, maximum 14 and the standard deviation was 2.9. This is considerably larger than the 2-3 per fruit reported at other New Zealand sites (Williams, Karl et al., 2000). On 2 December 2007 cleaned seed was placed in Petri dishes prepared with three filter papers in each. Seeds placed in each dish were of consistent origin to enable tracking; this led to varying numbers/dish with a total of 240 seeds in 12 dishes. The dishes were inspected every other day and watered as necessary.

Plate 4 - Seed in Trial 1

For the second trial, with newly gathered seed, it was anticipated that the germination rate would be much greater than that for the aged seed. A germination rate of 75% was employed for the calculation of the desired sample size and sample size of c. 140 was required to test the hypothesis that the actual proportion of viable seed was within 5% of the assumed 75% germination rate with a 90% probability.

Fruit was gathered from a single Hamilton location on 25 April 2008 and was immediately cleaned and soaked in a 0.2% solution of sodium hypochlorite for 10 minutes. It was then stratified for 30 days at 2-4^{0}C before being placed in Petri dishes as above. The trial was conducted in a home conservatory that was not air conditioned, exposing the seed to a much greater temperature range.

Results

First trial

One seed germinated at 28 days, two at 50 days, and one at 52 days. In all four seeds or 2% of the previous season's seed germinated. Over the period the minimum temperature was 16^{0}C, the maximum was 30^{0}C and the mean diurnal range was 9.0^{0}C.

Second Trial

In this trial 80 of 140 seeds germinated (57%). The time profile of germination is shown in Figure 10.

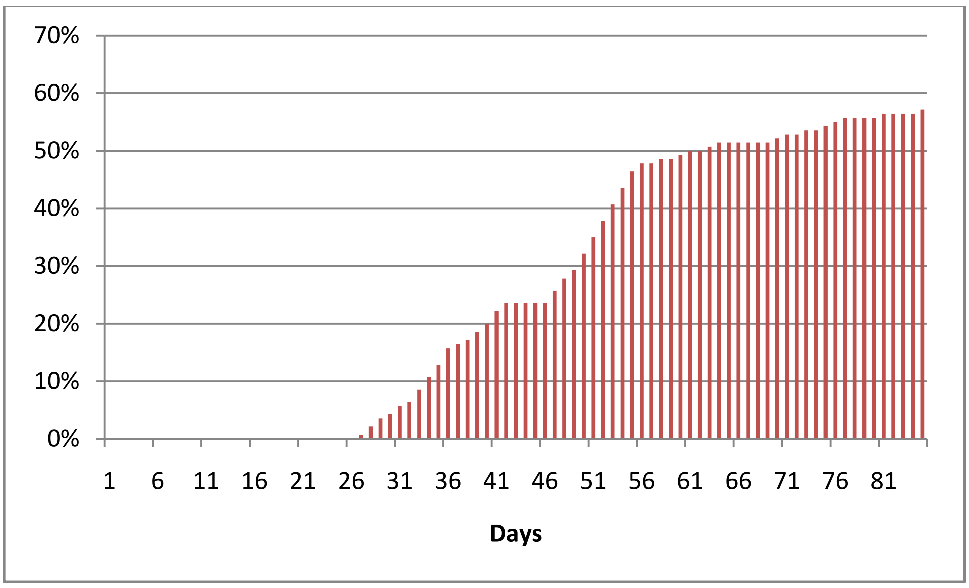

Figure 10 – Percentage total seeds germinated over time

Over the period the minimum temperature was -1.5°C and the maximum was 44.2°C. The mean diurnal range was 21.6°C. It should be noted that although the air temperature dropped below 0°C on a number of occasions, the moisture in the Petri dishes did not freeze.

Discussion

The number of seeds per fruit found in Hamilton was substantially greater than has been reported in the Eastern United States (Nuzzo, 1997) (2-3 as against a mean number of 8.3 in Hamilton). The germination results obtained for seed gathered in Hamilton (57% in the season of gathering; 2% after a year) were consistent with other studies (Haywood, 1994; Shelton and Cain, 2002; Fowler and Larson, 2004). It was concluded that dispersal by seed can occur in Hamilton and the implications for management of restorations sites should be considered further.

4.4 DISCUSSION – REPRODUCTION AND PROPAGULE SPREAD

The purpose of this section of the study was to gain an understanding of *L. japonica*'s ability to propagate vegetatively and from seed, comparing the position as described in the literature with results from investigations in Hamilton. The literature suggested that *L. japonica* would propagate easily from cuttings, and an *in vitro* study confirmed this; c. 72% of stems with nodes produced shoots. Thus distribution through disposal of garden waste or by fragments transported in the course of maintenance has the potential to be a significant means of spreading *L. japonica*.

At the primary study site plants are surviving with their growing points in light conditions c. 1% of available PAR. The canopy there is so broken that it is highly likely that parts of these plants will receive more light at some times of the day. Plainly however shoots have the ability to cross low light areas and thus help assure the wide spread of the plant within a site. Further, the plant's survival in low light conditions means that it is well placed to take advantage of light wells when they open through tree fall or clearance, e.g. in the course of ecological restoration.

Plants in Hamilton readily flower and set fruit in good light; the mean percentage available light for mature plants was 58.8%, by comparison with 3.4% for the juveniles. These results are comparable with those obtained in the Eastern United States. Germination trials demonstrate that *L. japonica* produces considerable viable seed (c. 57%), but that the seeds' viability declines steeply over time. Thus seed banking is unlikely to be a major consideration but spread by seed is possible within the season of production. As noted above (Overdyck, 2008), seed rain analysis in Hamilton has detected few *L. japonica* seedlings. Though potential avian and mammalian seed vectors are available, (Williams and Karl, 1996; Williams, Karl et al., 2000), seedlings found to date could plausibly have derived from gravity-dispersed seed.

As noted by (Schierenbeck, 2004), *L. japonica* requires a period of stratification at 5-8^{0}C for 60 days and germinates above 10^{0}C and preferably in the range 18-25^{0}C. In the three years 2006-2008 mean Hamilton temperatures for the months April-June were as follows:

	Max ^{0}C	Min ^{0}C	Grass ^{0}C
Mean	19.0	8.1	5.1
Min	10.4	-3.5	-6.2
Max	24.3	17.3	17.2
Mode	17.6	11.1	3.5

Figure 11 - Mean Hamilton (Ruakura) Temperatures, April-June, 2006-8

In the same period there was an average of 43 days when the grass minimum temperature was less than 8^{0}C and 11 when it was greater than 10^{0}C. From the above it can be inferred that germination of *L. japonica* seed is possible in Hamilton field conditions. Potential vectors exist, fertile seed is produced in quantity, and environmental factors suggest that germination is possible within the period in which seed remains viable. Therefore the possibility of propagation from seed should be taken into account in management strategies. Further trials along the lines of those conducted by Haywood would provide better information (Haywood, 1994).

The significance of reproduction from seed is that vectors can distribute it widely. Though few *L. japonica* seedlings appeared in a seed rain experiment, each seedling can potentially occupy a large area. Further, seed can be dispersed by birds or small mammals to virtually any point in a natural or restoration area. Though evidence of spread from seed is unclear at present, management strategies cannot disregard the possibility.

If dispersal by seed in Hamilton is uncertain, spread by fragments occurs readily. The trials conducted above establish that a large proportion of *L. japonica* fragments incorporating nodes will grow when in contact with a moist substrate. In Hamilton garden waste is often disposed of to gullies or over fences to natural areas, providing a ready source of *L. japonica* propagules.

CHAPTER 5 – DIRECT PLANT IMPACTS OF *L. JAPONICA*

5.1 INTRODUCTION

This chapter considers the direct impacts of *L. japonica* at two levels; first, a quantitative study of the propensity of plants to host *L. japonica*; and second, a qualitative study of the physical impacts on plants. Both questions are addressed through a consideration of the properties of plants, particularly their form, that condition their interactions with *L. japonica*.

5.2 LIKELIHOOD OF HOSTING

5.2.1 Background

In central and eastern North Island areas the native species most frequently associated with Japanese honeysuckle in vegetation other than wasteland are, in rank order, mahoe (*Melicytus ramiflorus*), karamu (*Coprosma robusta*), lacebark (*Hoheria sexstylosa*), kohuhu (*Pittosporum tenuifolium*), manuka (*Leptospermum scoparium*), bracken (*Pteridium esculentum*), and fivefinger (*Pseudopanax arboreus*). The most frequent weeds at the same sites are several species of Convolvulaceae, blackberry (*Rubus* sp.), and willows (*Salix* sp.) (Williams and Timmins, 1998). However no data were presented on which species are more prone to infestation.

Essentially a plant that is favourable to *L. japonica* as a host is one that enables the foliage of *L. japonica* to reach 10% available light or better (Thomas, 1980; Blair, 1992; Robertson, Robertson et al., 1994). For *L. japonica* plants this means a tree or plant that reaches the canopy with its stem <15 cm diameter (Williams and Timmins, 1998) because of the limitations of *L. japonica*'s twining climbing method. *L. japonica* may invade larger trees by transfer from other trees or they may have grown with the tree and now hang clear of the main trunk. In assessing invasibility by *L. japonica* there are other purely mechanical factors associated with plant life form that do not appear to have been addressed to any great extent in the literature. For example little attention has been paid to the form of the host plant and in particular the shape of its crown, the texture of its bark, its propensity to shed elements that the *L. japonica* may rely upon for support, and its likely diameter when reaching the canopy. A consideration of these factors suggests that among tree ferns, those that produce a dense skirt of dead fronds such as *Dicksonia fibrosa* and, to a lesser extent *D. squarrosa* will be less susceptible than, for instance *Cyathea medularis* with its relatively clear trunk immediately beneath the crown. However the external texture of the tree fern caudex may offer lodgement for *L. japonica*'s adventitious nodal roots, giving it both another climbing method and a source of water and nutrients above the ground and closer to canopy height where it will need to maximise leaf production. *Cordyline australis* typically has stems well within the twining range of *L. japonica* but it constantly sheds foliage, making it difficult for *L. japonica* to secure a lodgement in the crown of the tree.

5.2.2 Method

The data employed in this chapter were gathered in the course of the survey of the plant community at Totara Park reported in Chapter 2, where *L. japonica* plants were counted and their hosts recorded, distinguishing canopy/sub-canopy hosts and ground cover and seedlings. In the same survey ground cover was recorded by the point intercept method. Analysis of both levels was by a comparison of observed and expected frequencies of infestation (Chi square). Because the ground cover survey yielded an estimate of the relative abundance of ground cover species in the plot rather than absolute numbers, the ground cover analysis was carried out by comparing proportions. Non-vegetative points – e.g. bare ground, leaf litter, water – were excluded.

5.2.3 Results

Canopy/Sub-canopy

Table 24 shows the observed frequency of *L. japonica* hosting by canopy and sub-canopy plants (n>10) compared to the frequency that would occur if hosting occurred in proportion to total species composition. *S. cinerea*, *M. ramiflorus, S. Digitata* and *D. dacridioides* all hosted fewer *L. japonica* plants than expected, while *L. sinensis*, *C. robusta* and *D. squarrosa* all hosted more. The chi-square test shows that the result is significant, p=.000352.

Species	Total	Observed hosts	% hosts	Expected hosts	O - E	(O-E)**2
KAH	20	1	5%	5.5	-4.5	3.6
MAH	35	2	6%	9.5	-7.5	6.0
SCH	63	11	17%	17.2	-6.2	2.2
SAC	358	87	24%	97.6	-10.6	1.1
COA	49	16	33%	13.4	2.6	0.5
COPR	122	43	35%	33.3	9.7	2.9
DIC	75	33	44%	20.4	12.6	7.7
LIS	19	9	47%	5.2	3.8	2.8

Table 24 - Observed v. Expected Frequencies - *L. japonica* host plants (n=202) in canopy and sub-canopy.

Chi-Square = 26.86909 df = 7 p =0.000352

Table 24 also shows the percentage of each species hosting *L. japonica*. There is a wide range, from 5-47%. To test if these variations were a result of the distribution of the hosting species and *L. japonica*, a Spearman's rank order correlation matrix was calculated between prevalence of *L. japonica* and the hosting species across the plots (Table 26). No significant correlation emerged, suggesting that propensity to host was related to some aspect of plant form. Given the limitations of the twining climbing method, trunk diameter was tested.

Species	LJ index
COA	-0.1368
COPR	0.0902
MAH	0.0363
DIC	-0.3472
KAH	0.2290
LIS	-0.1966
SAC	-0.0764
SCH	0.1103

Table 25 - Correlations between numbers of canopy/subcanopy plants and *L. japonica* index.

No significant correlations at p <0.05000

The Spearman's rank order correlation between diameter and percentage of *L. Japonica* infestation was calculated and proved non-significant (Table 26). The diameter/infestation relationship may have been obscured by the fact that though *D. squarrosa* has a large mean diameter its caudex affords sites for root lodgement and thus eliminates *L. Japonica*'s reliance on twining. With *D. squarrosa* removed from the analysis, the Spearman's rank order correlation between diameter and percentage of plants hosting *L. japonica* was -0.5714, which is significant at the p <0.20 level. Mahoe's degree of infestation is aberrant, in that it has similar life form and mean diameter at this site to a number of other species with higher infestation rates. Further it is present on plots with substantial quantities of *L. japonica* so its low infestation rate cannot be explained by a lack of opportunity.

Species	Mean Diameter	% Hosts
LIS	1.8	47%
SCH	2.2	17%
COPR	2.8	35%
MAH	2.9	6%
SAC	7.4	24%
COA	7.8	33%
KAH	10.1	5%
DIC	12.2	44%

Table 26 - Mean species diameter and percentage of trees hosting *L. japonica*.

Spearman's Rank Order Correlation -.2143 (not significant at p <0.05

Species key for Table 25 and Table 26:
COA – *Cordyline australis* COPR – *Coprosma robusta* DIC – *Dicksonia squarrosa*
KAH – *Dacrycarpus dacridioides* LIS - *Ligustrum sinensis* SAC – *Salix cinerea*
SCH – *Schefflera digitata*

Groundcover/Seedlings

This section compares the overall percentage of groundcover species (and saplings/seedlings where these comprised the groundcover) and the proportion of *L. japonica* on these plants. Totara Park is characterized by a high prevalence of *Zantedeschia aethiopica*, comprising 53% of ground cover plants (n>10). However only 7.46% of *L. japonica* plants on groundcover or saplings were on *Z. aethiopica* (Table 27). Conversely *Blechnum novae-zelandiae* hosted 48% of *L. japonica* on groundcover/saplings but were only 7% of the point intercepts. Between these two extremes the differences between observed and expected proportions are not large.

Species	Observed (%)	Expected (%)	O - E	(O-E)**2
ZAE	7.5	53.0	-45.58	39.17
HED	0.0	4.4	-4.35	4.35
KAH	4.5	7.4	-2.91	1.15
SAC	13.4	13.9	-0.48	0.02
CARS	13.4	9.1	4.30	2.03
BAU sp	13.4	5.2	8.22	12.94
BLE	47.8	7.0	40.80	239.35

Table 27 **-** Observed v. Expected numbers of ground cover/saplings hosting *L. japonica*

(n of species > 10). Chi-Square = 298.9915 df = 6 p = 0.0000

Species key:
ZAE – *Zantedeschia aethiopica* HED - *Hedera canariensis* KAH – *Dacrycarpus dacridioides* (seedling or sapling) SAC – *Salix cinerea* (seedling or sapling) CARS – *Carex secta* BAU sp – *Baumea* species BLE – *Blechnum novae-zelandiae*

There was no correlation between plot presence of *L. japonica* and *Z. aethiopica* (Spearman's Rank Order Correlation coefficient -0.0281) nor between *L. japonica* and *B. novae-zelandiae* (Spearman's Rank Order Correlation 0.3233) so their markedly differing propensities to host *L. japonica* must be attributed to other factors. A plausible explanation may be sought in plant form. As noted above, *Z. aethiopica* has thick petioles that are well within *L. japonica*'s twining size range, but the leaves themselves are large (15-45 × 10-25 cm) (Edgar, 1980) and offer little support to stems of *L. japonica.* Consequently runners of *L. japonica* may be found traversing areas dominated by *Z. aethiopica*, but they are restricted by the low light conditions beneath the dense cover and will not thrive[1]. By contrast *L. japonica* can twine around the pinnae between individual laminae of *B. novae-zelandiae*, weighing down the whole frond, potentially growing over and killing the plant.

5.2.4 Conclusions

In sum, though the sample size is too small for detailed analysis, there is evidence that propensity to host *L. japonica* is negatively related to stem diameter unless the trunk or caudex affords lodgement for *L. japonica*'s nodal roots. Contrary to

[1] *Z. aethiopica* grows from the centre and the outer leaves progressively collapse and die, so that the vicinity of the plants is characterised by soft and blanketing leaf litter; allelopathy is a possibility though the literature appears only to have addressed its antialgal properties.

expectations the sole deciduous species represented (*Salix cinerea*) did not have a greater propensity to host *L. japonica* than evergreen species at the site.

In terms of ground cover, the most striking result is the marked contrast between *Z. aethiopica* and *B. novae-zelandiae*. The former comprises 53% of vegetative ground cover at Totara Park, but hosts only 7.5% of *L. japonica* on ground cover plants. *B. novae-zelandiae* comprises 7% of vegetative ground cover, yet hosts 48% of *L. japonica* specimens on ground cover. *L. japonica* is very widely dispersed through the study site, but where found in association with *Z. aethiopica* is usually in the form of trailing stems of low vigour.

Plate 5 - *L. japonica* scrambling on *B. novae-zelandiae*

5.3 PLANT IMPACTS

5.3.1 Introduction

There is a range of potential liane impacts on hosting species (Bell, Forseth et al., 1988; Gordon, 1998). In this section they are considered in a restoration context, and in relation to the form of plants important in restoration.

5.3.2 Background

Once a plant is host to *L. japonica*, it may become subject to some or all of the range of impacts lianes have on hosting vegetation. The nature of those impacts can be used to predict species' susceptibility. Bell et al. (op. cit.) and Gordon (op cit) identified the following: "mechanical damage (girdling), alteration of host plant allocation patterns due to competition for light, soil nutrients or water, causation of mechanical strain on stems and roots of their hosts, changing the probability of host falling by tying individual tree crowns together, and alteration of canopy gap and successional dynamics." Trees and shrubs with stems < 15 cm diameter and smooth, thin bark (e.g. *Melicytus ramiflorus, Coprosma robusta*, *Pittosporum sp.*) are likely to be susceptible to girdling damage in a way that trees with thick, hard bark (e.g. mature *Salix* sp) are not.

L. japonica's twining habit suggests that species that acquire height at relatively low stem diameter (e.g. *D. dacridioides*) are likely to be more susceptible to mechanical damage than species that attain large stem diameter and stiffness at low heights, such as tree ferns. On the other hand, some tree fern species are susceptible to having their crown over-topped by *L. japonica* if it bypasses the skirt of dead fronds (if present) or if the *L. japonica* transfers from another tree. The circumnutatory behaviour of *L. japonica* shoots makes this highly probable where canopies of adjoining trees are close. Finally, deciduous species are likely to be more affected by *L. japonica* because the latter remains photosynthetically active in a period when the host is not and indeed has thinned its shading effect considerably.

Ground cover plants least affected will be those that offer little support to *L. japonica* but are tall enough to overtop an unsupported mass of *L. japonica*. *Zantedeschia aethiopica* has relatively substantial petioles that *L. japonica* can twine around, but the leaf itself is broad and not particularly rigid, offering little support. Generally, *L. japonica* can coexist with ground cover species that do not out-compete it, particularly for light. This implies similar or slower growth rates in relation to local environmental conditions and similar or lesser tolerance of seasonal variations – e.g. frost and drought.

5.3.3 Method

This part of the study is based on a qualitative assessment of impacts under four headings on representative specimens across the study sites. The varieties of impact considered are:

- mechanical damage (girdling)
- diminished vigour or mortality due to competition for light
- mechanical strain on stems and roots of hosts

- alteration of canopy gap and successional dynamics

The plant forms considered against those types of impact are as follows:

- Tree fern
- *Cordyline australis*
- Tree - Multiple leader (e.g. *M. ramiflorus*, *Schefflera digitata*, *C. robusta*, *Pittosporum sp.*).
- Tree - Single trunk (e.g. *D. dacridioides*)

These categories have been selected on the basis of their differentiated response and susceptibility to *L. japonica* invasion*.* *C. australis* is included as the sole representative of its form that has local restoration importance. Not all of these groups are distinct in their susceptibility and where necessary categories are discussed together.

5.3.4 Results

Mechanical damage (girdling)

Neither tree ferns nor *C. australis* have been observed with girdling damage at any of the study sites. Though *L. japonica* stems may be included in tree fern caudices they are to be found in the fibrous layer surrounding the xylem and phloem and do not constrict it. Similarly as a monocot the primary vascular tissue of *C. australis* is contained in the stem's central part and is less susceptible to damage. Further, both tree ferns and *C. australis* attain relatively large diameters at a younger age than dicot trees and reduce their exposure to primary invasion by *L. japonica* in twining mode.

Plate 6 - *L. japonica* inclusion in tree fern caudex

M. ramiflorus and *C. robusta* and *Pittosporum* sp. are highly susceptible to girdling damage, both because of their dicotyledon structure, which places vascular tissue in vulnerable areas, and because of their formation of long, thin branches at all life stages. *L. japonica* twines on stems at small diameters. As both host and liane stems increase in diameter inclusion and mechanical construction impair the function of the phloem (Plate 7). Though the physical evidence is highly visible, it is unclear how significant this damage is and to what extent it impairs the host plant's vigour.

Plate 7 - *L. japonica* stem (diameter 0.75 cm) deeply incised in *M. ramiflorus*

No examples were found of *D. dacridioides* or similar with girdling damage.

Competition for light

Susceptibility to competition for light from *L. japonica* is closely related to form and size. Small plants up to (c. 1 m) can be overwhelmed by scrambling mats of *L. japonica* (see Plate 5). The vulnerability of larger plants and trees will depend on the distribution of their leaf mass and the ability or need of *L. japonica* to reach that leaf mass. Tree ferns are readily climbed by *L. japonica* but have a large crown (up to 5m diameter for *D. squarrosa*) that the liane will preferentially over top (Plate 8). Once they do so they are likely to occlude the central growth point, eventually killing the fern (Plate 9).

Plate 8 - *L. japonica* on *D. squarrosa*, Totara Park - early invasion

Plate 9 - Mature *L. japonica* on dead tree fern (*D. squarrosa*?)

Cordyline australis has a less concentrated leaf mass with a number of heads on a large plant. Its structure offers less lodgement for *L. japonica* and it sheds leaves prolifically. Also the crowns are smaller and an infestation of *L. japonica* on a stem will still receive good light.

Plate 10 illustrates the early stages of invasion of *C. australis* by *L. japonica.* The liane has not progressed into the crown of the host plants, but because of the relatively open canopy at this stage of the restoration it is receiving good light. *L. japonica* is present as scrambling ground cover throughout this site and is twining on most plants (see 2.6 Results – Qualitative Sites, Tauhara Park).

Plate 10 - *L. japonica* on *C. australis*, Tauhara Park - early invasion

Plate 11 - *L. japonica* on *C. australis*, Edgecumbe Park – established mature plant

Plate 11 illustrates a long standing infestation on a large *C. australis.* The tangle of stems characteristic of older infestations can be seen in the lower part of the photograph. The largest stems were in the size range 12-15 mm diameter, suggesting an age c. 9-11 years. The host is surviving and leaves of the crown can be seen above the mass of *L. japonica.*

Plate 12 - 3-5 year old *L. japonica* on *C. robusta*

Small trees with multiple leaders present no structural impediments to *L. japonica* invasion and are highly vulnerable. Plate 12 shows the impact of a 3-5 year old *L. japonica* on a specimen of *C. Robusta* whose main stem is 9 mm in diameter. Very little foliage of the *C. robusta* remains and the likely course from this point is the death of the host plant.

Plate 13 - *L. japonica* on *P. eugenioides*, Tauhara Park - early infestation

Plate 13 shows the early stages of invasion on a c. 2-3 years old *P. eugenioides*. *L. japonica* is throughout the plant's foliage and will clearly over top it if no maintenance is carried out.

Larger specimens may attain equilibrium with *L. japonica*, as evidenced at Mangakotukutuku gully where *P. eugenioides* and *M. ramiflorus* host *L. japonica* specimens that on stem diameter evidence is about 18 years old, compared to c. 30 years for the host plant (see Table 16).

Plate 14 - Mature *L. japonica* (c. 18 years old) on *P. eugenioides* (c. 30 years old)

Once past sapling size, *D. dacridioides* appears less vulnerable to *L. japonica* invasion than multiple leader small trees even at stem diameters below *L. japonica's* twining limit. This may relate to the tree's conifer-type structure, with multiple branches from a single central trunk; the extremities of the branches remain in light even when there is considerable *L. japonica* invasion closer to the main trunk.

Mechanical strain

Tree ferns and to a lesser extent *Cordyline australis* are less susceptible to mechanical strain than shrubs and trees because their diameter is large in relation to height at relatively young ages and their simple structure means less mass of *L. japonica* can accumulate. Both single trunk and multiple leader trees can generate stems of considerable length at small diameters, particularly if etiolated in low light conditions.

Plate 15 - *L. japonica* on collapsed *P. eugeniodes*, Tauhara Park.

Plate 15 shows a collapsed *P.eugeniodes*, part of a restoration planting at Tauhara Park. There are c. 16 *L. japonica* stems on the *P. eugenioides*, ranging in size from 5 to 8 mm. If upright the latter would be c. 3 m high and its main stem is c. 30 mm diameter. It is unusual to find a plant of this size collapsed under the weight of *L. japonica* as this one has, but weed mat was employed in this planting and the root system appears very shallow and under-developed.

Plate 16 - *L. japonica* on *D. dacridiodes* sapling

Plate 16 shows the mid- and upper portions of a Kahikatea sapling deformed by *L. japonica* so that is growing horizontally over a distance of c. 2 m. At a nominal 1m length along the stem the diameter of this specimen is 2.9 cm. Plainly it can never develop into a mature tree, since even if released now, its form has been set.

The deformation is not the result of twining by a single stem of *L. japonica*; rather it is restrained by multiple stems from a larger plant hosted by a neighbouring *S. cinerea*. Given the wide dispersal of *L. japonica* at natural areas in Hamilton, this seems a likely outcome for regenerating desirable species unless releasing is undertaken.

Alteration of canopy gap and successional dynamics

Where existing exotic canopy exists, the starting point for ecological restoration is the creation of canopy gaps. At the principal site for this study, canopy gaps occur frequently because of the instability of the canopy dominant, *S. cinerea*. *L. japonica* is present at most natural areas and restoration sites in Hamilton (see Table 5, Table 16). Where present, *L. japonica* is quick to respond to improved light conditions, limits sites for natural re-establishment and will quickly invade restoration plantings.

Plate 17 shows *D. dacridoides* seedlings amongst leaf litter and beneath canopy (available light < 5% PAR). If a canopy gap opens these seedlings will be out-competed by the *L. japonica* which is present but not currently vigorous.

Plate 17 - *D. dacridioides* seedlings and *L. japonica*

5.3.5 Discussion and conclusions

The most common situation in ecological restoration in Hamilton is the complete or near complete replacement of exotic vegetation. Thus tree size only becomes a factor over time, and the form of restoration plants as saplings is particularly relevant in considering their vulnerability to *L. japonica* impact. There are also implications arising from the possibility of *L. japonica* gaining a lodgement when restoration plants are young and growing with them, maintaining a place in the canopy beyond heights that they could reach if attempting to climb stems > 15cm diameter. This is very evident at older restoration plantings such as in the Mangakotukutuku Gully and the lower end of the Waitawhiriwhiri Gully in Edgecumbe Park.

In restoration plantings and canopy gaps, *L. japonica* is a threat to all plant forms in the first years of life and also restricts or prevents natural regeneration by reducing available loci for propagules. In established canopy, there is evidence of a hierarchy of vulnerability across plant form as well as size. Tree ferns are particularly susceptible because the single crown is the high point – which *L. japonica* grows to as offering the best light – and the centre of the crown is also the sole growing point, which may be completely occluded by a mass of *L. japonica*. *C. australis* is less vulnerable because it has multiple heads and affords less lodgement for *L. japonica.* Other trees and shrubs are vulnerable to being overwhelmed at smaller sizes but may achieve long term stability as hosts to mature *L. japonica.* However if those species are themselves short lived their death will lead to a rapid expansion of *L. japonica* into the resultant canopy gaps.

CHAPTER 6 – CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This thesis presents a study of the autecology and synecology of *L. japonica* in relation to ecological restoration in Hamilton, in an attempt to fill gaps in knowledge about a plant that to date has been intensively studied primarily in the Eastern United States. The research questions fall into three groups, relating to *L. japonica*'s place in the plant community, its reproduction and spread, and its direct impacts on other plants.

6.2 *L. JAPONICA*'S PLACE IN THE PLANT COMMUNITY

This section of the study sought to identify the role of *L. japonica* in the plant communities of Hamilton natural areas and restoration sites, and how it varies with environmental factors. The question was explored quantitatively at a naturally regenerating site and qualitatively and semi-quantitatively at eight other sites selected for varied in their physical characteristics and disturbance regimes.

It was hypothesised that analysis of the plant community at the naturally regenerating site would demonstrate:

- an inverse relationship between quantity of large, canopy entering *L. japonica* and species diversity
- a positive relationship between deciduous canopy and quantity of *L. japonica*
- an inverse relationship between the distance from the edge of the densely vegetated portion of the park and the quantity of *L. japonica.*

It was further hypothesised that at the other locations *L. japonica* would be most prevalent on disturbed sites with low quantities of evergreen canopy (using available light and canopy cover estimate as a joint measure) and low or non-existent maintenance regimes.

The results from Totara Park did not support the first three hypotheses. It seems probable that this is due to a methodological problem deriving from the definition of the study area and from the physical and temporal scale of the sampling. The first issue is that the elimination of a number of potentially confounding variables (particularly slope, soil type and water table) by excluding the sloping edges of the park meant that the study area proved much more homogeneous at the selected plot size than it had appeared on preliminary visits. A smaller plot size would have revealed spatial variation. Further, it had been intended that analysis of the plant community across a gradient of prevalence of *L. japonica* would substitute for processes that occurred over time with invasion, a longitudinal study being impractical within the framework of a thesis. The plot measurements revealed that *L. japonica* was prevalent throughout the study area, and no meaningful gradient across plots could be established. In any event a consideration of the results from Totara Park and the other sites suggests that the invasion process through established canopy may be protracted. The inferred age of *L. japonica* plants in parts of Totara Park and at other locations indicates coexistence over lengthy periods – c. 18 years on restoration planting at the Mangakotukutuku Gully, and c. 25 years at the Waitawhiriwhiri Gully. At these and other sites *L. japonica* is present in ground cover under the canopy, but is not vigorous. However if light conditions improve, either through tree fall or clearance for ecological restoration, it will expand rapidly.

The fourth hypothesis – that *L. japonica* would be most prevalent on disturbed sites with low quantities of evergreen canopy – found support at a number of sites, including Fairfield Esplanade, Mangaiti Gully and Tauhara Park (see Table 16). An unexpected result was an apparently synergistic relationship with *Ipomoea indica* where both exist on the same site. *I. indica* appears advantaged in full sun, though *L. japonica* is frequently to be found growing with it, but *L. japonica* is advantaged in semi-shade conditions. *I. indica* is more frost tender than *L. japonica* so there is also the possibility of a measure of seasonal alternation. At some locations such as the mid reaches of the Mangaiti (see Table 17) the result is a seamless cover of scrambling lianes.

There was no significant correlation between any environmental variable and prevalence of *L. japonica* (see Table 34) but its wide dispersal across Totara Park indicates tolerance of pH conditions at the low end of its optimal range according to studies in the US. This may reflect the absence of a competitor with superior tolerance to low pH.

A number of light measures were taken when assessing the likelihood of *L. japonica* flowering and setting seed in Hamilton. It was found that the median light received by juvenile plants (n=34) was 1.9% PAR, and for mature plants (n=20), 58.3% (Table 23). The results suggest that the most important determinant of the part *L. japonica* will play in the plant community is the light regime it receives. Using the indices described in Table 2, the average score for a juvenile plant (n=176) is 4.1, and for a mature plant (n=170) is 21.7. Mature plants are over four times the size of the juveniles and they receive much more light. It may be argued that this is a circular argument, in that a plant will usually have to be large to get into the light, certainly if it is in a site with a developed canopy. However the location of the large plants contradicts this. They are found in the open, in light wells, or on trees that have hosted them over an extended period. Plants beneath the canopy are small.

6.3 REPRODUCTION AND SPREAD

The trials carried out in Chapter 4 demonstrated that *L. japonica* can spread readily from sections of stem, with c. 72% of stems with nodes producing shoots in a glasshouse trial (see Figure 8). Garden waste, earth moving machinery and the like are clearly potential vectors for *L. japonica*, and given its wide dispersal such means have evidently been extremely effective. However the potential for dispersal by seed assumes considerable importance in a restoration context. The establishment of sanctuaries and natural areas with strong management protocols will mean that propagation by human transport of fragments is much less likely. Successful ecological restoration will mean the presence of a greater number of avian vectors for *L. japonica* seed. Chapter 4 has demonstrated that *L. japonica* sets considerable viable seed in Hamilton, and that despite its short period of viability (2% germination after one year storage in this trial), same season germination is a theoretical possibility, particularly in a warm autumn. The unknown element is the potential probability of dispersal to a given area and the likely development of a population from bird-born seed.

6.4 DIRECT PLANT IMPACTS

6.4.1 Introduction

This section of the study comprised a quantitative analysis of the propensity of species to host *L. japonica*, related to the aspects of their form that made them vulnerable to invasion, and a qualitative assessment of the impact of *L. japonica* on plants commonly employed in ecological restoration, grouped by form.

6.4.2 Propensity to host

Results in this section showed a negative correlation between mean species diameter and propensity to host *L. japonica*, with the exception of tree ferns, which had the highest mean diameter of all species at the study site, comprised 10% of canopy and sub-canopy species yet hosted 44% of *L. japonica* in the canopy and sub-canopy. Since there was no significant relationship or pattern of vegetation across the site, it seems likely that the difference is due to an aspect of plant form, and the nature of the exterior of the tree fern caudex is a plausible candidate, since it offers lodgement for nodal roots of *L. japonica*; this offers an alternative climbing method and source of water and nutrients. Among other native species, *D. dacridioides*, *M. ramiflorus* and *S. digitata* host fewer *L. japonica* than expected. This is an expected result for *D. dacridioides* at this site because of the relatively high mean trunk diameter; results for the other two species were not expected nor are they easily explained.

S. cinerea is the canopy dominant and *a priori* was expected to host *L. japonica* disproportionately, because of its large number of stems <15 cm diameter and its deciduous habit, affording *L. japonica* a light advantage in the period when it retains its leaves but *S. cinerea* does not. This relationship did not emerge. A possible explanation is that the temperatures do not support growth by *L. japonica* even though its light regime is improved by *S. cinerea*'s leaf fall.

Most ground cover species hosted *L. japonica* in similar proportions to their numbers at the site, but *Z. aethiopica* (53% of vegetative ground cover) hosts only 7.5% of *L. japonica* on ground cover, while *B. novae-zelandiae* comprises 7% of ground cover but hosts nearly 48% of *L. japonica* at that level. A tentative explanation of this disparity lies in the form and habit of *Z. aethiopica.* It is usually evergreen in Hamilton conditions and can form near mono-specific groundcover herbfields at a height of c. 1 m. Its stem and leaf structure offers poor lodgement for *L. japonica* and the density of its foliage creates very low light conditions at ground level. *L. japonica* stems will traverse *Z. aethiopica* herbfields but will not get above its canopy unless another, more climbable host is available. *B. novae-zelandiae* offers more broken shade and affords ready lodgement for climbing stems of *L. japonica*, which then weigh down the host stems. *B. novae-zelandiae* will quickly become the base of a scrambling heap of *L. japonica* (see Plate 5).

The conclusions to be drawn from this part of the study for ecological restoration are first, that increasing trunk diameter decreases vulnerability to *L. japonica* invasion because of the size limitation of the twining climbing method, but that tree ferns remain vulnerable at much larger diameters because of the nature of the surface of the caudex; and second, that desirable groundcover species are more vulnerable to *L. japonica* invasion than *Z. aethiopica*, a common pest at Hamilton restoration sites. Control of the latter is likely to lead to a rapid increase of *L. japonica*.

6.4.3 Species vulnerability

This section of the thesis considered the vulnerability of four plant forms (tree fern, *C. australis*, multiple leader tree, single leader tree) to three kinds of damage (girdling, light competition and mechanical strain on stems and roots). Impacts on canopy gap and successional dynamics were also briefly considered.

It was concluded that multiple leader trees and shrubs are vulnerable to *L. japonica* girdling damage at all life stages because of their architecture and stem structure. Single stem trees are vulnerable at the sapling stage, though little such damage was observed in the field. Tree ferns are protected from girdling damage in large degree because their growth mechanism places vulnerable structures out of reach of damage. Inclusions and root lodgement in the outer layer of the caudex are common but are not directly damaging. Similarly *C. australis*' vascular tissue is protected, reducing their vulnerability. Though *C. australis* stems grow radially throughout the plant's life, girdling damage has not been observed in the field. All growth forms are vulnerable to *L. japonica* competition for light when small. As noted above the vulnerability of all forms of tree declines progressively with increasing size, as *L. japonica* reaches its twining size limitation, but tree ferns remain vulnerable at all size classes because *L. japonica* nodal roots can lodge in the caudex; once the invader reaches the plant's highest point is likely to occlude the growth point and lead to the death of the host.

Tree ferns and *C. australis* are less vulnerable to mechanical strain than trees and shrubs because they attain larger diameter at a younger age and their simple structure affords less lodgement for large and weighty masses of *L. japonica*. Trees and shrubs are highly vulnerable to mechanical damage when young, being either overwhelmed and born down or deformed into an almost horizontal growth form in the case of *D. dacridioides*.

6.4.4 Canopy Gaps and Succession

L. japonica's wide dispersal and marked response to improved light conditions means that it will rapidly fill canopy caps caused by tree fall. This study did not detect any evidence that there is any difference across species or plant forms in response to competition in newly created light wells; few thrived. At Totara Park light wells are usually created by the fall of specimens of *S. cinerea*, that will then grow stems from the fallen log. These stems grow quickly and will maintain access to light. A plant growing from seed or a pre-existing seedling (common in the case of *D. dacridioides*) will not out compete *L. japonica.*

6.4 FURTHER WORK

There is a number of areas where further work could usefully be undertaken, addressing both research and restoration questions. In terms of plant community and plant impacts there is a need for longitudinal studies; at the plant community level, what is the progress and timescale of invasion, and what are the conditions for a relative equilibrium between *L. japonica* and other species. This could be done through the establishment and monitoring of permanent plots at restoration sites. An outcome should be a quantitative analysis of the demography of an *L. japonica* population. At the plant impact level, invasion of a purposive sample of specimens of restoration species could be monitored over time, with detailed and objective measures of the growth and vigour of host and invader.

As restoration areas and sanctuaries are established and management practices are established around them to limit the spread of *L. japonica* by stem fragments, dispersal by seed becomes a concern. This study and the work of Overdyck (Overdyck, 2008) has established it as a theoretical possibility; it would be useful to have a model of spread by seed dispersal in order to be able to assess the risk. The input parameters of the model would be numbers of frugivorous birds in a locality (and relevant mammals if they are not excluded from the target areas), the viability of seed consumed by the vectors, and the likelihood of vector visits to the target areas. It might also be helpful to carry out genetic studies of the current population to determine to what extent it is clonal, i.e. spread by dispersion of fragments as opposed to seed.

6.5 MANAGEMENT RECOMMENDATIONS

6.5.1 Introduction

This study has shown *L. japonica* to be very widely dispersed at natural areas in Hamilton, and its presence can usually be taken as a given. Management recommendations may be divided into those relating to established areas and to restoration areas. In both cases light control is the key consideration, since edaphic and water conditions at most restoration sites and natural areas are well within *L. japonica*'s range.

6.5.2 Management in Established Areas

The characteristic pattern of *L. japonica* presence in areas with established canopy is:

- scrambling heaps at edges and in light wells, that may have overwhelmed shrubs and small trees;
- runners and shoots on the ground beneath the canopy;
- long established (10 years +) specimens on mature canopy trees

The recommended management regime is to cut the mature canopy specimens as close to the ground as possible and wipe with a suitable gel herbicide (e.g. Vigilant); to carry out restoration planting in light wells as they occur, and manage as for restoration areas (see below); and to control the edge infestations only where the public profile of the area requires it or resources allow. The rationale for this approach is that control of specimens in the canopy can add to the vigour and longevity of the canopy and reduce the availability of propagules for new infestations. Light wells represent infestation opportunities within sites that should be managed in the interests of the larger area.

Management of scrambling heaps at the edge of natural areas should be determined on the basis of the objectives for the area and the ability to commit resources to continuing maintenance. At the edges of natural areas light conditions are ideal for *L. japonica* , eradication is unlikely to be possible, and spray application of herbicide would be followed by rapid re-invasion. If resources allow physical removal and replanting is possible but would require a long term maintenance commitment to manage re-infestation from the interior.

6.5.3 Management in Restoration Areas

Ideally restoration would start with eradication of *L. japonica* and other exotic lianes. Where there is existing vegetation of value this may not be possible, and in any case invasion across ownership or management boundaries is always likely. Consequently the management pattern in restoration areas should be first, to minimise edges through design, then to eliminate *L. japonica* to the greatest extent possible, to carry out the restoration planting in a mix that will establish canopy at the earliest possible time, and follow up with enrichment plantings to ensure the canopy's longevity. Maintenance visits to remove lianes should be carried out twice yearly until canopy cover is established (usually c. 3 years) and annually thereafter.

APPENDIX 1 – DATA CAPTURE SHEETS

Canopy/Sub-Canopy Record Sheet

Location: Totara Park, Plot

Plot GPS Coordinates (NW Corner):

Measured By: ____

Recorded By: ____

Date: ____

Species	Diameter	C/SC

Species	Diameter	C/SC

Ground Cover Record Sheet

Location: Totara Park, Plot

Plot GPS Coordinates (NW Corner):

Measured By: ____

Recorded By: ____

Date: ____

Point	**Groundcover**	**Presence (in contact with vertical rod)**
2.2		
2.4		
2.6		
2.8		
3.0		
3.2		
3.4		
3.6		
3.8		
4.0		
….		
7.0		
7.2		
7.4		
7.6		
7.8		
8.0		
8.2		
8.4		
8.6		
8.8		
9.0		
9.2		
9.4		

Point	Groundcover	Presence (in contact with vertical rod)
9.6		
9.8		
10.0		
10.2		
10.4		
10.6		
10.8		
11.0		
11.2		
11.4		
11.6		
11.8		
12.0		

L. japonica Record Sheet

Location: Totara Park, Plot

Plot GPS Coordinates (NW Corner):

Measured By: ____

Recorded By: ____

Date: ____

Size/host	**Small**	**Medium**	**Large**
Seedling			
Juvenile			
Mature			

Site Name	
GPS Location - S	
GPS Location - E	
Aspect (orientation)	
Aspect (slope)	
Drainage	
Soil Type	
Canopy type	
Canopy % cover	
Disturbance regime	
Site Shape/edge characteristics (length, width, shape)	
Prevalence of *Lonicera japonica* (verbal)	
Lonicera japonica - # Seedling, Ramet	
Lonicera japonica - # Juv, Ramet	
Lonicera japonica - # Mature	
Lonicera japonica relat other site vegetation	
Light	
Mature Light & stem size	
Juvenile	
Full sun	

Table 28 - Secondary sites specimen data capture sheet

APPENDIX 2 – SOIL ANALYSES

Hill Laboratories

R J Hill Laboratories Limited

Address: 1 Clyde Street, Private Bag 3205, Hamilton, New Zealand
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Facsimile: +64 (7) 858-2001
Email: mail@hill-labs.co.nz
Internet: www.hill-labs.co.nz

ANALYSIS RESULTS

Client: K Pudney
Address: 11 Bellwood Place, Chartwell, HAMILTON, New Zealand

Laboratory No.: 582122/1
Registered: 16-Dec-2008
Reported: 24-Dec-2008
Order No.: 180092
Submitted By: K Pudney
Client Ref:

Page 1 of 13

Sample Name: Plot 7
Sample Type: SOIL Mixed Pasture (S1)

Analysis		Level Found	Medium Range
pH		5.8	5.8 - 6.3
Olsen P	(mg/L)	12	20 - 30
Potassium	(me/100g)	1.65	0.50 - 0.80
Calcium	(me/100g)	41.0	6.0 - 12.0
Magnesium	(me/100g)	14.6	1.00 - 3.00
Sodium	(me/100g)	1.54	0.20 - 0.50
CEC	(me/100g)	81	12 - 25
Base Saturation	(%)	73	50 - 85
Volume Weight	(g/mL)	0.41	0.60 - 1.00
Available N (15cm Depth)	(kg/ha)	560	150 - 250

Base Saturation	K 2.1	Ca 51	Mg 18.1	Na 1.9
MAF Units	K 14	Ca 21	Mg 136	Na 29
Anaerobically Mineralisable N	899 ug/g			

Laboratory Comments

Analysis Comments

The high CEC level found in this soil indicates that it has a high capacity to retain cation nutrients (potassium, calcium, magnesium and sodium). The normal ranges and the derived histograms are based on a typical soil with a CEC level between 12 and 25 me/100g.

The % base saturation data for each element, shown at the base of the nutrient graph, provides an alternative presentation that may be more appropriate for soils with atypical CEC values.Normal %BS levels, as a general guide, are: K 2%-5%, Ca 50%-75%, Mg 5%-15%, Na 1%-2%.

End of Laboratory Comments

Submitter: K Pudney, 11 Bellwood Place, Chartwell, HAMILTON, New Zealand

Figure 12 - Sample Plot Soil Report

Hill Laboratories

R J Hill Laboratories Limited

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1 Clyde Street
Private Bag 3205,
Hamilton, New Zealand

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mail@hill-labs.co.nz
Internet:
www.hill-labs.co.nz

A N A L Y S I S   R E S U L T S

Client:	K Pudney	**Laboratory No.:**	582122	**Page 13 of 13**
Address:	11 Bellwood Place	**Registered:**	16-Dec-2008	
	Chartwell	**Reported:**	24-Dec-2008	
	HAMILTON	**Order No.:**	180092	
	New Zealand	**Submitted By:**	K Pudney	
		Client Ref:		

The following table gives a brief description of the analysis methods for this job. The COV (coeffient of variation) gives a measure of precision and is sometimes referred to as the Relative Standard Deviation, ie the standard deviation expressed as a percentage of the absolute value.

For further details and explanations, please contact the laboratory.
These samples were collected by yourselves (or your agent) and analysed as received at this laboratory.

Analyte	Method	COV(%)
Soil		
Base Saturation	Calculated from Extractable Cations and Cation Exchange Capacity.	4
CEC	Summation of extractable cations (K, Ca, Mg, Na) and extractable acidity.	4
Volume Weight	The weight/volume ratio of dried, ground soil.	2
Available Nitrogen*	Anaerobic incubation followed by extraction using 2M KCl followed by Berthelot colorimetry. (Calculation based on 15cm depth sample).	-
Anaerobically Mineralisable N*	As for Available Nitrogen but reported as ug/g.	-
Sample Registration*	Samples were collected by yourselves and analysed as received in the laboratory.	-
Soil Preparation (Dry and Grind)*	Air dried at 35 - 40°C overnight (residual moisture typically 4%) and crushed to pass through a 2 mm screen.	-
pH	1:2 (v/v) soil:water slurry followed by potentiometric determination of pH.	1
Potassium, Calcium, Magnesium, Sodium	1M Neutral ammonium acetate extraction followed by ICP-OES.	4
Phosphorus	Olsen extraction followed by Molybdenum Blue colorimetry.	6

* Indicates a non-accredited test.

This laboratory is accredited by International Accreditation New Zealand. The tests reported herein have been performed in accordance with its terms of accreditation, with the exception of tests indicated above. Accreditation also does not apply to comments and interpretations, i.e. the 'Normal Range' levels and the subsequent bar graph. This report may not be reproduced, except in full, without the written consent of the signatory.

Signatory:

Stephen Haylett-Petty
Technologist

Submitter: K Pudney, 11 Bellwood Place, Chartwell, HAMILTON, New Zealand

Figure 13 - Soil report methods

APPENDIX 3 – VEGETATION BY PLOT

Plot	**7**	*%*	**19**	*%*	**36**	*%*	**40**	*%*	**41**	*%*	**42**	*%*	**51**	*%*	**52**	*%*	**69**	*%*	**87**		90		96		Total	
Betula sp.							1	*4*																	1	*0*
Coprosma robusta	7	*19*			25	*74*			2	*7*			2	*5*	2	*6*					2	*3*	1	*8*	41	*11*
Cordyline australis					1	*3*	1	*4*	1	*3*	1	*6*	3	*7*	4	*11*	2	*8*			2	*3*			15	*4*
Dacrycarpus dacrydioides	5	*14*	5	*29*	1	*3*																			11	*3*
Dicksonia squarrosa	6	*17*	2	*12*	1	*3*	8	*32*													2	*3*			19	*5*
Fatsia japonica																					1	*1*			1	*0*
Geniostoma rupestre																							1	*8*	1	*0*
Melicytus ramiflorus	3	*8*	1	*6*	2	*6*			1	*3*											8	*11*			15	*4*
Pittosporum eugenioides																					1	*1*			1	*0*
Pittosporum tenuifolium																							1	*8*	1	*0*
Pseudopanax lessonii x crassifolius	2	*6*			1	*3*															1	*1*			4	*1*
Salix cinerea	13	*36*	9	*53*	3	*9*	13	*52*	25	*86*	16	*94*	39	*89*	29	*83*	22	*92*	22	*100*	56	*77*	10	*77*	257	*70*
Schefflera digitata							**2**	***8***																	**2**	***1***
Total	**36**		**17**		**34**		**25**		**29**		**17**		**44**		**35**		**24**		**22**		**73**		**13**		**369**	

Table 29 - Canopy - Species Count

Plot	**7**	**%**	**19**	**%**	**36**	**%**	**40**	**%**	**41**	**%**	**42**	**%**	**51**	**%**	**52**	**%**	**69**	**%**	**87**		90		96		Total	
Betula sp.							6	*2*																	6	*0*
Coprosma robusta	23	*7*			91	*61*			9	*3*			6	*2*	7	*3*					7	*2*	4	*4*	147	*5*
Cordyline australis					7	*5*	21	*7*	15	*4*	8	*4*	25	*8*	36	*16*	16	*6*			34	*9*			161	*5*
Dacrycarpus dacrydioides	96	*29*	64	*35*	6	*4*																			166	*6*
Dicksonia squarrosa	81	*25*	32	*17*	14	*9*	106	*37*													27	*7*			260	*9*
Fatsia japonica																					3	*1*			3	*0*
Geniostoma rupestre																							2	*2*	2	*0*
Melicytus ramiflorus	14	*4*	6	*3*	9	*6*			5	*1*											16	*4*			49	*2*
Pittosporum eugenioides																					2	*0*			2	*0*
P. tenuifolium																							4	*4*	4	*0*
Pseudopanax lessonii x crassifolius	8	*3*			3	*2*															2	*0*			13	*0*
Salix cinerea	**105**	***32***	**82**	***45***	**19**	***13***	**143**	***50***	**323**	***92***	**203**	***96***	**274**	***90***	**188**	***82***	**245**	***94***	**173**	***100***	**308**	***77***	**91**	***91***	**2152**	*72*
Schefflera digitata							11	***4***																	**11**	*0*
Total	328		184		148		286		351		211		305		231		261		173		399		100		**2975**	

Table 30 - Canopy - Sum of Species Diameter (cm)

Plot	7	%	19	%	36	%	40	%	41	%	42	%	51	%	52	%	69	%	87	%	90	%	96	%	Tot.	%
Coprosma robusta	3	*6*	1	*4*	2	*25*			11	*31*	8	*44*	13	*31*	8	*33*	10	*40*	10	*33*			3	*8*	69	*20*
Cordyline australis	4	*8*							3	*8*	4	*22*	11	*26*	3	*13*	6	*24*	1	*3*					32	*9*
Dacrycarpus dacrydioides			2	*7*					2	*6*															4	*1*
Dicksonia fibrosa																			1	*3*					1	*0*
Dicksonia squarrosa	3	*6*	5	*18*	1	*13*	21	*57*	7	*19*	3	*17*	7	*17*	1	*4*	6	*24*	1	*3*	1	*8*			56	*16*
Fatsia japonica									1	*3*															1	*0*
Geniostoma rupestre																							9	*24*	9	*3*
Gunnera sp.																					10	*77*			10	*3*
Ligustrum sinensis											2	*11*	1	*2*	3	*13*			10	*33*					16	*5*
Melicytus ramiflorus	9	*17*	2	*7*			5	*14*	1	*3*					1	*4*					1	*8*			19	*5*
Pittosporum tenuifolium	1	*2*																	1	*3*					2	*1*
Pseudopanax crassifolius									1	*3*															1	*0*
P. lessonii x crassifolius	1	*2*							2	*6*													2	*5*	5	*1*
Salix cinerea	7	*13*	3	*11*	4	*50*	8	*22*	2	*6*	1	*6*	9	*21*	8	*33*	3	*12*	2	*7*			23	*62*	70	*20*
Schefflera digitata	25	*47*	15	*54*	1	*13*	3	*8*	6	*17*			1	*2*					4	*13*	1	*8*			56	*16*
Total	53		28		8		37		36		18		42		24		25		30		13		37		351	

Table 31 - Sub-Canopy - Species Count

Plot	**7**	*%*	**19**	*%*	**36**	*%*	**40**	*%*	**41**	*%*	**42**	*%*	**51**	*%*	**52**	*%*	**69**	*%*	**87**	*%*	**90**	*%*	**96**	*%*	**Tot.**	*%*
Coprosma robusta	8	*4*	1	*1*	3	*8*			30	*18*	15	*16*	33	*15*	16	*20*	22	*15*	21	*23*			7	*5*	156	*9*
Cordyline australis	39	*20*							13	*7*	26	*27*	67	*30*	20	*25*	37	*24*	6	*7*					209	*12*
Dacrycarpus dacrydioides			5	*4*					3	*2*															8	*0*
Dicksonia fibrosa																			17	*19*					17	*1*
Dicksonia squarrosa	38	*19*	60	*50*	11	*27*	237	*74*	88	*52*	48	*49*	79	*35*	10	*11*	72	*48*	13	*14*	1	*1*			656	*39*
Fatsia japonica									2	*1*															2	*0*
Geniostoma rupestre																							22	*18*	22	*1*
Gunnera sp.																					51	*75*			51	*3*
Ligustrum sinensis											2	*2*	5	*2*	5	*6*			19	*21*					31	*2*
Melicytus ramiflorus	19	*9*	2	*2*			12	*4*	1	*1*					1	*2*					16	*23*			51	*3*
Pittosporum tenuifolium	3	*2*																	2	*2*					5	*0*
Pseudopanax crassifolius									5	*3*															5	*0*
Pseudopanax lessonii x crassifolius	2	*1*							13	*8*													3	*2*	18	*1*
Salix cinerea	32	*16*	20	*16*	24	*61*	68	*21*	5	*3*	7	*7*	38	*17*	31	*37*	20	*13*	4	*5*			89	*74*	337	*20*
Schefflera digitata	58	*29*	32	*27*	2	*4*	5	*2*	10	*6*			2	*1*					9	*10*	1	*1*			119	*7*
Total	**199**		**121**		**39**		**322**		**169**		**98**		**223**		**83**		**151**		**92**		**68**		**120**		**1685**	
***L. japonica* index**	**333**		**293**		**200**		**65**		**532**		**341**		**220**		**184**		**316**		**369**		**315**		**271**			

Table 32 - Sub-canopy - Sum of Species Diameters (cm)

APPENDIX 4 – PLOT ENVIRONMENTAL VALUES

Plot	%cover	Mean_Hgt	Max_Hgt	Min_Hgt	Water Table (mm)	pH	P (mg/L)	K (me/100 gm)	Ca (me/100 gm)	Mg (me/100 gm)	Na (me/100 gm)	VW (g/ml)	N (kg/ha)
7	60	20	40	1.5	170	5.8	12	1.65	41.0	14.6	1.54	0.41	560
19	60	20	35	10	400	5.2	13	1.52	36.9	19.7	1.56	0.30	227
36	40	5	10	1	110	5.9	18	2.84	48.4	18.2	2.00	0.18	294
40	75	5	6	4	150	5.6	12	1.73	48.0	22.7	1.69	0.32	182
41	60	7	12	2	15	5.9	25	2.51	56.2	24.2	2.03	0.33	353
42	40	10	15	1	110	5.8	17	2.64	47.2	15.6	2.00	0.21	319
51	40	8	10	1	10	6.0	22	3.35	47.2	15.7	2.08	0.22	345
52	30	5	10	2	0	5.9	25	3.95	46.7	15.7	3.63	0.18	308
69	60	10	10	10	30	5.6	19	2.68	35.8	11.2	1.33	0.33	370
87	70	5	10	2	30	5.9	13	2.29	47.1	17.3	1.69	0.25	321
90	80	4	5	1	110	5.8	25	3.26	46.7	24.2	2.20	0.18	217
96	10	2	10	0	240	5.4	19	1.26	32.4	16.0	2.37	0.34	599
Average	**52**	**8**	**14**	**3**	**115**	**5.7**	**18**	**2.47**	**44.5**	**17.9**	**2.01**	0.**27**	**341**

Table 33 - Plot Environmental Factors

APPENDIX 5 – CORRELATION MATRIX BETWEEN ENVIRONMENTAL AND VEGETATION VARIABLES

	Minimum Dist.	Water Table	pH	P (mg/L)	K (me/100gm)	Ca (me/100 gm)	Mg (me/100 gm)	Na (me/100 gm)	VW (g/ml)	N (kg/ha)	Cation exch. capacity
LJ Index	-0.0220	-0.0290	0.0425	0.3911	-0.0512	0.2517	0.2801	0.0136	0.1939	0.2268	0.2486
Native groundcover	-0.1178	-0.1413	0.1484	-0.0072	0.1018	-0.2390	-0.3320	-0.3705	0.2811	0.2568	-0.4583
Exotic groundcover	-0.2573	-0.1786	0.0156	0.7273	0.2983	-0.2683	-0.0707	0.5281	-0.1607	0.3686	-0.1453
Bare ground	0.1135	0.5195	-0.4067	-0.1959	-0.4488	-0.0476	0.1612	-0.3169	0.2476	0.0577	0.2153
Leaf litter	-0.0049	-0.0130	0.0595	-0.3984	-0.1413	0.3050	0.3078	-0.1860	-0.0690	-0.4442	0.3479
% Canopy cover	-0.1484	-0.0368	0.0498	-0.2518	-0.0493	0.3164	0.4837	-0.5386	0.1169	-0.5559	0.2895
Mean Canopy Height	0.2546	0.4992	-0.3400	-0.4910	-0.3607	-0.2998	-0.2401	-0.4736	0.4710	0.1210	-0.2892
Deciduous canopy	-0.0667	-0.4947	0.2607	0.6893	0.3586	0.2194	0.1844	0.1853	-0.0532	0.0413	0.0214
C. australis canopy	0.2913	-0.5022	0.3595	0.7355	0.7510	0.3254	0.2363	0.6174	-0.5056	-0.3928	0.2299
Evergreen canopy	-0.2623	0.5337	-0.2009	-0.3755	-0.4487	-0.2837	-0.0437	-0.2118	0.3576	0.4194	-0.0329
Tree Fern canopy	-0.2152	0.3732	-0.2295	-0.5864	-0.4623	-0.0127	0.2917	-0.3476	0.4496	-0.1367	0.0676
Deciduous subcanopy	-0.2898	0.3102	-0.4006	-0.2248	-0.4591	-0.4524	-0.1477	0.1321	0.3799	0.3995	-0.2688
Evergreen subcanopy	-0.7080	0.2746	-0.2064	0.0314	-0.4663	-0.3456	0.0770	-0.0281	0.5293	0.7031	-0.2241
Tree Fern subcanopy	0.1545	0.0082	-0.1391	-0.3578	-0.2683	0.2414	0.2983	-0.3722	0.3402	-0.3977	0.1513
C. australis subcanopy	0.3661	-0.3900	0.3518	0.1570	0.2718	-0.1029	-0.6294	-0.0214	0.1324	0.4237	-0.6013

Table 34 – Pearson's correlation matrix between environmental variables and vegetation classified by life form

Highlighted items significant at p=0.10 level

APPENDIX 6 – QUALITATIVE SITES

Riverbank, Pine Beach

Location: 37 46 34.3 S, 175 16 33.8 E

Aspect: 210^0 (SW)

Slope: 1:4 to 1:3 (NB contour lines in Figure 14 not reliable under canopy and close to the bridge)

Drainage: Free draining

Soil Type: Kirikiriroa Complex (steepland soils related to yellow brown loams, from rhyolitic alluvium, Hinuera formation, Kirikiriroa series) ((HCC, 2006)).

Light: Under canopy, c.0.5% full sun.

Canopy Type: *Melicyctus ramiflorus, Cyathea medullaris, Pittosporum eugenioides*, *Alnus glutinosa*.

Canopy Cover: See Figure 14 – c. 90%, though seasonally oblique light would be greater as the canopy is somewhat layered up the bank.

Canopy Height: To 20 m.

Disturbance Regime: Planting c. 30 y. old. No ground cover - ?sprayed.

Site Shape/Characteristics: Section of riverbank. 20 m x 20 m sampled.

Figure 14 - Aerial photograph of RPB, Pine Beach

L. japonica Presence

Four large mature plants, all on *M. ramiflorus*. Eight major stems, size range0.6 – 1.9 cm. One Mahoe severely affected. Ground cover evidently sprayed – only one juvenile on bank, though they are present at the river's edge on and around *S. cinerea*.

Riverbank, Fairfield Esplanade

Location: 37 46 20.6 S, 175 16 16.5 E

Aspect: 240^0 (WSW)

Slope: 1:20, 1:5

Soil Type: Waikato loamy sand - yellow-brown pumice soils from rhyolitic alluvium (Taupo Pumice Alluvium) Waikato series ((HCC, 2006)).

Light: Full sun, c. 1% beneath scrambling *L. japonica*.

Canopy Type: None

Canopy Cover: None

Canopy Height: -

Figure 15 –Aerial photograph of RFE, Fairfield Esplanade

Drainage: Free draining

Disturbance Regime: No maintenance and no restoration planting. Garden rubbish dumped.

Site Shape/Characteristics: Lower river terrace.

L. japonica Presence: Bottom part of site (see Plate 18) comprises a scrambling mat c. 10 m wide, covering stumps and dead shrubs or small trees.

Plate 18 - - RFE - Fairfield Esplanade site, general view

Plate 19 - - RFE - Underside of tangle on dead *S. cinerea*

Plate 19 shows the underside of a large mass of *L. japonica* on a small dead *S. cinerea.* The larger stems beneath this tangle are c. 8 mm diameter and the smaller a c. 4 mm, suggesting an age range for the initial infestation of 6 years +- 2 years (*insert cross reference*). Despite the low light conditions new shoots with leaves are visible. This is the western edge of the scrambling mass and receives slanting afternoon sun.

Stems of *L. japonica* occur throughout the currently grassed portions of the site and it appears that coverage is still expanding. *L. japonica* is flowering throughout the scrambling mass.

Gully behind Porritt – Snell to Crosby GPO

Location: 37 45 23.3 S, 175 17 18.5 E

Aspect: Gully runs NE – SW at this point.

Slope: Flat

Drainage: Water table ranges from c. 10 cm to surface water.

Soil Type: Tamahana soils derived from alluvium and organic debris, heavily organic and saturated.

Light: Generally c. 50% full sun, down to 4-9% under canopy

Canopy Type: *S. cinerea, C. medullaris*

Canopy Cover: 40%

Canopy Height: 7.5 m

Disturbance Regime: Removal of canopy at W. edge of site c. 2006, some control of *Z. aethiopica* and *L. japonica* in body of site. *C. secta* regenerating where willow removed.

Site Shape/Characteristics: 20 x 10 m section of back swamp starting c. 20 m from stream.

L. japonica presence: Two broad classes of plant within site: mature stems on canopy species and shoots and occasional small scrambling mats through the lower vegetation. Within the study area there were 52 canopy-reaching stems, average diameter 13.2 mm, median 13.0, max. 22.5. Size distribution is thus quite even, suggesting an initial invasion c. 16 years ago and the steady addition of stems since then. Scrambling shoots radiate out from these larger plants and are to be found throughout the *Carex secta* at the West edge of the site.

Figure 16 - Aerial photograph of GPO - Porritt Gully

Mangaiti Gully, Huntingdon to Hukanui Rd GMGT

Location: 37 44 24.8 S, 175 16 31.8 E

Aspect: N-S at plot, gully runs E-W, curves S, then curves W.

Slope: 1:20

Drainage: Poor – gully bottom and stream bank

Soil Type: Tamahana soils – Tamahana soils derived from alluvium and organic debris saturated at some points but less so at localised high points. ((HCC, 2006)).

Light: C. 1% full sun beneath canopy, 50% and greater at flowering points.

Canopy Type: *S. cinerea, S. fragilis*

Canopy Cover: 20%

Canopy Height: 3 m

Disturbance Regime: No maintenance apparent; surrounding land was farmed till c. 1985.

Site Shape/Characteristics: 20 x 10 parallel to stream in bottom of wide gully (c. 100 m at this point)

L. japonica Presence: Large tangle on *Salix fragilis*, (7 x 3 m, to 3 m height) some runners out into *Glyceria maxima* and *C. secta* in open, also mixed with but dominated by *Ipomoea indica* in scrambling heaps – see Plate 20.

Stem sizes of *L. japonica* on the *S. cinerea* ranged from 5 to 20 mm, suggesting an initial infestation c. 14 years BP (i.e. around 1995) and subsequent continued growth.

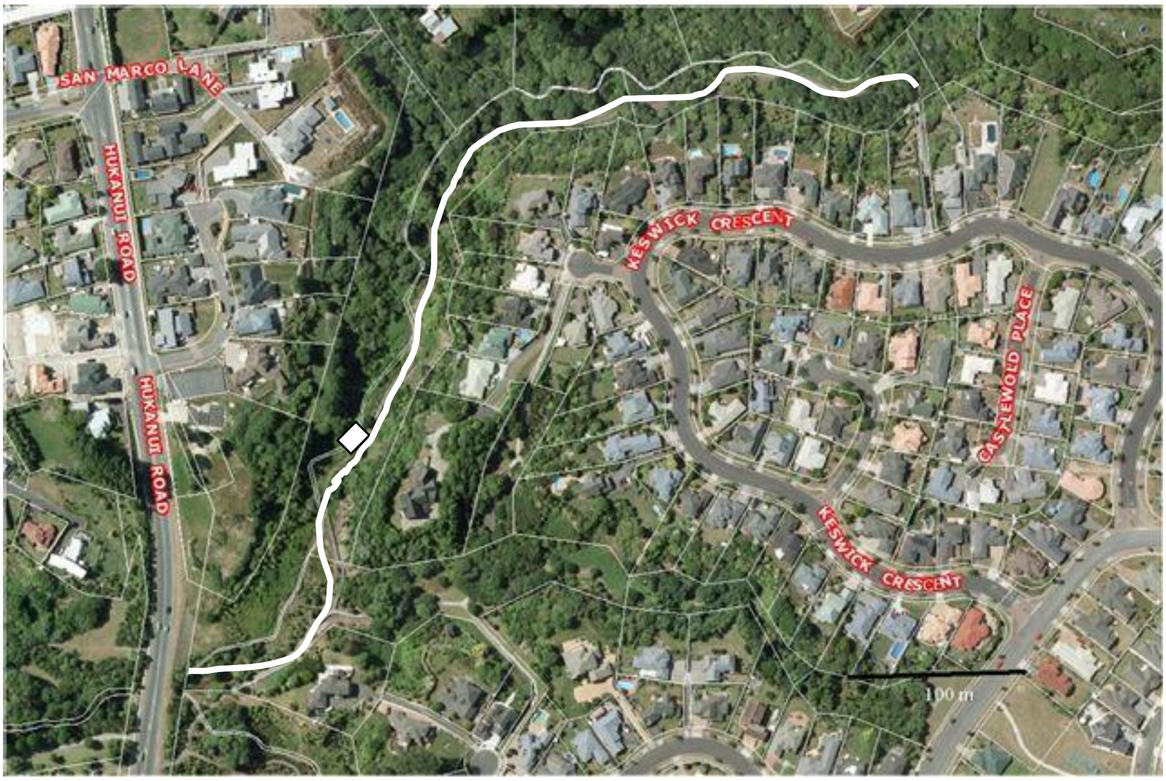

Figure 17 - Aerial photograph of GMGT, Mangaiti Gully, showing approx. location of study site (white rectangle) and route of *L. japonica* census (white line)

Plate 20 - GMGT, Mangaiti Gully – mixed infestation of *Ipomoea indica* and *L. japonica* on *S. fragilis*

Tauhara Park (Kirikiriroa Gully), Wairere Bridge GTA

Location: 37 44 39.3 S, 175 16 12.3 E

Aspect: 240^0 – open to west.

Slope: 1:12

Drainage: Free draining

Soil Type: Top half anthropic – worked over in course of construction of Wairere Drive, topsoil of unknown origin but appears to be silt loam; lower portion Tamahana soils derived from alluvium and organic debris.

Light: *L. japonica* was flowering at all points on the site except beneath the canopy; mean available light at flowering points was 95% available PAR, and beneath the canopy and next to immature ramets was c. 4%.

Canopy Type: *Pittosporum eugenioides, Alnus glutinosa, Cordyline australis*

Canopy Cover: < 10%

Canopy Height: 2 m

Disturbance Regime: Site falls into two halves – top portion artificial contour that has been covered with weed mat and had the canopy species noted above together with *Leptospermum scoparium* planted into it; and a lower area that has been allowed to revert following the cessation of farming. Maintenance has been carried out sporadically since this planting (see Figure 18).

Site Shape/Characteristics: This site is an irregularly shaped strip between a boardwalk and stream, c. 20 m long x 10 m wide.

L. japonica Presence: There are two large scrambling areas of *L. japonica* in the lower part of the site, 20 x 10 and 5 x 5. There are runners across the other parts of the site, and each of the of the restoration specimens has some degree of invasion by *L. japonica,* ranging from a single shoot to canopy occlusion. Plant impacts are described more fully in (insert cross reference)

Figure 18 - Aerial photograph of GTA - Tauhara Gully, adjacent to Wairere Bridge

Waitawhiriwhiri Gully between Ulster St and Seddon Rd GWA

Location: 37 46 47.7 S, 175 15 55.5 E

Aspect: 260^0

Slope: 1:3

Drainage: Free draining

Soil Type: Anthropic – soil pushed over gully wall in course of construction of adjoining park; sandy loam.

Light: Restricted by topography. Flowering points c. 80% of available light, juvenile growing points c. 14%

Canopy Type: Stand of *Populus nigra* to S. of plot, 20 m + in height. Remainder of canopy is restoration plantings at age 2.5 years – *L. scoparium, D. dacridioides, P. tenuifolium, P. eugenioides, Phormium tenax, C. robusta, Kunzea ericoides.*

Canopy Cover: 20%

Canopy Height: 2.5- 3m, *Populus nigra* to 20 m at edge of site

Disturbance Regime: Clearance and restoration plantings c. 2006. Minimal maintenance since then.

Site Shape/Characteristics: 20 m. section of east bank of deep (c. 20 m.), steep sided gully.

L. japonica Presence: Sparse throughout site, usually present in association with *I. indica* but in lesser quantities. Flowering on *C. Robusta, P. tenuifolium* at stem sizes of 3.8 and 3.5 respectively, suggesting an age similar to that of the restoration plantings themselves. Generally *I. indica* is more vigorous on this site than *L. japonica.*

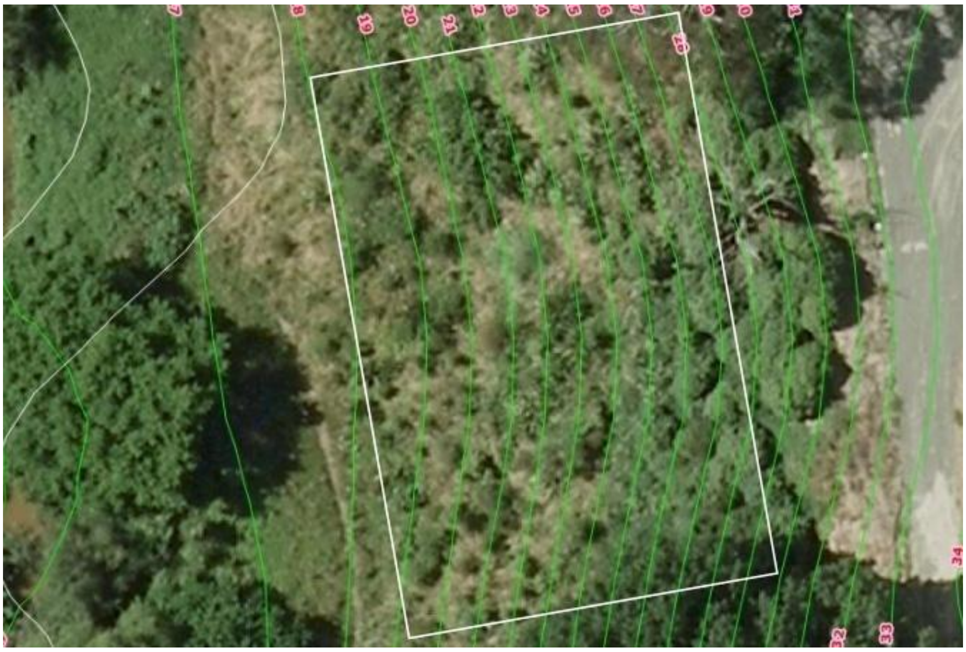

Figure 19 - Aerial photograph of GWA, Waitawhiriwhiri Gully

Riverbank, Mangakotukutuku Gully confluence RMA

Location: 37 48 28.3 S, 175 17 54.7 E

Aspect: 60^0

Slope: 1:10 at upper terrace, then 1:2 to river's edge

Drainage: free draining

Soil Type: upper part of site anthropic – site works for pipe line. Remainder of site Waikato loamy sand - yellow-brown pumice soils from rhyolitic alluvium (Taupo Pumice Alluvium) Waikato series ((HCC, 2006)).

Light: Considerable diurnal range – good light in morning, but shaded in the afternoon. *L. japonica* was flowering at 5-15% of available afternoon light, and levels beneath the full canopy were < 1%.

Canopy Type: Eucalyptus sp., *Ligustrum sinensis, Coprosma robusta, S. cinerea,*

Canopy Cover: 75% +

Canopy height: 5-10 m

Disturbance Regime: Site heavily modified in work to install pipes. No apparent restoration planting or maintenance.

Site Shape/Characteristics: Strip approx. 12 x 20 m. Terrace created for pipe work, falling to the river and enclosed by a steep bank to the West.

L. japonica Presence: First part of site has *Tradescantia fluminensis* as ground cover; this blends into scrambling *L. japonica* which is prevalent throughout the rest of the site as ground cover or climbing on other vegetation. There is substantial cover of a *L. sinensis*, a *C. robusta* and there is also a dead and now unidentifiable plant. The cover over the *L. sinensis* (see Figure 20) is approximately 3 x 5 m, and is supported by at least six stems ranging in size from 8 to 16 mm, suggesting an age of c. 11 years for the oldest stems.

Figure 20 - Aerial photograph of RMA, River bank at Mangakotukutuku confluence.

Plate 21 - *L. japonica* on *L. sinensis*

Plate 22 - Stems of *L. japonica* covering *L. sinensis* shown in Plate 21

Mangakotukutuku Gully, Sandford Park GMA Old restoration planting, some maintenance

Location: 37 48 43.1 S, 175 17 59.9 E

Aspect: 100^0 (E)

Slope: 1:2

Drainage: Free draining

Soil Type: Kirikiriroa Complex (steepland soils related to yellow brown loams, from rhyolitic alluvium, Hinuera formation, Kirikiriroa series) ((HCC, 2006)).

Light: Considerable diurnal range – good light in morning, but shaded in the afternoon. A measure beneath the canopy was 14% of available light, c. 55% in a light well in the canopy, 28-55% at mature plants, and 3-7% for immature plants under the canopy.

Canopy Type: Mixed – *P. eugeniodes, Dicksonia fibrosa, Cyathea medullaris, Cupressus sp., Pinus radiata, Robinia pseudoacacia, Melocytus ramiflorus*

Canopy Cover: 75%

Canopy Height: 20 m+

Disturbance Regime: Restoration plantings c. 1980. Minor pest plant maintenance since, mostly at the lower edges of the bank.

Site Shape/Characteristics: Approx. 30 x 40 m. of gully bank. Backswamp formerly at its foot has been filled.

L. japonica Presence: Eight large canopy-reaching growths of *L. japonica* through the study area, with runners at ground level. On *M. ramiflorus* –major stems 13 mm, 13 mm. On *C. medullaris* (reaching into *R. pseudoacacia*) stems at 24 mm, 14 mm, 8 mm, 12 mm, 7 mm, 11 mm

Figure 21 - GMA - Aerial Photograph, Mangakotukutuku Gully, (Sandford Park)

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