What Factors Influence the Success of *Senecio* (Asteraceae) in Canterbury, New Zealand? A Phylogenetic and Ecological Study.

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“It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change.”

- *Charles Darwin*

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Abstract

Senecio is one of the largest genera in the Asteraceae family with 28 *Senecio* species in New Zealand and over 1200 species worldwide. Native *Senecio* in the Canterbury region are typically naturally uncommon and exhibit extreme fluctuations in population size. Contrary to native *Senecio*, exotic *Senecio* in the Canterbury region are thriving. Why some exotic species thrive in a novel environment while native species decline has been an area of intense study since the era of Darwin. However, despite extensive study, we are still unsure about the underlying mechanisms of this phenomenon. This thesis looks at several hypotheses that have been proposed to explain differences in success between native and exotic species including four that have been frequently mentioned in the literature: phylogenetics, natural enemy release and biotic resistance, allopolyploidy and habitat modification.

In order to determine if phylogenetic relatedness influences the abundance and distribution of *Senecio* species in Canterbury, DNA phylogenies of New Zealand's *Senecio* were constructed using nuclear (ITS, ETS) and plastid (*trnL, trnL-F* and *psbA-trnH*) DNA sequences. The resulting cladograms were used to determine the areas of origin of New Zealand's *Senecio* lineages, the identity of their closest relatives and lineages and species that are of allopolyploid origin. The data provided by the phylogenetic analyses was to provide context for analyses of ecological data of 86 native and exotic *Senecio* populations from the Canterbury region. My results indicate that phylogenetic relatedness is a poor predictor of the amount of folivory experienced by *Senecio*, although some natural enemies of native and exotic *Senecio* displayed a positive preference for *Senecio* depending on their clade. The strongest effects on *Senecio* and the occurrences of their natural enemies came from the surrounding land use which influenced the amount of folivory and the abundances of natural enemies on *Senecio*. Enemy release and biotic resistance were land use specific within Canterbury and by themselves cannot explain the variance in folivory when applied to a landscape scale. According to my results, the biggest factor influencing *Senecio* folivory, abundance and distribution in the Canterbury region is change in the surrounding land use.

Chapter One:

General Introduction

As primary producers, plants form the foundations of many ecosystems because of the ecosystem services and functions that they provide such as nutrient cycling and retention as well as the maintenance of hydrologic cycles (Hooper and Vitousek 1997, Loreau et al. 2001). Despite the value of the Earth's species, which are estimated at an average of US$ 38 trillion per year (Costanza et al. 1997), the rate of extinction has been calculated to be 100 to 1000 times pre human levels (Pimm et al. 1995). Ecosystems that are most at risk of extinction are found in the 25 biodiversity hotspots outlined by Myers et al. (2000). Each of Myers et al. (2000) biodiversity hotspots have 0.5% or more of the world's flora. Many of these areas have already lost around 70% of their original vegetation area due to anthropogenic factors but when all areas are combined together they contain approximately 44% of the world's vascular plant species (Myers et al. 2000, Brooks et al. 2002). Although important, species richness is not what makes an ecosystem tick. The models of Macarthur (1955) and May et al. during the 1970s (see McCann et al. 2000) illustrate that if there are too many species within an ecosystem, the ecosystem can become unstable and collapse (McCann 2000). As a result, it has become recognised that species diversity which includes the number and composition of genotypes, functional traits and species richness is a better measure of an ecosystem's performance (Diaz and Cabido 2001). Grassland experiments during the late 1990s illustrated the importance of species diversity by showing that the amount of net primary productivity (NPP) increased with greater plant diversity (Hooper and Vitousek 1997, Hooper et al. 2005). The greater diversity of plant species within the experiments maximised the use of available resources through the complementarity of functional traits resulting in greater NPP (Hooper and Vitousek 1997, Hooper et al. 2005). Therefore, the composition of species and their functional traits are more valuable than the number of species in any ecosystem.

Functional traits are traits that influence ecosystem properties or species responses depending on environmental conditions (Hooper et al. 2005). The biotic functions of an ecosystem are therefore governed by the functional traits of the species present within it. The combination of all species and their functional traits within a community ecosystem is referred to as functional diversity (Diaz and Cabido

2001). If species that display important functional traits become extinct within a community their loss has been theorised to reduce the stability of the system due to the loss of functional redundancy (i.e. the degree to which species perform similar ecological functions) (Walker 1992, Loreau et al. 2001, Hooper et al. 2005). Despite the amount of theory in the literature regarding functional redundancy, there are few supporting empirical studies (Diaz and Cabido 2001, Sasaki et al. 2009, Gerisch et al. 2012). However, an increasing body of literature has started to focus on the functional diversity and redundancy of community ecosystems when impacted by habitat disturbance (Diaz and Cabido 2001, Flynn et al. 2009, Sasaki et al. 2009, Bihn et al. 2010). For example, the meta-analysis by Laliberte et al. (2010) across five biomes found that increasing land use intensification significantly reduced the functional diversity and response diversity of plant communities. Similar results were found by Sasaki et al. (2009) and their study on Mongolian grasslands. In addition, Sasaki et al. (2009) mention that disturbance may cause the community to change to a alternative stable state because the community becomes dominated by disturbance resistant species over time. The change to an alternate stable state in the community may be followed by subsequent species extinctions due to changes in species interactions and the loss of mutualisms (Scheffer et al. 2001, Folke et al. 2004, Schweiger et al. 2010).

The global spread of humanity has lead to increased extinction rates via five major drivers of global environmental change (CO(2) enrichment, nitrogen deposition, climate change, land use and biotic invasions) (Sala et al. 2000, Tylianakis et al. 2008). The two most prominent drivers are land use change and invasive species (Didham et al. 2007). Land use change is a well known cause of species loss and ecosystem change (Lawton et al. 1998, Scheffer et al. 2001, Fischer and Lindenmayer 2007). In the last two decades there has been an increased focus on the interactive effects between land use change and invasive species in the decline of native species and communities (Didham et al. 2007, Tylianakis et al. 2008, Potts et al. 2010). The interactive effects between land use change and invasive species can have a major bearing on community compositions and ecosystem functioning (Didham et al. 2007). For example, habitats that experience widespread disturbance such as deforestation not only experience a loss in species richness but they also suffer from a decline in functional diversity (Flynn et al. 2009). As a result, recently disturbed habitats represent a land of opportunity for invading species because invading species tend to invade habitats where there is an absence of species with similar functional traits or where empty niches are available (Funk et al. 2008, Vila and Ibanez 2011). For example, the study by Flory and Clay (2009) found that plant invasions were determined by the age of the habitat being invaded and that young heterogeneous habitats that had been recently created by disturbance promoted invasive shrub growth. Furthermore, following a natural or anthropogenic disturbance the abundance of an invasive species tends to increase (Lonsdale 1999, Mitchell et al. 2006, Richardson and Pysek 2006). Invasion of a new habitat occurs in four stages: transport/ dispersal, colonisation, establishment and spread. During the four stages exotic species typically transition from introduced (cultivated but not reproducing), vagrant (i.e plants which do not form self sustaining populations), established/ naturalised (i.e. self sustaining natural populations over 10 years old) and finally invasive (self sustaining populations, which are increasing in size and range) (Richardson and Pysek 2006, Theoharides and Dukes 2007). Once an exotic species establishes within an environment it can have a detrimental influence on ecosystem properties and function (Mack et al. 2000, Ives and Carpenter 2007) but it can also have little to no impact because of biotic resistance by native natural enemies within the community that it is invading (Elton 1958, Levine et al. 2004, Thuiller et al. 2010).

Exotic species that invade a novel habitat are not guaranteed to succeed within the habitat (Verhoeven et al. 2009). There are several hypotheses why invading species either succeed or fail to establish within a habitat. The two most prominent hypotheses are the enemy release hypothesis and the biotic resistance hypothesis. The enemy release hypothesis proposes that invading species benefit from the release of their coevolved enemies and are therefore more likely to become invasive (Keane and Crawley 2002). The benefit experienced by the invading species is because of reduced regulation by herbivores and other natural enemies in their new environment resulting in an increase in distribution and abundance (Keane and Crawley 2002). For example, Mitchell and Power (2003) found that exotic plant species that have naturalised in the United States from Europe encountered, on average, 84% fewer fungi species and 24% fewer virus species than in their home ranges. At the other end of the theoretical spectrum of enemy release is the biotic resistance hypothesis which proposes that novel natural enemies such as generalist herbivores prevent the establishment and spread of invading species through strong interactions, which regulate an invading species to a greater extent than in their natural habitat (Elton 1958, Maron and Vila

2001). Both the enemy release hypothesis and biotic resistance hypothesis are not mutually exclusive (Mitchell et al. 2006). Rather they explain why some species succeed and why others fail (Verhoeven et al. 2009). For example, the study by Carpenter and Cappuccino (2005) found that low leaf herbivory was strongly correlated with invasiveness amongst non-native plant species, which supported the enemy release hypothesis. They also found evidence which supports the biotic resistance hypothesis because invasive species such as *Barbaria vulgaris,* experienced high leaf damage. Carpenter and Cappuccino (2005) therefore, suggest that herbivores in the community are effective at preventing some species of colonising plants from becoming invasive, which is also supported by the meta-analysis of Levine et al. (2004). Because of studies such as the Carpenter and Cappuccino (2005) study, an increased focus has been taken towards understanding the underlying mechanisms of why invading species can become invasive (Verhoeven et al. 2009, Jenkins and Keller 2011, te Beest et al. 2012).

Darwin’s theory of naturalisation proposes that species that are phylogenetically distant to species of local communities should be more successful because they are able to occupy unfilled ecological niches (Darwin 1859a, Rejmanek and Richardson 1996, Thuiller et al. 2010). The theory assumes that the success of an invading species is related to its ability to display niche differentiation as well as fill niche gaps. In addition, Darwin wrote a secondary hypothesis which suggests that species that have a greater degree of phylogenetic relatedness are more likely to succeed within an environment due to adaptations shared with local species in the environment. The two paradoxical hypotheses have been dubbed Darwin’s naturalisation conundrum (Diez et al. 2008) and in recent years a number of studies have set out to answer the two hypotheses with equivocal results (Agrawal and Kotanen 2003, Diez et al. 2008, Hill and Kotanen 2009, Thuiller et al. 2010). For example, the meta-analysis by Parker et al. (2012) found that invasive plant species that were phylogenetically isolated from native species in the community experienced greater impacts by herbivores than closely related species supporting some aspects of Darwin’s theory of naturalisation. However, phylogenetically isolated invasive plant species were more abundant than native species indicating that factors other than phylogenetic isolation are affecting invasive species.

A high percentage of invasive plant species display polyploidy (Pandit et al. 2006, te Beest et al. 2012). Researchers have proposed polyploidy as a mechanism for the successful invasion of novel habitats (Treier et al. 2009, te Beest et al. 2012). Polyploidization can lead to greater environmental tolerances, novel or additional chemical defences, increased competitive ability as well as a range of other potential benefits (te Beest et al. 2012). As a result of polyploidization, newly formed polyploids often undergo an extension in range (Pandit et al. 2006, Treier et al. 2009, Thebault et al. 2011). By having a greater genetic diversity via polyploidy, species can adapt within one to a few generations in fluctuating environmental conditions which can allow them to exploit empty niches and absences in functional traits within an ecosystem (Leitch and Leitch 2008). Therefore, a polyploid species is ideally placed to extend its range and influence into communities that have recently been disturbed by land use change. In addition, should an invading plant species hybridise with a native species and produce a viable allopolyploid, the allopolyploid offspring may become extremely invasive because they can display the phenotypic and genotypic traits of both parents (Huxel 1999, Ellstrand and Schierenbeck 2000). The creation of an allopolyploid from native and non-native parents in a novel environment would fit with Darwin’s secondary hypothesis because the allopolyploid offspring may display inherited adaptations to the local environment conditions from its native parent (Darwin 1859a, Thuiller et al. 2010). In addition, because allopolyploids have additive chromosome numbers of both parents, they may also display greater genetic diversity which allows them to adapt to a fluctuating environment and become more invasive in the community (Treier et al. 2009, te Beest et al. 2012). Therefore, allopolyploid species with high dispersal rates, environmental tolerances and the ability to hybridise with other members in their genus are likely to become successful invasive species.

In the last 700 years, New Zealand has undergone anthropogenic land use change on a massive scale with only 23% of the original indigenous habitat remaining since human arrival (Atkinson and Cameron 1993, Walker et al. 2006). In addition, New Zealand has seen the introduction of over 25,000 plant species of which, ~2200 species have established self sustaining populations (Atkinson and Cameron 1993, Duncan and Williams 2002). Amongst the ~2200 established species are members of the *Senecio* genus. *Senecio* is a part of the tribe Senecioneae and is one of the largest genera in Asteraceae with over 1200 species worldwide (Pelser et al. 2007). *Senecio* centres of diversity are found in southern Africa and South America but representatives of the genus are found on every continent except Antarctica (Bartoli et al. 2004, Garcia-Serrano et al. 2004, Kadereit et al. 2006, Pelser et al. 2007, Brennan et al. 2009). Despite the biogeographical range of *Senecio*, the genus is only five to eight million years old (Pelser et al. 2007). The rapid spread of *Senecio* is perhaps due its highly plastic genotypic and phenotypic traits. For example, *Senecio* possess powerful pyrrolizidine alkaloids, which act as potent chemical defences against herbivores (Hol and Van Veen 2002, Macel et al. 2002, Pelser et al. 2005, Barros et al. 2007). The ability to hybridise with other members of the genus is a common phenomenon (Kirk et al. 2004, Kirk et al. 2005, Brennan et al. 2009). These traits (as well as others) combined with a high dispersal ability have allowed *Senecio* to invade a wide range of environments (Pelser et al. 2007), including most of the terrestrial environments in New Zealand.

New Zealand is represented by 28 species of *Senecio,* 13 are native endemic and 8 are native (Sykes 1987, Webb 1988.). The 8 native species are also native to Australia. The remaining 8 species are *Senecio* that have been introduced in the last 150 years from Australia, southern Africa and Europe (Wilson et al. 1992, de Lange et al. 2004, Sullivan et al. 2008). Native New Zealand *Senecio* are distributed throughout New Zealand and occur in the majority of indigenous habitats, which include coastal regions and alpine and glacial habitats (Webb et al. 1988). However, native New Zealand *Senecio* are typically sparse in abundance and have extreme fluctuations in population size according to the New Zealand threat classification system list (2002) by the New Zealand Department of Conservation. Native *Senecio* are particularly scarce around coastal areas, and are thought to be declining due to competition from exotic *Senecio* species and non-native grasses (Sullivan pers comms.). Exotic *Senecio* are most common in modified habitats such as roadsides and urban areas (Wilson et al. 1992, Sullivan et al. 2008). In addition, exotic species are expanding their ranges into indigenous habitats (Sullivan et al. 2005). New Zealand *Senecio* are fed on by a variety of native and naturalised invertebrate species which vary in their host specialisations (Spiller and Wise 1982, Sullivan et al. 2008). For example, the endemic specialist herbivore *Nyctemera annulata* (Arctiidae; Lepidoptera), predominately feeds on *Senecio,* however it is known to feed on other members of the Senecioneae tribe (Spiller and Wise 1982, Wardle 1987). Whereas, generalist species such as aphids (Aphidoidea: Homoptera) feed on a variety of plant species including *Senecio*. The exact number of New Zealand invertebrate species that rely on *Senecio* is unknown and the loss of indigenous *Senecio* species could have an impact on the surrounding *Senecio*-based food web. An aim of this thesis is to determine whether or not exotic *Senecio* species are experiencing enemy release or biotic resistance from natural enemies of *Senecio* in New Zealand's Canterbury region. In addition, I hope to discover factors that are influencing the abundance and distribution of native *Senecio* and if land use change is aiding in the colonisation of non-native *Senecio* species. To aid in the determination of the factors influencing native New Zealand *Senecio,* my thesis will include phylogenetic analyses, which will include all New Zealand *Senecio* species including exotic species that have been recently introduced as well as representatives of most of the major *Senecio* clades to determine where New Zealand *Senecio* have originated from (Webb 1988., Pelser et al. 2007).

The Senecioneae phylogeny of Pelser et al. (2007) indicates that colonisation of Australasia by *Senecio* has occurred three times. The Pelser et al. (2007) phylogeny places Australasian *Senecio* in three clades, which have a southern African origin. Within the Australasian clades of Pelser et al. (2007) are nine New Zealand native endemic and native *Senecio* species. Each of the Australasian clades is phylogenetically isolated from one another as well as from the non-native *Senecio* species from southern Africa and Europe that are present in New Zealand (Pelser et al. 2007). Because the phylogeny of Pelser et al. (2007) only includes nine native New Zealand *Senecio* species there is a possibility that other native New Zealand *Senecio* have invaded New Zealand from geographical areas such as South America (Sanmartin and Ronquist 2004). If New Zealand *Senecio* species are found to originate from South America and other land masses, then the traits of these *Senecio* may be different to those that have originated from southern Africa, because of different evolutionary histories. In addition, because some native invertebrate species specialise on native *Senecio,* the loss of a *Senecio* species from one biogeographic area may lead to host switching by specialist invertebrate herbivores to a closely related relative (Percy et al. 2004) or the loss of those species altogether (Mack et al. 2000). Therefore, one of my aims is to create a phylogeny of New Zealand's *Senecio* that will allow phylogenetic relatedness to be determined as well as where New Zealand's *Senecio* have originated from and the number of colonisations.

Hybridisation, as previously mentioned, is a common phenomenon in *Senecio.* The potential that some New Zealand *Senecio* may have allopolyploid origins is high. Genetic studies on native New Zealand *Senecio* indicate that a number of *Senecio* species have comparatively high chromosome numbers (Sykes 1987, Webb 1988, de Lange et al. 2004). The average number of chromosomes for native New Zealand species is 2n=40, 80 or 100. *Senecio* species found outside of New Zealand however, commonly have a chromosome number of 2n=20 or 40 (Robinson et al. 1997). Because the chromosome numbers of New Zealand *Senecio* are high, there is the potential that hybridisation(s) have occurred resulting in allopolyploids. I intend to identify native New Zealand allopolyploids by creating phylogenies of New Zealand's *Senecio*, which will help identify allopolyploid species through their positions in plastid and nuclear phylogenies and the potential incongruence between the two phylogenies (Pelser et al. 2010). The identification of allopolyploid species in combination with ecological data will allow the evaluation of whether or not allopolyploids benefit in a range of habitats and sustain less herbivory than diploid species. In addition, by determining which species are allopolyploids we will be able to predict whether or not co-occurring *Senecio* populations are at risk due to competitive exclusion by these species.

This thesis will be divided into four chapters, which includes two data chapters. The first data chapter is a phylogenetic study of New Zealand *Senecio* focused on the identification of clades and allopolyploids as well as determining the number of colonisations by *Senecio* into New Zealand. The second data chapter will utilise phylogenetic results of the first data chapter that will be incorporated with ecological data on the natural enemies of the Canterbury regions *Senecio* in order to determine whether or not there is a phylogenetic link between the amount of folivory and phylogenetic relatedness. In addition, my second data chapter will quantify the relative importance of *Senecio* biostatus, size and reproductive state and environment (land use) on herbivory and pathogen damage. I do this to assess the degree to which enemy release and biotic resistance are likely to influence the distribution and abundance of native and naturalised *Senecio* species in Canterbury.

Chapter Two

Molecular phylogeny and biogeography of New Zealand's Senecio (Senecioneae: Asteraceae).

2.1. Abstract

Senecio L. is one of the largest genera in the Asteraceae family with over 1200 species. *Senecio* has a worldwide distribution with 28 species in New Zealand. A DNA phylogeny of New Zealand's *Senecio* was constructed using nuclear (ITS, ETS) and plastid (*trnL*, *trnL-F* and *psbA-trnH*) DNA sequences. The resulting cladograms were used to determine the areas of origin of New Zealand's *Senecio* lineages, their closest relatives and lineages that are of allopolyploid origin. Bayesian and Parsimony analyses indicate that all native New Zealand *Senecio* have colonised New Zealand via a dispersal route originating in southern Africa. There have been at least three colonisation events by *Senecio* into Australasia; resulting in three clades. The nuclear phylogeny indicates that there have been at least twenty two trans-Tasman colonisation events between New Zealand and Australia, occurring in both directions. This suggests that the Tasman Sea is not a major barrier to the dispersal of *Senecio* species. The three Australasian clades are isolated from one another but patterns of incongruence within the two phylogenies indicate that there have been at least three hybridisation events by species from New Zealand and Australia. The hybridisation events have resulted in one clade displaying allopolyploid origins along with five other species from the remaining two clades.

2.2. Introduction

Senecio L. is a member of the tribe Senecioneae and is one of the largest genera (> 1200 species) in Asteraceae (Pelser et al. 2007). *Senecio* has a worldwide distribution with centres of diversity in Southern Africa and South America (Grulich and Hodalova 1994, Hind 1999, Radford and Cousens 2000, Pelser et al. 2007, Lopez et al. 2008, Hawkes et al. 2010). Molecular phylogenetic studies indicate that *Senecio* originated in Southern Africa and that it is an evolutionarily young genus of 5-8 million years (my) old (Pelser et al. 2007). *Senecio* are able to tolerate a wide range of environmental conditions which has enabled them to colonise habitats on every continent except Antarctica (Kadereit 1984, Lowe and Abbott 1996, Radford and Cousens 2000, Lafuma et al. 2003, de Lange et al. 2005, James and Abbott 2005, Pelser et al. 2007, Tsutsumi 2011). In addition, *Senecio* have colonised geographically isolated islands throughout the world (Wilson et al. 1992, de Lange et al. 2005, Goodson et al. 2006, Pelser et al. 2007, Pelser et al. 2012). The phylogeny constructed by Pelser et al. (2007) indicates that Australasia has been colonised by *Senecio* from southern Africa on three different occasions resulting in at least three large clades. When combined, these clades are comprised of 107 species of *Senecio* (Thompson 2006). However, Thompson (2006) states that further revision of Australian *Senecio* is needed to confirm the exact number of species and clades in Australasia.

New Zealand is represented by 30 species of *Senecio*, including native and naturalised species (Table 1; (Drury 1974, Kadereit 1984, Webb et al. 1988, Pelser et al. 2004). New Zealand shares eight native *Senecio* species, including one subspecies with Australia, and these species are widely distributed in both countries (Ornduff 1964, Drury 1974, Wilson et al. 1992). Nine naturalised species have colonised New Zealand from Southern Africa, Europe and Australia in the last 150 years (Drury 1974, Kadereit 1984, Webb 1987, 1988, Webb et al. 1988, Pelser et al. 2004). The remaining 13 species are endemic to New Zealand. The Senecioneae ITS phylogeny of Pelser et al. (2007) includes nine native New Zealand *Senecio* species, and places them within all three Australasian *Senecio* clades. Because this phylogeny only included a small portion of New Zealand’s *Senecio* species it is possible that some New Zealand *Senecio* have colonised New Zealand from other geographical areas such as South America which has been proposed as an area of origin for New Zealand plant species (Winkworth et al. 2002, Sanmartin and Ronquist 2004). A detailed understanding of how many times *Senecio* have colonised New Zealand and where the colonising species have originated from is therefore currently lacking. By conducting a phylogenetic analysis, my aim is to determine the level of threat that introduced *Senecio* pose to native *Senecio* species through hybridisation and the level of threat due to herbivory by natural enemies. Phylogenetic analyses may help to identify hybrids by revealing patterns of incongruence between different gene regions (Pelser et al. 2010, Pelser et al. 2012). Knowledge of the relationships between native and introduced species may help assess whether introduced *Senecio* which are phylogenetically distant from native *Senecio* experience a release from natural enemies.

By naturalising in a novel environment an introduced species can benefit in a variety of ways that directly or indirectly leads to the extinction of native species in the community (Mack et al. 2000, Keane and Crawley 2002). Darwin hypothesised that introduced species are more likely to naturalise when they belong to a genus with no native species in the region (Darwin 1859a). The review by Colautti et al. (2004) supports Darwin's hypothesis. Their findings suggest that species from biogeographically isolated areas display a release from natural enemies when invading a novel community (Colautti et al. 2004). Biogeographic isolation has been suggested to strongly correlate with phylogenetic relatedness with Rejmanek and Richardson (1996) interpreting Darwin's hypothesis as the greater the phylogenetic distance between an invading species and the local community the more successful an introduced species is expected to be. For example, Hill and Kotanen (2009) found that introduced plant species that were phylogenetically isolated from native species in a community were more likely to become invasive and displace native species. In addition, exotic plant species that are closely related to native plant species in a novel environment do not benefit from a release from natural enemies and are therefore less likely to pose a direct threat to native plant species (Agrawal and Kotanen 2003). If New Zealand *Senecio* species originated in areas that are biogeographically isolated from one another they may be influenced by natural enemies differently. In addition, *Senecio* from different biogeographical areas will have different chemical defences and phenotypic traits as a result of their evolutionary histories which may benefit them and any hybrids that occur with native species. In this study, I therefore aim to study how the native and non-native *Senecio* species are related to each other and how and from where the different *Senecio* lineages have colonised New Zealand.

If a colonising species enters an environment in which closely related species are present then there is the potential for herbivores and natural enemies to switch from their native hosts to the invader (Keane and Crawley 2002). By incorporating the invader into their host range, native herbivores and other natural enemies may increase in number due to greater resource availability and therefore negatively affect native species (Smith and Quin 1996, Carpenter and Cappuccino 2005, Parker and Gilbert 2007, Moleon et al. 2008, Carvalheiro et al. 2010). Because *Senecio* have colonised New Zealand multiple times, including nine naturalisations within the last 150 years, (Sullivan et al. 2005, Pelser et al. 2007, Sullivan et al. 2008) it is therefore important that we determine how closely related all New Zealand's native and naturalised *Senecio* species are to one another. By combining this with ecological studies (Chapter 3) it will be possible to determine the potential impact that current and future invasive *Senecio* may have on New Zealand's native *Senecio* and their ecosystems through comparative studies of *Senecio* already present in New Zealand.

The ability of *Senecio* to hybridise with each other is a common phenomenon (Kirk et al. 2004, Kirk et al. 2005, Lopez et al. 2008, Brennan et al. 2009, Abbott et al. 2010, Pelser et al. 2012). Allopolyploid *Senecio* lineages that have directly or indirectly (through subsequent speciation) originated from hybridisation events may have novel chemical defences and phenotypic traits through the combination of the genomes of their parental species (Petit et al. 1999, Hegarty and Hiscock 2007, Prentis et al. 2008, te Beest et al. 2012). Allopolyploids can also show increased growth (both size and speed of growth) and fitness compared to their parental species. This is commonly referred to as hybrid vigour (Rieseberg and Carney 1998, Keane and Crawley 2002, Hegarty and Hiscock 2007). Hybrid species that display greater evolutionary fitness than one or both of their parental species can subsequently replace the parental species throughout their/its range and potentially be responsible for the extinction of the parent(s) through direct and indirect means (Allendorf et al. 2001). In addition, recent studies have argued that species with polyploid origins are more likely to become invasive within new environments than diploid species (Hegarty and Hiscock 2007, te Beest et al. 2012). The reason for this increased invasiveness is greater genetic diversity, which allows polyploids to adapt to a wide range of environmental conditions (te Beest et al. 2012). Increased genetic diversity as a result of allopolyploidy has potentially played an important part in the evolution of New Zealand *Senecio*. Native New Zealand *Senecio* typically have chromosome numbers between n=20 and 50 (Sykes 1987, Webb 1987, 1988, de Lange and Murray 1998, de Lange et al. 2004). In comparison, chromosome numbers for *Senecio* outside of New Zealand typically tend to be n=10-20 (Robinson et al. 1997). Because New Zealand *Senecio* typically have high chromosome numbers, recent allopolyploids potentially have novel defences, which may confer benefits in the New Zealand environment and aid in their establishment in novel habitats. Therefore it is important to identify recent allopolyploids in order to determine if they pose a risk to older native *Senecio* species. Phylogenetic analyses in combination with published chromosome counts for New Zealand native and non-native species are used in this study to identify potential allopolyploids and their parental species.

The main aim of this study is to reconstruct a phylogeny of New Zealand's *Senecio* species. This will be used to determine 1) how native species are related to *Senecio* species that have recently naturalised within New Zealand, 2) how many times *Senecio* have successfully colonised New Zealand and where they have colonised from and 3) how many *Senecio* clades in New Zealand have allopolyploid origins.

2.3. Material and Methods

Taxon Selection

A total of 74 species were selected for DNA sequence analyses. These include representatives of all 21 *Senecio* species native to New Zealand (Drury 1974, Webb et al. 1988) including six subspecies of four of these. Nine naturalised New Zealand species have been added in order to determine how closely related recently arrived *Senecio* species are to clades that contain native New Zealand species. New Zealand's native *Senecio* species have been shown to be present in clades containing Australian and Sub-Saharan African species (Pelser et al. 2007). A total of 37 *Senecio* species from these two regions have been included as they may be closely related to New Zealand species. Their addition will help to determine the number of New Zealand *Senecio* clades and therefore the number of introductions into New Zealand. Nine species were included to represent most of the major *Senecio* clades (Pelser et al.

2007). These species represent the European (*S. nevadensis*, *S. vulgaris*), Sub-Saharan African (*S. madagascariensis*), Central American (*S. oerstedianus*), South American (*S. algens, S. fistulosus*), Eurasian (*S. nemorensis*) and Central and North American (*S. mairetianus*) *Senecio* clades as recovered by Pelser et al. (2007). The addition of these species will determine how distantly or closely related the main clades that contain Australasian species are to one another. *Crassocephalum crepioides* was selected as the outgroup because of its close relationship with the *Senecio* clade (Pelser et al. 2007).

New DNA sequences were generated for all 21 native *Senecio* species, 4 of their subspecies and 4 of the naturalised *Senecio* species. Leaf tissue samples for DNA extraction were collected from populations from the South Island of New Zealand as well as from herbarium specimens from the CANU, CHR and LINC herbaria. DNA sequences of the remaining *Senecio* species were collected from Genbank and the unpublished data of Pieter Pelser.

DNA Extraction, PCR Amplification and Sequencing.

DNA was extracted using the Qiagen DNeasy Plant Mini Kit (Qiagen GmbH, Hilden, Germany) following the manufacturer's protocol. Three plastid regions (the *trnL* intron, *trnL-F* intergenic spacer (igs) and *psbA-trnH* igs) and two nuclear regions (the internal transcribed spacer (ITS) and external transcribed spacer (ETS)) were sequenced. Polymerase chain reaction (PCR) amplification of all regions was carried out using the methodology described by Pelser et al. (2002, 2003). The PCR amplification of the *trnL* intron was conducted using the primers described by Taberlet et al. (1991). The *psbA-trnH* region was amplified using the primers described by Sang et al. (1997) The ITS region was amplified using primers developed by Blattner (1999) and the primers used for the ETS region were developed by Baldwin and Markos (1998), Markos and Baldwin (2001) and Bayer et al. (2002). PCR clean-up of successful PCR reactions was conducted using the Promega Wizard SV gel and PCR clean-up system (Promega Corporation, Madison, WI, USA). The BigDye Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems, Foster City, CA, USA) was used for cycle sequencing according to manufacturer's protocol. This was carried out with the same primers that were used in the PCR amplifications. The sequences were run on an Applied Biosystems 3130xl Genetic Analyzer at the Canterbury Sequencing and Genotyping facility at the University of Canterbury (Christchurch, New Zealand). Geneious Pro 5.4.5 (Biomatters Ltd.) was used for trace file editing.

DNA Sequence Alignment and Phylogenetic Analyses.

DNA sequences were manually aligned in Se-Al v2.0a11 (Rambaut, 1996). Prior to phylogenetic analyses, Jmodeltest 0.1.1 (Posada 2008) was used to select nucleotide substitution models for all five DNA regions using the Akaike Information Criterion (AIC). These analyses selected GTR+G for the *trnL, trnL-F* and ITS datasets and TIM3+G for the *psbA-trnH* and ETS datasets. A python script (Richard Ree, Field Museum, Chicago) was then used to code insertion and deletion events as binary characters for their presence or absence in the dataset, using the method of Simmons & Ochoterena (2000). The indel characters were included in the DNA sequence matrix as additional characters and were classified as restriction characters in the Bayesian analyses. Phylogenetic reconstruction using Bayesian Inference (BI) methods was carried out using MrBayes v3.1.2 (Ronquist and Huelsenbeck 2004) on processors connected in the Australian Research Collaboration Service through the Grisu 0.2.2 interface. The Markov Chain Monte Carlo Analyses (MCMC; (Geyer 1991) were run for 1,000,000 generations at a temperature of 0.001 with eight chains per analysis and one tree per 1000 generations saved. BI analyses were run until the average deviation of split frequencies of the analysis fell below 0.01. Following the analyses, MrBayes was used to determine the number of trees to omit as “burn in”, and a consensus tree and posterior probabilities were computed from the remaining trees. FigTree v1.3.1 (Rambaut 2009) was used to view the consensus tree and posterior probabilities. Maximum parsimony (MP) analysis was carried out using the program TNT v1.1 (Goloboff et al. 2008). Analyses were performed using the new technology search option with default settings for sectorial searches (RSS, CSS and XSS), ratchet, drift fusing and tree fusing; using 10 initial random addition sequences and terminating the search after minimum length trees were found five times. Bootstrap support was calculated using Poisson independent reweighting and 1000 replicates.

Combined plastid and nuclear data set analyses:

The phylogenetic analyses for the individual *trnL*, *trnL-F* and *psbA-trnH* data matrices resulted in poorly resolved and supported trees. The ETS phylogeny displayed a similar lack of resolution and branch support, contrary to the moderately resolved ITS phylogeny. Trees obtained from individual plastid regions showed some phylogenetic incongruence, as was also observed between the nuclear data sets. This incongruence is most likely due to a lack of phylogenetically informative characters present in the data. Because of the lack of well supported topological incongruence (high posterior probability values (>0.94) or bootstrap values (>75%) among the plastid data sets and between the nuclear data sets, I constructed a combined plastid dataset using the *trnL*, *trnL-F* and *psbA-trnH* data matrices as well as a combined nuclear dataset using the ETS and ITS datasets. The combined data matrices were analysed using Bayesian Inference and Maximum Parsimony using the same methods as previously mentioned.

Area Optimisation:

After obtaining the Bayesian Inference consensus tree of the nuclear data I used the program MacClade 4.08 (Maddison & Maddison, 2005) to perform an area optimisation analysis using Fitch parsimony. The nuclear data was used for the area optimisation because of the higher degree of resolution compared to the combined plastid data, which resulted in poorly resolved trees. The biogeographic reconstruction was then used to determine the number of colonisations into Australasia and New Zealand.

2.4. Results

Phylogenetic Relationships

Plastid data

The aligned plastid dataset has a total length of 1528 base pairs (bp). The *psbA, trnL* and *trnL-F* regions could not be sequenced for three specimens due to PCR amplification problems.

The MP 50% majority rule consensus tree (not shown) and the BI consensus tree (Fig. 2.1) of the combined plastid dataset display similar patterns of relationship. Both identify three main clades that include Australasian *Senecio* species (Fig. 2.1). The 'Lautus clade' (*S. lautus, S. pinnatifolius* and one of the *S. radiolatus* accessions) is well supported in the Bayesian consensus tree, but not in the bootstrap consensus tree (1 PP, <50% BS). The 'Hispidulus clade' containing for example, accessions of *S. hispidulus, S. glomeratus* and 19 other species is similarly supported (0.99 PP, <50% BS), whereas the 'Biserratus clade' which contains for example, *S. biserratus, S. minimus* and 10 other species is poorly supported (0.90 PP, <50% BS). The BI analysis indicates that the Hispidulus and Biserratus clades are more closely related to each other than to the Lautus clade, but this hypothesis is only poorly supported in the MP bootstrap tree (0.99 PP, <50% BS). The Lautus clade is more closely related to the Southern African species *S. cadiscus* than to species from other clades (0.75 PP, <50% BS). Accessions of *S. radiolatus* and *S. bipinnatisectus* failed to group together in the phylogenies. The position of the *S. radiolatus* and *S. bipinnasectus* accessions may be due to the failed amplification of the *trnL, trnL-F* or *psbA-trnH* regions. For example, *S. bipinnatisectus*2584 only has *psbA-trnH* amplified and *S. bipinnatisectus*2585 only *trnL and trnL-F* amplified. In addition, both of these samples came from herbarium collections and one may have been misidentified due to the phenotypic plasticity found in Australasian *Senecio*.

Nuclear data

The combined nuclear dataset (Fig. 2.2) displays greater resolution and branch support than the separate ITS and ETS consensus trees (not shown). The MP 50% majority rule consensus tree (not shown) and the BI consensus tree of the nuclear dataset display similar topologies. Both BI and MP analyses display three main clades that contain all Australasian species used in the study (Fig. 2.2) The three clades have strong BI support (Fig. 2.2, ≥0.95 PP) and low to high BS support (Fig. 2.2). The three clades differ in species composition from the three Australasian clades found in the plastid dataset. The 'Minimissia' clade is represented by, for example *S.*

glomeratus, S. diaschides and *S. minimus* forms the largest clade and is highly supported (0.96 PP, 97% BS, Fig. 2.2). The ‘Lautusoid’ clade, which contains accessions of *S. lautus* and ten other species displays low to high support values (1.0 PP, 61% BS, Fig. 2.2) as does the Magnificus clade (containing *S. quadridentatus* and *S. dunedinensis*) (0.98 PP, <50% BS, Fig. 2.2). The BI analyses indicate that the Lautusoid clade is more closely related to the Magnificus clade than to the Minimissia clade (1.0 PP, <50% BS, Fig. 2.2).

The 32 species within the Minimissia clade are divided into seven sub-clades that are composed of accessions of more than a single species, but only two of these display high posterior probabilities (Fig. 2.2). The ‘Odoratus’ sub-clade contains the accessions of *S. hypoleucus* and *S. cunninghamii* DC., as well as five other species and is both poorly (54% BS) and highly (1.0 PP) supported (Fig. 2.2). This sub-clade is exclusively composed of species of the Odoratus group sensu Thompson (2006). The ‘Hispidulus’ sub-clade contains the accessions for *S. hispidulus*, *S. scaberulus* and *S. repangae* (0.98 PP, <50% BS; Fig. 2.2). Six of the seven sub-clades contain both Australian and New Zealand species. The sixth sub-clade is composed of *S. bathurstianus* and *S. picridioides* from Australia. The seventh sub-clade contains the species *S. ilicifolius, S. rosmarinifolius* and *S. variifolius,* which are all southern African species (Fig. 2.1).

The Lautusoid clade is comprised of ten species. The Lautusoid clade is represented in New Zealand by six native species including four native subspecies as well as one naturalised species (Table .3.1, Fig. 2.2). The Lautusoid clade is comprised of two sub-clades (≤0.58 PP, <50% BS) in a polytomy with an accession of *S. spanomerus* and one of *S. biserratus* and is primarily made up of the native New Zealand species *S. glaucophyllus, S. carnosulus, S. radiolatus* and *S. sterquilinus*

Seventeen species are present within the Magnificus clade, five of which are considered native to New Zealand (Fig. 2.2). The remaining twelve species are endemic to Australia. There are no sub-clades within the Magnificus clade because of a lack of species accessions (i.e. greater than one species) within each isolated “group” in the clade (Fig. 2.2).

Incongruence

The plastid and nuclear cladograms are incongruent with one another (Figs. 2.1-2.4). A hypothesis for the incongruence found between the datasets is hybridisation. In the Minimissia clade, which has been coloured red in Figs. 2.3 & 2.4, the typical number of chromosomes is 2n=60 (Fig. 2.4). A hybridisation between a maternal species from the Minimissia clade (Fig. 2.3) and an ancestral paternal 2n=20 southern African *Senecio* (Fig. 2.4) could have resulted in the Magnificus clade (2n=40), which has been coloured green in figures 3 & 4. The exception within the Magnificus clade is *S. marotiri*, which has 2n=80 (de Lange et al. 2004) and has potentially arisen via autopolyploidy from *S. quadridentatus* (2n=40). A second hybridisation event may explain the chromosome number 2n=80 for *S. carnosulus* (coloured brown in Figs. 2.3 & 2.4). The paternal side is possibly from the Lautusoid clade (coloured blue in Figs. 2.3 & 2.4), while the maternal side is most likely from the Magnificus clade (Fig. 2.3 & 2.4).

A third hybridisation event(s) may explain a portion of the Lautusoid and Minimissia clades. A maternal species from the Minimissia clade (2n=60) (Fig. 2.3) and a paternal species from the Lautusoid clade (2n=40) (Fig. 2.4) could explain the presence of 2n=100 species *S. glaucophyllus* and *S. biserratus* within the Lautusoid clade (Fig. 2.4) and 2n=100 *S. distalilobatus* and *S. repangae* within the Minimissia clade. All 2n=100 species have been coloured yellow in Figs. 2.3 & 2.4.

Biogeography

Area optimisation using the nuclear dataset indicates that there have been at least three colonisation events by *Senecio* into Australasia with all three Australasian clades originating from African *Senecio*. This dataset indicates at least twenty two colonisations by *Senecio* species into New Zealand by natural and anthropogenic means (including *Senecio sylvaticus* which has not been included in this chapter), (Fig. 2.2). Because the results of the area optimisation are equivocal, I cannot be sure whether Australia or New Zealand was colonised first by the ancestors of each Australasian clade. The Minimissia clade has diversified into six sub-clades in Australasia. Assuming that there has not been any extinction of *Senecio* in New Zealand and that the nuclear phylogeny provides a good approximation of the biogeographical history of Australasian *Senecio*, New Zealand has been colonised by *Senecio* from the Minimissia clade a minimum of 12 times. Three native non-endemic species (*S. glomeratus, S. diaschides* and *S. esleri*) and two native endemic (*S. banksii* and *S. kermadecensis*) are likely to have recent ancestors that originated in Australia and then colonised New Zealand. The area optimisation is equivocal regarding the land mass that the sub-clade containing *S. minimus*, one of two accessions of *S. kermadecensis* and both *S. hauwai* accessions originated in. In addition, the clade containing *S. hispidulus, S. repangae* and *S. scaberulus* shows a similar equivocal pattern regarding where it originated. The Minimissia clade includes four species (*S. hypoleucus, S. bipinnatisectus, S. australis* and *S. linearifolius*) that have colonised New Zealand from Australia in the last 150 years by anthropogenic means (Table 2.1). There have been at least three colonisations by the Lautusoid clade into New Zealand from Australia. Two colonisations between Australia and New Zealand are from the sub-clade containing the accessions for *S. spanomerus* which has a vagrant status (i.e. introduced by not self sustaining) and *S. biserratus,* which is now considered native (Fig. 2.2). The presence of *S. lautus* in New Zealand and Australia suggests that there have been colonisation events by *S. lautus* between New Zealand and Australia, however the direction of these colonisation events cannot be determined by my results (Fig. 2.2). The Magnificus clade also displays equivocal biogeographic patterns for the ancestral species, which form the backbone of the clade. These patterns make it impossible to determine whether their southern African ancestors colonised New Zealand or Australia first. The nuclear dataset indicates that New Zealand has been colonised by Magnificus *Senecio* species via Australia at least four times. The fourth colonisation includes the species *S. quadridentatus* and *S. marotiri* and indicates that they have ancestors that originated in Australia before colonising New Zealand.

2.4. Discussion

Biogeography

Species from biogeographically isolated landmasses can have a major impact on native biota (Hierro et al. 2005, Thuiller et al. 2010, Parker et al. 2012). Therefore it is important to determine where the *Senecio* lineages of New Zealand have originated from. My results and those of Pelser et al. (2007) indicate that prior to recorded history, Australasia has been colonised at least three times by *Senecio*. In addition, the colonisation of Australasia indicates a strong eastward drift by *Senecio* dispersing from southern Africa which has resulted in approximately 107 species native to Australasia (Webb et al. 1988, Thompson 2006). The Pelser et al. (2007) study suggests that southern Africa is the most likely source area for *Senecio* native to Australasia, which is supported by my data (Fig. 2.2).

According to Thompson (2006) eighteen *Senecio* species have been introduced into Australasia in the last 200 years. The sudden influx of colonising *Senecio,* although at a more rapid speed, follows a trend of colonisations illustrated by Pelser et al. (2007) who suggested that there have been multiple independent colonisations over evolutionary history from southern Africa into Australasia. Assuming the absence of extinction of *Senecio* species in New Zealand and that the nuclear phylogeny provides a good source of biogeographical information, New Zealand has been colonised at least 22 times by *Senecio,* including nine recent introductions (Table 2.1, Fig. 2.2). The recent colonisations into New Zealand have been by the African migrants *S. skirrhodon* and *S. elegans* as well as introductions from Europe by the species *S. vulgaris* and *S. sylvaticus*. Via Australia there have been five recent introductions (*S. hypoleucus, S. linearifolius, S. bipinnatisectus* and the vagrant status species *S. australis* and *S. spathulatus*) (Fig. 2.2). In addition, over pre-recorded history there have been at least 11 colonisation events into New Zealand from Australia. Australia is the most likely source of the 11 colonisation events, shown by the presence of New Zealand species such as *S. banksii, S. glomeratus, S. diaschides, S. esleri* and *S. marotiri* within Australian sub-clades (Fig. 2.2). However, my area optimisation indicates a possible history of back and forth colonisations between Australia and New Zealand, which has resulted in equivocal patterns (Fig. 2.2). The equivocal patterns in my area optimisation account for six colonisation events.

The characteristics of native New Zealand *Senecio* make them excellent dispersers because all of them are annual to perennial herbs with high levels of fecundity and small, easily dispersed seeds (Webb 1988, Webb et al. 1988, Wilson et al. 1992). Herbaceous species are renowned as excellent long distance dispersers and make up 32% of endemic and 78% of non-endemic flora in New Zealand (McGlone et al. 2001). In addition, studies have linked New Zealand as a dispersal point for plant species that occur in Australia (Jordan 2001, Sanmartin and Ronquist 2004, Sanmartin et al. 2007, Perrie et al. 2010, Gillespie et al. 2012). Therefore, dispersal between the two land masses may be responsible for the equivocal patterns in my area optimisation. Dispersal from Australia is strongly facilitated by the west wind drift, which has had a major bearing on New Zealand's biota (Pole 1994, Winkworth et al. 2002, 2005, Sanmartin et al. 2007). If more Australian species were included into my phylogenies, the greater phylogenetic resolution may indicate that Australia is the source for the six equivocal colonisation events. However, because seed dispersal can be mediated by a variety of different mechanisms, such as dispersal by birds (Sanmartin and Ronquist 2004), there is the potential that *Senecio* from New Zealand have colonised Australia.

Phylogenetic Relationships between Native and Introduced Senecio

Phylogenetic relationships between native and non native *Senecio* in New Zealand may be an important factor in their ability to deter natural enemies and is therefore important to determine how closely related New Zealand *Senecio* are to one another (Rejmanek and Richardson 1996, Hill and Kotanen 2009). The nuclear phylogeny (Fig. 2.2) indicates that there are three isolated clades, which match the Australian *Senecio* clades in the ITS phylogeny of Pelser et al. (2007). The clades are a mixture of New Zealand and Australian species, which indicate that Australian species are closely related to endemic New Zealand species. For example, the recently introduced species *S. hypoleucus*, which is found within the Minimissia clade, is closely related to an accession of the endemic New Zealand species *S. kermadecensis* (Fig. 2.2). In addition, the six species native to both Australia and New Zealand (*S. glomeratus, S. minimus, S.hispidulus, S. quadridentatus, S. lautus* and *S. biserratus*) are all closely related to both endemic Australian and New Zealand species (Fig. 2.2). The African and European species present in New Zealand appear to be more distantly related to the Australasian clades (Fig. 2.2), which is supported by the ITS phylogeny of Pelser et al. (2007). Species that are native to Australia and have colonised New Zealand are unlikely to undergo a enemy release within New Zealand as they are closely related to New Zealand species (Rejmanek and Richardson 1996, Parker et al. 2012) (Fig. 2.2). The African and European species however, display a greater degree of phylogenetic separation from Australasian species and are more likely to benefit from enemy release in New Zealand and pose a threat to native *Senecio* species.

Hybridisation

Species with allopolyploid origins may display benefits, which can result in the decline of native co-competitors (Rieseberg and Carney 1998, te Beest et al. 2012). Because of the potential benefit that allopolyploids can receive through hybridisation, one of my aims was to determine, which New Zealand *Senecio* species have allopolyploid origins. African species are known to be able to hybridise with Australasian species (Prentis et al. 2007) and Australasian species can hybridise with one another (Ornduff 1964). The number of hybridisations that have occurred in Australasian *Senecio* has been speculated on for several species but is lacking in data (Ornduff 1964, Ali 1966, Prentis et al. 2007). The complex incongruence found between the plastid and nuclear phylogenies indicates that allopolyploidy may be common within New Zealand *Senecio* species (Fig 3 & 4). My biogeographical data and the Pelser et al. (2007) study, suggest three colonisations into Australasia over pre-recorded history. When combined with my phylogenies, my results indicate that there have been at least three hybridisation events between colonising and naturalised Australasian *Senecio*. For example, in the nuclear phylogeny, the Magnificus clade is isolated from the other clades (Fig. 2.4). However, within the plastid phylogeny, members of the Magnificus clade are found inter-dispersed between members of the Minimissia clade (Fig. 2.3). Chloroplast (plastid) DNA is inherited from the maternal side and nuclear DNA is biparently inherited (Ferris et al. 1997). Therefore, if a colonising paternal 2n=20 ancestral southern African species hybridised with an Australasian maternal Minimissia species (2n=60), the resulting patterns could match the chromosome numbers of the Magnificus clade (2n=40) and its placement in my phylogenies (Fig 3 & 4).

The formation of the Magnificus clade via hybridisation would then allow subsequent hybridisation with a member of the Lautusoid clade within New Zealand resulting in *S. carnosulus* (2n=80) (Fig. 2.3 & 4). In the nuclear phylogeny, *S. carnosulus* is found within the Lautusoid clade suggesting that the Lautusoid clade contains the paternal parent (Fig. 2.4). In the plastid phylogeny however, *S. carnosulus* is placed within the Hispidulus clade which contains Magnificus and

Minimissia species (Fig 3). The chromosome number of *S. carnosulus* (2n=80) makes hybridisation with a Minimissia species (2n=60) unlikely and instead indicates that the Magnificus clade contains the most likely maternal parent (2n=40) (Fig. 2.3).

The third hybridisation event in my dataset is between the Minimissia and Lautusoid clades resulting in the 2n=100 species *S. biserratus, S. distalilobatus, S. glaucophyllus, S. hauwai* and *S. repangae*. The morphological similarities between *S. lautus* and *S. glaucophyllus* and the difference in chromosome number (*S. lautus* 2n=40, *S. glaucophyllus* 2n=100) has lead past researchers to suggest that *S. glaucophyllus* is the allopolyploid of *S. lautus* and another endemic New Zealand *Senecio* (Ali 1966, de Lange et al. 2004). My research supports this hypothesis and indicates that the maternal parent is a member of the Minimissia clade. *S. biserratus, S. distalilobatus* and *S. repangae* display a similar pattern to *S. glaucophyllus* in relation to their parentage with the exception that *S. distalilobatus, S. hauwai* and *S. repangae* are found within the Minimissia clade in both phylogenies (Fig. 2.3 & 4). The hybrid parentage of *S. distalilobatus* and *S. repangae* is supported by the literature, which suggests that they are closely related to the Lautus complex (de Lange et al. 2004, Thompson 2006).

The patterns of incongruence in my phylogenies suggest that the entire Magnificus clade and five species from the Lautusoid and Minimissia clades have allopolyploid origins (Fig. 2.3 & 4). In the last 700 years New Zealand's indigenous habitat has been reduced by 77% through anthropogenic land use change (Atkinson and Cameron 1993). Land use change is a well known cause of species loss, which can create empty niches and remove species, which display important functional traits (Tylianakis et al. 2008, Flynn et al. 2009). Allopolyploids, which have high genetic diversity, can become quickly invasive within an ecosystem because they are able to adapt within one to a few generations to a fluctuating environment and therefore fill potential gaps within the system (Treier et al. 2009, Thebault et al. 2011). If my hypothesis is correct and the incongruence in my phylogenies has been caused by hybridisation; then hybridisation has played an important role in the colonisation of New Zealand by *Senecio*.

There are other explanations for the patterns found in my phylogenies as incongruence can indicate differences in the evolutionary history of the DNA regions, which can be caused by hybridisation and/ or incomplete lineage sorting effects (Pelser et al. 2010). Incomplete lineage sorting effects and hybridisation are difficult to differentiate as incomplete lineage sorting effects are the failure of ancestral polymorphisms to track speciation events accurately, which results in a similar phylogenetic patterns to hybridisation (Pelser et al. 2010). The study by Pelser et al. (2010) found that incongruence between the plastid and ITS/ ETS DNA regions within the Senecioneae tribe is a common phenomenon and is most likely due to incomplete lineage sorting effects and/ or hybridisation. Because quantifying lineage sorting effects is beyond the scope of this study, I suggest that further study is undertaken to determine whether or not hybridisation has created the incongruent patterns in my phylogenies. If hybridisation is the explanation for the incongruence then nine native New Zealand species from the Magnificus, Minimissia and Lautusoid clades are allopolyploids. Because of their origins these nine species may therefore possess additional chemical defences and traits that increase their competitive fitness and ability to deter herbivores and other natural enemies.

Conclusion:

Further research is needed on Australasian and southern African *Senecio*. The poor resolution found in my phylogenies, particularly the plastid dataset can be improved by increasing the number of species and the number of plastid and nuclear regions amplified and sequenced. By improving the resolution of my phylogenies it should be possible to determine with increased accuracy, how many colonisations into New Zealand have occurred and where the species that display equivocal origins in my phylogenies have come from. In addition, increased resolution and the number of accessions should help shed light on whether or not back and forth colonisation has occurred. By confirming if colonisations and counter colonisations are a common occurrence in the Southern Hemisphere, it will increase our knowledge by providing data that indicates that biogeographically isolated land masses are not as isolated as we once thought. In addition, that long distance dispersal has potentially played an important role in the composition of biotas in the Southern Hemisphere. By creating an in depth phylogeny, it will also help unravel the complex incongruence in my phylogenies and determine when colonisations and hybridisation events by *Senecio* occurred within Australasia.

Chapter Two: Tables and Figures

Table 2.1. *Senecio* species and subspecies present in New Zealand and biostatus. Red labelled species are naturally uncommon, Blue= critically endangered, Green= relict, Black= Non-threatened.

Species	**Biostatus**
Senecio australis Willd.	Introduced
Senecio banksii Hook.F.	Native endemic
Senecio bipinnatisectus Belcher	Naturalised
Senecio biserratus Belcher	Native
Senecio carnosulus (Kirk) C.J.Webb	Native endemic
Senecio diaschides D.G.Drury	Native
Senecio dunedinensis Belcher	Native endemic
Senecio elegans L.	Naturalised
Senecio esleri C.J.Webb	Native
Senecio glastifolius Hook.F.	Naturalised
Senecio glaucophyllus subsp. basinudus Ornduff	Native endemic
Senecio glaucophyllus subsp. discoideus (Cheeseman) Ornduff	Native endemic
Senecio glaucophyllus subsp. glaucophyllus	Native endemic
Senecio glaucophyllus subsp. toa C.J.Webb	Native endemic
Senecio glomeratus Desf. ex Poir. subsp. glomeratus	Native
Senecio hauwai Sykes	Native endemic
Senecio hispidulus A.Rich	Native
Senecio hypoleucus F.Muell. ex Benth.	Naturalised
Senecio kermadecensis Belcher	Native endemic
Senecio lautus subsp. esperensis (Sykes) de Lange	Native endemic
Senecio lautus subsp. lautus	Native
Senecio linearifolius A.Rich	Naturalised
Senecio marotiri C.J.Webb	Native endemic
Senecio minimus Poir.	Native
Senecio quadridentatus Labill.	Native
Senecio radiolatus subsp. antipodus (Kirk) C.J.Webb	Native endemic
Senecio radiolatus subsp. radiolatus	Native endemic
Senecio repangae subsp. pokohinuensis de Lange & B.E.Murray	Native endemic
Senecio repangae subsp. repangae	Native endemic
Senecio rufiglandulosus Colenso	Native endemic
Senecio scaberulus (Hook.f.) D.G.Drury	Native endemic
Senecio skirrhodon DC.	Naturalised
Senecio sterquilinus Ornduff	Native endemic
Senecio sylvaticus L.	Naturalised
Senecio vulgaris L.	Naturalised
Senecio wairauensis Belcher	Native endemic

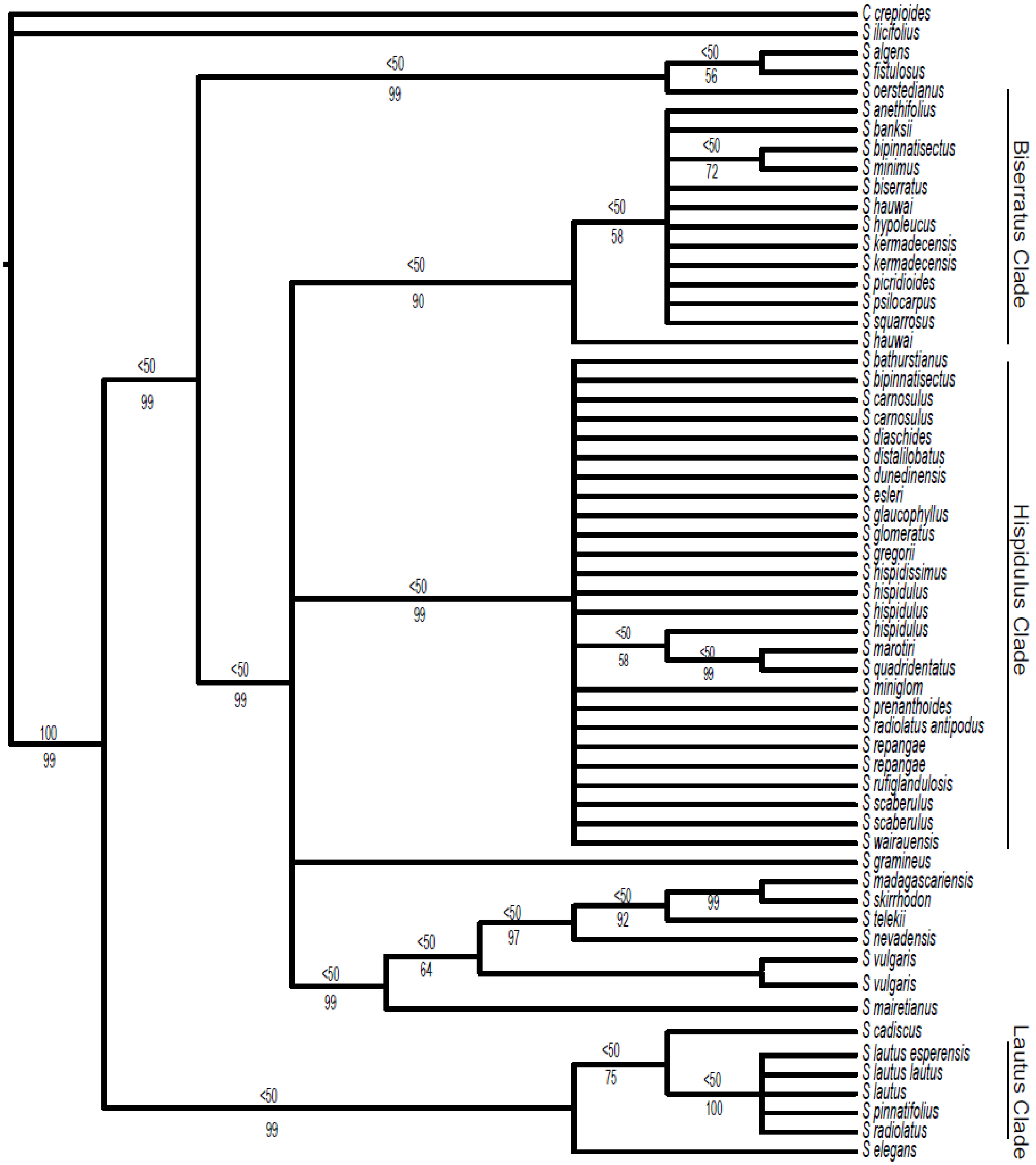

Figure 2.1. Consensus tree from the Bayesian Inference Analysis of the plastid dataset. Bootstrap values are indicated above branches. Bayesian consensus percentages (posterior probabilities x100) are placed below the branches.

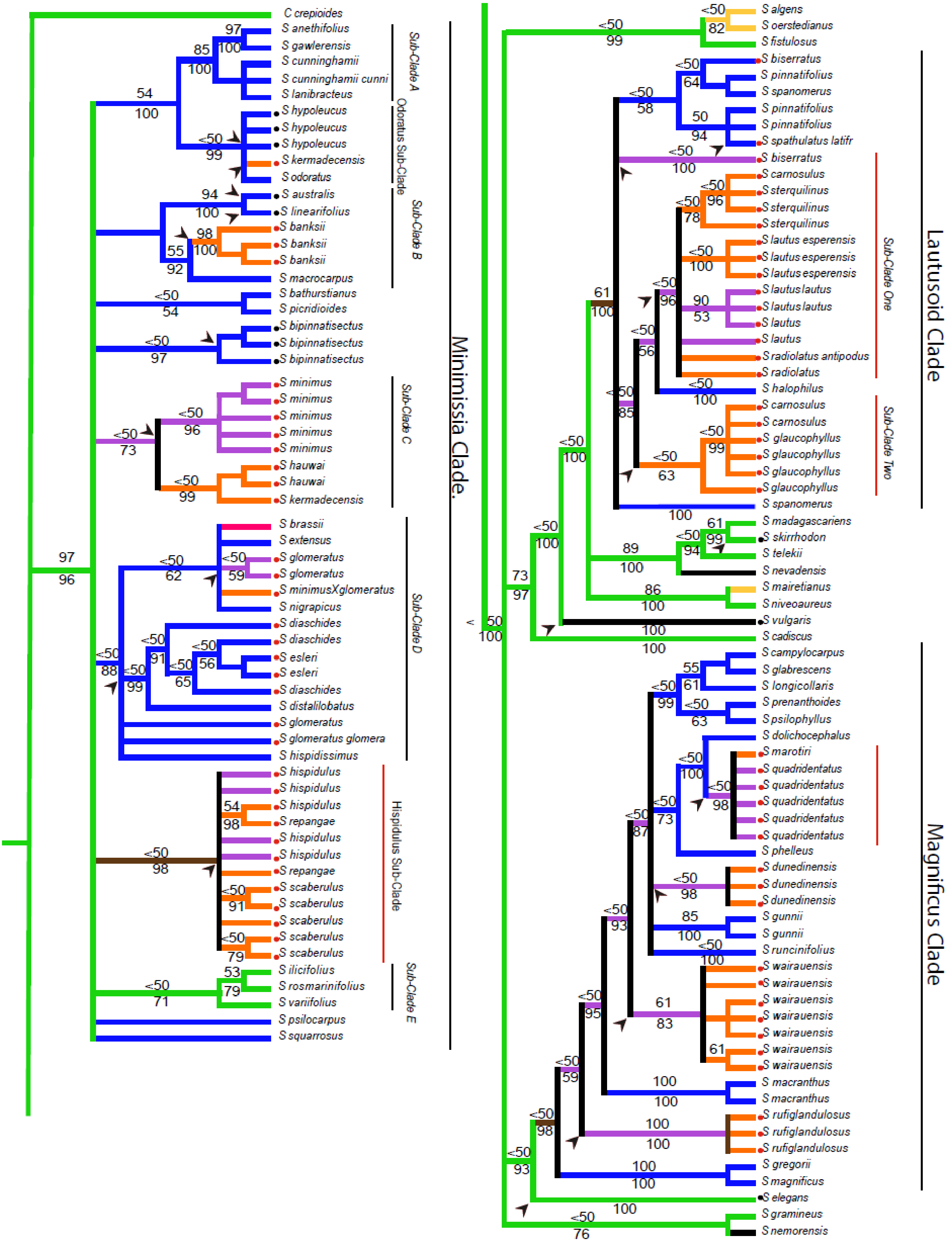

Figure. 2.2: Consensus tree from the Bayesian Inference Analysis of the nuclear dataset. Bootstrap values are indicated above branches. Bayesian consensus percentages (posterior probabilities x100) are placed below the branches. Branches are coloured to show the results of an area optimisation analysis using MacClade: Green: Africa, Blue: Australia, Orange: New Zealand, Pink: Caribbean, Black: Europe and Continental Asia, Yellow: North, South and Central America, Brown: New Zealand, Australia or Africa, Purple; Australia or New Zealand. The black arrows are the number of colonisations by *Senecio* into New Zealand. The black dots next to species names are species which have arrived in recorded history and the red dots are species which have arrived during pre-recorded history.

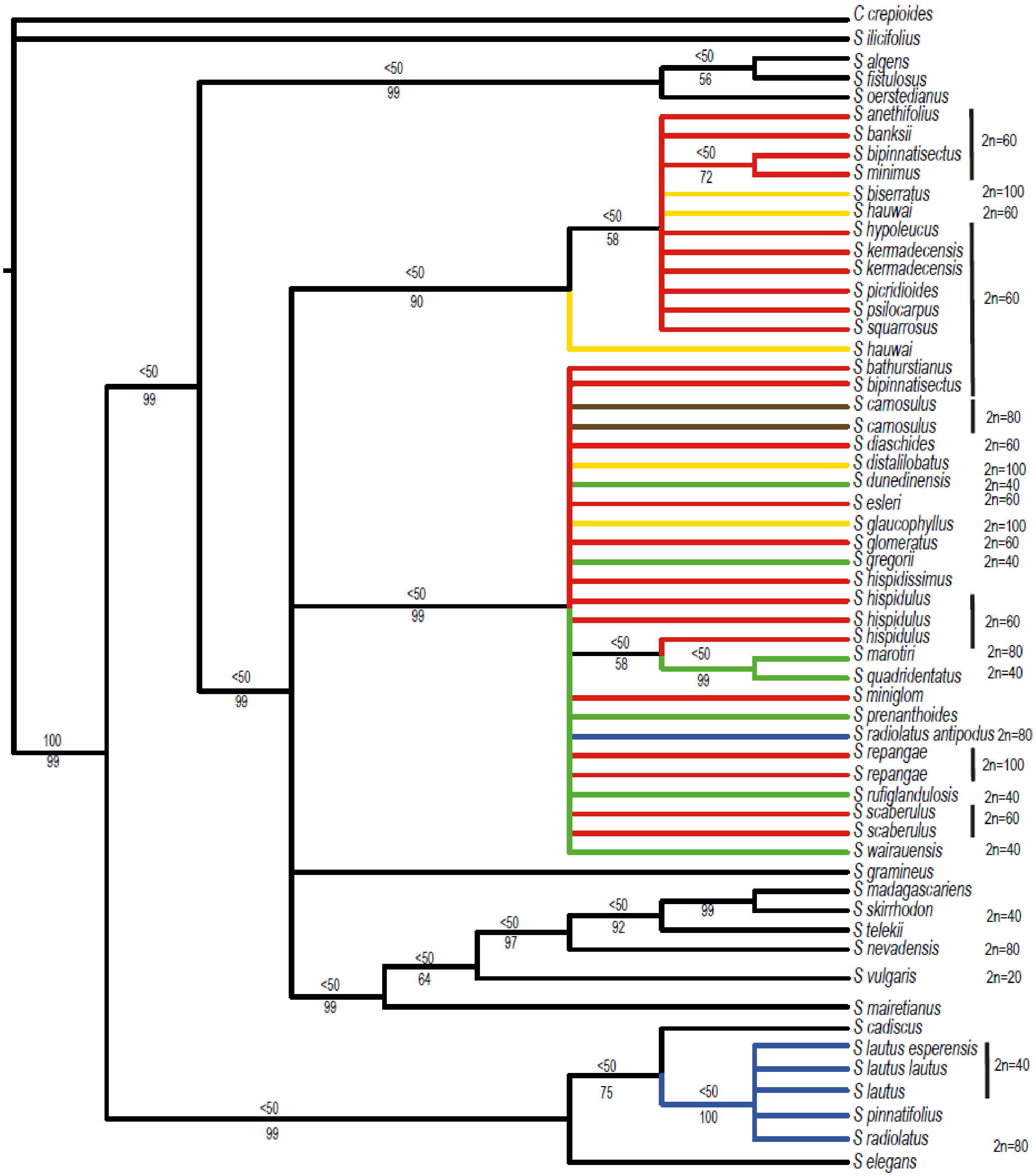

Figure. 2.3. Consensus tree from the Bayesian Inference Analysis of the plastid dataset. Chromosome counts are found along side each species name. Bootstrap values are indicated above branches. Bayesian consensus percentages (posterior probabilities x100) are placed below the branches. The branches are coloured according to the clades in which they are found in the nuclear consensus tree: Red: Minimissia, Green: Magnificus, Blue: Lautusoid, Yellow: Hybrids between the Minimissia and Lautusoid clades, Brown: Hybrids between the Magnificus and Lautusoid clades.

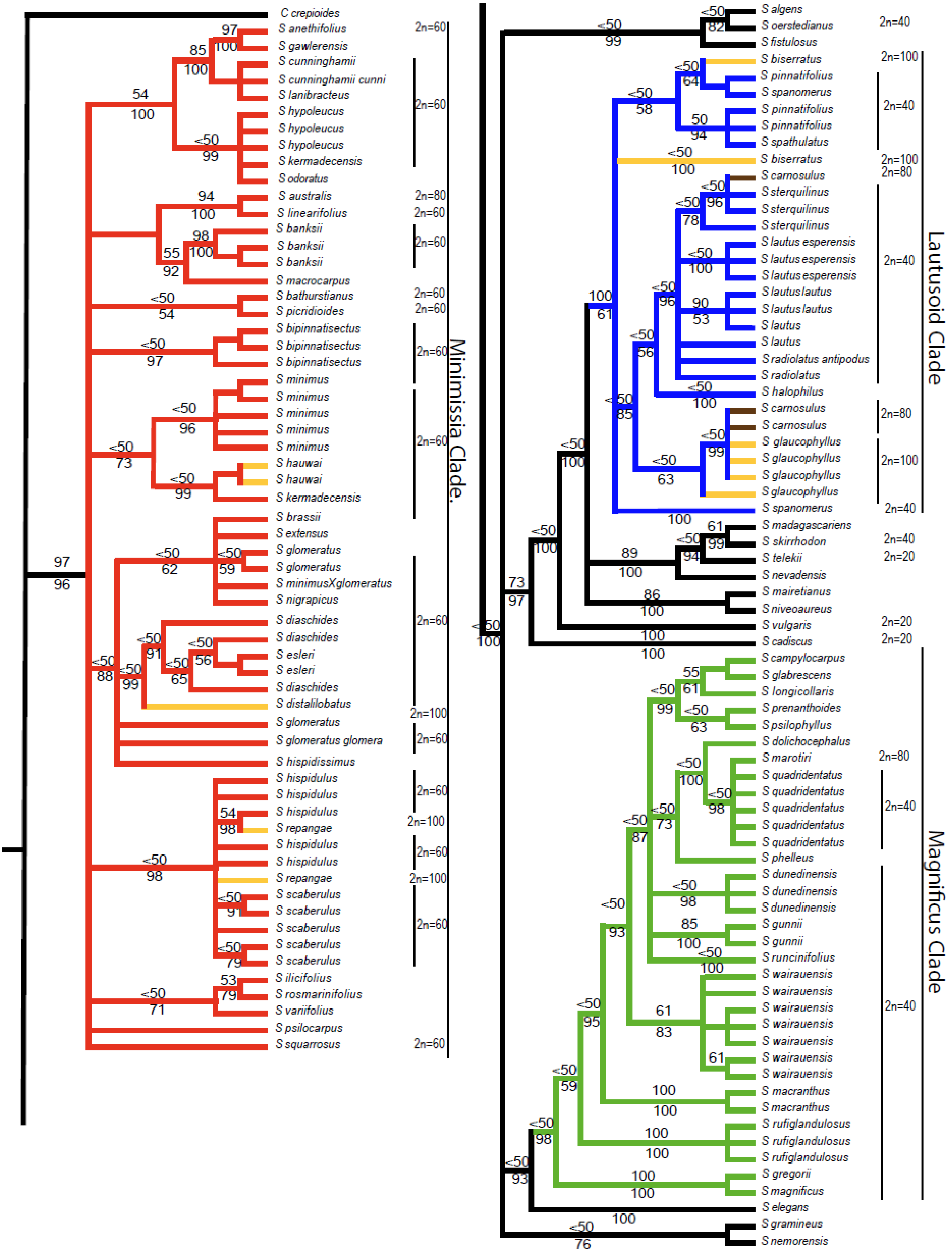

Figure 2.4. Consensus tree from the Bayesian Inference Analysis of the nuclear dataset. Chromosome counts are found along side each species name. Bootstrap values are indicated above branches. Bayesian consensus percentages (posterior probabilities x100) are placed below the branches. The branches are coloured to emphasise clades: Red: Minimissia, Green, Magnificus, Blue: Lautusoid, Yellow: Hybrids between the Minimissia and Lautusoid clades, Brown: Hybrids between the Lautusoid and Magnificus clades.

Chapter Three

Phylogenetic effects on enemy release and biotic resistance are minor and inconsistent compared with strong habitat and plant effects.

3.1. Abstract

In the Canterbury region, native *Senecio* (Senecioneae: Asteraceae) are typically naturally uncommon with extreme fluctuations in population size. Canterbury is home to four species of exotic *Senecio* which are thriving and occur in similar habitats to native *Senecio* species. To determine what factors influence the abundance and distribution of *Senecio* I visited 293 sites throughout the Canterbury region. At each site, twenty nine ecological variables were measured to determine their influence on herbivory and pathogen damage on *Senecio*. In addition, phylogenetic relatedness between *Senecio* was included to determine if enemy release and biotic resistance are influenced by where a *Senecio* has originated from and its lineage. My results indicate that phylogenetic relatedness has a significant but comparatively weak effect on the amount of folivory sustained by *Senecio* when compared to other factors. However, three generalist natural enemies displayed a significant preference for *Senecio* in native clades and one endemic specialist herbivore displayed a significant preference for *Senecio* that originated outside of New Zealand. In addition, my results indicate that enemy release and biotic resistance are land use specific and across a landscape scale are unlikely to significantly influence the abundance and distribution of *Senecio*. The factors that had the strongest effects on *Senecio* and their natural enemies are land use, maturity of the *Senecio*, time of season and population density. Because both phylogenetic relatedness and enemy release/ biotic resistance explained a small part of the variance my results suggest that the biggest threat to the abundance and distribution of native *Senecio* species is from their surrounding land use.

3.2. Introduction

The introduction of non-indigenous (exotic) plant species into new ranges can lead to localised extinctions, the formation of new ecosystems and cause changes to existing ecosystem properties, which can alter the composition and community structure of invaded areas (Mack et al. 2000, Colautti et al. 2004, Wilson et al. 2009). Exotic species typically go through four stages of colonisation when entering a new habitat: introduced (cultivated but not reproducing), vagrant (i.e plants which do not form self sustaining populations), established/ naturalised (i.e. self sustaining natural populations over 10years old) and finally invasive (self sustaining populations, which are increasing in size and range) (Richardson and Pysek 2006, Theoharides and Dukes 2007). The mechanisms that allow exotic species to naturalise (i.e. form self perpetuating populations) and become invasive (i.e. naturalised exotic species, which reproduce in large numbers away from the parent population and across a large area) are still not completely understood (Richardson et al. 2000, Richardson and Pysek 2006, Parker and Gilbert 2007, Verhoeven et al. 2009, Vasquez and Meyer 2011). Invasions by exotic species have been facilitated dramatically through human pathways over the last 500 years, with a drastic increase in the last 200 years because of improved transportation and trade (Mack et al. 2000, Botham et al. 2009, Wichmann et al. 2009). For example, 70% of species that naturalised in Australia between 1971 and 1995 were introduced intentionally (Groves 1998). Pysek et al. (2011) found that small amounts of human investment in cultivating exotic plants species can lead to a significant increase in the chance of exotic species naturalising in indigenous habitats. Minton and Mack (2010) found that the founder populations of exotic species displayed significant increases in reproductive ability, size and survival rates depending on the degree of irrigation in their surrounding environment. However, not all invasions are facilitated through human propagules and not all invasions are guaranteed to result in successful establishment (Maron and Vila 2001, Richardson and Pysek 2006, Pysek et al. 2011). Because invasion success is not guaranteed in exotic species, a large amount of research has been conducted to determine why some species succeed and others fail to establish within a novel environment (Mack et al. 2000, Richardson and Pysek 2006, Parker and Gilbert 2007, Theoharides and Dukes 2007, Schweiger et al. 2010).

The traits which species possess such as genome size, fecundity, chemical defences, and dispersal ability as well as the ecological interactions experienced by exotic species have been cited as factors that affect their success in novel environments (Didham et al. 2005, MacDougall and Turkington 2005, Mitchell et al. 2006). One of the most prominent hypotheses for why an exotic species becomes invasive is the natural release hypothesis, which states that species are freed from natural enemies such as pathogens, herbivores and predators upon entering a novel habitat and therefore have a competitive edge over co-occurring native species (Darwin 1859b, Maron and Vila 2001, Mitchell and Power 2003, Colautti et al. 2004, Vasquez and Meyer 2011). The most commonly studied of the natural release hypotheses is the enemy release hypothesis (Keane and Crawley 2002).

The enemy release hypothesis states that when plant species are introduced into an exotic region, they experience a decrease in regulation by herbivores and other natural enemies resulting in an increase in distribution and abundance (Keane and Crawley 2002). For example, Mitchell and Power (2003) found that exotic plant species that have naturalised in the United States from Europe encountered, on average, 84% fewer fungi species and 24% fewer virus species than in their home ranges. Contrary to the enemy release hypothesis is the biotic resistance hypothesis, which proposes that natural enemies native to the habitat prevent the establishment of exotic species through strong interactions, which regulate the invader to a greater extent than in their natural habitat (Elton 1958, Maron and Vila 2001). The meta-analysis by Levine et al. (2004) however, found that biotic interactions with native species failed to completely repel invasions by exotic species but instead helped to constrain the abundance of an exotic species once it has established. For example, Carpenter and Cappuccino (2005) found that the invasive plant species *Barbarea vulgaris* displayed high levels of herbivory compared to other invasive species, which Carpenter and Cappuccino (2005) suggest prevents *B. vulgaris* from becoming more invasive in natural areas.

Other invasion theories suggest that exotic species become invasive because of their functional traits. For example, the meta-analysis by van Kleunen et al. (2010) found that the invasiveness of a species was in part determined by performance based traits (physiology, leaf-area allocation, shoot allocation, growth rate size and fitness). The traits of invasive species had a strong effect on their performance in novel environments when compared to the traits of native species (van Kleunen et al. 2010).

Another invasion theory is Darwin’s theory of naturalisation (Rejmanek and Richardson 1996, Thuiller et al. 2010). Darwin’s theory of naturalisation proposes that some species that are phylogenetically distant to local communities should be more successful because they are able to occupy unfilled ecological niches (Rejmanek and Richardson 1996, Thuiller et al. 2010). The benefits of phylogenetic isolation are small and have been found to have a weak effect on the interactions experienced by exotic plant species compared to other explanatory factors (Agrawal and Kotanen 2003, Dawson et al. 2009). For example, the meta-analysis by Parker et al. (2012) found that invasive plant species that were phylogenetically isolated experienced greater impacts by herbivores than closely related species supporting the biotic resistance hypothesis and some aspects of Darwin’s theory of naturalisation. However, phylogenetically isolated invasive plant species were more abundant than native species indicating that factors other than phylogenetic isolation are affecting invasive species. Darwin also offers a second contradictory hypothesis, which suggests that species with closer phylogenetic relatedness are more likely to succeed in a new environment due to shared adaptations with native species (Thuiller et al. 2010). However, as illustrated by Percy et al. (2004); closely related species are more likely to be the subject of host switches by native specialist herbivores and thereby encounter biotic resistance. The success of Darwin’s hypotheses regarding the benefit of phylogenetic relatedness may be due to the scale of the experiments. For example, Diez et al. (2008) found that the phylogenetic relatedness of plant species can influence community composition, however the scale of the experiment is important in determining how strong the effect of phylogenetic relatedness is. Therefore, phylogenetic relatedness may have a stronger effect on the abundance and distributions of invasive plant species depending on whether the study is conducted over a landscape or in a localised habitat.

Polyploidy is a mechanism with growing support in the invasion biology world because of the benefits that polyploidy may give invading plant species (Pandit et al. 2006, Treier et al. 2009, te Beest et al. 2012). Polyploids often display high levels of phenotypic plasticity and genetic diversity because of chromosome duplication (Pandit et al. 2006, Thebault et al. 2011). Increased phenotypic plasticity and genetic diversity gives polyploids greater adaptive potential in fluctuating environments, allowing them to adapt within one to a few generations and fill empty niches or absent functional traits within a community (Agrawal 2001, te Beest et al.

2012). For example, Treier et al. (2009) found that tetraploid variants with polycarpic life cycles of the invasive species *Centauria maculosa* Lum., were more prevalent in introduced ranges than the monocarpic diploid *C. maculosa* variants, which dominated their native habitat. The success of tetraploid *C. maculosa* is in part due to its polycarpic life cycle, which increases fecundity and its abundance within exotic habitats. In addition, tetraploid *C. maculosa* has a greater tolerance to climatic variations than diploid conspecifics in their home range allowing a greater range of habitats to be colonised (Treier et al. 2009). Pandit et al. (2006) found that five highly invasive plant species in Singapore all displayed allopolyploid origins and the review by te Beest et al. (2012) suggest that polyploidization may aid in the early establishment phases of exotic plant species due to increased survival and fitness as demonstrated by the tetraploid *C. maculosa*. Because of the ability to adapt, species with high genetic diversity or adaptive potential are ideally placed to invade environments that have recently been disturbed.

In the last 700 years, New Zealand has witnessed significant land-use changes with only 23% of the original indigenous habitat remaining since Polynesian arrival (Atkinson and Cameron 1993, Walker et al. 2006). During this period more than 25,000 plant species have been introduced into New Zealand with ~2200 exotic plant species naturalising in New Zealand up to the year 2000 (Atkinson and Cameron 1993, Vitousek et al. 1997, Gatehouse 2000, Duncan and Williams 2002). Among the naturalised species are members of the genus *Senecio*. *Senecio* is one of the largest genera in Asteraceae with over 1200 species (Pelser et al. 2007). New Zealand has 28 species of *Senecio,* 18 are native with most endemic species displaying sparse populations with extreme population fluctuations according to the New Zealand threat classification system list (2002). Native *Senecio* form three clades, which are comprised of endemic and non endemic native species (Chapter 2). The three native clades also contain exotic Australian species (Chapter 2). The South Island has 17 species of *Senecio,* which includes all three native clades as well as four exotic clades (Table 3.3). Thirteen of the species in the South Island are native and four are exotic southern African and European species (Table 3.1), which are phylogenetically distant from Australasian species (Pelser et al. 2007). In addition, there are closely related Senecioneae species such as *Jacobaea vulgaris*, *J. maritima* and *Senecio angulatus* within the South Island. *S. angulatus* is in need of revision as Pelser et al. (2007) showed that it is not a part of the *Senecio* genus but has not yet been reclassified.

Therefore, I will be referring to it as *S. angulatus* throughout my thesis. South Island *Senecio* are an ideal focal group for investigating enemy release hypotheses and underlying mechanisms of species invasion.

The presence of three clades and exotic outliers provides a degree of phylogenetic separation allowing Darwin's theory of naturalisation to be tested. In addition, because New Zealand's *Senecio* occur in disturbed habitats they are likely to be impacted by habitat modification, which has been widely reported on as an ecological driver of community change and biodiversity loss (Didham et al. 2007, Tylianakis et al. 2008). Nine of New Zealand's *Senecio* species display a high level of genetic diversity through allopolyploidy (hybridisation) (Table 3.3.1). Five of the species are found within the 'Magnificus' clade, which according to my phylogenies is of allopolyploid origin (Chapter 2). In addition, the invertebrate herbivores, which feed upon *Senecio* are a mixture of specialist and generalist herbivores (Spiller and Wise 1982, Sullivan et al. 2008).

The primary aim of this study is to quantify the relative importance of *Senecio* biostatus, phylogeny, size and reproductive state and environment (land use) on herbivory and pathogen damage. I do this to assess the degree to which enemy release and biotic resistance are influencing the distribution and abundance of native and naturalised *Senecio* species in Canterbury.

3.3. Methods

Study site and focal species

All *Senecio* species found in the Canterbury region are annual or perennial herbs and are commonly found in disturbed habitats in a variety of environments (Webb et al. 1988). Knowledge of the invertebrate species which use New Zealand's *Senecio* species as hosts is limited, and only nine invertebrate species have been described as New Zealand *Senecio* herbivores from ten species of native and naturalised *Senecio* (Spiller and Wise 1982, Sullivan et al. 2008). Field studies were conducted throughout Canterbury in 2010 and 2011. Field work was separated into two periods from December 2010 until April 2011 and then from September until December 2011. Because of the life histories of New Zealand's *Senecio*, my studies were conducted from Spring until Autumn, which are the dominant growth, flowering and emergence periods for New Zealand's *Senecio* and their natural enemies. Field sites were selected using records from the University of Canterbury Herbarium, Landcare Herbarium, New Zealand Bio-Recording Network and the collection records of Jon Sullivan. Only sites that had geographic coordinates recorded in their details were used in order to maximise efficiency in the field (Appendix 2). Ten sites per species were randomly selected from the records. After the sites were selected, I used a stratified random sampling method according to areas of Canterbury. The ten sites per species were sorted into the six areas throughout Canterbury: Kaikoura, Hurunui, Christchurch, Banks Peninsula, Craigieburn ranges and Mt Cook. Sites within each locality were randomly divided into three sampling runs. Each locality was visited three times over the course of the field season and the order in which they were visited was randomised for each sampling run. By placing a randomisation process on both site selection and site visitation, it ensured that there was no bias between sites and the time spent within localities. In addition, randomisation prevented bias being introduced into the dataset by spatial or seasonal covarying variation in plant or natural enemy phenology.

All *Senecio* species in the Canterbury region and the closely related Senecioneae species *J. vulgaris*, *J. maritima* and *S. angulatus* were selected for the study. The 20 species resulted in 200 field sites being visited throughout the South Island over the December-April 2010/ 2011 period. A further 93 fields sites were visited during the September-December 2011 period and included 16 sites that were sampled in the December-April field period. By repeat sampling I was able to compare changes between the two periods to determine if there were any significant differences over the course of the study.

Sampling Design

At each site, a global positioning system (GPS: Garmin GPSmap 60CSx) was used to locate the co-ordinates given by the historical records. A 50 m by 50 m quadrat was set up with the centre of the quadrat on the specified coordinates. Twenty minutes was spent searching the quadrat for the target *Senecio* species, which was recorded as present or absent, along with an abundance count. The identity and abundance of all other *Senecio* species present within the quadrat was also recorded. For a further 120 minutes, 10 randomly selected mature individuals of the target species were surveyed. The survey recorded the height of the plants (cm), maximum width of the plant (cm) and the minimum width of the plant (cm), number of congenerics within a 10 m radius (up to a maximum of 25), number of stems, number of capitula and the number of mature leaves. For each plant, the number of leaves, which displayed herbivore damage of 5% or more by leaf area were also counted. The diversity and abundance of invertebrate herbivores were recorded on each plant. In the event that identification of invertebrate herbivores proved difficult, they were collected in plastic vials with 70% ethanol and brought to the lab for identification. Fungal infection for each plant was recorded and focused on rust, smut and brown blotches. The common red rust species on Canterbury *Senecio* may be either *Puccinia lagenophorae* Cooke., or *Coleosporium senecionis* Pers. White smut can be *Albugo tragopogonis* DC. Gray., and brown blotches *Ramularia coleosporii* Sacc. For each plant the overall percentage of leaf area with fungal infection was visually estimated and placed in one of five categories of infection (0-20%, 21-40%, 41-60% etc.). If one or more Senecioneae species were present at the site, other than the selected species, they were recorded in the same method as above. Once the sampling of 10 plants of the target species was completed, photos showing the size and morphological characteristics of the plants and invertebrates were taken as well as photos of the surrounding area. A voucher was collected from each Senecioneae species present at the site and then placed into the plant press with a tag attached with details. In addition, a single leaf displaying no fungal infection or herbivore damage was collected and placed into a small zip lock bag containing silica gel for DNA extraction.

In order to measure the effects of anthropogenic habitat modification at each site I visually assessed and categorised the habitat (Table 3.2) using the conceptual outlines suggested by McIntyre and Hobbs (1999), Ewers and Didham (2006) and Fischer and Lindenmayer (2007). In addition to visual assessments I also utilised the Land Cover Database Version 2 (LCDBV2) (Ministry of Environment), which is a thematic classification of 43 land use and land classes, simply put it is a geographic information system (GIS). Using the Land Cover Database I recorded the most common land use class within a one and five kilometre radius of each site.

Statistical Analysis:

Taxonomic identification of some *Senecio* species within Canterbury is difficult because they displayed a high level of phenotypic plasticity, which is influenced by their surrounding environment. The high level of phenotypic plasticity makes the taxonomic identification of three Canterbury species (*S. lautus, S. glaucophyllus* & *S. carnosulus*) difficult due to morphological similarities (Webb 1988, 1988., Thompson 2006). Along with *S. biserratus* the three species represent the Lautusoid clade in Canterbury (Chapter 2). Therefore, my analysis has grouped all *Senecio* species into their respective clades in order to eliminate any potential field misidentifications created by these three species (Table 3.3). Because of the greater resolution, I have chosen to group *Senecio* into the clades that were found in my nuclear phylogeny (Chapter 2). For the exotic clades I have used the names utilised in the ITS phylogeny of Pelser et al. (2007). Because my phylogenies (Chapter 2) indicate that Australian species are phylogenetically closely related to New Zealand *Senecio* and are found in the same clades. I have defined clades containing Australasian species as native clades. In addition, the region of origin, which *Senecio* originate from is included in the analysis to determine if New Zealand species experience greater herbivore and pathogen presence than Australian, southern African and/ or European species.

General linear models (GLM) with binomial response variables were used to analyse my dataset using the statistical program R 2.13.0 (R Development Core Team 2011). In addition, I used the R packages: Vegan (Oksanen et al. 2012), lme4 (Bates et al. 2012) and car (Fox et al. 2012). Plant herbivory was modelled with the number of leaves >5% folivory and those without >5% folivory. All individual enemy species models used a presence/ absence response variable since in all cases the data was strongly skewed by plants lacking each enemy. I included 29 explanatory variables (Table 3.5). I created many ecologically plausible candidate GLM models with different combinations of explanatory variables within my dataset (Table 3.3). The wide variety of models were used to determine whether a small or large number of variables describe my dataset most accurately. All landscape variables within one and five kilometre radius of the site were log transformed. I also added a polynomial term to the models, which included: plant volume, days from the winter solstice, season and the conspecific and congeneric density effect to test for enemy satiation at high densities. Akaike Information Criteria (AIC) was used to compare GLMs to determine, which models best fitted the dataset. Once the best model or models were selected, I used an ANOVA with a Chi squared test to further describe the explanatory variables on folivory.

I applied the same set of plausible candidate models to the following enemies: aphid species combined (Aphidoidea, Hemiptera), magpie moth (*Nyctemera annulata* (Boisduval 1832): Arctiidae, Lepidoptera), spittlebug (*Cercopidae*: Homoptera), stem-galler (*Sphenella fascigera*: (Malloch, 1931)), *Senecio* leaf miners combined (*Phytomyza syngenesiae* (Hardy 1849) & *Chromatomyia syngenesiae* (Hardy 1849): Agromyzidae, Diptera), red rust *C. senecionis* & *P. lagenophorae*, white smut *A. tragopogoni* and brown blotches *R. coleosporii* (Table 3.4). The analysis of *Senecio* herbivores used the same explanatory variables used in the folivory analysis. The candidate models are the same models that were used in the folivory analysis (Table 3.5). The herbivore species selected were chosen because they occurred most frequently and therefore are most likely to have a significant impact on *Senecio* across a range of habitats. Aphid abundance refers to generalist aphid species and does not include specialist aphid species. The Ragwort Aphid *Aphis jacobaeae* is the only recorded specialist aphid herbivore of *Senecio* present in New Zealand and is a specialist herbivore of *J. vulgaris* and *Senecio vulgaris*. *A. jacobaeae* was not found on any *Senecio* or *J. vulgaris* plants during the survey nor has it been recorded on native *Senecio* species (Paynter et al. 2004).

3.4. Results

Summary

In my analysis the strength of the explanatory variables on *Senecio* folivory and natural enemy abundance are explained by the deviance of the estimate (trend) from the overall variance (at the top of Tables 3.8, 3.9 & 3.10). According to the variances in Table 3.8, 3.9 & 3.10, my results indicate that the level of herbivory experienced by *Senecio* varied in space, time, phylogeny, density and condition of the plants. The most important factors influencing *Senecio* were time and space, which had the strongest effects on the level of herbivory and pathogen damage sustained by Canterbury *Senecio*. The strongest effects within time and space were the level of habitat modification, season, days since the winter solstice and the surrounding land use, which all strongly influenced the amount of folivory and the occurrence of natural enemies on *Senecio* (Tables 3.8, 3.9 & 3.10). The density and maturity of *Senecio* had strong effects on the amount of folivory but a weak effect on the occurrence of natural enemies (Tables 3.8, 3.9 & 3.10). The plant condition (volume) had a moderate effect on the amount of folivory and weak effects on the number of occurrences by natural enemies (Tables 3.8, 3.9 & 3.10). Phylogenetic relatedness had a comparatively weak effect on the amount of folivory (Table 3.8, 3.9 & 3.10). However, phylogenetic relatedness did have a strong effect on the occurrence of three natural enemies (Table 3.9 & 3.10).

Study sites:

Out of the 293 field sites that were visited over the two field seasons only 86 sites contained *Senecio* populations, which were sampled (Figure 1). Six sites had two or more *Senecio* species present at the site. The *Senecio* species *Senecio dunedinensis, S rufiglandulosis, S. diaschides* and *S. sterquilinus* were unable to be found. The species *S. biserratus, S. hauwai* and *S. angulatus* had only one population located within the Canterbury region. The *S. angulatus* population became extinct locally after the first season due to cliff collapse caused by the Canterbury earthquakes.

Geographic Origin

The geographic region where a *Senecio* species originated had no significant effect on the occurrence of folivory sustained by *Senecio* (Table 3.8). However, the presence of the explanatory variable: region of origin, in the folivory model n106 indicates that region of origin may be a contributing factor to folivory (Table 3.7).

The AICc model comparison for *S. fascigera* selected model n106 as the model, which had the greatest goodness of fit score (Table 3.7). The region of origin had a significant effect on the presence of *S. fascigera* on Canterbury *Senecio* (Table 3.9). Native and native endemic New Zealand species encountered the lowest *S.*

fascigera presence followed by Australian (Table 3.9), European and finally southern African species (Table 3.9).

Phylogeny

My results indicate that the clade that a *Senecio* belongs to influences the amount of folivory encountered by *Senecio* species (Table 3.8). The results from folivory model n90 indicate that *Senecio* in exotic clades experienced less herbivory than *Senecio* in native clades (Table 3.8).

Some of the natural enemies of Canterbury *Senecio* displayed preferences for *Senecio* species depending on which clade they belonged to. According to the combined aphid model n90, clade had a significant effect on aphid presence on *Senecio* (Table 3.9). The data indicates that *Senecio* in native clades carried aphids significantly more often than *Senecio* in exotic clades (Table 3.9). According to model n138 of *Senecio* leaf miners combined, *Senecio* leaf miner presence was greater on *Senecio* in native clades than *Senecio* in exotic clades (Table 3.9). The Brown blotch fungus *R. coleosporii* model n90 indicates that *R. coleosporii* displayed a clade preference with *Senecio* in native clades carrying *R. coleosporii* more often than *Senecio* in exotic clades (Table 3.10).

Size, reproductive state and allopolyploidy:

The maturity and volume of *Senecio* influenced the occurrence of folivory on Canterbury *Senecio* (Table 3.8). Mature plants in the process of seeding displayed the least amount of folivory, while plants in the process of budding displayed the highest (Table 3.8). Volume had a negative effect on folivory suggesting that the larger the plant the fewer the leaves that have experienced folivory (Table 3.8).

The maturity of the plant had a significant effect on *Senecio* leaf miners (Table 3.9). *Senecio* leaf miner presence displayed a binomial distribution with flowering plants and flowering seeding plants displaying fewer *Senecio* leaf miner occurrences than plants in the process of seeding or budding (Table 3.9). *Senecio* leaf miners were also significantly affected by volume with a negative effect on *Senecio* leaf miner occurrence as the plants increased in size (Table 3.9). The stage of maturity of *Senecio* influenced the occurrence of spittlebugs & *S. fascigera* (Table 3.9).

Spittlebugs and *S. fascigera* occurrence decreased as the plants matured with the lowest occurrence rate on plants which were seeding (Table 3.9). Both spittlebugs and *S. fascigera* were negatively affected by volume with larger plants displaying fewer occurrences than younger plants (Table 3.9). *Nyctemera annulata* was positively affected by volume and occurred more as plants increased in size (Table 3.9). The fungi species were not influenced by the volume or the maturity of the plants (Table 3.10).

Allopolyploidy did not influence the occurrence of folivory nor natural enemy abundance in any *Senecio* species. However, allopolyploidy did feature in the folivory models n122 & n138, *N. annulata* model n130, aphid model n138, *Senecio* leaf miner model 138, *C. senecionis* & *P. lagenophorae* model n114 and *R. coleosporii* model n138.

Environment

The occurrence of folivory was significantly influenced by habitat modification (Table 3.8). The occurrence of folivory was greatest at intermediate disturbance levels (Table 3.8). The land use type surrounding the sites at 1km and 5km had varying effects on the occurrence of folivory depending on the land use type. Horticulture, built up areas and indigenous grassland within a 1km radius of the sites had positive effects on folivory (Table 3.8). Exotic scrub and open ground within a 5km radius of the site had negative effects on folivory (Table 3.8). Exotic trees and water within a 1km radius of the site had negative effects on folivory (Table 3.8.). In addition, agriculture, indigenous forest and exotic trees within a 5km radius had negative effects on folivory (Table 3.8). Seasonal differences on the occurrence of folivory are the number of days since the winter solstice and the number of congenerics found at each site (Table 3.8). The second season found the two explanatory variables highly significant with the analysis indicating a strong negative effect (Table 3.8). The congenerics and days since the winter solstice in the first field season did not have a significant effect on the level of folivory (Table 3.8).

Aphid, *Senecio* leaf miner and *S. fascigera* occurrence was significantly influenced by habitat modification (Table 3.9). Aphids displayed low occurrence rates at intermediate disturbance levels and high occurrence in pristine and highly modified environments (Table 3.9). *Senecio* leaf miners displayed a positive increase in occurrence with increasing habitat modification (Table 3.9). *S. fascigera* declined in occurrence as the level of habitat modification decreased. The occurrence of aphids was influenced by indigenous scrub, exotic scrub and water within a 1km radius of the site, which had positive effects (Table 3.9). Horticulture, built up areas, exotic trees, open ground and water within a 5km radius of the site had negative effects. The number of congenerics, days since the winter solstice and the season/ date had positive effects on aphid abundance (Table 3.9). The occurrence of *Senecio* leaf miners was influenced by open ground within a 1km radius, which had a positive effect on *Senecio* leaf miners (Table 3.9). Exotic trees and water within a 1km radius had negative effects (Table 3.9). Within a 5km radius of the site; built up areas, indigenous scrub and water had positive effects (Table 3.9). Within a 5km radius indigenous grassland and open ground had negative effects on the presence of *Senecio* leaf miners (Table 3.9). Season/date, days since the winter solstice and congenerics had a negative effect on *Senecio* leaf miner occurrence (Table 3.9). The effect of season/ date on *Senecio* leaf miner occurrence differed between seasons with the first season indicating a positive effect and the second season a negative effect (Table 3.9). The occurrence of spittlebugs was influenced by indigenous scrub, indigenous forest, exotic trees and exotic scrub when combined, which had a positive effect on spittle bug presence (Table 3.9). Congenerics and days from the winter solstice had negative effects on spittlebug presence (Table 3.9). The occurrence of *S. fascigera* within a 1km radius was negatively affected by indigenous scrub, indigenous forest, exotic trees and open ground (Table 3.9). Within a 5km radius indigenous scrub and indigenous forest had positive effects (Table 3.9). Exotic scrub and water within a 5km radius had negative effects on *S. fascigera* (Table 3.9). Days since the winter solstice and season/ date had a positive effect on *S. fascigera* occurrence (Table 3.9).

The red rust fungi *C. senecionis* & *P. lagenophorae* displayed the greatest occurrence rates at intermediate levels of disturbance (Table 3.10). Open ground within a 1km radius of the site had a negative effect on *C. senecionis* & *P. lagenophorae* occurrence (Table 3.10). Agriculture and built up areas within a 5km radius had a positive effect on *C. senecionis* & *P. lagenophorae* occurrence (Table 3.10). *R. coleosporii* occurrence was positively affected by habitat modification with occurrence at its highest in highly disturbed environments (Table 3.10). The occurrence of *R. coleosporii* within a 1km radius was positively effected by built up areas, exotic scrub, indigenous forest and water (Table 3.10). Horticulture and indigenous scrub within a 1km radius had a negative effect on *R. coleosporii* (Table 3.10). Within a 5km radius, exotic scrub and water had a negative effect on *R. coleosporii* occurrence (Table 3.3.10). Days from the winter solstice and the number of congenerics had negative effects on *R. coleosporii* (Table 3.10). Season/ date had a positive effect on *R. coleosporii* (Table 3.10). The white smut species *A. tragopogoni* did not display any significant effects from my explanatory variables and therefore has not been presented.

3.5. Discussion

The primary aim of this study was to quantify the relative importance of *Senecio* biostatus, phylogeny, size, reproductive state and environment (land use) on herbivory and pathogen damage. My results indicate that the level of herbivory experienced by *Senecio* varied in space, time, phylogeny, density and condition of the plants. By quantifying the importance of herbivore and pathogen damage in relation to the factors that influence *Senecio,* I have shown that there are a variety of factors influencing enemy release and biotic resistance, which in turn are likely to influence the distribution and abundance of native and naturalised *Senecio* species in Canterbury.

The enemy release hypothesis stipulates that upon introduction to an exotic environment a plant species should experience a decrease in regulation by herbivores and other natural enemies resulting in an increase in range and abundance (Keane and Crawley 2002). For example, White et al. (2008) found that ovipositing female magpie moth, *Nyctemera amica* and larval *N. amica,* preferred the native *Senecio pinnatifolius* over the introduced *Senecio madagascariensis* in lab based experiments. In the field the amount of foliage damage on *S. pinnatifolius* was significantly greater than on *S. madagascariensis* (White et al. 2008). Contrary to the conclusions of White et al. (2008) whose results suggest that *S. madagascariensis* experienced a clear release from native herbivores, my results show that exotic *Senecio* are encountering both enemy release and biotic resistance within Canterbury. *Senecio* in native clades experienced a greater amount of folivory than *Senecio* in exotic clades as well as higher occurrences of aphids, *Senecio* leaf miners and the brown blotch fungi *R.*

coleosporii (Table 3.8, 3.9 & 3.10). The high occurrence of aphids, *Senecio* leaf miners and *R. coleosporii* on native *Senecio* had a strong phylogenetic influence, which suggests that these natural enemies may be selecting host species depending on the clade that the host belongs to (Table 3.9 & 3.10). Similar results have been found by Parker and Gilbert (2007) who found that native clovers were preferred by herbivores over phylogenetically related introduced clovers. Hypotheses proposed by Parker and Gilbert (2007) for why native clovers encountered greater herbivory than introduced clovers is that introduced clovers may not be recognised by native natural enemies in the exotic environment and/ or introduced clovers may have a chemical defence trait, which native species lack. The chemical defences in *Senecio* and closely related Senecioneae species are heritable and can vary depending on environmental conditions (Cano et al. 2009, Macel and Klinkhamer 2010, Hol 2011). Therefore, exotic *Senecio* may have a novel chemical defence which is aiding in the deterrence of aphids, *Senecio* leaf miners and *R. coleosporii*.

Exotic *Senecio* are also encountering biotic resistance from specialist and generalist natural enemies present in the Canterbury plains. The natural enemies *N. annulata*, spittlebugs, *C. senecionis* and *P. lagenophorae* displayed no significant differentiation between native and exotic *Senecio* clades when selecting a host plant (Table 3.9 & 3.10). Exotic *Senecio* also encountered biotic resistance from the endemic specialist herbivore *S. fascigera*. However unlike biotic resistance from other natural enemies, *S. fascigera* herbivory was determined by the area where *Senecio* originated and not by which clade they occupied. Exotic *Senecio* species from biogeographical isolated areas were strongly preferred as host plants by *S. fascigera* over native *Senecio* and along with the lack of host/ clade differentiation by *N. annulata*, spittlebugs, *C. senecionis* and *P. lagenophorae* supports the biotic resistance hypothesis (Elton 1958, Maron and Vila 2001) (Table 3.9). The preference by *S. fascigera* for exotic *Senecio* may be because exotic *Senecio* lack the defences to deter *S. fascigera* as well as *N. annulata*, spittlebugs, *C. senecionis* and *P. lagenophorae.* The conclusions of Macel et al. (2002) suggest that variation in the chemical defences of *J. vulgaris* populations do little to prevent herbivory from the specialist moth *Tyria jacobaeae* but may deter generalist herbivores. Therefore, a hypothesis for why exotic *Senecio* are experiencing enemy release and biotic resistance is that their chemical defences are able to deter generalist herbivores such as aphids and the generalist *Senecio* leaf miner *C. syngenesiae* but are unable to deter some of Canterbury's specialist herbivores such as *N. annulata* and *S. fascigera*. The review by Colautti et al. (2004) suggests that when a plant species is introduced into a novel environment it can experience an invasion bottleneck, which is a reduction in genetic diversity and can influence the traits and defences of the invading plant species. For example, Cano et al. (2009) found that the genotypes for *S. inaequidens* and *S. pterophorus* in invasive European populations displayed a higher concentration of pyrrolizidine alkaloids than the genotypes found native populations, which reduced their palatability to the molluscan herbivore *Helix aspersa*. Exotic *Senecio* in Canterbury may therefore be more susceptible to *S. fascigera*, *N. annulata*, spittlebugs, *C. senecionis* and *P. lagenophorae* because of chemical defences that they have inherited from their founding populations which lack the ability to deter these natural enemies. However, as illustrated in the meta-analysis by Levine et al. (2004) biotic resistance from natural enemies does not repel exotic species completely and is more likely to regulate their abundance within the habitat. Therefore, further study is needed to determine if *N. annulata*, spittlebugs, *C. senecionis* and *P. lagenophorae* and the preference of *S. fascigera* for exotic *Senecio* are regulating factors and thereby a form of biotic resistance.

Polyploidy is considered a potential mechanism which enables an invasive species to increase its range and occupy novel environments due to greater genetic diversity and adaptive potential (Pandit et al. 2006, Thebault et al. 2011, te Beest et al. 2012). Because of the benefit that polyploidy may provide to nine native allopolyploid *Senecio* in Canterbury (Chapter 2), I included allopolyploidy within my analysis and aims of this thesis. Allopolyploidy featured highly in seven of the candidate models selected by the AIC (Table 3.7). The presence of allopolyploidy in the models signifies that allopolyploidy may have an effect on the level of folivory sustained by *Senecio* and the occurrences of their natural enemies but that this effect is not strong when compared to other explanatory variables. Allopolyploidy may provide benefits other than folivory deterrence which are influencing the level of folivory and the occurrence of natural enemies. Should allopolyploidy be influencing folivory and the occurrence of natural enemies it may explain the prominence of allopolyploidy within the candidate models (Table 3.7). To determine the role of allopolyploidy in *Senecio*, further study is required to see whether or not allopolyploid *Senecio* display beneficial traits, which may increase their persistence across different landscapes in the Canterbury region.

The surrounding land use had a moderate effect on the occurrence of generalist natural enemies on Canterbury *Senecio* suggesting that spill-over effects may be occurring. A spill-over effect is where a subsidised mobile antagonist such as a natural enemy moves from an anthropogenic habitat into a neighbouring native habitat (Rand et al. 2006). For example, Holzschuh et al. (2008) found that landscapes composed of organic crops had a significant effect on the diversity and abundance of bee species in neighbouring fallow strips. The surrounding organic crops provided increased food resources, which were needed to sustain greater pollinator richness in non-crop habitats. A similar process may be occurring in the landscape matrices surrounding *Senecio* communities. The generalist natural enemies, aphids, *Senecio* leaf miners, *C. senecionis* & *P. lagenophorae* and *R. coleosporii* displayed context specific changes in the number of occurrences on *Senecio* depending on the composition of the surrounding landscape (Table 3.9 & 3.10). My results display parallels to the study by Rand and Tscharntke (2007) who found that specialist and generalist natural enemies increased and decreased depending on the complexity of the surrounding landscape. In addition, Rand and Tscharntke (2007) mention that changes in landscape composition can augment consumer-prey interactions in native habitats. Therefore, the surrounding landscape may be influencing the pressure of generalist natural enemies on native *Senecio*, which is demonstrated by *Senecio* in native clades experiencing higher occurrences of Aphids, *Senecio* leaf miners and *R. coleosporii* than exotic *Senecio* (Table 3.9 & 3.10). However, my folivory results indicate that factors other than the spill-over effects by generalist natural enemies are influencing the amount of folivory in Canterbury *Senecio*.

The strongest effects on herbivory and pathogen damage came from land use, habitat modification, time (season and days from the winter solstice), plant maturity and the density of *Senecio* (Table 3.8). Land use and habitat modification are well documented as factors which influence ecosystem processes and functioning (Fahrig 2003, Tylianakis et al. 2007, Tylianakis et al. 2008). For example, Evans et al. (2012) found that the quality and size of native habitat patches in fragmented landscapes had a strong effect on the amount of herbivory that occurred within those patches. My results support the results of Evans et al. (2012) with the scale of the surrounding landscape having a strong effect on the level of folivory experienced by *Senecio*. In addition, habitats that were modified to an intermediate level displayed high levels of folivory (Table 3.8). The studies by Billeter et al. (2008) and Hendrickx et al. (2007)

found that species richness across seven taxa was greatest in semi natural habitats, such as scrub and woodlands in European agricultural landscapes because they provided habitat heterogeneity and reduced effects from agricultural fertilisers, agrochemicals and other variables, which were found to reduce species richness. Therefore, *Senecio* in semi-natural habitats in Canterbury landscapes may be experiencing greater folivory due to greater species richness and hence a greater abundance of generalist herbivores (Collins et al. 1995). However, the strength of the interactions between *Senecio* and folivory may be mitigated due to time, maturity and density of *Senecio* populations in semi-natural environments.

The age of plant can have a strong effect on the level of herbivory it sustains (Read et al. 2003, Brenes-Arguedas et al. 2006). Both Read et al. (2003) and Brenes-Arguedas et al. (2006) found that younger leaves encountered remarkably higher levels of herbivory than mature leaves despite having greater phenolic and other chemical defences. My results support the conclusions of Read et al. (2003) and Brenes-Arguedas et al. (2006) because as *Senecio* matured and increased in volume the occurrence of folivory strongly decreased (Table 3.8). In addition, the decline in folivory in *Senecio* was correlated with days from the winter solstice and the number of congenerics indicating that as *Senecio* emerged in the spring they encountered higher rates of folivory compared to mature plants later on in the season. My results also indicate that the season and date had a strong positive effect on the occurrence of folivory in *Senecio.* However, the positive effect of season contradicts other explanatory variables such as maturity and days since the winter solstice. A hypothesis for why season had a strong positive effect on folivory may be due to the emergence periods of the natural enemies of *Senecio*. For example, aphids appeared early in the season and declined in the number of occurrences as the season progressed, whereas herbivores such as *Senecio* leaf miners and *S. fascigera* displayed strong increases in occurrence as the season progressed (Table 3.9). Therefore, the type of herbivore feeding on *Senecio* may have a major influence on the amount of folivory sustained by *Senecio* over a season and hence why season had such a strong effect on my dataset.

The strong effect of the surrounding land use indicates that the release of *Senecio* from natural enemies is likely to be land use specific, which is illustrated by the variation in generalist natural enemy occurrence in different land uses (Table 3.8). Therefore, the effects of enemy release from generalist natural enemies are unlikely to play a large role in the abundance and distribution of *Senecio* across a wider heterogeneous landscape. For example, Aphid presence on *Senecio* was highest in land uses where horticulture and exotic forests formed the surrounding habitat but in habitats such as built up areas and open ground they occurred in low abundance. However, *Senecio* populations in horticulture and exotic forest experienced significantly less folivory than in any other land use. In addition, natural enemies did not increase in indigenous grasslands within 1km of *Senecio* populations, despite folivory being significantly higher in these environments (Chapter 3). In addition, because biotic resistance by natural enemies and their ability to regulate exotic *Senecio* has not been quantified, I cannot state whether or not biotic resistance is influencing exotic *Senecio* abundance and distribution. Instead evidence from my results indicates that the abundance and distribution of native and exotic *Senecio* is being strongly driven by past and present land use choices and the functional traits of *Senecio*. The distribution of invasive species is considered to be strongly influenced over time by the invasibility of ecosystems and the availability of propagules across the landscape (Vila and Ibanez 2011). For example, With (2004) found that colonisation of landscapes was highest when >20% of the landscape was disturbed because propagules are more likely to encounter a disturbed environment. Therefore, Canterbury *Senecio*, which are good dispersers and have rapid growth and maturation rates are likely to succeed to a greater extent within the Canterbury landscape due to the variation in herbivory between habitats and the low occurrence of herbivory on reproductively mature *Senecio.* Further research is needed to determine the propagules of native and exotic *Senecio* and whether or not the growth rates of exotic *Senecio* are greater than native species. Determination of *Senecio* propagules and growth rates may explain why exotic *Senecio* sustain less folivory than native and therefore how the distribution and abundance of native *Senecio* may be affected in the future.

Chapter 3: Tables and Figures

Table 3.1. *Senecio* species and subspecies present in New Zealand and biostatus. Red labelled species are naturally uncommon, Blue= critically endangered, Green= relict, Black= Non-threatened.

Species	**Biostatus**
Senecio australis Willd.	Introduced
Senecio banksii Hook.F.	Native endemic
Senecio bipinnatisectus Belcher	Naturalised
Senecio biserratus Belcher	Native
Senecio carnosulus (Kirk) C.J.Webb	Native endemic
Senecio diaschides D.G.Drury	Native
Senecio dunedinensis Belcher	Native endemic
Senecio elegans L.	Naturalised
Senecio esleri C.J.Webb	Native
Senecio glastifolius Hook.F.	Naturalised
Senecio glaucophyllus subsp. basinudus Ornduff	Native endemic
Senecio glaucophyllus subsp. discoideus (Cheeseman) Ornduff	Native endemic
Senecio glaucophyllus subsp. glaucophyllus	Native endemic
Senecio glaucophyllus subsp. toa C.J.Webb	Native endemic
Senecio glomeratus Desf. ex Poir. subsp. glomeratus	Native
Senecio hauwai Sykes	Native endemic
Senecio hispidulus A.Rich	Native
Senecio hypoleucus F.Muell. ex Benth.	Naturalised
Senecio kermadecensis Belcher	Native endemic
Senecio lautus subsp. esperensis (Sykes) de Lange	Native endemic
Senecio lautus subsp. lautus	Native
Senecio linearifolius A.Rich	Naturalised
Senecio marotiri C.J.Webb	Native endemic
Senecio minimus Poir.	Native
Senecio quadridentatus Labill.	Native
Senecio radiolatus subsp. antipodus (Kirk) C.J.Webb	Native endemic
Senecio radiolatus subsp. radiolatus	Native endemic
Senecio repangae subsp. pokohinuensis de Lange & B.E.Murray	Native endemic
Senecio repangae subsp. repangae	Native endemic
Senecio rufiglandulosus Colenso	Native endemic
Senecio scaberulus (Hook.f.) D.G.Drury	Native endemic
Senecio skirrhodon DC.	Naturalised
Senecio sterquilinus Ornduff	Native endemic
Senecio sylvaticus L.	Naturalised
Senecio vulgaris L.	Naturalised
Senecio wairauensis Belcher	Native endemic

Table 3.2. Habitat modification level, classification and descriptions.

Modification level	**Classification**	**Description**
1	Urban industrial areas.	Factories, railways and other industrial areas.
2	Urban residential areas	Urban homes, gardens, car parks and verges.
3	Rural agricultural areas	Areas utilised by crop and livestock.
4	Abandoned agricultural areas	Flood plains or areas reclaimed by the Department of Conservation.
5	Small native reserves	Comprised completely of edge habitat.
6	Large native reserves	Large areas characterised by an edge and an interior as outlined by Didham et al (2006)

Table 3.3. Native and exotic species and the clades that they occupy.

Clade	**Species**
Native (Chapter 2)	
Minimissia	*S. glomeratus, S. minimus, S. hauwai, S. diaschides* and *S. hispidulus*
Magnificus	*S. wairauensis, S. quadridentatus, S. dunedinensis* and *S. rufiglandulosis*
Lautusoid	*S. lautus, S. glaucophyllus, S. biserratus, S. sterquilinus* and *S. carnosulus*
Exotic (see Pelser et al. (2007))	
Nevadaensis-inaequidens	*S. skirrhodon*
Senecio Clade A (Clade Vernalis)	*S. vulgaris* and *S. sylvaticus*
Jacobaea	*J. vulgaris* and *J. maritime*
Outside Clade (Unknown)	*S. elegans*
Senecio bulbinefolius-Curio acaulis clade	*S. angulatus*

Table 3.4. Common herbivores and fungal pathogens of Canterbury *Senecio*, their type of natural enemy, biostatus host preference.

Species	**Type of natural enemy**	**Biostatus**	**Host Preference**
Sphenella fascigera	Dipteran	Endemic	Generalist
Nyctemera annulata	Lepidopteran	Endemic	Specialist
Chromatomyia syngenesiae	Dipteran	Exotic	Specialist
Phytomyza syngenesiae	Dipteran	Native	Specialist
Puccinia lagenophorae	Urediniomycetes	Native	Generalist
Coleosporium senecionis	Pucciniomycetes	Endemic	Generalist
Albugo tragopogonis	Oomycete	Exotic	Generalist
Cercopidae	Hemipteran	Exotic	Generalist
Aphidoidea	Hemipteran	Exotic	Generalist

Table 3.5. Candidate models used in the analysis. Y represents the response variables: folivory, aphid abundance, spittlebug abundance, *Senecio* leaf miners abundance, and magpie moth abundance. The explanatory variables are Habitat Modification (HM), Season (S), Conspecifics (CS), Congenerics (CG), Maturity (M), Volume (V), Clade (CL), Allopolyploidy (A), Days since the winter solstice (WS), Region of origin (RO), Horticultural surrounding 1km of the site (H1), Agriculture surrounding 1km of the site (AG1), Built up areas surrounding 1km of the site (BU1), Indigenous scrub surrounding 1km of the site (IS1), Indigenous forest surrounding 1km of the site (IF1), Indigenous grassland surrounding 1km of the site (IG1), Exotic scrub surrounding 1km of the site (ES1), Exotic trees surrounding 1km of the site (ET1), Water surrounding 1km of the site (WR1), open ground surrounding 1km of the site (OG1), Horticultural surrounding 5km of the site (H5), Agriculture surrounding 5km of the site (AG5), Built up areas surrounding 5km of the site (BU5), Indigenous scrub surrounding 5km of the site (IS5), Indigenous forest surrounding 5km of the site (IF5), Indigenous grassland surrounding 5km of the site (IG5), Exotic scrub surrounding 5km of the site (ES5), Exotic trees surrounding 5km of the site (ET5), water surrounding 5km of the site (WR5), and open ground surrounding 5km of the site (OG5).

Model	**Variables**
n	Null
n0	y~RO
n1	y~Cl
n2	y~A
n3	y~CL+A
n4	y~V1
n5	y~V2
n6	y~V3
n7	y~M
n8	y~HM
n9	y~BU1+WR1+OG1
n10	y~H1+A1
n11	y~IS1+IF1+IG1+ES1+ET1
n12	y~IG1
n13	y~H1+A1+BU1
n14	y~H1+A1+BU1+IS1+IF1+IG1+ES1+ET1
n15	y~H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1
n16	y~BU5
n17	y~H5+A5
n18	y~IS5+IF5+ES5+ET5
n19	y~IG5
n20	y~H5+A5+BU5
n21	y~H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n22	y~H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5
n23	y~CS
n24	y~CG
n25	y~S
n26	y~M+V
n27	y~CS+M+V
n28	y~HM+RO
n29	y~A+HM
n30	y~HM+CL

n31	y~HM+CL+A
n32	y~HM+BU1
n33	y~HM+H1+A1+ES1+ET1
n34	y~HM+IS1+IF1+ES1+ET1
n35	y~HM+IG1
n36	y~HM+H1+A1+BU1
n37	y~HM+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1
n38	y~HM+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1
n39	y~HM+BU5
n40	y~HM+H5+A5
n41	y~HM+IS5+IF5++ES5+ET5
n42	y~HM+IG5
n43	y~HM+H5+A5+BU5
n44	y~HM+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n45	y~HM+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5
n46	y~S+RO
n47	y~CL+S
n48	y~A+S
n49	y~CL+A+S
n50	y~S+V
n51	y~S+M
n52	y~HM+S
n53	y~S+BU1
n54	y~S+H1+A1
n55	y~S+IS1+IF1+ES1+ET1
n56	y~S+IG1
n57	y~S+H1+A1+BU1+ES1+ET1
n58	y~S+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1
n59	y~S+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1
n60	y~S+BU5
n61	y~S+H5+A5
n62	y~S+IS5+IF5+IG5+ES5+ET5
n63	y~S+IG5
n64	y~S+H5+A5+BU5

n65	y~S+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n66	y~S+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5
n67	y~S+CS
n68	y~S+CG
n69	y~HM+S+RO
n70	y~HM+S+CL
n71	y~A+HM+S
n72	y~CL+A+HM+S
n73	y~S+M+V
n74	y~S+M+V+CS
n75	y~CL+HM+S+CG+M+V+WS
n76	y~CL+M+HM+S+WS+V+BU1
n77	y~CL+H1+A1
n78	y~CL+HM+S+CG+M+V+WS+IS1+IF1+ES1+ET1
n79	y~CL+HM+S+CG+M+V+WS+IG1
n80	y~CL+HM+S+CG+M+V+WS+H1+A1+BU1
n81	y~CL+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1
n82	y~CL+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1
n83	y~CL+HM+S+CG+M+V+WS+BU5
n84	y~CL+HM+S+CG+M+V+WS+H5+A5
n85	y~CL+HM+S+CG+M+V+WS+IS5+IF5+ES5+ET5
n86	y~CL+HM+S+CG+M+V+WS+IG5
n87	y~CL+HM+S+CG+M+V+WS+H5+A5+BU5
n88	y~CL+HM+S+CG+M+V+WS+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n89	y~CL+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5
n90	y~CL+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5
n91	y~RO+HM+S+CG+M+V+WS
n92	y~RO+HM+S+CG+M+V+WS+BU1
n93	y~RO+HM+S+CG+M+V+WS+H1+A1
n94	y~RO+HM+S+CG+M+V+WS+IS1+IF1+ES1+ET1

n95	y~RO+HM+S+CG+M+V+WS+IG1
n96	y~RO+HM+S+CG+M+V+WS+H1+A1+BU1
n97	y~RO+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1
n98	y~RO+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1
n99	y~RO+HM+S+CG+M+V+WS+BU5
n100	y~RO+HM+S+CG+M+V+WS+H5+A5
n101	y~RO+HM+S+CG+M+V+WS+IS5+IT5+ES5+ET5
n102	y~RO+HM+S+CG+M+V+WS+IG5
n103	y~RO+HM+S+CG+M+V+WS+H5+A5+BU5
n104	y~RO+HM+S+CG+M+V+WS+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n105	y~RO+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n106	y~RO+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5
n107	y~A+HM+S+CG+M+V+WS
n108	y~A+HM+S+CG+M+V+WS+BU1
n109	y~A+HM+S+CG+M+V+WS+H1+AG1
n110	y~A+HM+S+CG+M+V+WS+IS1+IF1+ES1+ET1
n111	y~A+HM+S+CG+M+V+WS+IG1
n112	y~A+HM+S+CG+M+V+WS+H1+A1+BU1
n113	y~A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1
n114	y~A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1
n115	y~A+HM+S+CG+M+V+WS+BU5
n116	y~A+HM+S+CG+M+V+WS+H5+A5
n117	y~A+HM+S+CG+M+V+WS+IS5+IF5+ES5+ET5
n118	y~A+HM+S+CG+M+V+WS+IG5
n119	y~A+HM+S+CG+M+V+WS+H5+A5+BU5
n120	y~A+HM+S+CG+M+V+WS+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n121	y~A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n122	y~A+HM+CL+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5

n123	y~A+HM+CL+S+CG+M+V+WS
n124	y~A+HM+CL+S+CG+M+V+WS+BU1
n125	y~A+HM+CL+S+CG+M+V+WS+A1+H1
n126	y~CL+A+HM+S+CG+M+V+WS+IS1+IF1+ES1+ET1
n127	y~A+CL+HM+S+CG+M+V+WS+IG1
n128	y~A+CL+HM+S+CG+M+V+WS+H1+A1+BU1
n129	y~CL+A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1
n130	y~CL+A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1
n131	y~CL+A+HM+S+CG+M+V+WS+BU5
n132	y~CL+A+HM+S+CG+M+V+WS+H5+A5
n133	y~CL+A+HM+S+CG+M+V+WS+ES5+ET5+WR5+OG5
n134	y~CL+A+HM+S+CG+M+V+WS+IG5
n135	y~CL+A+HM+S+CG+M+V+WS+H5+A5+BU5
n136	y~CL+A+HM+S+CG+M+V+WS+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n137	y~CL+A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5
n138	y~CL+A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5

Table 3.6. Description of the explanatory variables, the affect that they will have on folivory and an explanation for the direction of that effect.

Explanatory Variable	**Effect on folivory**	**Explanation for the direction of significance**
Habitat Modification (HM)	Negative	Evans et al. (2012) found that the amount of herbivory on plant species decreased as patches became more fragmented and lost "core" habitat.
Season (S)	Negative	Herbivory should be greatest when *Senecio* populations are at highest density. Therefore, herbivory should increase towards the end of the season (Parmesan 2000).
Conspecific (CS)	Non-linear	Underwood and Halpern (2012) found that the level of herbivory of the perennial *Solanum carolinense* was highest at intermediate densities.
Congeneric (CG)	Positive	There should be a direct positive correlation between the number of congenerics and the number of generalist herbivores, therefore there should be an increase in herbivory (Parker et al 2012).
Maturity (M)	Negative	Read et al. (2003) found that developing leaves had significantly higher levels of phenolics than mature leaves. However, they were also the ones that were selected by herbivores due to higher nitrogen.
Volume (V)	Negative	A larger plant should be more mature and therefore be a less palatable host for herbivores (Read et al. 2003).
Clade (CL)	negative	The greater the taxonomic distance a clade is from native clades, the more likely that it will benefit from enemy release and therefore experience reduced herbivory (Table 3; (Parker et al. 2012)).
Allopolyploidy (A)	Negative	Allopolyploids should sustain less damage than non allopolyploids because of potentially novel chemical defences and other traits (te Beest et al. 2012).
Days since the winter solstice (WS)	Non-linear	Because Senecio are annual to perennial, they should increase in density from spring until Autumn. Therefore, folivory should increase until intermediate densities (Underwood and Halpern 2012).
Region of origin (RO)	Negative	Australasian species should sustain less herbivory than exotic species due to a co-evolutionary history with native natural enemies (Percy et al. 2004).
Horticulture surrounding 1km of the site	Positive	I expect a positive effect on folivory in sites surrounded by horticulture because of spillover effects from crops (Rand et al. 2006).
Agriculture surrounding 1km of the site	Positive	I expect a positive effect on folivory in sites surrounded by agriculture because of spillover effects from crops (Rand et al. 2006).

Built up areas surrounding 1km of the site	Positive	Built up areas are typically highly modified with large amounts of disturbed ground, which supports fast growing Senecio and a potentially large population of associated herbivores and pathogens. In addition, increased urban fragmentation can lead to increased herbivory rates (Christie and Hochuli 2005).
Indigenous scrub surrounding 1 & 5km of the site	Positive	Indigenous scrub can be an intermediate habitat between highly modified urban habitat and indigenous forest. Therefore, a greater number of specialist and generalist species may be present which could influence the amount of folivory (Collins et al. 1995).
Indigenous forest surrounding 1 & 5km of the site	Positive	I expect a significant positive effect on folivory in sites surrounded by indigenous forest because of the forest composition, which may have a herbivore permeable edge habitat, (Ewers and Didham 2006)
Indigenous grassland surrounding 1 & 5km of the site	Neutral	The effect of herbivory may depend on the plant diversity of the grassland and the number of Senecio species available to support Senecio herbivores (Stein et al. 2010).
Exotic scrub surrounding 1 & 5km of the site	Positive	Exotic scrub should have a high diversity of species and potential herbivores because it is an intermediate habitat with diverse resources enabling different natural enemies to survive within it. (Collins et al. 1995).
Exotic trees surrounding 1 & 5km of the site	Negative	Positive because forestry plantations tend to have a high level of disturbance due to clear felling, which may allow fast growing *Senecio* to occupy these habitats.
water surrounding 1 & 5km of the site	Neutral	Neutral because of the distance herbivores will have to travel in order to feed upon the plant species. In addition, water environments such as river bed may provide habitat for Senecio and their natural enemies.
open ground surrounding 1 & 5km of the site	Positive	In open ground, *Senecio* should be easier to see and in some species more abundant, allowing herbivores to cause greater damage to the plant.

Table 3.7. Top candidate models for the response variables used in the GLM for folivory, insect abundances and fungal infection.

Model	Variables	Delta AICc
Folivory		
n90	y~CL+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5	0.67
n122	y~A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5	0
n138	y~CL+A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5	2.82
n106	y~RO+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5	1.98
N.annulata		
n82	y~CL+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1	0
n130	y~CL+A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1	2.19
Aphid abundance		
n90	y~CL+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5	0
n138	y~CL+A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+OG5	2.1
Senecio Leaf Miners		
n138	y~CL+A+HM+S+CG+M+V+WS+H1+A1+BU1+IS1+IF1+IG1+ES1+ET1+WR1+OG1+H5+A5+BU5+IS5+IF5+IG5+ES5+ET5+WR5+O	0.075

Table 3.8. P Values ($P<0.05$) and trends of the four best candidate models of folivory: n90 (with estimates), n122, n138 and n106 (See Table 3.5 for details).

Explanatory variable	**n90**	**Estimate (Trend)**	**N122**	**n138**	**n106**
Variance		0.4004 ± 0.63277			
Habitat Modification (HM).	2.20E-16		2.20E-16	2.20E-16	2.20E-16
Habitat Modification: level 2	NA	1.381	NA	NA	NA
Habitat Modification: level 3	NA	0.630	NA	NA	NA
Habitat Modification: level 4	NA	0.316	NA	NA	NA
Habitat Modification: level 5	NA	-0.017	NA	NA	NA
Habitat Modification: level 6	NA	-4.917	NA	NA	NA
Season (S).	2.20E-16	2.709	2.20E-16	2.20E-16	2.20E-16
Congenerics (CG).	3.14E-12	-3.223	6.21E-12	3.15E-12	4.13E-12
Maturity (M):	2.20E-16	NA	2.20E-16	2.20E-16	2.20E-16
Maturity: budding	NA	0.309	NA	NA	NA
Maturity: flowering	NA	-0.092	NA	NA	NA
Maturity: flowering and seeding	NA	-0.134	NA	NA	NA
Maturity: Seeding	NA	-1.052	NA	NA	NA
Volume (V).	1.19E-06	-0.635	1.96E-06	1.18E-06	1.83E-06
Clade (CL).	0.022	NA	NA	0.022	NA
Clade Jacobaea (exotic)	NA	0.507	NA	NA	NA
Clade Lautusoid (native)	NA	-0.675	NA	NA	NA
Clade Magnificus (native)	NA	0.742	NA	NA	NA
Clade Nevadaensis-inaequidens (exotic)	NA	-1.255	NA	NA	NA
Outside clade 3 (exotic)	NA	-1.085	NA	NA	NA
Clade Vernalis (exotic)	NA	-0.768	NA	NA	NA
Allopolyploidy (A).	NA	NA	0.72	0.74	NA
Days since the winter solstice (WS).	2.20E-16	-5.755	2.20E-16	2.20E-16	2.20E-16
Region of origin (RO).	NA	NA	NA	NA	0.42
Horticulture forming a 1km radius around the site (H1).	0.014	-0.026	0.011	0.015	0.01
Agriculture forming a 1km radius around the site (AG1).	0.82	0.003	0.58	0.83	0.64
Built up areas forming a 1km radius around the site (BU1).	6.49E-05	0.034	4.02E-05	6.34E-05	3.56E-05
Indigenous scrub forming a 1km radius around the site (IS1).	0.47	0.005	0.54	0.47	0.51
Indigenous forest forming a 1km radius around the site (IF1).	0.54	-0.006	0.44	0.55	0.46
Indigenous grassland forming a 1km radius around the site (IG1).	6.10E-05	0.257	5.52E-05	5.90E-05	6.16E-05

Exotic scrub forming a 1km radius around the site (ES1).	0.62	-0.004	0.58	0.635	0.54
Exotic trees forming a 1km radius around the site (ET1).	2.20E-16	-0.068	2.20E-16	2.20E-16	2.20E-16
Water forming a 1km radius around the site (WR1).	5.08E-07	-0.046	7.17E-07	5.06E-07	6.56E-07
Open ground forming 1km radius around the site (OG1).	0.76	0.003	0.81	0.75	0.74
Horticulture forming a 5km radius around the site (H5).	0.39	0.008	0.027	0.39	0.29
Agriculture forming a 5km radius around the site (A5).	1.37E-07	-0.573	2.19E-07	1.43E-07	2.73E-07
Built up areas forming a 5km radius around the site (BU5)	0.44	-0.017	0.03	0.045	0.03
Indigenous scrub forming a 5km radius around the site (IS5).	0.009	0.026	0.005	0.009	0.01
Indigenous forest forming a 5km radius around the site (IF5).	2.66E-08	-0.067	1.90E-08	2.72E-08	1.95E-08
Indigenous grassland forming 5km radius around the site (IG5).	0.55	0.007	0.59	0.54	0.59
Exotic scrub forming 5km radius around the site (ES5).	5.29E-11	0.097	6.25E-11	4.99E-11	4.02E-11
Exotic trees forming 5km radius around the site (ET5).	6.90E-09	-0.123	5.12E-09	6.92E-09	3.61E-09
Water forming 5km radius around the site (WR5).	0.09	-0.018	0.06	0.1	0.06
Open ground forming 5km radius around the site (OG5).	0.05	0.028	0.03	0.05	0.03

Table 3.9. P-values (P<0.05) and trends for the abundance of each insect species found on Canterbury *Senecio* in relation to the explanatory variables in Table 3.6. NA= not retained in the best model.

Explanatory variable Variance	***N. annulata***	**Estimate (Trend)** 5.15e-12 ± 2.27e-06	**Aphids**	**Estimate (Trend)** 0 ± 0	***Senecio* leaf miners**	**Estimate (Trend)** 2.14e-18 ± 1.46e-09	**Spittlebugs**	**Estimate (Trend)** 5.43e-14 ± 2.33e-07	***S. fascigera***	**Estimate (Trend)** 5.43e-14 ± 2.33e-07
Habitat Modification (HM).	1		0.03		0		0.18		0.02	
Habitat Modification: level 2	NA	71.4	NA	-1.7	NA	7.45	19.06	NA	NA	-6.75
Habitat Modification: level 3	NA	37.24	NA	-2.37	NA	4.09	22.27	NA	NA	-1.83
Habitat Modification: level 4	NA	-1.53	NA	-3.04	NA	3.36	23.62	NA	NA	-1.72
Habitat Modification: level 5	NA	49.13	NA	-2.52	NA	5.05	18.23	NA	NA	-2.09
Habitat Modification: level 6	NA	266.6	NA	-0.05	NA	3.98	-5.04	NA	NA	-1.22
Season (S).	0.99	-164.7	0.01	0.01	0	-0.95	0	9.39	0.01	6.34

Congenerics (CG).	0.29	-599.9	0	2.76	0.6	-3.11	0.04	-4.44	0.56	10.39
Maturity (M): overall	0.13	NA	0.43	NA	0.03	NA	0.03	NA	0.02	NA
Maturity: budding	NA	-1.6	NA	1.63	NA	0.56	NA	5.01	NA	0.93
Maturity: flowering	NA	-2.3	NA	1.22	NA	-0.39	NA	3.11	NA	0.58
Maturity: flowering and seeding	NA	-5.18	NA	0.6	NA	-3.42	NA	-16.25	NA	-1.25
Maturity: Seeding	NA	-8.45	NA	1.48	NA	0	NA	3.95	NA	2.64
Volume (V).	0.02	4.69	0.18	-1.64	0.01	-12.82	0.01	-35.64	0.23	-3.66
Clade (CL).	0.99	NA	0	NA	0		0.21	NA	NA	NA
Clade Jacobaea (exotic)	NA	-90.61	NA	-3.08	NA	-3.65	NA	-10.62	NA	NA
Clade Lautusoid (native)	NA	-110.6	NA	-0.34	NA	-1.27	NA	-3.59	NA	NA
Clade Magnificus (native)	NA	-17.68	NA	0.19	NA	-1.66	NA	0.97	NA	NA
Clade Nevadaensis-inaequidens (exotic)	NA	42.36	NA	-4.27	NA	-1.64	NA	16.38	NA	NA
Outside clade 3 (exotic)	NA	-123.5	NA	-2.26	NA	-4.53	NA	-22.06	NA	NA
Clade Vernalis (exotic)	NA	-1.34	NA	-0.72	NA	-2.32	NA	-4.58	NA	NA
Allopolyploidy	NA	NA	NA	NA	0.14	-0.93	NA	NA	NA	NA

(A).									
Days since the winter solstice (WS).	0.99	-146.6	0	-4.48	0	-12.9	0	-104.27	0	7.07
Region of origin (RO).	NA	NA	NA	NA	NA	NA	NA	NA	0	
Europe	NA	NA	NA	NA	NA	NA	NA	NA	NA	2.25
New Zealand	NA	NA	NA	NA	NA	NA	NA	NA	NA	-12.34
southern Africa	NA	NA	NA	NA	NA	NA	NA	NA	NA	3.23
Horticulture forming a 1km radius around the site (H1).	0.99	-1.58	0.6	-0.53	0.59	-0.03	NA	NA	0.12	0.17
Agriculture forming a 1km radius around the site (AG1).	0.99	1.96	0.39	-0.85	0.14	-0.13	NA	NA	0.96	0.01
Built up areas forming a 1km radius around the site (BU1).	0.99	1.02	0.29	1.04	0.54	-0.01	NA	NA	0.48	-0.07
Indigenous scrub forming a 1km radius around the site (IS1).	0.99	-1.89	0.03	2.23	0.06	0.09	NA	NA	0.03	-0.2

Indigenous forest forming a 1km radius around the site (IF1).	0.99	2.6	0.7	-0.38	0.47	0.02	NA	NA	0.02	-0.4
Indigenous grassland forming a 1km radius around the site (IG1).	0.99	-17.23	0.16	1.41	0.78	-0.03	NA	NA	0.95	0.14
Exotic scrub forming a 1km radius around the site (ES1).	0.99	4.5	0.43	2.02	0.82	0.01	NA	NA	0.12	0.19
Exotic trees forming a 1km radius around the site (ET1).	0.99	-2.47	0.76	0.29	0.09	-0.11	NA	NA	0.03	-0.23
Water forming a 1km radius around the site (WR1).	0.99	0.83	0.01	2.66	0	-0.24	NA	NA	0.61	0.06
Open ground forming 1km radius around the site (OG1).	0.99	-3.73	0.27	1.09	0	0.2	NA	NA	0	-0.57
Horticulture forming a 5km radius around the site (H5).	NA	NA	0	4.92	0.59	-0.03	NA	NA	0.3	0.11

Agriculture forming a 5km radius around the site (A5).	NA	NA	0.06	-1.88	0.02	1.34	NA	NA	0.81	0.26
Built up areas forming a 5km radius around the site (BU5)	NA	NA	0.01	-2.71	0	0.13	NA	NA	0.25	-0.1
Indigenous scrub forming a 5km radius around the site (IS5).	NA	NA	0.57	0.56	0	0.2	0	1.86	0.01	0.52
Indigenous forest forming a 5km radius around the site (IF5).	NA	NA	0.06	1.88	0.97	0.04	0	1.86	0.05	0.27
Indigenous grassland forming 5km radius around the site (IG5).	NA	NA	0.39	-0.86	0	-0.14	NA	NA	0.07	-0.24
Exotic scrub forming 5km radius around the site (ES5).	NA	NA	0.37	-0.9	0.95	-0.01	0	1.86	0.05	-0.42
Exotic trees forming 5km radius around the site (ET5).	NA	NA	0	2.98	0.29	0.14	0	1.86	0.88	0.1

Water forming 5km radius around the site (WR5).	NA	NA	0.04	-2.08	0	0.21	NA	NA	0	-0.53
Open ground forming 5km radius around the site (OG5).	NA	NA	0	-3	0	-0.32	NA	NA	0.12	0.32

Table 3.10. P-values and trend of the three fungal species most common on Canterbury *Senecio* and their responses to explanatory variables.

Explanatory variable	***C. senecionis* & *P. lagenophorae***	**Trend (Estimate)**	***R. coleosporii***	**Trend (Estimate)**
Variance		0 ± 0		2.38e-13 ±4.88e-07
Habitat Modification (HM).	0.03		0	
Habitat Modification: level 2	NA	-22.39	NA	-5.6
Habitat Modification: level 3	NA	-3.31	NA	-3.05
Habitat Modification: level 4	NA	-2.6	NA	-3.03
Habitat Modification: level 5	NA	-1.37	NA	-4.47
Habitat Modification: level 6	NA	-8.96	NA	-17.89
Season (S).	0.74	20.19	0.02	1.8
Congenerics (CG).	0.49	2.89	0.03	-4.95
Maturity (M):	0.14	NA	0.63	
Maturity: budding	NA	0.71	NA	-0.46
Maturity: flowering	NA	0.84	NA	-0.14
Maturity: flowering and seeding	NA	2.44	NA	-0.85
Maturity: Seeding	NA	0.92	NA	-0.13
Volume (V).	0.85	4.64	0.98	0.07
Clade (CL).	NA	NA	0	
Clade Jacobaea (exotic)	NA	NA	NA	-1.61
Clade Lautusoid (native)	NA	NA	NA	-1.26
Clade Magnificus (native)	NA	NA	NA	-0.53
Clade Nevadaensis-inaequidens (exotic)	NA	NA	NA	-1.63
Outside clade 3 (exotic)	NA	NA	NA	0.08
Senecio clade A (exotic)	NA	NA	NA	-1.56
Allopolyploidy (A).	0.97	-0.02	0.42	
Days since the winter solstice (WS).	0.1	-17.4	0	-27.21
Horticultural forming a 1km radius around the site (H1).	0.13	0.1	0.01	-0.13
Agriculture forming a 1km radius around the site (AG1).	0	0.3	0.11	-0.07
Built up areas forming a 1km radius around the site (BU1).	0.02	0.18	0	0.19

Indigenous scrub forming a 1km radius around the site (IS1).	0.46	-0.06	0	-0.15
Indigenous forest forming a 1km radius around the site (IF1).	0.94	-0.01	0	0.14
Indigenous grassland forming a 1km radius around the site (IG1).	0.99	-0.82	0.14	1.08
Exotic scrub forming a 1km radius around the site (ES1).	0.14	-0.1	0	0.17
Exotic trees forming a 1km radius around the site (ET1).	0.96	0	0.27	-0.07
Water forming a 1km radius around the site (WR1).	0.13	-0.19	0.01	0.13
Open ground forming 1km radius around the site (OG1).	0.01	-0.16	0.27	0.04
Horticultural forming a 5km radius around the site (H5).	NA	NA	0.67	-0.02
Agriculture forming a 5km radius around the site (A5).	NA	NA	0.21	0.61
Built up areas forming a 5km radius around the site (BU5)	NA	NA	0.2	-0.05
Indigenous scrub forming a 5km radius around the site (IS5).	NA	NA	0.09	0.09
Indigenous forest forming a 5km radius around the site (IF5).	NA	NA	0.05	-0.1
Indigenous grassland forming 5km radius around the site (IG5).	NA	NA	0.45	-0.03
Exotic scrub forming 5km radius around the site (ES5).	NA	NA	0	-0.22
Exotic trees forming 5km radius around the site (ET5).	NA	NA	0.74	0.03
Water forming 5km radius around the site (WR5).	NA	NA	0	-0.04
Open ground forming 5km radius around the site (OG5).	NA	NA	0.71	-0.18

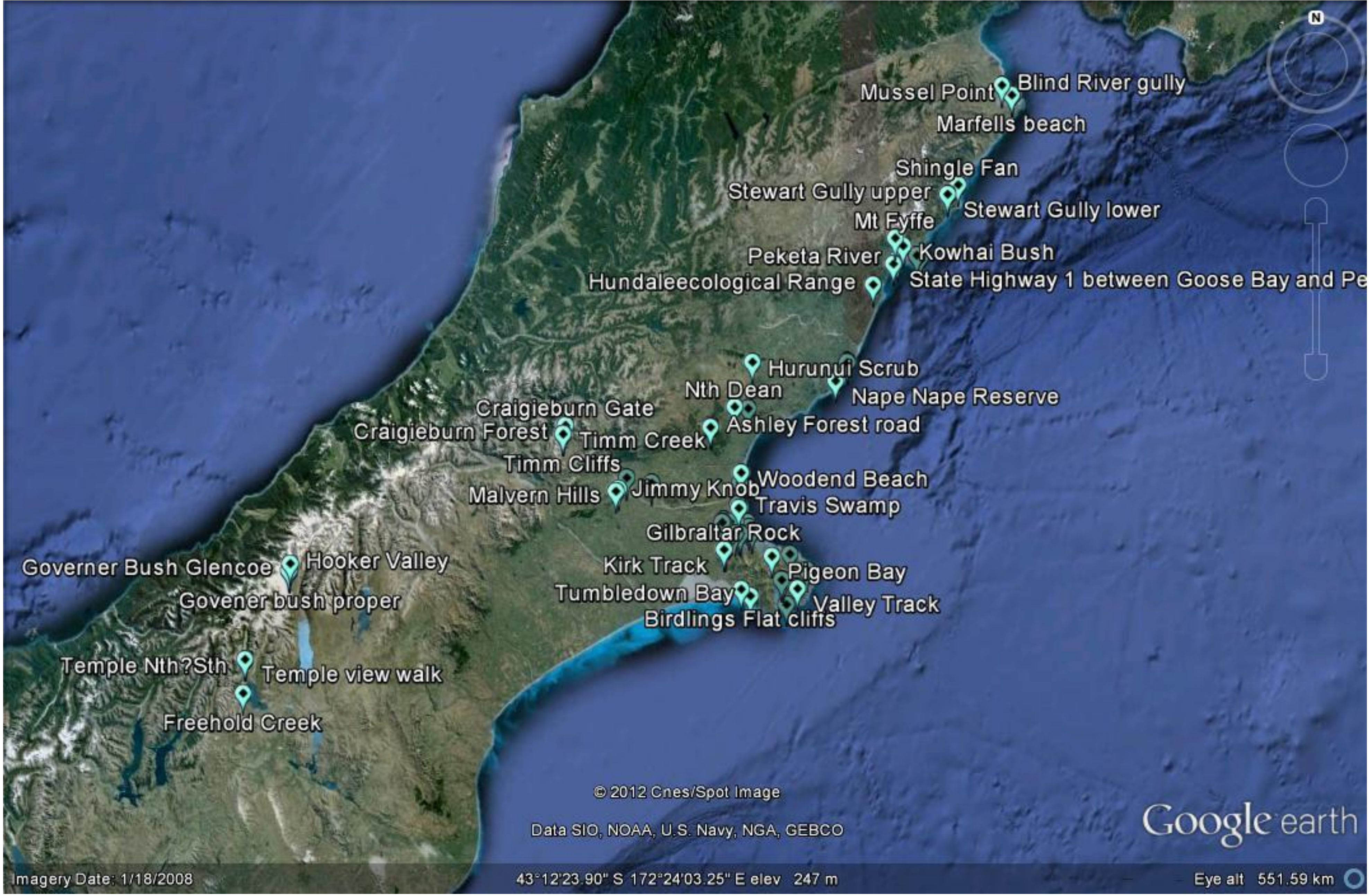

Figure 3.1. Field sites with *Senecio* populations present in the Canterbury region of the South Island of New Zealand.

Chapter Four

4.1. General Discussion

The decline of species around the globe is a worrying trend with land use change and invasive species considered the primary drivers of biodiversity loss (Didham et al. 2007, Tylianakis et al. 2008). The loss of key species within an ecosystem can have a severe impact on the functional diversity of a system and can lead to changes in ecosystem services and function (Loreau et al. 2001, Hooper et al. 2005). In addition, the loss of native species can lead to empty niches, which may allow exotic species to establish within the ecosystem (Mack et al. 2000, Flynn et al. 2009). Since the era of Darwin, but especially in the last two decades, extensive studies have been conducted to determine how exotic species become established within a novel environment and the effect that they have on species interactions within communities (Darwin 1859a, Mitchell and Power 2003, Didham et al. 2005, Funk et al. 2008, Vila and Ibanez 2011). Despite the extensive coverage in the literature, we still do not fully understand the mechanisms that make an exotic species become invasive (Verhoeven et al. 2009, Vila and Ibanez 2011). A steadily increasing body of literature suggests that multiple global change drivers such as landscape composition have a strong effect on the abundance of native and exotic species (Tylianakis et al. 2008, Verhoeven et al. 2009, Schweiger et al. 2010, te Beest et al. 2012). In addition, the conclusions from these studies indicate that there are complex interactive mechanisms which are context and species specific influencing the invasiveness of exotic species and the decline of native species.

The purpose of this thesis is to examine native and exotic New Zealand *Senecio* and the importance of their biostatus, phylogeny, plant size and reproductive state and land use on herbivory and pathogen damage. In addition, my thesis has aimed to explain how these factors influence *Senecio* distribution and abundance throughout the Canterbury region. According to the New Zealand threat classification system list (2002) by the New Zealand Department of Conservation, endemic New Zealand *Senecio* in Canterbury are sparse, range restricted and typically display extreme fluctuations in population size. My results suggest that Canterbury *Senecio* populations are naturally ephemeral with only 86 out of the 293 recorded field sites containing *Senecio* populations in 2010 and 2011, indicating that Canterbury *Senecio* are possibly land use/ disturbance dependent (Chapter 3, Appendix 2).

To determine what factors influence *Senecio* abundance and distribution, the first aim of my study was to reconstruct a phylogeny, which would be used as a tool to determine how New Zealand's *Senecio* are related to one another and how many New Zealand colonisations have occurred. My phylogenies indicate that the colonisation of New Zealand by *Senecio* is a common occurrence with at least twenty two colonisations into New Zealand by *Senecio* (Chapter 2). New Zealand's *Senecio* form three distinct clades according to my nuclear phylogeny and are phylogenetically isolated from one another (Chapter 2). The incongruent patterns within my phylogenies indicate that hybridisation(s) have occurred at least three times between Australasian *Senecio* clades and may form the origins of the Magnificus clade. The exotic species in my phylogenies occupy outlying clades, which according to the Senecioneae phylogeny by Pelser et al. (2007) are phylogenetically isolated from all three Australian clades. The ephemeral nature of *Senecio* populations, their annual/ perennial life history and the minimum of twenty two colonisations *Senecio* have made into New Zealand indicate a potential reliance on disturbed habitats that are easy to colonise and establish within.

Further work is still needed to improve the accuracy of the number of colonisations by *Senecio* into New Zealand as well to conduct molecular dating of the arrival times of New Zealand's *Senecio* (Chapter 1). Molecular dating may explain how frequent colonisations are into New Zealand as well as the preference of the endemic specialist *S. fascigera* for exotic *Senecio*. The preference of *S. fascigera* indicates that there may be an underlying mechanism that influences their host choice. An explanation for *S. fascigera* host preference is that native *Senecio* have novel genotypic and phenotypic traits, which provide less suitable cues to *S. fascigera* adults when selecting a suitable host plant (Mack et al. 2000, Mitchell et al. 2006, Cano et al. 2009). The study by Pelser et al. (2005) concludes that pyrrolizidine alkaloids which are secondary metabolites that are used as powerful chemical defences in *J. vulgaris* and *Senecio* are due to the transient switching on and off of the expression of genes responsible for pyrrolizidine alkaloid specific pathway enzymes. The expression of genes responsible for different pyrrolizidine alkaloids are thought to have evolved due to selection pressure (Pelser et al. 2005). For example, Cano et al. (2009) found that the European invasive populations of *Senecio inaequidens* and

Senecio pterophorus were less palatable than populations in their native ranges to the snail herbivore *Helix aspersa*. The genotypes for both *S. inaequidens* and *S. pterophorus* in invasive European populations displayed a higher concentration of pyrrolizidine alkaloids than native species, which was attributed to their reduced palatability. *Senecio* species and populations may therefore differ in which pyrrolizidine alkaloids are expressed depending on the selection pressure in their environment and over time. If molecular dating can determine the length of time native *Senecio* have been present in New Zealand and have been co-occurring with *S. fascigera*, it may explain why native *Senecio* encounter significantly less occurrences from *S. fascigera* because they express genes that deter *S. fascigera.*

The construction of a phylogeny also enabled me to test if differences in the amount of folivory that *Senecio* species experience from their generalist and specialist herbivores can be explained by differences in their phylogenetic histories. The results of my studies indicate that the clade that a *Senecio* species belongs to has a significant but comparatively weak effect on the amount of folivory that *Senecio* sustain when compared to other factors (Chapter 3). However, three generalist natural enemies of Canterbury *Senecio* displayed strong preferences for *Senecio* in native clades and the endemic specialist herbivore *S. fascigera* displayed a strong preference for *Senecio*, which have originated outside of New Zealand (Chapter 3). Several natural enemies displayed no differentiation in host selection between native and exotic clades. In addition, contrary to my hypotheses the allopolyploids identified in my phylogenies displayed no significant ability to deter herbivores than non-allopolyploid species. However, allopolyploidy was a significant variable in the candidate models created in the third chapter suggesting that allopolyploidy in *Senecio* may provide benefits in a heterogeneous landscape.

My third chapter illustrated that in a heterogeneous landscape, the effects of enemy release and biotic resistance are land use specific. For example, Aphid presence on *Senecio* was highest in land uses where horticulture and exotic forests formed the surrounding habitat but in habitats such as built up areas and open ground they occurred in low abundance. However, *Senecio* populations in horticulture and exotic forest experienced significantly less folivory than in any other land use. In addition, no natural enemies displayed increases in presence in indigenous grasslands within 1km of *Senecio* populations, despite folivory being significantly higher in these environments (Chapter 3). Therefore, enemy release and biotic resistance are unlikely to have a strong effect on *Senecio* abundance and distribution over a landscape scale. However, if the Canterbury region became a simple homogeneous or complex heterogeneous landscape, *Senecio* may encounter increased enemy release and biotic resistance. Rand and Tscharntke (2007) concluded that homogenous landscapes can favour generalist species, which in the case of *Senecio* in native clades may result in higher occurrences of generalist species (i.e. Aphids, *Senecio* leaf miners and *R. coleosporii* (Chapter 3)). However, Rand and Tscharntke (2007) also conclude that if the landscape becomes more complex specialist species can increase in abundance, which may increase the amount of biotic resistance experienced by *Senecio* in exotic clades. Therefore, how *Senecio* in Canterbury respond to increased abundances of natural enemies may influence their abundance and distribution.

My thesis set out to discover the factors which are important for the abundance and distribution of *Senecio* in the Canterbury region. The creation of phylogenies enabled underlying genetic factors to be taken into consideration for variations in abundance, enemy release and biotic resistance. When combined with my ecological analyses, my result indicates that the clade that a *Senecio* is from has a weak bearing on the amount of folivory experienced. However, some of the natural enemies of *Senecio* displayed strong preferences for *Senecio* depending on their clade and biogeographical origin, which may be due to the chemical defences that native and exotic *Senecio* express. The surrounding land use had the strongest effect on *Senecio* folivory, followed by maturity and time of season (Chapter 3). Because of the influence of land use on *Senecio* communities, the likelihood that enemy release and biotic resistance provide a strong influence on *Senecio* abundance and distribution across a heterogeneous landscape is small. Therefore, I suggest that the biggest threat to the survival of native *Senecio* in the Canterbury plains is not the threat from competitively stronger exotic *Senecio* species but the surrounding land use that has been created through anthropogenic means. Further research is needed on the Canterbury *Senecio* community because additional studies may help provide a greater understanding of the underlying mechanisms of why native species are now mostly uncommon in the Canterbury region.

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Appendix I

Taxon	Voucher Number	Voucher data	Voucher location	Date Collected	Collector _ seednr.
Senecio wairauensis Belcher	2602	New Zealand, South Island, Canterbury, McKenzie district, Mt. Cook, Hooker valley	CANU	09/01/2011	A.E Memory 1
Senecio minimus Poir. x Senecio glomeratus Desf. ex Poir.	2603	New Zealand, South Island, Canterbury, Waimakariri, Eyrewell Scientific Reserve.	CANU	04/12/2011	A.E Memory 2
Senecio glomeratus Desf. ex Poir.	2604	New Zealand, South Island, Canterbury, Kaikoura District, Mt Fyffe, Mt Fyffe Trail.	CANU	01/03/2011	A.E Memory 3
Senecio minimus Poir.	2605	New Zealand, South Island, Canterbury, Hurunui District, Ashley Forest, Ashley Forest Road	CANU	04/01/2011	A.E Memory 4
Senecio lautus G.Forst. ex Willd.	2606	New Zealand, South Island, Canterbury, Kaikoura District, Kaikoura, Kaikoura Peninsula	CANU	30/12/2010	A.E Memory 5
Senecio glaucophyllus Cheesem.	2607	New Zealand, South Island, Canterbury, Christchurch District, Christchurch, Port Hills, Mount Vernon	CANU	27/12/2010	A.E Memory 6
Senecio carnosulus (Kirk) C.J. Webb	2608	New Zealand, South Island, Canterbury, Banks Peninsula, Birdlings Flat, Lake Forsyth, Kaitorete Spit	CANU	23/12/2010	A.E Memory 7
Senecio biserratus Belcher	2609	New Zealand, South Island, Canterbury, Christchurch District, Christchurch, Port Hills, Summit Road, Omahu Bush	CANU	20/01/2011	A.E Memory 8
Senecio vulgaris L.	2610	New Zealand, South Island, Canterbury, Kaikoura District, Kekerengu, Shingle Fan	CANU	07/12/2010	A.E Memory 9
Senecio quadridentatus Labill.	2611	New Zealand, South Island, Canterbury, Kaikoura District, Kekerengu, Shingle Fan	CANU	07/12/2010	A.E Memory 10
Senecio hispidulus A.Rich.	2612	New Zealand, South Island, Canterbury, Kaikoura District, Kekerengu, Stewart's Gully	CANU	07/12/2010	A.E Memory 11
Senecio quadridentatus Labill.	2613	New Zealand, South Island, Canterbury, Hurunui District, Waipara, North Dean	CANU	16/12/2010	A.E Memory 12
Senecio glomeratus Desf. ex Poir.	2614	New Zealand, South Island, Canterbury, Banks Peninsula, Robinson's Bay	CANU	23/12/2010	A.E Memory 13
Senecio glomeratus Desf. ex Poir.	2615	New Zealand, South Island, Canterbury, Banks Peninsula, Le Bons Bay	CANU	23/12/2010	A.E Memory 14
Senecio elegans L.	2616	New Zealand, South Island, Canterbury, Banks Peninsula, Le Bons Bay	CANU	23/12/2010	A.E Memory 15

Jacobaea vulgaris Gaertn.	2617	New Zealand, South Island, Canterbury, Waimakariri, Jimmy's Knob.	CANU	29/12/2010	A.E Memory 16
Senecio lautus G.Forst. ex Willd.	2618	New Zealand, South Island, Canterbury, Hurunui District, Cheviot, Gore Bay, Manukau Bluffs	CANU	30/12/2010	A.E Memory 17
Senecio elegans L.	2619	New Zealand, South Island, Canterbury, Hurunui District, Cheviot, Gore Bay	CANU	30/12/2010	A.E Memory 18
Senecio glomeratus Desf. ex Poir.	2620	New Zealand, South Island, Canterbury, Kaikoura District, Peketa, State Highway 1	CANU	30/12/2010	A.E Memory 19
Senecio hispidulus A.Rich.	2621	New Zealand, South Island, Canterbury, Kaikoura District, Peketa, State Highway 1	CANU	30/12/2010	A.E Memory 20
Senecio lautus G.Forst. ex Willd.	2622	New Zealand, South Island, Canterbury, Kaikoura District, Peketa, State Highway 1	CANU	30/12/2010	A.E Memory 21
Senecio quadridentatus Labill.	2623	New Zealand, South Island, Canterbury, Kaikoura District, Peketa, State Highway 1	CANU	30/12/2010	A.E Memory 22
Senecio wairauensis Belcher	2624	New Zealand, South Island, Canterbury, Kaikoura District, Peketa, State Highway 1	CANU	30/12/2010	A.E Memory 23
Jacobaea maritima (L.) Pelser & Meijden	2625	New Zealand, South Island, Canterbury, Kaikoura District, Kaikoura, Kaikoura Peninsula, UC Edward Percival Field Station	CANU	30/12/2010	A.E Memory 24
Senecio hispidulus A.Rich.	2626	New Zealand, South Island, Canterbury, Kaikoura District, Kekerengu, Stewart's Gully	CANU	31/12/2010	A.E Memory 25
Senecio glomeratus Desf. ex Poir.	2627	New Zealand, South Island, Canterbury, Kaikoura District, Kekerengu, Stewart's Gully	CANU	01/02/2010	A.E Memory 26
Senecio vulgaris L.	2628	New Zealand, South Island, Canterbury, Kaikoura District, Kekerengu, Stewart's Gully	CANU	02/02/2010	A.E Memory 27
Senecio wairauensis Belcher	2629	New Zealand, South Island, Canterbury, McKenzie district, Mt. Cook, Governer's Bush, Glencoe.	CANU	09/01/2011	A.E Memory 28
Senecio wairauensis Belcher	2630	New Zealand, South Island, Canterbury, McKenzie district, Mt. Cook, Governer's Bush Proper, Glencoe.	CANU	09/01/2011	A.E Memory 29
Senecio wairauensis Belcher	2631	New Zealand, South Island, Canterbury, McKenzie district, Hopkins Valley, Temple Valley, Temple View Walk	CANU	10/01/2011	A.E Memory 30
Senecio wairauensis Belcher	2632	New Zealand, South Island, Canterbury, McKenzie district, Hopkins Valley, Freehold Creek	CANU	10/01/2011	A.E Memory 31

Jacobaea vulgaris Gaertn.	2633	New Zealand, South Island, Canterbury, McKenzie district, Hopkins Valley, Temple Valley, Temple North/South Apex	CANU	11/01/2011	A.E Memory 32
Senecio quadridentatus Labill.	2634	New Zealand, South Island, Canterbury, Banks Peninsula, Pigeon Bay	CANU	14/01/2011	A.E Memory 33
Senecio glomeratus Desf. ex Poir.	2635	New Zealand, South Island, Canterbury, Banks Peninsula, Pigeon Bay	CANU	14/01/2011	A.E Memory 34
Senecio glomeratus Desf. ex Poir.	2636	New Zealand, South Island, Canterbury, Banks Peninsula, Takamatua	CANU	14/01/2011	A.E Memory 35
Senecio glomeratus Desf. ex Poir.	2637	New Zealand, South Island, Canterbury, Christchurch, Bottlelake Plantation	CANU	20/01/2011	A.E Memory 36
Senecio vulgaris L.	2638	New Zealand, South Island, Canterbury, Christchurch, Bottlelake Plantation	CANU	20/01/2011	A.E Memory 37
Senecio sylvaticus L.	2639	New Zealand, South Island, Canterbury, Christchurch, Bottlelake Plantation	CANU	20/01/2011	A.E Memory 38
Senecio biserratus Belcher	2640	New Zealand, South Island, Canterbury, Christchurch District, Christchurch, Port Hills, Summit Road, Omahu Bush	CANU	20/01/2011	A.E Memory 39
Senecio quadridentatus Labill.	2641	New Zealand, South Island, Canterbury, Banks Peninsula, Little Akaloa	CANU	14/02/2011	A.E Memory 40
Senecio elegans L.	2642	New Zealand, South Island, Canterbury, Banks Peninsula, Okains Bay	CANU	14/02/2011	A.E Memory 41
Senecio carnosulus (Kirk) C.J. Webb	2643	New Zealand, South Island, Canterbury, Banks Peninsula, Akaroa, Akaroa Head Reserve	CANU	14/02/2011	A.E Memory 42
Senecio glomeratus Desf. ex Poir.	2644	New Zealand, South Island, Canterbury, Banks Peninsula, Birdlings Flat, Lake Forsyth, Kaitorete Spit	CANU	15/02/2011	A.E Memory 43
Senecio glaucophyllus Cheesem.	2645	New Zealand, South Island, Canterbury, Banks Peninsula, Tumbledown Bay	CANU	15/02/2011	A.E Memory 44
Senecio glaucophyllus Cheesem.	2646	New Zealand, South Island, Canterbury, Christchurch District, Christchurch, Port Hills, Gibraltar Rock	CANU	16/02/2011	A.E Memory 45
Senecio glaucophyllus Cheesem.	2647	New Zealand, South Island, Canterbury, Christchurch District, Christchurch, Port Hills, Castle Rock	CANU	16/02/2011	A.E Memory 46
Senecio hispidulus A.Rich.	2648	New Zealand, South Island, Canterbury, Kaikoura District, Peketa, State Highway 1	CANU	28/02/2011	A.E Memory 47

Senecio hispidulus A.Rich.	2649	New Zealand, South Island, Canterbury, Hurunui District, Hundalees, State Highway 1	CANU	28/02/2011	A.E Memory 48
Senecio lautus G.Forst. ex Willd.	2650	New Zealand, South Island, Canterbury, Kaikoura District, Kaikoura, Kaikoura Peninsula, Seal Colony	CANU	28/02/2011	A.E Memory 49
Senecio vulgaris L.	2651	New Zealand, South Island, Canterbury, Kaikoura District, Kaikoura, Kaikoura Peninsula, UC Edward Percival Field Station	CANU	02/03/2011	A.E Memory 50
Senecio quadridentatus Labill.	2652	New Zealand, South Island, Canterbury, Hurunui District, Waipara, South Dean	CANU	03/03/2011	A.E Memory 51
Senecio vulgaris L.	2653	New Zealand, South Island, Canterbury, Hurunui District, Hurunui Scrub Underneath the Hurunui Bridge	CANU	03/03/2011	A.E Memory 52
Senecio vulgaris L.	2654	New Zealand, South Island, Canterbury, Christchurch District, Christchurch, Woolston, Hargood Street	CANU	26/03/2011	A.E Memory 53
Senecio wairauensis Belcher	2655	New Zealand, South Island, Canterbury, Cass Ecological District, Craigieburn Forest	CANU	28/03/2011	A.E Memory 54
Senecio wairauensis Belcher	2656	New Zealand, South Island, Canterbury, Cass Ecological District, Craigieburn Forest	CANU	28/03/2011	A.E Memory 55
Senecio skirrhodon DC.	2657	New Zealand, South Island, Canterbury, Christchurch District, Christchurch, Old Stock Yards, Deans Ave	CANU	04/04/2011	A.E Memory 56
Senecio hispidulus A.Rich.	2658	New Zealand, South Island, Canterbury, Hurunui District, Hundalees, State Highway 1	CANU	40602	A.E Memory 57
Senecio quadridentatus Labill.	2659	New Zealand, South Island, Canterbury, Cass Ecological District, Craigieburn Forest	CANU	40806	A.E Memory 58
Senecio minimus Poir.	2660	New Zealand, South Island, Canterbury, Christchurch District, Christchurch, Port Hills, Summit Road, Omahu Bush	CANU	16/02/2011	A.E Memory 59
Microseris lanceolata	2661	New Zealand, South Island, Canterbury, Marlborough district, Marfells Beach, Mussel Point	CANU	12/09/2011	A.E Memory 60
Senecio dunedinensis Belcher	2662	New Zealand, South Island, Canterbury, Kaikoura District	Lincoln University Herbarium	23/11/2011	JJS-111007-51
Senecio sterquilinus Ornduff	2663	New Zealand, South Island, West Coast, Cape Foulwind, Tauranga Bay	Landcare Herbarium	23/11/2011	CHR479217
Senecio radiolatus radiolatus F.Muell	2664	New Zealand, Chatham Islands	Landcare Herbarium	23/11/2011	CHR301153

Senecio dunedinensis Belcher	2665	New Zealand, South Island, Canterbury, The Growler, Two Thumb Range	Landcare Herbarium	23/11/2011	CHR469206
Senecio glomeratus Desf. ex Poir.	2666	New Zealand, South Island, Canterbury, Hurunui district, Woodend Beach	CANU	27/09/2011	A.E Memory 61
Senecio glomeratus Desf. ex Poir.	2667	New Zealand, South Island, Canterbury, Hurunui, The Pines	CANU	27/09/2011	A.E Memory 62
Senecio sylvaticus L.	2668	New Zealand, South Island, Canterbury, Christchurch, Bottlelake Plantation	CANU	6/09/2011	A.E Memory 63
Senecio hispidulus A.Rich.	2669	New Zealand, South Island, Canterbury, Kaikoura District, Peketa, State Highway 1	CANU	10/09/2011	A.E Memory 64
Senecio glomeratus Desf. ex Poir.	2670	New Zealand, South Island, Canterbury, Christchurch, Travis Swamp	CANU	6/09/2011	A.E Memory 65
Senecio glomeratus Desf. ex Poir.	2671	New Zealand, South Island, Canterbury, Christchurch, Bottlelake Plantation	CANU	6/09/2011	A.E Memory 66
Senecio vulgaris L.	2672	New Zealand, South Island, Canterbury, Christchurch, Addington, CBS Arena	CANU	5/09/2011	A.E Memory 67
Senecio elegans L.	2673	New Zealand, South Island, Canterbury, Christchurch, Sumner, Cave Rock	CANU	6/09/2011	A.E Memory 68
Senecio elegans L.	2674	New Zealand, South Island, Canterbury, Christchurch, New Brighton Beach	CANU	6/09/2011	A.E Memory 69
Senecio quadridentatus Labill.	2675	New Zealand, South Island, Canterbury, Kaikoura district, Kowhai Bush	CANU	13/09/2011	A.E Memory 70
Senecio glaucophyllus Cheesem.	2676	New Zealand, South Island, Canterbury, Marlborough district, Marfells Beach, Mussel Point	CANU	12/09/2011	A.E Memory 71
Senecio quadridentatus Labill.	2677	New Zealand, South Island, Canterbury, Cass Ecological District, Craigieburn Forest, Timm's Creek	CANU	18/09/2011	A.E Memory 72
Senecio minimus Poir.	2678	New Zealand, South Island, Canterbury, Hurunui District, Ashley Forest, Ashley Forest Road	CANU	26/09/2011	A.E Memory 73
Senecio quadridentatus Labill.	2679	New Zealand, South Island, Canterbury, Sheffield, Malvern Hills Road	CANU	27/09/2011	A.E Memory 74
Senecio quadridentatus Labill.	2680	New Zealand, South Island, Canterbury, Sheffield, Malvern Water Race	CANU	27/10/2011	A.E Memory 75
Senecio elegans L.	2681	New Zealand, South Island, Canterbury, Hurunui District, Cheviot, Gore Bay	CANU	21/10/2011	A.E Memory 76
Senecio lautus G.Forst. ex Willd.	2682	New Zealand, South Island, Canterbury, Hurunui District, Cheviot, Gore Bay, Manukau	CANU	21/10/2011	A.E Memory 77

		Bluffs			
Senecio lautus G.Forst. ex Willd.	2683	New Zealand, South Island, Canterbury, Marlborough district, Marfells Beach, Mussel Point	CANU	23/10/2011	A.E Memory 78
Senecio hauwai Skyes	2684	New Zealand, South Island, Canterbury, Marlborough district, Marfells Beach, Blind Stream Gully	CANU	23/10/2011	A.E Memory 79
Senecio carnosulus (Kirk) C.J. Webb	2685	New Zealand, South Island, Canterbury, Banks Peninsula, Birdlings Flat, Lake Forsyth, Kaitorete Spit	CANU	30/10/2011	A.E Memory 80
Senecio elegans L.	2686	New Zealand, South Island, Canterbury, Banks Peninsula, Birdlings Flat, Lake Forsyth, Kaitorete Spit	CANU	30/10/2011	A.E Memory 81
Senecio glaucophyllus Cheesem.	2687	New Zealand, South Island, Canterbury, Banks Peninsula, Tumbledown Bay	CANU	30/10/2011	A.E Memory 82
Senecio minimus Poir.	2688	New Zealand, South Island, Canterbury, Banks Peninsula, Hinewai Bush, Valley Track	CANU	29/10/2011	A.E Memory 83
Senecio minimus Poir.	2689	New Zealand, South Island, Canterbury, Banks Peninsula, Hinewai Bush	CANU	29/10/2011	A.E Memory 84
Senecio carnosulus (Kirk) C.J. Webb	2690	New Zealand, South Island, Canterbury, Banks Peninsula, Akaroa, Akaroa Head Reserve	CANU	30/10/2011	A.E Memory 85
Crassocephalum crepidioides (Benth.) S.Moore	354	Pelser, Gravendeel & Van der Meijden			Pelser cult. 354
Senecio sterquilinus Ornduff.	2571		CHR 479560		P.J. de Lange 1516 with G.M. Crawcroft
Senecio anethifolius A.Cunn. ex DC.	2058		MSC		R.D. Pearce 134
Senecio australis Willd.	1729		MO		W.T. Stearn 5
Senecio banksii Hook.f.	2582	New Zealand, North Island, Gisborne Land District, Urewera National Park, above Whanganui Inlet. Rocky cliff	CHR		Druce s.n.
Senecio bathurstianus (DC.) Sch.Bip.	1478	Australia, Victoria, Kilmore	MEL		I.R. Thompson 910
Senecio bipinnatisectus Belcher	541	New Zealand, North Island, Waitema County, Milford, Penning Rd., Map: N42 277705, 36.46S 174.45E, 20-Feb-1979.	L		E.B. Bangerter 5409
Senecio biserratus Belcher	540	Australia, New South Wales, Billangabee Creek, Ben Boyd National Park (19 km SE. of Eden), 37.13S 150.01E, 16-Oct-1974.	L		R. Coveny 5802 & J. Armstrong

Senecio cadiscus B.Nord. & Pelser	1217	South Africa, Western Cape, 3319 (Cape Town) AB. Vernal pools at Sandvlei turnoff, 13 km east of Hopefield, 24-AUG-1997	MO	P. Goldblatt & J. Manning 10690
Senecio campylocarpus I.Thomps.	1483	Australia, Victoria, Cockatoo	MEL	I.R. Thompson 917
Senecio cunninghamii DC. var. cunninghamii	1479	Australia, New South Wales, 2 miles W of Balranald - Ivanhoe rd. on rd. to Arumpo, 14-Oct-1971	L	I.R. Thompson 911
Senecio cunninghamii DC.	634	Australia, Victoria, Durham Ox	MEL	C.W.E Moore 6074
Senecio diaschides D.G.Drury	1495	Australia, Victoria, Licola	MEL	I.R. Thompson 976
Senecio distalilobatus I.Thomps	1492	Australia, Victoria, Bentley Plain	MEL	I.R. Thompson 947
Senecio dolichocephalus I.Thomps.	1839	Australia, Victoria, Glenlee FFR, October 2007	MEL	I.R. Thompson 987
Senecio dunedinensis Belcher	2576	New Zealand, South Island, Otago Land District, St Bathans Ra., Dunstan Creek. Rocky slopes.	CHR	J. Barkla s.n.
Senecio dunedinensis Belcher	2577	New Zealand, Southland Land District, Mount Campbell, In open vegetation on steep slope. West face of mountain.	CHR	Wardle 96/29 with R.P. Buxton
Senecio esleri C.J. Webb	2592	New Zealand, North Island, Auckland, West Auckland, Waitemata. Near old graves in waste place. Stems erect, c. 35 cm high. A number of plants; not yet flowering.	CHR	W.R. Sykes 491/87
Senecio esleri C.J. Webb	2593	New Zealand, North Island, Waikato Ecological Region, Hamilton Ecological District, Hamilton City, Rototuna, Sexton Road, Oderlings Nursery Grounds	CHR	P.J. de Lange 7031 with T.J. de Lange & F.J.T. de Lange
Senecio elegans L.	1549	South Africa, Wilderness, dunes near Flat Bed beach, 3422BA	J	Cron & Goodman 687
Senecio extensus I.Thomps.	1846	Australia, Victoria, Howitt Plains, February 2002	MEL	I.R. Thompson s.n.
Senecio gawlerensis M.E. Lawrence	2061	Australia, South Australia, Gawler Ranges near the summit of Mt. Nott, 9 km S of Thurlga H.S. Yardea sheet grid 381979,	MSC	D.E. Symon 8046A
Senecio glaucophyllus Cheesem. ssp. basinudus Ornduff	2062	New Zealand, Okairns Bay, Banks Peninsula	MSC	W.R. Sykes 496/69
Senecio glaucophyllus Cheesem. ssp. glaucophyllus	2599	New Zealand, South Island, Canterbury, Birdlings Flat	CHR	I. Hanken s.n.
Senecio glomeratus Desf. ex Poir. ssp. glomeratus	1477	Australia, Victoria, Upper Beaconsfield	MEL	I.R. Thompson 909
Senecio glomeratus Desf. ex Poir.	2487	New Zealand, South Island, Canterbury, Port Hills, Kennedy’s Bush, c. 200 m south of coordinates	CANU	P.B. Pelser 2487 with C. Mennes

Senecio gramineus Harv.	939	Lesotho 2929CC (Underberg). Sehlabathebe Nat'l Park: matsa a Mafikeng. Alt. 2450m. 1-Dec-1978.	WAG	F.K. Hoener 2104
Senecio gregorii F.Muell.	666	Australia, NSW, Fowlers Gap near Broken Hill, 31.05S 141.40E, 7-Oct-1975	L	S. Jacobs 2180
Senecio gunnii (Hook.f.) Belcher	1493	Australia, Victoria, Bentley Plain	MEL	I.R. Thompson 948
Senecio halophilus I.Thomps.	1470	Australia, Victoria, Lake Goldsmith	MEL	I.R. Thompson 902
Senecio hispidissimus I.Thomps.	1487	Australia, Victoria, Mt. Richmond	MEL	I.R. Thompson 927
Senecio hispidulus A.Rich.	1476	Australia, Victoria, Upper Beaconsfield	MEL	I.R. Thompson 908
Senecio hispidulus A.Rich.	2499	New Zealand, South Island, Westland, Kelly’s Creek, along Cockayne Nature Trail	CANU	P.B. Pelser & J.F. Barcelona 10
Senecio hypoleucus F.Muell. ex Benth.	2098	Australia, South Australia, Mt. Lofty Range, Mt. Lofty Botanic Garden, ca. 12 km south-east of Adelaide. CULTIVATED	US	R.H. Kuchel 1495
Senecio kermadecensis Belcher	2093	New Zealand, Raoul, Darcy Point Rdige	US	W.R. Sykes 1183/K
Senecio lanibracteus I.Thomps.	2097	Australia, South Australia, Region 5, Flinders, 1 km S Bruce on Hammond Carrieton road	US	R. Merrill King 9627 & L. Haegi
Senecio pinnatifolius A.Rich.	1732	Australia, Victoria, Lowan Mallee. Little Desert National Park, central block. Broughtons Waterhole, 23 km SSE of Kaniva. Vic. grid ref.: C 30.	MO	I.C. Clarke 2318
Senecio pinnatifolius A.Rich.	2064	Australia, New South Wales, Millfield on the Cessnock-Wollombi Road	MSC	R. Coveny 6497 & J. Powell
Senecio lautus G.Forst. ex Willd. ssp. esperensis (Sykes) de Lange	2581	New Zealand, Kermadec Islands [North Auckland Land District], L'Esperance, near helipad. Growing near summit by fuel dump and helipad.	CHR	R. Williams s.n.
Senecio lautus G.Forst. ex Willd. ssp. lautus	2489	New Zealand, South Island, Canterbury, north of Kaikoura, along main road and rail way	CANU	P.B. Pelser & J.F. Barcelona 6
Senecio linearifolius A.Rich. var. linearifolius	1484	Australia, Victoria, Simpson	MEL	I.R. Thompson 919
Senecio longicollaris I.Thomps.	1849	Australia, Victoria, Numurkah, July 2002	MEL	I.R. Thompson 766
Senecio macrocarpus F.Muell. ex R.O. Belcher	1847	Australia, Victoria, Deep Lead, August 2001	MEL	I.R. Thompson 658
Senecio madagascariensis Poir.	KAD73	Argentina, Yala-Tal. Cultivated at Botanischer Garten der Johannes Gutenberg-Universität Mainz	MJG	Kubitzki s.n.
Senecio magnificus F.Muell.	2066	Australia, South Australia, Flinders Ranges, 14.8 km east north east of Lyndhurst on main road to Mt. Lyndhurst H.S.	MSC	P. Short 749

Senecio mairetianus DC.	616	Mexico, Mexico, Mpio. de Atlautla. Tlamacas, 500 m. al Norte del albergue, 4000m., 18-Oct-1976	L	J. Garcia P. 151
Senecio minimus Poir.	1488	Australia, Victoria, Gorae West	MEL	I.R. Thompson 935
Senecio minimus Poir.	2488	New Zealand, South Island, Westland, along Tourist Cave trail	CANU	P.B. Pelser 2488 with C. Mennes
Senecio nigrapicus I.Thomps.	1848	Australia, Victoria, Howitt Plains, February 2002	MEL	I.R. Thompson 760a
Senecio odoratus Horn.	1474	Australia, Victoria, Tyabb	MEL	I.R. Thompson 906
Senecio phelleus I.Thomps.	1471	Australia, Victoria, Tyabb	MEL	I.R. Thompson 903
Senecio picridioides (Turcz.) M.E.Lawr.	1490	Australia, Victoria, Moyston	MEL	I.R. Thompson 941
Senecio prenanthoides A.Rich.	1482	Australia, Victoria, Upper Beaconsfield	MEL	I.R. Thompson 915
Senecio psilocarpus R.O. Belcher & D.E. Albrecht	1489	Australia, Victoria, Gorae West	MEL	I.R. Thompson 937
Senecio psilophyllus I.Thomps.	1841	Australia, New South Wales, Booderee, September 2003	MEL	I.R. Thompson 790a
Senecio quadridentatus Labill.	1469	Australia, Victoria, Moyston	MEL	I.R. Thompson 899
Senecio rosmarinifolius L.f.	2126	South Africa, Cape, Die Kanolle, Helpmekaar, Koue-Bokkeveld, 3219 CD	US	W.J. Hanekom 2553
Senecio rufiglandulosis Colenso	2596	New Zealand, Wellington Land District, Whana Huia Range, below Rangi Hut.	CHR	D. Glenny 6796
Senecio rufiglandulosis Colenso	2597	New Zealand, South Island, Fyfe G., NW Nelson, side of large marble boulder. Feb 1989	CHR	A.P. Druce s.n.
Senecio runcinifolius J. H. Willis	1842	Australia, Victoria, Numurkah, September 2001	MEL	I.R. Thompson 679
Senecio scaberulus (Hook.f.) D.G.Drury	2568	New Zealand, South Auckland Land District, Hunua, Kawakawa Bay, Papanui Point, Coastal forest in semi-shade. Scarce - scattered plants amongst Senecio hispidulus growing on an old slip and in cracks of argillite bluffs just above the sea.	CHR	P.J. de Lange 1827
Senecio scaberulus (Hook.f.) D.G.Drury	2569	Cultivated in New Zealand, North Island, Auckland, 16 Jesmond Tce, Mt Albert	CHR	P.J. de Lange 5379
Senecio spanomerus I.Thomps.	1844	Australia, Victoria, Glenlee FFR, August 2001	MEL	I.R. Thompson 657
Senecio spathulatus A.Rich. var. latifructus I.Thomps.	1494	Australia, Victoria, Lakes Entrance	MEL	I.R. Thompson 953
Senecio squarrosus A.Rich.	1475	Australia, Victoria, Bittern	MEL	I.R. Thompson 907
Senecio telekii (Schweinf.) O.Hoffm.	856	Tanzania, Kilimanjaro, between Horombo Hut and Saddle, S-slope; 3950m; 17-Jul-1967.	U	E. Zogg & H. Gassner 05/16

Senecio vulgaris L.		188	Cult. Grown from seed from: Austria, S, Sbg, Rott, Siezenheim, Ruderal, Schotter, 420 m.s.m., 5/98 M	L	Pelser cult. 188
Senecio wairauensis Belcher		2096	New Zealand, Jims Stream, Craigeburn Range, Canterbury	CANU	P.B. Pelser 2501
Senecio wairauensis Belcher		2389	New Zealand, South Island, Canterbury, Arthur's Pass National Park, Otira Valley, along track near bridge, in wet grassland	CANU	P.B. Pelser 2389 with J.F. Barcelona
Senecio wairauensis Belcher		2501	New Zealand, South Island, Canterbury, Craigieburn Forest Park, Craigieburn Ski Field, along road between parking lot and ski field; approximate coordinates	US	D.G. Drury 175201
Senecio ilicifolius L.		1548	South Africa, Prince Alfred's Pass, c. 2 km from Avontuur, 3323CC	J	Cron & Goodman 686
Senecio variifolius DC.		1782	South Africa, W. Cape, Wuppertal, 3219 CA, Citrusdal; Kleinplaas.	MO	W.J. Hanekom 2889
Senecio oerstedianus Benth. ex Oerst.	B3		Costa Rica 1993	S	B. Nordenstam 9160
Senecio fistulosus Poepp. ex Less.		710	Bolivia, Depto. Tarija, prov. O'Connor. Entre Rios 8 kms. Hacia Villamontes. 1180m. 23-Oct-1983	S	S.G. Beck & M. Liberman 9672
Senecio algens Wedd.		683	Bolivia, Depto. La Paz, prov. Omasuyo(?), del camino principal a Penas. 40 km via mina Fabulosa: Moro-Khala. 5000m. 18-Feb-1980	S	S.G. Beck 2879
Senecio nevadensis Boiss. & Reut. ssp. malacitanus (Huter) Greuter		1668	Spain, Prov. Almeria, Cantera de Yeso, El Duende, Grid Ref.: 30S 589503E 4128859N	RNG	S.L. Jury 20211
Senecio brassii Belcher		538	New Guinea, Northern slopes of Sugarloaf complex (near Wapu river), Wabag subdistrict, Western Highlands, Terr. Of New Guinea, 9500 ft., 19-Jul-1960.	L	R.D. Hoogland & R. Schodde 7160
Senecio macranthus A.Rich.		2065	Australia New South Wales, Edwards Look-out at Wollomombi Falls	MSC	N.S. Lander 505
Senecio macranthus A.Rich.		618	Australia, New South Wales, Gulf Stream, Winburndale Nature Reserve (20 km east of Bathurst) 33.25S 149.48E, 2-Oct-1977	L	R. Coveny 9627
Senecio glabrescens (DC.) Sch.Bip.		1845	Australia, Victoria, Victoria Valley, Grampians, February 2003	MEL	N. Middleton s.n.
Senecio banksii Hook.f.		2582		CHR	Druce s.n.
Senecio banksii Hook.f.		2583	New Zealand, North Island, Gisborne Land District, Urewera National Park, above Whanganui Inlet. Rocky cliff	CHR	I. Breitwieser 2190 with K. Ford & S. Wagstaff
Senecio bipinnatisectus Belcher		2584	New Zealand, North Island, North Auckland District, Waitemata County. Milford, Penning Road	CHR	E.B. Bangerter 5409

Senecio bipinnatisectus Belcher	2585		CHR	Ogle 1054
Senecio biserratus Belcher	2590	New Zealand, South Island, Marlborough, Monkey Bay, between Rarangi Beach and Whites Bay. in sharp shingle below rocks in sea spray zoneAssociate species Senecio sp. aff. Senecio lautus/carnosulus. Plants of Marlborough. New ZealandNon-flowering. Lvs purple below, green and rough above. One plant only. This is very far north for this coastal species.	CHR	D.G. Drury s.n.
Senecio carnosulus (Kirk) C.J. Webb	2595	New Zealand, South Island, Otago Land District, Green Island. Coastal terrace herbfield.	CHR	J. Barkla s.n.
Senecio diaschides D.G.Drury	2586	New Zealand, North Auckland District, Aupori Ecological District, Mt Camel, Waingarara Stream. Common along stream sides in open seral forest.	CHR	P.J. de Lange 1879
Senecio diaschides D.G.Drury	2587		CHR	Mason & Esler 11399
Senecio glaucophyllus Cheesem. ssp. glaucophyllus	2599	New Zealand, South Island, Canterbury, Birdlings Flat	CHR	I. Hanken s.n.
Senecio hauwai Sykes	2559	New Zealand, South Island, Marlborough, Marfell Beach, From cuttings collected during September 1991.	CHR	P.J. de Lange 1020 with P. Simpson
Senecio hauwai Sykes	2560	New Zealand, South Island, Marlborough, Kekerengu, eastern extremity of Marfells Beach, First gully at end of beach, on siltstone cliffs usually devoid of other species.	CHR	P.J. de Lange 1912
Senecio hypoleucus F.Muell. ex Benth.	2588	Cultivated at Christchurch Botanic Gardens, Christchurch	CHR	D. Barwick s.n.
Senecio hypoleucus F.Muell. ex Benth.	2589	Seedlings from plant cultivated at Christchurch Botanic Gardens, Christchurch	CHR	D. Barwick s.n.
Senecio kermadecensis Belcher	2561	New Zealand, Kermadec Islands, Raoul Island, Mahoe, on track	CHR	J. Parkes s.n.
Senecio lautus G.Forst. ex Willd. ssp. lautus	2579	New Zealand, South Island, Nelson Land District, Punakaiki. Soil in rock crevices on roadside.	CHR	C.J. Webb & M. O’Brian s.n.
Senecio lautus G.Forst. ex Willd. ssp. esperensis (Sykes) de Lange	2580	Cultivated, Botany Division, Lincoln, glasshouse	CHR	W.R.Sykes 894/K
Senecio lautus G.Forst. ex Willd. ssp. esperensis (Sykes) de Lange	2581	New Zealand, Kermadec Islands [North Auckland Land District], L'Esperance, near helipad. Growing near summit by fuel dump and helipad.	CHR	R. Williams s.n.
Senecio marotiri C.J.Webb	2562		CHR	P.J. de Lange CH585 with P.B. Heenan

Senecio radiolatus F.Muell. ssp. radiolatus	2572		CHR	W.R. Sykes s.n.
Senecio radiolatus F.Muell. ssp. radiolatus	2573		CHR	W.R. Sykes 431/93
Senecio radiolatus F.Muell. ssp. antipodus (Kirk) C.J.Webb	2574		CHR	Godley s.n.
Senecio radiolatus F.Muell. ssp. antipodus (Kirk) C.J.Webb	2575		CHR	Godley s.n.
Senecio repangae de Lange & B.G.Murray ssp. pokohinuensis de Lange & B.G.Murray	2564	New Zealand, North Auckland Land District, Taranga, Eastern Northland Ecological Region, Mokohinau Islands, Motukono (Fanal) Island	CHR	P.J. de Lange s.n.
Senecio repangae de Lange & B.G.Murray ssp. pokohinuensis de Lange & B.G.Murray	2565		CHR	P.J. de Lange 5374
Senecio sterquilinus Ornduff	2570	New Zealand, Wellington, Wellington Ecological District, Somes (Matiu) Island, Throughout coastal areas in guano enriched soils, on rock and gravel. Up to 1.2m tall, very large, succulent plants with villous leaf under-sides and capitula 2-3cm in diameter (on some plants). Sympatric with S. Lautus.	CHR	P.J. de Lange 1041
Senecio sterquilinus Ornduff	2571	Wellington, Wellington Ecological District, Wellington Harbour, Mokopuna Island, Rock outcrops and cliff faces along southern and SE side of island only.Also growing with Elymus sp. ` blue '. confined to southeastern side of the island where it is a common component of rockstack and coastal turf vegetation.	CHR	P.J. de Lange 1516 with G.M. Crawcroft

Appendix II

Taxon	Site	Collection Date	Site Coordinates
Senecio sylvaticus L.	Canterbury, Banks Peninsula: above Goughs Bay.	2 JAN 1984	173.068333333333 - 43.7666666666667
Senecio sylvaticus L.	Banks Peninsula, North side of Lake Forsyth	10-Jan-80	
Senecio glaucophyllus Cheeseman subsp. basinudus Ornd.	Canterbury, Le Bons Bay, Banks Peninsula.	12 JAN 1983	173.094446 - 43.743487
Senecio glaucophyllus Cheeseman	Zig Zag, Canterbury	7/07/1971	173.094446 - 43.743487
Senecio angulatus L.f. (Cape ivy)	Cape ivy Naturalised 0.75 hours Overcast Governors Bay	9/06/1971	S8416447
Senecio elegans L.	Canterbury, Okains Bay seafront	7-Nov-85	173.06062237 - 43.69412719
Senecio glaucophyllus Cheeseman subsp. basinudus Ornd.	Canterbury, Le Bons Bay, Banks Peninsula.	12-Jan-83	173.094446 - 43.743487
Senecio carnosulus	Kaitorete Spit	8-Oct-08	2461628 5705873
Senecio carnosulus (Kirk) C.J.Webb	Canterbury, Kaitorete, near Lake Forsyth outlet	2-Sep-85	M37 865 088 S94 062 199
Senecio carnosulus (Kirk) C.J.Webb	Dan Roger's Creek, Akaroa Heads, Canty	30-Nov-01	
Senecio elegans L.	Canterbury, Okains Bay seafront	7 Nov.1985	S85 376 357 N36 149 237
Senecio elegans	Le Bons Bay		
Senecio glaucophyllus Cheesem.	nr. Akaroa Lighthouse.	7.11.1974	
Senecio glaucophyllus Cheeseman subsp. basinudus Ornd.	Canterbury, Le Bons Bay, Banks Peninsula.	12-Jan-83	E36 52- 12- S86 40- 30-
Senecio sylvaticus	Banks Peninsula, Hinewai Reserve, The Stones Track near The Stones.	01 02 2001	N37 125 080
Senecio elegans L.	Birdlings Flat, Lake Ellesmere/Lake Forsyth	8-Feb-00	M37 863 089
Senecio hispidulus	Banks Peninsula, Port Hills, Dyers Pass Road between Victoria Park and the Sign of the Kiwi.	27 9 00	M36 811 345
Senecio carnosulus	Kaitorete Spit	8-Oct-08	2461628 5705873
Senecio carnosulus (Kirk) C.J.Webb	Canterbury, Kaitorete, near Lake Forsyth outlet	2-Sep-85	M37 865 088 S94 094 187
Senecio carnosulus (Kirk)	Banks Peninsula: Hikuraki Bay	Apr-87	M37 894 077

C.J.Webb			S94 094 187
Senecio glaucophyllus Cheeseman subsp. basinudus Ornd.	Banks Peninsula, Tumbledown Bay	8-Aug-85	N37 916 059 S94 117 167
Senecio glomeratus Poir.	Le Bons Bay Stream, Banks Peninsula		Orig.Geo.Ref.: N36, N37 2512050 5717071
Senecio glomeratus Poiret	Banks Peninsula: Le Bons Bay	12-Jan-83	S95
Senecio lautus G.Forst. ex Willd. (Shore groundsel)	NA, Canterbury	3/09/1971	
Senecio wairauensis Belcher	Banks Peninsula: Okuti, upper Kaituna Valley	Nov-83	M36 886 224 S84 088 348
Senecio biserratus Belcher	Hinahina Cove	31/12/1997	MAP: G47, METE: 22535, METN: 54034.
Senecio biserratus Belcher	Wickliffe Bay Otago Pen	31/12/1997	MAP: J44, METE: 23338, METN: 54855.
Senecio biserratus Belcher	Aramoana Dune Slacks	31/12/1997	MAP: J44, METE: 23314, METN: 54900.
Senecio carnosulus (Kirk) C.J.Webb	Oamaru, North otago.	30-Nov-01	S136 499 589
Senecio carnosulus (Kirk) C.J.Webb	Moeraki Point, E. Otago	30-Nov-01	
Senecio carnosulus	Green Island	3-Sep-08	I45 073 695
Senecio carnosulus	Green Island	3-Sep-08	I45 073 695
Senecio elegans L.	St. Clair, Dunedin.	27/08/1954	
Senecio jacobea	Otago Peninsula, Broad Bay	10.1.1982	I44 251 814
Senecio minimus	Dunedin City	11 3 2002	2316075 5477800
Senecio minimus	Dunedin City	11 3 2002	2316075 5477800
Senecio glomeratus Poiret	Banks Peninsula: Le Bons Bay	12 JAN 1983	NZMS1: S95
Senecio glomeratus Poiret	Canterbury, Evans Pass Rd, Port Hills		43 35 31.756 S 172 44 23.287 E
Senecio glomeratus Poir.	Akaroa		
Senecio glaucophyllus Cheeseman	Akaroa		
Senecio glaucophyllus Cheeseman subsp. basinudus Ornd.	Akaroa Heads Scenic Reserve	6 MAR 1988	NZMS1: S94 301126
Senecio glaucophyllus Cheeseman subsp. basinudus Ornd.	Banks Peninsula, Tumbledown Bay	Collection date: 14 APR 1983	NZMS1: S94 117167
Senecio wairauensis	Diamond Harbour		43°37′43.6″S

			172°43′53.6″E
Senecio lautus Willd.	Canterbury, Banks Peninsula, Pigeon Bay, Groundsel Point	Collection date: 12 SEP 1989	NZMS1: S84 234372
Senecio lautus Willd.	Banks Peninsula: coast near Crown Island, between Hickory and Gough Bays	Collection date: 13 FEB 1986	NZMS1: S95 421232
Senecio lautus G.Forst. ex Willd. (Shore groundsel)	Banks Peninsula		
Senecio carnosulus (Kirk) C.J.Webb	Banks Peninsula: Hikuraki Bay	Collection date: 28 APR 1987	NZMS1: S94 094187
Senecio carnosulus (Kirk) C.J.Webb	Banks Peninsula: Harris Bay near Taylors Mistake	Collection date: 25 NOV 1983	NZMS1: S84 13-49-
Senecio carnosulus (Kirk) C.J.Webb	Canterbury, Kaitorete, near Lake Forsyth outlet	Collection date: 2 SEP 1985	NZMS1: S94 062199
Senecio carnosulus (Kirk) C.J.Webb	Banks Peninsula: Pa Island, SE of Okains Bay.	Collection date: 4 FEB 1987	NZMS1: S85 41-35-
Senecio vulgaris L. (Groundsel)	Arthurs Pass NP, Canterbury	1/01/1996	5290839 1638482
Senecio glomeratus		Cass	42°59'S, 171°46'E
Senecio glaucophyllus subsp. discoideus (Cheeseman) Ornduff	Torlesse Ecological District	Date01 1883	K35
Senecio glaucophyllus Cheeseman subsp. glaucophyllus	Mount Torlesse .,	Date01 1880	171.75 -43.25
Senecio dunedinensis	Torlesse Ecological District, Lake Lyndon, slopes	28-Nov-62	1490022 5198379
Senecio dunedinensis Belcher	Lincoln, Experimental Gardens, Provenance: Canterbury, Craigieburn Range, Timm's Creek, Limestone Crags	Collection date: 12 AUG 1968	NZMS1: S66 163995
Senecio dunedinensis Belcher	Craigieburn Valley skifield from gate	26/11/2003	MAP: K34, METE: 24048, METN: 57875.
Senecio dunedinensis	Craigieburn Ecological District, Craigieburn Range	12-Aug-68	1493022 5218475
Senecio quadridentatus	Lake Coleridge		43 36 29.582 S 171 55 59.934 E
Senecio quadridentatus Labill. (Pekapeka)	End Rubicon Rd Waimakariri River Bank, Canterbury	2008-04-26	
Senecio quadridentatus Labill. (Pekapeka)	Lake Coleridge Island, Canterbury	1995-04-16	
Senecio jacobaea L. (Ragwort)	Arthurs Pass NP, Canterbury	1996-01-01	
Senecio jacobaea L. (Ragwort)	Malvern Hills Rd below Jimmmys Knob, Canterbury	2008-04-26	
Senecio jacobaea L.	Eyrewell Sci Res, Canterbury	2002-01-01	

(Ragwort)			
Senecio sylvaticus L. (Wood groundsel)	Arthurs Pass NP, Canterbury	1996-01-01	
Senecio minimus Poir.	Cass Ecological District	Date04 1950	S66 2-- 1--
Senecio glaucophyllus	Porters Pass		42°59'S, 171°46'E
Senecio cineraria DC. (Dusty miller)	Waimakariri WW - Brooklands lagoon, Canterbury	2002-02-23	
Senecio rufiglandulosus Colenso	Fyffe Gorge (Mt Owen), Tasman	1999-02-10	
Senecio rufiglandulosus Colenso	Arthurs Pass NP, Canterbury	1996-01-01	
Senecio glaucophyllus subsp. discoideus (Cheeseman) Ornduff	Mountains behind Castle Hill	Date01 1883	K35
Senecio glaucophyllus subsp. discoideus (Cheeseman) Ornduff	Trelissick Basin, Castle Hill	Date 23 12	K34 59-751
Senecio dunedinensis Belcher	Craigieburn Ecological District, Craigieburn Range, Timms Creek, Linestone Crags.	12-Aug-68	K34 030 801 S66 163 995
Senecio dunedinensis Belcher	North Canterbury, Cass Ecological District, Castle Hill, Enys Reserve.	Collection date: 29 JAN 1974	NZMS1: S66 20-95-
Senecio jacobaea L. (Ragwort)	Arthurs Pass NP, Canterbury	1996-01-01	
Senecio lautus Willd.	West Coast, Heaphy Ecological District, Scotts Beach Rock Stack	Collection date: 13 AUG 1992	NZMS1: S12 554530
Senecio lautus Willd. var. lautus	West Coast, Heaphy Ecological District, Scotts Beach Rock Stack	1992/08/13/	L26 346 125 S12 554 530
Senecio lautus Willd. var. lautus	West Coast, Heaphy Ecological District, Scotts Beach Rock Stack	13-Aug-92	L26 346 125 S12 554 530
Senecio rufiglandulosus Colenso var. solandri (Allan) Allan	Between Otira and Jacksons, Main Road	10-Jan-98	S59 029 434
Senecio rufiglandulosus Colenso	Westland, near Otira.	Collection date: 6 DEC 1988	NZMS260
Senecio rufiglandulosus Colenso var. solandri (Allan) Allan	Between Otira and Jacksons, Main Road	Collection date: 10 JAN 1998	NZMS260
Senecio rufiglandulosis Colenso var. solandri (Allan) Allan	Arthur`s Pass	1996	MAP: K32, METE: 23928, METN: 58060.
Senecio sterquilinus Ornd.	Westland, Punakaiki Ecological District, Seal Island	11-Aug-92	K30 74- 06- S37 87- 38-
Senecio sterquilinus Ornd.	Westland, Foulwind Ecological District, Tauranga Bay	14-Aug-92	K29 816 369 S23 960 714

Senecio sterquilinus Ornd.	Cape Foulwind, Wall Island	Collection date: 27 SEP 1996	NZMS1: S23 958713
Senecio sterquilinus Ornd.	Westland, Punakaiki Ecological District, Seal Island	Collection date: 11 AUG 1992	NZMS1: S37 87-38-
Senecio sylvaticus L.	Craigieburn Forest Park, upper reaches of Basin Creek	Collection date: 15 JAN 1998	NZMS1: S65 943100
Senecio dunedinensis Belcher	Torlesse Ecological District, Lake Lyndon, slopes above lake.	28-Nov-62	K35 0-- 6--
Senecio jacobaea	Roadside verge.	Jan-77	K33 91- 26-
Senecio sterquilinus ?	Point Elizabeth Walkway, Greymouth	18/08/1999	J31 633 680
Senecio sterquilinus Ornd.	Westland, Foulwind Ecological District, Tauranga Bay	Collection date: 14 AUG 1992	NZMS1: S23 960714
Senecio sylvaticus L.	Craigieburn Forest Park, upper reaches of Basin Creek	Collection date: 15 JAN 1998	NZMS1: S65 943100
Senecio wairauensis Belcher	Loch Burn, Stuart Mountains, Fiordland	6 Aug. 2004	C42 2088199 555 5284
Senecio jacobaea L.	Hokitika River bridge approach on s	Jan-95	J33 429 289
Senecio sterquilinus Ornd.	Westland, Foulwind Ecological District, Tauranga Bay	Collection date: 14 AUG 1992	NZMS1: S23 960714
Senecio sterquilinus Ornd.	Cape Foulwind, Wall Island	Collection date: 27 SEP 1996	NZMS1: S23 958713
Senecio sterquilinus Ornd.	Westland, Punakaiki Ecological District, Seal Island	Collection date: 11 AUG 1992	NZMS1: S37 87-38-
Senecio sterquilinus Ornd.	Nelson, Dolomite Point.	6-Dec-88	K30 717 978
Senecio sterquilinus Ornd.	Nelson, Dolomite Point.	6-Dec-88	K30 717 978
Senecio sterquilinus Ornd.	Nelson, Dolomite Point.	Collection date: 6 DEC 1988	NZMS1: S37 844289
Senecio sterquilinus Ornd.	Nelson, Dolomite Point.	Collection date: 6 DEC 1988	NZMS1: S37 844289
Senecio	Franz Josef		NZBRN
Senecio vulgaris L. (Groundsel)	Wilberforce EA, Canterbury	1885-01-01	5252560 1580898
Senecio vulgaris L.	Canterbury Plains, Leeston	Collection date: 10 DEC 1994	NZMS1: S93 6--2--
Senecio vulgaris	Matata Scenic Reserve	26-May-98	5078976 1429655
Senecio wairauensis Belcher	near The Hermitage, Glencoe Track	Date 19 01 1965	H36 7-- 1--
Senecio wairauensis Belcher	Hooker Valley, Governors Bush	Date01 1898	H36 60 0 m
Senecio wairauensis Belcher	S Temple Forest, Canterbury	1985-01-01	NZBRN

Senecio wairauensis Belcher	Governors Bush Mt Cook NP, Canterbury	2002-02-01	NZBRN
Senecio wairauensis Belcher	Hopkins River Flats, Canterbury	1986-01-01	NZBRN
Senecio wairauensis Belcher	Freehold Stream Ohau Range, Canterbury	2002-01-03	NZBRN
Senecio wairauensis Belcher	Temple View Walk - Ohau, Canterbury	2002-01-03	NZBRN
Senecio wairauensis Belcher	Hooker Glacier Walk, Canterbury	2001-12-30	NZBRN
Senecio elegans L. (Purple groundsel)	Washdyke Lagoon, Canterbury	1987-11-13	NZBRN
Senecio dunedinensis	Ahuriri Valley, Snowy Gorge Creek	23-Apr-08	1336680 5091057
Senecio dunedinensis		14-Jan-85	1449428 5198078
Senecio dunedinensis		23-Apr-08	1336680 5091057
SENECIO DUNEDINENSIS		1986-01	NZGD1949
SENECIO QUADRIDENTATUS		1986-03	NZGD1949
Senecio jacobaea	Huxley Conservation Area	04-Feb-99	1344018 5124556
Senecio jacobaea	Ahuriri Conservation Area	15-Jan-99	1328718 5097438
Senecio sylvaticus L.	Canterbury, Amuri Range, near Lyndon Pass	Collection date: 8 FEB 1993	
Senecio sylvaticus L. (Wood groundsel)	Huxley	2001-01-17	Waitaki
Senecio sylvaticus L. (Wood groundsel)	Godley	1983-01-01	Mackenzie
Senecio sylvaticus L. (Wood groundsel)	Mt Cook	1978-01-01	Mackenzie
Senecio sylvaticus L. (Wood groundsel)	Mt Cook	1973-01-01	Mackenzie
Senecio biserratus Belcher	Lake Tekapo/Alexandrina area wetlands	1/01/2001	MAP: I37, METE: 23056, METN: 59943.
Senecio biserratus Belcher	Motunau Island	23/04/1971	S68+69404124
Senecio elegans L. (Purple groundsel)	Rangitata, Canterbury	1977-01-01	
Senecio dunedinensis	Hawkdun Range, Little Kye Burn	2001/11/00/	I41 929 828
Senecio dunedinensis	Hawkdun Range, Little Kye Burn	2001/11/23/	I41 938 822
Senecio dunedinensis Belcher	Two Thumb Range, The Growler	Collection date: FEB 1991	NZMS1: S80 31-57-
Senecio dunedinensis Belcher	Mt Cook National Park, Mt Cook Ecological District, Kea Point track.	Collection date: FEB 1969	NZMS1: S79 75-33-
Senecio dunedinensis Belcher	Liebig Range, Mount Cook Station, Andrews Creek	Collection date: 2 MAY 1964	NZMS1: S89 82-22-

Senecio dunedinensis Belcher	The Growler, Two Thumb Range	Collection date: FEB 1991	NZMS1: S80 31- 57-
Senecio dunedinensis Belcher	South Canterbury, Mount Cook, Liebig Range, Littles Creek	Collection date: 27 DEC 1962	NZMS1: S79 9-- 31-
Senecio jacobaea	Ahuriri Conservation Area	15-Jan-99	1328718 5097438
Senecio jacobaea	Ahuriri Conservation Area	15-Jan-99	1328718 5097438
Senecio quadridentatus Labill. (Pekapeka)	Mesopotamia - 2 Thumb	5/01/1981	MAP: J36, METE: 23341, METN: 57272.
Senecio quadridentatus Labill.	Mackenzie Ecological Region	16/01/1984	S100 93- 80-
Senecio quadridentatus Labill.	Lake Tekapo, Mackenzie Co.	27.6.1971	Mar-72
Senecio sylvaticus L. (Wood groundsel)	Temple stream, North Branch, Canterbury	2001-01-17	
Senecio wairauensis Belcher	Freehold Stream Ohau Range, Canterbury	2002-01-03	
Senecio wairauensis Belcher	Mount Cook Ecological District	Date01 1898	
Senecio wairauensis Belcher	near The Hermitage, Glencoe Track	Date 19 01 1965	H36 7-- 1--
Senecio biserratus Belcher	Lake Tekapo/Alexandrina area wetlands	31/12/1996	MAP: I37, METE: 23056, METN: 59943.
Senecio jacobaea L. (Ragwort)	Temple stream, North Branch	17/01/2001	MAP: H38, METE: 22541, METN: 56748.
Senecio vulgaris L. (Groundsel)	Hurunui scrub, Canterbury	1986-01-01	5315528 1650481
Senecio minimus Poir.	Ngaroma Stn	6/06/1987	MAP: O31, METE: 25368, METN: 58486.
Senecio minimus Poir.	Mt Grey	1/01/1980	MAP: M34, METE: 24709, METN: 57881.
Senecio minimus Poir.	Lottery Bush	1/01/1972	MAP: N32, METE: 25173, METN: 58505.
Senecio glaucophyllus Cheeseman subsp. discoideus (Cheeseman) Ornd.	Canterbury, Lawrence Valley (Headwaters of Rangitata River) immediately down valley (true right bank) of Bush Basin	Collection date: 11 MAR 1977	
Senecio glaucophyllus subsp.	Canterbury, W. of Waipara, North Dean	Collection date: JUN 1991	NZMS1: S68 022159
Senecio glaucophyllus subsp. raoulii	North Canterbury, Lower Waipara, South Dean	Collection date: 14 JAN 1986	NZMS1: S68

Senecio wairauensis Belcher	N. Canterbury, Upper Hope Valley	Collection date: MAR 1978	NZMS1: S53 64- 74-
Senecio lautus Willd.	North Canterbury, Napenape Scenic Reserve, 3km south of mouth of Blythe River on coast	Collection date: 28 NOV 1974	NZMS1: S62 55- 25-
Senecio vulgaris L. (Groundsel)	Culverden	1986-01-01	5315528 1650481
Senecio glaucophyllus subsp. raoulii	North Canterbury, Lower Waipara, South Dean	Collection date: 14 JAN 1986	NZMS1: S68
Senecio rufiglandulosis	South Branch, Hurunui River		42 46 14.164 S 171 59 21.780 E
Senecio dunedinensis Belcher	Haumuri Bluffs from Oaro	1/01/2000	MAP: O32, METE: 25510, METN: 58513.
Senecio quadridentatus Labill. (Pekapeka)	Ashley forest, Canterbury	1986-01-01	
Senecio jacobaea	Hurunui River W. Balmoral	Collection date: 31 1 2000	M33 837183
Senecio jacobaea	Hanmer Forest Park	10-Feb-97	1574105 5296745
Senecio sylvaticus L.	Lawrence Valley (Headwaters of Rangitata River) immediately down valley (true right bank) of Bush Basin	Collection date: 11 MAR 1977	NZMS1: S72 45- 70-
Senecio glomeratus Poir.	Wilsons Swamp, Canterbury	1993-01-01	
Senecio hispidulus var. hispidulus		3/03/1970	Orig.Geo.Ref.: [NZMS 1:] S55 & 56: 63.60 (,); : Sheets A to B. (,);
Senecio hispidulus var. hispidulus		3/03/1970	Orig.Geo.Ref.: [NZMS 1:] S55 & 56: 63.60 (,); : Sheets A to B. (,);
Senecio jacobaea L.	near Winterslow Hd, between Bowyers and Taylors Strms, Alford Forest area, mid-Canterbury.	20-Jan-71	S81 95- 46-
Senecio jacobaea	Clarke Flat, Peel Forest	13-Feb-84	K37 705 006
Senecio jacobaea	Hurunui River W. Balmoral	Collection date: 31 1 2000	M33 837183
Senecio minimus Poiret	North Canterbury, Napenape Scenic Reserve, 3km south of mouth of Blythe River on coast	28-Nov-74	N33 29- 06-
Senecio quadridentatus	Hurunui River W. of Belmoral	3/12/1999	M33 837 183
Senecio quadridentatus Labill.	North Canterbury, Napenape Scenic Reserve boundary line	28-Nov-74	O33 30- 06-

Senecio vulgaris L. (Groundsel)	Hurunui scrub	31/12/1981	MAP: M32, METE: 24909, METN: 58142.
Senecio vulgaris	Little Kowai River, Canterbury.	30.10.1976.	S74 383 829
Senecio dunedinensis Belcher	Rakaia River, Hakatere Ecological District, Shaggy Hill.	Collection date: 14 JAN 1985	NZMS1: S73 682781
Senecio hispidulus var. hispidulus	Cold Strem, N.of Leader R., nr.Hawkswood, Canty.	3/03/1970	Orig.Geo.Ref.: [NZMS 1:] S55 & 56: 63.60
Senecio hispidulus var. hispidulus	Cold Strem, N.of Leader R., nr.Hawkswood, Canty.	3/03/1970	Orig.Geo.Ref.: [NZMS 1:] S55 & 56: 63.60
Senecio jacobaea	Clarke Flat, Peel Forest	B.P.J. Molloy & A.P. Druce	13-Feb-84
Senecio jacobaea	Hurunui River W. Balmoral	Collection date: 31 1 2000	M33 837183
Senecio glomeratus	Woodend Beach, Canterbury	1968/12/13/	S76 06- 80
Senecio glomeratus Desf. ex Poiret.	The Pines, Kairaki (nr. Christchurch).	1967/06/18/	S76 068 748
Senecio dunedinensis Belcher	Rakaia River, Hakatere Ecological District, Shaggy Hill.	Collection date: 14 JAN 1985	NZMS1: S73 682781
Senecio jacobaea L. (Ragwort)	Malvern Hills Rd below Jimmmys Knob, Canterbury	2008-04-26	
Senecio lautus Willd.	North Canterbury, Napenape Scenic Reserve, 3km south of mouth of Blythe River on coast	Collection date: 28 NOV 1974	NZMS1: S62 55- 25-
Senecio minimus	Clarke Flat, Peel Forest	13-Feb-84	K37 70- 00-
Senecio minimus Poir.	Ashley Forest		
Senecio quadridentatus Labill. (Pekapeka)	Malvern Water Race Waimak intake , Canterbury, Selwyn District, High Plains	3/04/2001	MAP: K23, METE: 24069, METN: 57453.
Senecio minimus	Malvern Water Race Waimak intake , Canterbury, Selwyn District, High Plains	3/04/2001	MAP: K23, METE: 24069, METN: 57453
Senecio glomeratus Poir.	Brooklands Lagoon, Canterbury	1987-01-01	NZMS1: S76 049613
Senecio glomeratus Poiret	Travis Wetlands	Collection date: 8 FEB 1996	NZMS1: S84 982580
Senecio glomeratus Poiret	Christchurch, Fendalton	Collection date: 20 NOV 1997	T9 ---2--
Senecio lautus Willd.	Castle Rock	Collection date: 6 OCT 1971	Christchurch
Senecio lautus G.Forst. ex Willd. (Shore groundsel)	Mt Vernon	1971-06-05	
Senecio lautus G.Forst. ex Willd. (Shore groundsel)	Port Hills	1971-05-31	

Senecio elegans	South Shore, New Brighton		Grid ref only: 1573987/5173264, Canterbury
Senecio elegans L.	Christchurch, South New Brighton spit Christchurch	Collection date: 13 FEB 1984	NZMS1: S84 10-54-
Senecio elegans L.	Canterbury, McCormacks Bay, Avon-Heathcote estuary	Collection date: 23 NOV 1986	NZMS1: S84 082529
Senecio elegans L.	Canterbury: Taylors Mistake Banks Peninsula.	Collection date: OCT 1982	NZMS1: S84 12-49-
Senecio elegans L.	Christchurch, corner Barbadoes Street and Oxford Terrace, Star and Garter Hotel site	Collection date: 28 NOV 1996	
Senecio skirrhodon DC.	Canterbury, Christchurch between Main Trunk line and Moorhouse Ave.	Collection date: 2 FEB 1994	NZMS1: S84 99-54-
Senecio skirrhodon DC.	Christchurch, Linwood Railway Yards, Wilsons Rd end, behind commercial buildings.	Collection date: 21 MAR 1995	NZMS1: S84 020544
Senecio skirrhodon DC.	Canterbury, Christchurch, Fitzgerald Avenue near Tuam Street intersection.	Collection date: 10 DEC 1993	
Senecio skirrhodon DC.	Canterbury, Christchurch, railway overbridge, Waltham Rd	Collection date: 11 MAR 1986	NZMS1: S84 01-54-
Senecio skirrhodon DC.	Christchurch, Waltham Railway Yards	Collection date: 10 MAY 1990	NZMS1: S84 01-54-
Senecio skirrhodon DC.	Christchurch, Linwood, railway reserve.	Collection date: 15 APR 1991	
Senecio skirrhodon DC.	Christchurch, Waltham Bridge	Collection date: 15 FEB 1986	NZMS1: S84
Senecio skirrhodon DC.	Christchurch, corner Barbadoes Street and Oxford Terrace, Star and Garter Hotel site	Collection date: 28 NOV 1996	
Senecio skirrhodon DC.	Canterbury, roadside between Kaiapoi and Rangiora	Collection date: 16 APR 1981	
Senecio skirrhodon DC.	Landcare Research, Lincoln, Provenance: Christchurch	Collection date: NOV 1988	NZMS1: S84 98-55-
Senecio quadridentatus Labill. (Pekapeka)	Bridle Path to Mt Cavendish ridge, Canterbury	2009-04-11	
Senecio quadrideutatus Labill.	Canterbury, Christchurch, Addington, Railways workshop site.	Collection date: 28 FEB 1994	NZMS1: S84 98-54-
Senecio jacobaea L.	Canterbury, Christchurch, Addington, Railways workshop site.	Collection date: 2 FEB 1994	NZMS1: S84 98-54-
Senecio vulgaris	Canterbury Agricultural and Science Centre	Collection date: 15 12 [19]99	Canterbury Land District

Senecio glomeratus Poir.	Wilsons Swamp, Canterbury	1993-01-01	
Senecio glaucophyllus ssp. basinudus Ornduff	Lyttleton Reserve, Port HIlls	22/12/1970	S84 091 476
Senecio glaucophyllus subsp. basinudus Ornduff	Port Hills, Christchurch	19.12.1940	H.H.Allan
Senecio lautus Willd. var. lautus	Canterbury, southside of Taylors Mistake	2-Dec-83	N36 926 359
Senecio skirrhodon	Waltham Road Overbridge, Christchurch.	1986/02/13/	NZMS 260 (M36 81- 39-) M36 82- 39- (M35 83- 40-) (Cerri C., 21.11.06);
Senecio skirrhodon DC	Middleton Marshalling yards, Christchurch.	1972/04/22/	NZMS 260 M35 76- 40- (Cerri C., 21.11.06);
Senecio skirrhodon DC.	Christchurch, Linwood, railway reserve.	1991/04/15/	NZMS 260 M35 81- 40- (Cerri C., 21.11.06); : Sheets A and C. (,);
Senecio skirrhodon DC.	Port Hills, Summit Road, Sign of the Kiwi	27-Sep-08	
Senecio vulgaris	Christchurch, Travis Wetlands	19-Jan-02	M35 85- 46-
Senecio vulgaris	Hargood Street, Woolston, Christchurch	18/03/2011	
Senecio elegans L.	Canterbury: Taylors Mistake Banks Peninsula.	NZMS1: S84 12-49-	Collection date: OCT 1982
Senecio elegans L.	Christchurch, South New Brighton spit Christchurch	NZMS1: S84 10-54-	Collection date: 13 FEB 1984
Senecio hispidulus	Banks Peninsula, Port Hills, Dyers Pass Road between Victoria Park and the Sign of the Kiwi.	27 9 00	M36 811 345
Senecio biserratus Belcher	Omahu bush		
Senecio minimus Poiret	Omahu bush		
Senecio elegans L.	Christchurch, South New Brighton spit Christchurch	Collection date: 13 FEB 1984	NZMS1: S84 10-54-
Senecio elegans Linn.	Sumner near Christchurch, Canterbury, near Cave Rock Tearooms.	D.G.Drury	28-Oct-71
Senecio glomeratus Poiret	Travis Wetlands	Collection date: 8 FEB 1996	NZMS1: S76 049613
Senecio quadridentatus Labill. (Pekapeka)	Bridle Path to Mt Cavendish ridge	3/11/2005	
Senecio sylvaticus	Bottle lake		
Senecio minimus Poir.	Summit Rd U Worsleys Rd Port Hills	7/02/2004	

Senecio elegans L.	Canterbury, Gore Bay district	Collection date: JAN 1980	
Senecio hauwai Sykes	Marfell Beach	May-74	Q29 103 415
Senecio hauwai Sykes	Near Lake Grassmere, Marfells Beach	21-Mar-70	Q29 1-- 4--
Senecio hauwai Sykes	White Bluffs	1-Jul-85	
Senecio hauwai Sykes	Marfell Beach	Dec-75	
Senecio hauwai Sykes	Cape Campbell	Jul-64	
Senecio hauwai Sykes	Blind River	Collection date: 26 MAY 1993	NZMS1: S29 430763
Senecio hauwai Sykes	Cape Campbell, near lighthouse surrounds	Collection date: 29 OCT 1970	NZMS1: S29 524714
Senecio lautus	Manukau Bluff, Gore Bay		42°52'S 173°19'E
Senecio lautus G.Forst. ex Willd. var. lautus	Kaikoura Peninsula, Canterbury	Kaikoura Peninsula, Canterbury	
Senecio hauwai Sykes	Eastern extremity of Marfells Beach	13-Sep-91	
Senecio hauwai Sykes	Marlborough, Marfell Beach	Sep-91	Q29 1-- 4--
Senecio hauwai Sykes	Cape Campbell	Collection date: JUL 1964	NZMS1: S29 458704
Senecio glaucophyllus ssp. basinudus Ornduff	Lyttleton Reserve, Port HIlls	22/12/1970	S84 091 476
Senecio glaucophyllus subsp. basinudus Ornduff	Port Hills, Christchurch	19.12.1940	
Senecio lautus Willd. var. lautus	Canterbury, southside of Taylors Mistake	2-Dec-83	N36 926 359
Senecio skirrhodon	Waltham Road Overbridge, Christchurch.	13-Feb-86	NZMS 260 (M36 81- 39-) M36 82- 39- (M35 83- 40-)
Senecio skirrhodon DC	Middleton Marshalling yards, Christchurch.	22/04/1972	NZMS 260 M35 76- 40- (Cerri C., 21.11.06);
Senecio skirrhodon DC	Christchurch, Linwood, railway reserve.	15-Apr-91	NZMS 260 M35 81- 40-
Senecio skirrhodon DC.	Port Hills, Summit Road, Sign of the Kiwi	27-Sep-08	
Senecio elegans L.	Canterbury: Taylors Mistake Banks Peninsula.	Collection date: OCT 1982	NZMS1: S84 12- 49-
Senecio biserratus Belcher	Omahu bush		
Senecio minimus Poiret	Omahu bush		
Senecio sylvaticus	Bottle lake		
Senecio jacobaea		13-Feb-84	K37 705 006
Senecio glomeratus	Woodend Beach, Canterbury	1968/12/13/	S76 06- 80
Senecio glomeratus Desf. ex Poiret.	The Pines, Kairaki (nr. Christchurch).	1967/06/18/	S76 068 748

Senecio dunedinensis Belcher	Hakatere	Collection date: 14 JAN 1985	NZMS1: S73 682781
Senecio jacobaea L. (Ragwort)	Malvern Hills Rd below Jimmmys Knob, Canterbury		
Senecio minimus	Clarke Flat, Peel Forest	13-Feb-84	K37 70- 00-
Senecio sylvaticus L. (Wood groundsel)	Temple stream, North Branch, Canterbury	2001-01-17	
Senecio wairauensis Belcher	Temple view walk	2002-01-03	
Senecio biserratus Belcher	Lake Tekapo/Alexandrina area wetlands	31/12/1996	MAP: I37, METE: 23056, METN: 59943.
Senecio jacobaea L. (Ragwort)	Temple stream, North Branch	17/01/2001	H38, METE: 22541, METN: 56748.
Senecio dunedinensis	Ahuriri Valley, Snowy Gorge Creek	23-Apr-08	1336680 5091057
Senecio dunedinensis Belcher	Craigieburn Ecological District, Craigieburn Range, Timms Creek, Linestone Crags.	12-Aug-68	K34 030 801
Senecio dunedinensis Belcher	North Canterbury, Cass Ecological District, Castle Hill, Enys Reserve.	Collection date: 29 JAN 1974	NZMS1: S66 20- 95-
Senecio rufiglandulosus Colenso var. solandri (Allan) Allan	Between Otira and Jacksons, Main Road	13-Jan-98	K33 9-- 2--
Senecio rufiglandulosus Colenso	Westland, near Otira.	Collection date: 6 DEC 1988	NZMS260
Senecio rufiglandulosus Colenso var. solandri (Allan) Allan	Between Otira and Jacksons, Main Road	Collection date: 10 JAN 1998	NZMS260
Senecio sterquilinus Ornd.	Westland, Punakaiki Ecological District, Seal Island	11-Aug-92	K30 74- 06-
Senecio sterquilinus Ornd.	Westland, Foulwind Ecological District, Tauranga Bay	14-Aug-92	K29 816 369
Senecio sterquilinus Ornd.	Foulwind	Collection date: 27 SEP 1996	NZMS1: S23 958713
Senecio sterquilinus Ornd.	Punakaiki	Collection date: 11 AUG 1992	NZMS1: S37 87- 38-
Senecio jacobaea	Two miles below Jacksons, Taramakau Valley, Westland.	Jan-77	K33 91- 26-
Senecio sterquilinus	Point Elizabeth Walkway, Greymouth	18/08/1999	J31 633 680
Senecio carnosulus	Kaitorete Spit	8-Oct-08	2461628 5705873
Senecio carnosulus (Kirk) C.J.Webb	Dan Roger's Creek, Akaroa Heads, Canty	30-Nov-01	
Senecio elegans L.	Canterbury, Okains Bay seafront	7 Nov.1985	N36 149 237

Senecio elegans	Le Bons Bay		
Senecio glaucophyllus Cheesem.	nr. Akaroa Lighthouse.	7.11.1974	W.R.Sykes 52/74
Senecio glaucophyllus Cheeseman subsp. basinudus Ornd.	Canterbury, Le Bons Bay, Banks Peninsula.	12-Jan-83	E36 52- 12-
Senecio sylvaticus	Banks Peninsula, Hinewai Reserve, The Stones Track near The Stones.	1 2 01	N37 125 080
Senecio elegans L.	Birdlings Flat, Lake Ellesmere/Lake Forsyth	8-Feb-00	M37 863 089
Senecio hispidulus	Banks Peninsula, Port Hills, Dyers Pass Road between Victoria Park and the Sign of the Kiwi.	27 9 00	M36 811 345
Senecio carnosulus (Kirk) C.J.Webb	Canterbury, Kaitorete, near Lake Forsyth outlet	2-Sep-85	M37 865 088
Senecio glaucophyllus Cheeseman subsp. basinudus Ornd.	Banks Peninsula, Tumbledown Bay	8-Aug-85	N37 916 059

TRIBUTE

REST IN PIECE

FIAT TIPO DGT: A.K.A GIUSEPPE, A.K.A THE STARSHIP ENTERPRISE, A.K.A THE MIGHTY TIPO
MADE: 1989; EUROPEAN CAR OF THE YEAR.
DRIVEN: 400,8584 KM.
LAST SONG PLAYED IN STERIO BEFORE CRASH: BOB DYLAN: LILY OF THE WEST
DIED: 09/03/2011.