

Notes on the ecology of *Tradescantia fluminensis* and a biological control programme for its management

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Distribution and dispersal of *T. fluminensis*

Tradescantia fluminensis is indigenous to the tropical rainforests of SE Brazil and NE Argentina. It has been grown worldwide as an ornamental, and has either naturalised or become invasive in:

- Australia – invasive
- Italy
- Japan
- Kenya
- New Zealand – invasive
- Portugal – invasive (Almeida et al. 2003)
- Puerto Rico
- Russian Federation
- South Africa
- Swaziland – invasive
- USA – invasive in Florida

(<http://www.issg.org/database/species>)

Distribution within New Zealand is said to be restricted by intolerance of frost (Bannister 1986). It occurs in all regions, but is presumably restricted to sheltered habitats in frost-prone areas.

The related species *T. virginiana* L. and *T. cerinthoides* Kunth. are both fully naturalised in New Zealand (Ngā Tipu o Aotearoa database), although field records are limited. There are other species of *Tradescantia* in cultivation but none are as widespread as *T. fluminensis*. *T. zebrina* Bosse has green and white stripes with deep purple undersides. *T. cerinthoides* Kunth is shortly creeping, and rather succulent and velvety or hairy. There has only been one unpublished record of seed production in New Zealand (Graeme Bourdôt, AgResearch), and so reproduction appears to be almost exclusively vegetative. Stem fragments as small as 10 mm can successfully establish new plants if there is a node (Kelly & Skipworth 1984a).

Tradescantia fluminensis disperses widely by the spread of fragments, and the predominant pathways for invasion appear to be the dumping of garden refuse in forest remnants or naturally via carriage of fragments in streams (Esler 1988). Its absence from

large tracts of forest may be related to lack of anthropogenic dispersal. However, in 2001 it was present in 11 of 13 DOC conservancies (not listed as a problem weed by Taupo-Tongariro, Otago or Southland conservancies) (Owen 1997). It continues to invade within conservancies in which it is present, and has also spread to offshore islands such as Stephens Island (Brown & Rees 1995), and Matiu, Mana, Chatham and Rangitoto islands (Standish 2001).

The National Pest Plant Accord is a cooperative agreement between the Nursery and Garden Industry Association, regional councils, and government departments with biosecurity responsibilities. Under the Accord *T. fluminensis* has been declared an 'unwanted organism' under Sections 52 and 53 of the Biosecurity Act 1993, and cannot be sold, propagated, or distributed in New Zealand (<http://www.biosecurity.govt.nz/pests-diseases/plants/accord.htm>).

Biology of *T. fluminensis*

Based on its biological capability and its potential effect on systems, it has a weed ranking of 25, compared with a ranking of 22 for periwinkle and 23 for selaginella, two other weeds that also colonise forest margins in urban areas (Owen 1997).

The vertical profile of a tradescantia mat has three intergrading zones: erect, soft stems that can be 40 cm long with fleshy leaves; a horizontal mat of intersecting, chlorotic stems with no leaves, but with adventitious roots; and a lower zone near the ground where tissues are dying (Kelly & Skipworth 1984a). The dense mat of horizontal overlying stems is commonly 60 cm deep. A single stem may be 1.5 m long with many branches. Kelly and Skipworth (1984a) estimated that a square metre of ground with standing crop of 1400 g could comprise 300 tradescantia plants with a total stem length of 900 m. This enables *T. fluminensis* to persist as an invasive weed of natural areas, where it carpets the ground and prevents native regeneration.

In another study Maule et al. (1995) found that tradescantia grew 0.2–0.3 cm per day in summer and 0.04–0.06 cm per day in winter. Overall, plants grew 60–70 cm per year. In one site dry matter production was 477 ± 177 g/m² and there were 303 ± 19 stems/m² in March.

The physiology of *T. fluminensis* enables rapid response to the availability of two key resources, light and nitrogen. Maule et al. (1995) found that it could grow under canopy at 1% irradiance as well as in the open, and that irradiance level is likely to be the primary factor limiting the extent of colonisation of forest remnants. Incident light is greatest at the edges of forest remnants.

Kelly and Skipworth (1984a) found a close, apparently linear relationship between the standing crop of tradescantia and incident light as irradiance rose to about 10% of that on open ground. Maule et al. (1995) found that as irradiance increased to 30%, the rate of dry matter accumulation reached an asymptote. *T. fluminensis* can therefore be categorised as a facultative shade plant. Standish et al. (2004) record that edge effects or

microclimate extend at least 40–50 m in New Zealand forest remnants, so remnants of <9 ha are dominated by edge effects.

Damp fertile soils support the densest swards of *T. fluminensis* whereas growth is sparse on rocky substrates (Smale & Gardner 1999; <http://www.issg.org/database/welcome>).

Ecological consequences of *T. fluminensis* infestation

The adverse effects of *T. fluminensis* are evident at several trophic levels. Reasonably extensive ecological research shows that *T. fluminensis* alters litter decomposition, nutrient cycling, the successional trajectory amongst plant species, and invertebrate biodiversity in New Zealand lowland podocarp-broadleaved forests, and probably adversely affects the integrity of native ecosystems elsewhere.

Conservation of biological diversity, including invertebrate biodiversity, is thought to be important for the stability and functioning of ecosystems (Toft et al. 2001). Conservation of regional biotas worldwide depends heavily on the retention and management of fragmented areas of the original vegetation. In New Zealand only vestiges of the original pre-European landscape remain intact, often as forest remnants in heavily modified or peri-urban areas (Whaley et al. 1997; Smale & Gardner 1999). Those reserves close to towns have more weeds than those further away (Timmins & Williams 1991), often as a result of the dumping of garden rubbish. If these reserves are to continue to protect natural values, they will require regular attention to prevent the establishment of weeds (Timmins & Williams 1991), although future population pressure on such amenities will make this a difficult task using current management methods.

Tradescantia can slowly penetrate quite shaded forest (zone 1 in Fig. B1), but its biomass here is no threat until a light gap appears (e.g. a tree dies). Then it can quickly become dense enough to prevent regeneration, creating an internal forest ‘edge’. All edges, real (zone 2) or internal, tend to expand because of the lack of native regeneration, so trees are not replaced as they die. At higher light levels (zone 3) *tradescantia* is out-competed by other exotic weeds, perhaps even facilitating the invasion of serious weedy vines that can kill remaining trees. In general, the margins of forest remnants are likely to remain weedy unless ‘armoured’ with vegetation (Standish 2001), so it may be pointless to remove *T. fluminensis* from this zone (unless to control spread). If a forest remnant is damaged, then irradiance through canopy gaps makes the effects of *T. fluminensis* important throughout the remnant, not just at the margins.

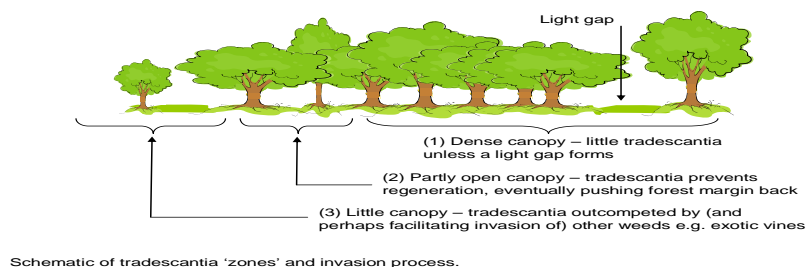


Fig. 1 Shade zones within a forest as they affect *Tradescantia fluminensis*.

Esler (1988) noted that *T. fluminensis* invaded forest when disturbance (such as tree fall and stock grazing) caused canopy degeneration. This disturbance increased available nitrogen, the element limiting growth, which made the disturbed area more invasible. When the canopy closes once more, its ability to survive low irradiance allows mats to persist. Increased irradiance facilitates encroachment of tradescantia from elsewhere in the remnant.

Esler expressed concern about the serious effect of *T. fluminensis* invasion on the age structure of forest remnants. Earlier, Kelly and Skipworth (1984a) had found many small seedlings under tradescantia, but showed a strong negative relationship between the presence of tall seedlings and the presence of tradescantia, implying the death of small seedlings under tradescantia. This relationship has been measured many times since. Tradescantia is now seen as one of the weeds that most threaten the integrity of important forest remnants in the North Island.

Standish (2001) estimated that a dry biomass of $>200 \text{ g/m}^2$ of *T. fluminensis* (equating to 70–90% cover) prevented any regeneration of indigenous New Zealand forest plants. In a preliminary study of the relationship between plant biomass in different light levels in Brazil, it was found that, unlike in New Zealand, the biomass level in Brazil seldom exceed 200 g/m^2 (Landcare Research, unpublished data).

Species richness and abundance of native seedlings increase with decreasing *T. fluminensis* biomass (Kelly & Skipworth 1984a; Standish 2001; Standish et al. 2001). The biomass often reaches 800 g/m^2 in the 'middle' zone surrounding forest remnants. Reduction of this biomass by 75% to 200 g/m^2 or less (estimated to be equivalent to 70–90% cover) would allow regeneration of tolerant native species (Standish 2001). In another paper Standish suggested that 80 g/m^2 (40% cover, 90% reduction in biomass) was necessary for good regeneration.

A degree of shade tolerance is generally necessary for tree species to survive in New Zealand lowland forest communities (Standish et al. 2001). The biomass of *T. fluminensis* in two forest remnants increased logistically to peak at 10–15% of full light. At 500 g/m², incident light beneath was reduced to <1% irradiance. Species richness and abundance of native seedlings were reduced exponentially with increasing weed biomass, falling from 3.4 to 0.37, and 81.5 to 6.3 g/m² respectively at maximum weed biomass. *Dysoxylum spectabile* seedlings were relatively shade tolerant, and established under the weed, but survival after 20 months was only 6% under the weed compared with 84% in full light. Standish et al. (2001) concluded that invasion by *T. fluminensis* is likely to result in changes to the composition of the native plant community because of the differential effects on native seedling survival, resulting in more *Dysoxylum spectabile* and less *Macropiper excelsa* in the canopy in those remnants. Ultimately the persistence of a species in such a remnant will be driven by its ability to tolerate the effects of *T. fluminensis*, which in turn determines long-term species composition. This weed can therefore be seen as an ecosystem modifier.

The presence of heavy infestations of *T. fluminensis* does not always result in irreversible loss of plant species. Smale and Gardner (1999) found that, contrary to experience elsewhere, dominants appeared to be replacing themselves in a Mt Eden reserve infested with *T. fluminensis*, the only reserved fragment of primary broadleaved forest on basaltic lava on the Auckland isthmus. This may be because the rocky nature of the substrate did not allow the weed to form unbroken dense mats, as it does elsewhere in New Zealand. *Tradescantia* was a major invasive herbaceous weed suppressing regeneration on moist fertile alluvial soils in Claudelands Bush (Hamilton), and was a major factor in the loss of species from this remnant. One-third of the indigenous vascular flora of 122 species that survived grazing and was present in 1933 became locally extinct between 1954 and 1980, mostly ground layer species and small shrubs with small populations (25 species). Smothering by the locally dominant *T. fluminensis* and desiccation resulting from drainage and habitat fragmentation were implicated in this loss (Whaley et al. 1997). This forest remnant has been the subject of a recovery programme. Smale et al. (2005) concluded that fencing for 20 years may be sufficient to return grazed forest remnants elsewhere in the Waikato, but also acknowledged that the widespread presence of weeds such as *tradescantia* might well alter the recovery pathway.

Seedling abundance does not ‘protect’ a species from the threat of local extinction in *tradescantia*-infested forest remnants (Standish et al. 2003), as the mortality attributable to shading is not density-dependent.

Tradescantia fluminensis not only causes direct mortality of regenerating seedlings, but also modifies the habitat in which they grow. Infestations increase litter decomposition and alter nutrient availability. Standish et al. (2004) found that the productivity of several sites examined was high, but that litter breakdown was particularly rapid where *tradescantia* occurred. Available nitrogen was higher under weed mats than in non-*tradescantia* plots. They concluded that these differences were probably due to differences in vegetation structure between *tradescantia*-infested plots and *tradescantia*-free plots, and associated differences in microclimate.

There is also an indirect relationship between the presence of *T. fluminensis* and the nature of the invertebrate communities in lowland forests. In a comparison of the effect of tradescantia on communities of beetles and fungus gnats flying above tradescantia-infested and tradescantia-free forest floor, the proportion of tradescantia was a poor predictor of species richness or abundance. This may be because a proportion of the insects sampled by Malaise traps above tradescantia may have been vagrant, and not closely associated with the weed mat. However, effects on individual species were evident. The strongest predictor of species richness was the richness of the vegetation within the forest. Changes in forest structure as a result of tradescantia presence would therefore also influence the species richness of the insect fauna.

In another study, removal of tradescantia within 50-m² plots by hand weeding or herbicide spraying did not lead to any major impacts on the ground-dwelling invertebrate community. Invertebrate abundance and taxonomic richness were similar in hand-weeded, herbicide-treated, and non-treated plots 7 weeks after treatment (Standish 2004). Nevertheless, Standish (2004) concluded that *T. fluminensis* could impact invertebrate communities because:

1. It forms dense layers of vegetation > 60 cm tall, contrasting with natives, which are of small stature.
2. It produces litter that decomposes faster than litter of the mixed-species forests it invades, and alters nutrient availability.
3. Soil moisture is greater under tradescantia than under sparse native subcanopy.
4. Invasion is closely associated with decreases in abundance and species richness of native forest seedlings, and hence on their characteristic fauna.

In a study of the soil microfauna, Yeates and Williams (2001) found similar relationships. Although the presence or absence of tradescantia was not a strong predictor of species richness or abundance, infestation with tradescantia was associated with detection of seven additional taxa of nematodes, while eight fell below the level of detection, indicating significant alteration/turnover in community composition that was not picked up well by the indices. The density of herbivorous nematodes was higher under tradescantia than in plots where the weed was absent.

Other microfauna also varied between sites with and without tradescantia, reflecting the physical qualities of the litter under different vegetation, for example, rotifer abundance was affected.

Such differences in the array of invertebrates associated with tradescantia can benefit rather than adversely affect species of conservation significance. Standish et al. (2002) measured the abundance and population structure of the endangered snail *Powelliphanta t. traversii* in 18 forest remnants. Overall, tradescantia affected only a small part of the total habitat. Seven sites had *P. traversii* but no tradescantia, indicating that the weed is not essential for snail survival. However, five snail colonies were definitely affected by the presence of the weed. Snails commonly occurred under tradescantia, and in some cases exclusively in this habitat. Some snails foraged from and returned to the weed mat.

Standish et al. (2002) found that tradescantia was an important refuge for young snails, and in this case removal of the weed could be detrimental to recruitment. They suggested that graduated control of tradescantia, with replacement by native cover, would be of mutual benefit to the snails while achieving other biodiversity maintenance goals.

Forest regeneration has been identified as a key component in securing the status of many species on Stephens Island (Takapourewa), including Hamilton's frog and the striped gecko, *Hoplodactylus stephensi* (Brown & Rees, 1995). The growth of tradescantia in the two remaining forest remnants on the island has prevented or greatly reduced the establishment of seedling tree and understorey plants, and greatly impaired the access of tuatara and fairy prion to their burrows. However, in the process of hand-removal of the weed, Brown and Rees (1995) found that tradescantia-infested areas carried higher densities of striped gecko, snails (*Rhytida stephensis*), and native earthworms than tradescantia-free areas, possibly because the weed mat provided partial protection from predation by tuatara. An attempt has been made to eradicate the weed from the island. Although individuals of these animal species may have been lost in the eradication process, the effect on populations across the whole island appears to be insignificant (Brown & Rees 1995).

Current control strategies for *T. fluminensis*

Standish et al. (2002) noted that weed control measures themselves constitute a significant disturbance to communities, and any benefits they offer need to be weighed up against potential side effects and the estimated impact of continued weed invasion in the event of no weed control.

A number of regional councils distribute factsheets describing the threat of tradescantia and methods for its management. Manual weed removal is considered to be a suitable tactic for the control of small infestations because it has least impact on non-target plants growing near or amongst the weed. Stem fragments as small as 10 mm can successfully establish new plants (Kelly & Skipworth 1984a), so great care must be taken to remove every small piece of stem. For this reason repeated efforts are usually required to achieve eradication.

For larger infestations chemical control is currently considered to be the only practical method (McCluggage 1998). Non-target impacts on native flora (e.g. Kelly & Skipworth 1984b; Brown & Rees 1995) are generally accepted in the light of the perceived benefits. In Northland *T. fluminensis* invades damp shady areas of forest and of stream banks, and prevents the regeneration of any other vegetation. McCluggage (1998) found that Grazon (Triclopyr) had the superior kill rate, and was the most cost-efficient herbicide. Using this technique on a 3.4-ha infestation gave 90% die-off on first spray, whereas other mixes required two retreatments. The cost of four tankloads, labour costs for two people plus equipment, and spot-spray follow-up was \$1,366 per day (in 2007 dollars).

In another case study, Ogle and Lovelock (1989) noted that initial treatment of tradescantia mats at 'Rangitawa' with the herbicide Roundup™ was likely to cause loss of indigenous seedlings and herbs, including sedges, but the patchy distribution of

wandering Jew meant there would be adequate replacements for those in sprayed areas. They warned that particular care would be needed with species that were of limited distribution but occurred with tradescantia. They found that repeat treatment was required, and in 2007 dollars the control cost per hectare equated to \$4,343.

Standish (2002) also found control using herbicides difficult. Herbicide spray and hand-weeding applied to separate plots did not prevent regrowth after three treatments.

Standish (2002) suggested that shading using artificial means or by restoration of native species showed potential as a means to suppress the weed by shading. Artificial shading to 2.5% of full light was the best approach to control, yielding $81.3 \pm 10.6 \text{ g/m}^2$ of biomass compared with $597.6 \pm 6.6 \text{ g/m}^2$ in unshaded (15–27% of full light) plots after 17 months. Native seedlings were planted into *T. fluminensis*. After 2.5 years, 61% of the seedlings had emerged successfully from that cover, but the effects of this future canopy in shading out the weed remained uncertain.

Kitchener Park is an 11-ha forest reserve near Fielding. It is an important remnant of original Manawatu forest, containing 140 plant species in 1928. For various reasons, by 1961 only 80 of these remained. Restoration has been in progress since 1991. *T. fluminensis* was well-established in the reserve by 1944. Since then thousands of hours of labour, much of it voluntary, has been applied to the removal of tradescantia, and by 1995, two-thirds of the area had been cleared (Anon. 1995).

The following mixtures are suitable for knapsack application (ARC 1999):

- Glyphosate (Roundup G2 or Nufarm).....200 ml + 10 ml Pulse per 10 litres of water
- Escort5 g + Glyphosate 100 ml + Pulse 10 ml
per 10 litres of water
- Grazon 60 ml + 10 ml Pulse per 10 litres of water
- Yates Hydrocotyl Killer150 ml + 10 ml Pulse per 10 litres of water
- Renovate120 ml per 10 litres of water (no Pulse reqd)
- Amitrol 4L200 ml + 10 ml Pulse per 10 litres of water

Tradescantia afforded protection to several native animals on Stephens Island, but on balance, the decision was made to eradicate the weed (Brown & Rees 1995). Manual removal of the weed proved ineffective. Although Grazon was capable of killing non-target plants, careful use protected canopy species while killing 85% of the weed in one pass.

The search for biocontrol agents

There are no native or naturalised relatives of *T. fluminensis*, nor a significant trade of plants that would preclude the use of a control agent with genus-or family-specific host range.

Standish (2001) completed a biocontrol feasibility study, and found the biomass of *T. fluminensis* often reaches 800 g/m^2 in the semi-shaded margins of forest remnants. Species richness and abundance of native seedlings increase with decreasing

T. fluminensis biomass. She suggested that for native forest regeneration to occur, biological control needed to reduce the standing biomass of weed by 75% to less than 200 g/m² (which equates to 70–90% ground cover), and considered this goal to be realistic. Control of *T. fluminensis* on forest margins, by whatever means, opens the possibility of invasion of other weeds such as kahili ginger and selaginella. However, she concluded that the gradual reduction in biomass typical of biological control might reduce the chance of reinvasion. She also concluded that integration of biological control with restoration planting may assure greater success than using either method in isolation. Following this report a biological control project was initiated by the Department of Conservation in 2002/03.

To assist in the selection of the most appropriate control agents to introduce, Winks et al. (2003) surveyed the fauna and pathogens associated with *T. fluminensis* at 18 sites in New Zealand. Forty-nine herbivores and two potentially pathogenic fungi were recorded. The total damage attributable to herbivores was minimal (<2% foliage damage). The only herbivores found at levels we classified as ‘abundant’ (>200 individuals collected and present at 10 or more sites) were small, native snails (shells 2–5 mm diameter) that are probably feeding on microflora on the leaf surface rather than being actual folivores. Fungal colonies were cultured from plant parts that had possible pathogen damage. A total of 27 fungal species were identified, of which only a *Phomopsis* species and a *Colletotrichum* species are likely to be pathogens of *T. fluminensis*. Given the low levels of observed damage in the field we are not investigating these species further. The survey indicated that there were no specialist natural enemies attacking *T. fluminensis* in New Zealand.

The predator and parasitoid fauna was also assessed to help identify any potential natural enemies of introduced control agents. Spiders were common at all sites. Six species of predaceous Carabidae were encountered, including four indigenous species. The most common of these was found at only four of the 18 sites. One predaceous clerid beetle and two coccinellids were also encountered. One of these, *Halmus chalybeus*, was present at 50% of sites, but is known to be a specialist predator of scale insects. Earwigs (Dermaptera) can be significant predators, but were present in samples at only two of the 18 sites. Vespulid wasps were only recorded at one site. The most common of the four ant species was present at only four of the 18 sites. The most common facultative predators present were small ground wētā (Rhaphidophoridae), which were found at eight of the 18 sites. Apart from spiders, the biomass of generalist predators was therefore relatively low, possibly because of the low density of herbivores on which to prey. At this level general predation would be unlikely to influence the population dynamics of an insect such as *Lema obscura*, but if prey populations grew following the introduction of the beetle, then there could be a numerical response amongst one or more of these generalist predators (Winks et al. 2003), possibly affecting agent efficacy and food web interactions.

The plant is little studied, either as an alien invasive weed in other countries such as Australia, Portugal and the USA, or as a native plant in SE Brazil and northern Argentina. In particular, the potential natural enemies associated with the plant in its native range

that might offer potential for introduction as biocontrol agents into New Zealand were almost completely unknown. Surveys for potential biocontrol agents in Brazil were initiated in 2003. The surveys have focused on SE Brazil (Fig. B2) because this area has a good climate match to the warmer regions of New Zealand (Standish 2001). Surveys have extended as far north as Rio de Janeiro and Belo Horizonte, but more effort has been put into the lower latitude, higher altitude, and hence cooler, areas in the southern three states (Parana, Santa Catarina and Rio Grande do Sul).

Local surveys for natural enemies of *T. fluminensis* with potential as biocontrol agents in New Zealand have been conducted periodically by Brazilian collaborators, and Landcare Research entomologists carried out surveys in SE Brazil in Jun/Jul 2003, Nov 2003, Nov/Dec 2005, and in Feb 2007. Field surveys have identified a total of 42 insect species associated with *T. fluminensis*. Many of these have yet to be reared to allow full identification, and/or are undescribed species.

However, based on available knowledge and field/laboratory assessments in Brazil, the species listed in Table B1 could be selected as biocontrol agents.

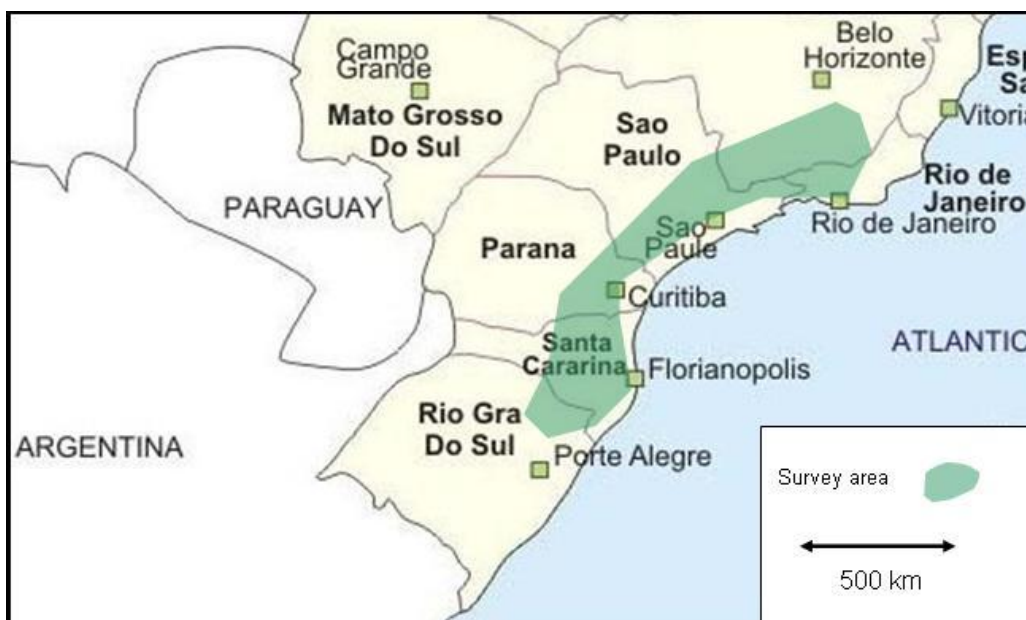


Fig. 2.2 Area surveys for natural enemies of *T. fluminensis* in SE Brazil.

Surveys in New Zealand and Brazil have been undertaken to allow a comparison of dry biomass levels in *T. fluminensis* stands in the two countries, and to provide a pre-biocontrol baseline dataset for New Zealand. This research is ongoing, and detailed methods and results will be published elsewhere (S. Fowler, pers comm.). However, preliminary analyses show that the samples taken to date from New Zealand have dry biomasses ranging from 116 to 3999 g/m², with 83% of quadrats exceeding 200 g/m². In Brazil, comparable dry biomass samples ranged from 46 to 296 g/m², with only 12%

exceeding 200 g/m². If this is due to natural enemies then a classical biological control programme has good prospects. The comparison is conservative, because selected sites in both countries had a high percentage cover (100% where possible) of *T. fluminensis*. In Brazil, this 'snapshot' approach will overestimate the real dry biomass of a typical *T. fluminensis* stand over time. The rationale is that many sites in Brazil are likely to suffer damage from natural enemies that, over time, would reduce the levels of cover such that we would not have selected these sites in a subsequent survey. For example, in February 2007, at sites located in November 2005, the biomass of healthy *T. fluminensis* was so low that completely new sites needed to be located. When sites in New Zealand have been revisited, normally the weed has completely infilled the quadrats where the biomass samples were taken.

Table 2.1 Insect species associated with *Tradescantia fluminensis* potentially suitable for biological control

	Insect species/RTU (recognisable taxonomic unit):								
	<i>Lema obscura</i>	<i>Lema</i> sp. 2 (‘stripy’)	<i>Lema</i> sp. 3 (‘knobbly’)	<i>Buckibrotica cinctipennis</i>	Sawfly	<i>Scirtothrips</i> sp.	<i>Idioglossa</i> sp.	<i>Mouralia tinctorides</i>	Gall midge
Organism type	Coleoptera: Chrysomelidae	Coleoptera: Chrysomelidae	Coleoptera: Chrysomelidae	Coleoptera: Chrysomelidae	Hymenoptera	Thysanoptera	Lepidoptera: Coleophoridae	Lepidoptera: Noctuidae	Diptera: Cecidomyiidae
Observed field damage	Low–moderate	Low–moderate	Low–moderate	Can be high	Can be high	Can be high	Can be high	Low	Low
Damage in cages	High	High	High	High	Unknown	High	Unknown	Unknown	Unknown
Type of adult damage	External on leaves	External on leaves	External on leaves	External on leaves	None	Sucking: distorts shoots	None	None	None
Type of larval damage	External on leaves	Older larvae bore into growing tips	Older larvae bore into older stems	Probably root or older stem feeder	External on leaves	Sucking: distorts shoots	External feeder in web on leaves	External fn leaves	Galls young leaves
Climate match	Good	Good	Good	Good	Good	Good	Poor	Good	Good
Attacks NZ <i>Tradescantia</i>?	Yes	Yes	Yes	Yes	Probably	Probably	Probably	Almost certain	Unknown
Ease of rearing and testing	Good	Good	Good	Some challenges	Probably difficult	Difficult	Unknown	Good	Probably difficult
Host specificity	High	Likely high	Likely high	Likely high (but larvae?)	Likely high	Unknown	Likely high	Acceptable	Likely high
Escape from specialist enemies in NZ?	Likely high	Likely high	Likely high	Likely high	Likely high	Unknown	Unknown (possibly high)	Likely low	Unknown (possibly high)
Escape from generalist enemies in NZ?	Likely high	Likely high	Likely high	Likely high	Likely high	Unknown	Unknown (possibly high)	Likely low	Unknown (possibly high)

Damage levels from plant pathogens and insect or other herbivores are also being quantified during surveys in Brazil and New Zealand. At each of the 35 sites in Brazil and 26 sites in New Zealand, five shoots with 5–10 leaves were randomly selected. In total, 1376 leaves from Brazil and 1028 leaves from New Zealand were assessed visually for several damage types. Detailed methods and results will be presented elsewhere, but a preliminary analysis shows that mean foliar damage was much higher in the samples from Brazil compared with those from New Zealand, i.e. pathogens $3.62 \pm 0.36\%$ cf. $0.12 \pm 0.08\%$ ($P < 0.0001$, $t = 12.01$, d.f. = 1507); insect/other herbivores $6.99 \pm 0.40\%$ cf. $0.83 \pm 0.17\%$ ($P < 0.0001$, $t = 20.88$, d.f. = 1939) respectively.

While the higher damage levels in Brazil are encouraging, the overall mean damage levels even in Brazil did not exceed 10% of leaf area. Care is needed in interpreting this figure though for the same reasons discussed under the biomass sampling, i.e. these samples are a ‘snapshot’ of damage levels, at sites that had sufficient *T. fluminensis* to be of interest to the survey (which was primarily aimed at collecting natural enemies and biomass samples). A better measure of damage would be obtained by marking individual shoots and monitoring these over time. This was beyond the scope of the current survey.

To summarise, if biomass levels of *T. fluminensis* in New Zealand could be reduced to the levels found in the native range in Brazil then the weed would largely cease to interfere with native regeneration. There is limited data on the damage caused by natural enemies to *T. fluminensis* in its native range, and although mean levels recorded were <10%, there were sites where much higher levels were recorded, and anecdotal observations from repeat visits to some sites were very encouraging. The next section reports on the results of the field collections of insect herbivores and plant pathogens, which was the most important aim of the field surveys.

Field-collected insect herbivore and plant pathogens

Lema obscura is an external foliage feeder as both larva and adult. It was collected only from *T. fluminensis* during field surveys in Brazil, and was not observed in sporadic examinations of related plants such as *Commelina bengalensis* and *Tripogandra diuretica*. It was observed causing moderate damage in the field, but in laboratory conditions readily caused major defoliation to potted plants. *L. obscura* was accorded top priority for further development because of its proven ability to damage tradescantia in the field, plus the relative ease with which it can be collected and reared.

Early in the project, formal collaborative agreements were set up with the Universities of Paraná and Viçosa in Brazil, and the project supports the relevant research groups, respectively under Professor Macedo Pedrosa and Dr Roberto Barreto, with ongoing and essential subcontracts. Additional research on the genetics/ecology of the plant in Brazil and New Zealand, its population dynamics, and the effectiveness of chemical and biological herbicides is supported by funding from the FRST project ‘Beating Weeds’, at Landcare Research and AgResearch.

Preliminary evaluation of the host-range was conducted at the University of Paraná, Brazil, and on the basis of these results an application to ERMA to import this species

into containment in New Zealand was made in January 2007. Several populations were collected in February 2007.

Host range testing on two populations has been conducted in containment by Landcare Research staff at Lincoln between March and September 2007. The results of this testing are reported here.

Plant pathogenic organisms are also being sought as biocontrol agents for this weed. Five fungal species have now been collected during surveys in Brazil: three Basidiomycetes – a rust fungus (*Uredo* sp.), *Kordyana tradescantiae* and *Ceratobasidium* sp.; a hyphomycete – *Cercospora apii*; and an ascomycete – *Mycosphaerella* sp. The *Uredo* rust fungus and *Kordyana tradescantiae* were the most widespread diseases observed to be damaging *T. fluminensis*. Both are leaf diseases that cause necrosis and dieback of the shoot material. However, further testing has shown that none of these isolates is able to infect New Zealand plants of *T. fluminensis* growing at the University of Viçosa. This suggests that there are different biotypes of both fungi in the native range. Work to progress these agents is ongoing whereby ‘trap’ plants (New Zealand origin) will be placed across the native range to capture biotypes that can attack the New Zealand ecotype of *T. fluminensis*. The third fungal candidate, *Cercospora apii*, is able to infect and damage NZ material so this pathogen is now being assessed in host-range tests for its specificity. Pathogenicity testing on the remaining two leaf diseases, *Ceratobasidium* sp. and *Mycosphaerella* sp., is planned, following research on three further species of *Lema*.

2.3 References

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