DEPARTMENT OF
PRIMARY INDUSTRIES

Impact of Chilean needle grass on biodiversity in Australian native grasslands

Research Update November 2008

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Background

A clear need has been identified to better determine and quantify the biodiversity impact of Australia's Weeds of National Significance (WONS). Anecdote, expert opinion and a few limited studies indicate that Chilean Needle Grass (*Nassella neesiana*), one of Australia's twenty WONS, is one of the most significant weed threats to native grasslands, which are amongst the most threatened of Australian ecosystems. *N. neesiana* appears to be reducing biodiversity by 1. occupying inter-tussock spaces formerly occupied by a diverse assemblage of native forbs; 2. outcompeting dominant native tussock grasses; 3. replacing native invertebrate food plants and altering food webs; and 4. altering the structure of grasslands, making them less suitable for use by native animals.

A PhD project on the biodiversity impacts of *N. neesiana* on Australia's indigenous grasslands has been funded by the Australian Government Department of Agriculture, Fisheries and Forestry under the 'Defeating the Weeds Menace Programme'. The project is supported by DPI Victoria, Victoria University and Environment ACT and has concentrated on Kangaroo Grass (*Themeda triandra*) grasslands in Victoria and the ACT.

The project is focused on identifying major components of the biodiversity at risk from, and affected by *N. neesiana* and the ecological mechanisms by which *N. neesiana* invades and causes impact. It is also attempting to determine whether invasion results from major disturbance, rather than from a superior competitive ability of the weed. If invasion is disturbance-dependent, the increasing resources devoted to direct *N. neesiana* control might be better spent on other management actions. The project is also attempting to compare the biodiversity values of rehabilitated areas with those of uninvaded and invaded (unrehabilitated) areas and quantify the effectiveness of new approaches to management.

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Aims

The project aims to answer the following questions, by undertaking a series of studies (shown in bold) that are experimental, observational or analytical:

1. Does disturbance & nutrient enrichment facilitate invasion? **Seed inundation & disturbance experiment**.
2. What biodiversity is impacted and how effective are remedial actions? **Floristics and invertebrate survey of invaded / not-invaded / successfully rehabilitated / unsuccessfully rehabilitated areas**.
3. Does *N. neesiana* support fewer species than a dominant native grass that it displaces? **Invertebrate faunistics of *N. neesiana* and Kangaroo Grass *Themeda triandra.***
4. What is the timescale of the biodiversity impact? **Floristics of transects from invaded to non-invaded areas**.
5. What is the geographical extent and severity of infestations and how are they related to landscape scale disturbance? **Invasion history / invaded site analysis.**

Results

1. Seed inundation and disturbance experiment

This was set up in *Themeda triandra* grassland at Iramoo Reserve, St Albans, in July 2007. It was designed to:

- test the 'invasion requires disturbance' hypothesis
- determine what types of disturbance facilitate invasion under known propagule pressure

The experiment involved the application of various disturbances to *Themeda triandra* grassland and inundation with seed of *N. neesiana* at 500 seeds m^{-2}. In total there were 30 different treatments applied to $1 m^2$ plots, with three replicates of each treatment.
Three **pre-treatments** –
1. Kill all tussocks of dominant native grass with glyphosate herbicide (= 'full kill').
2. Kill half the tussocks with herbicide (= 'half kill').
3. No kill of existing vegetation (= 'no kill').
Five **nutrient treatments**:
1. Nitrogen (granular urea). 2. Phosphorus (triple superphosphate). 3. N + P.
4. Sugar (to immobilise nutrients). 5. None.
Two ***N. neesiana* seeding treatments**:
1. Seed at 500 seed per square metre. 2. No seed.

Sugar provides a carbon source for soil microbes and stimulates their population growth, leading to rapid depletion of plant-available soil nutrients. Applications of sugar or other carbon sources such as sawdust and woodchips have been widely used to suppress plant growth in experimental situations.

N. neesiana seedlings established in the largest numbers on areas where pre-existing vegetation had been fully killed, and in the next largest numbers on 'half kill' plots (Figure 1, Table 1). A maximum of c. 60-70 juvenile plants was recorded after six months on plots where the best establishment occurred. Extremely few seedlings established and only 2 juvenile plants survived on 'no kill' plots as of August 2008. Application of fertiliser had no significant impact on the number of seedlings that established. However sugar significantly decreased seedling establishment.

Killing of the existing grass sward is known to release nutrients locked up in the grass biomass – the major nutrient store in such grasslands. The suppressive effect of sugar treatment indicates that sufficient quantities of major nutrients were available in the system after 'kill' treatments to enable seedling establishment without any additional fertilisation. However immobilisation of nutrients via sugar made seedling establishment more difficult.

Small numbers of established juvenile plants were lost over summer and autumn due to drought stress and grasshopper predation. Competition between juvenile plants led to some thinning out of the densest populations, but the clear pattern remains, after 16 months, of strong establishment in plots where existing vegetation was killed and extremely little establishment where the existing vegetation was not disturbed.

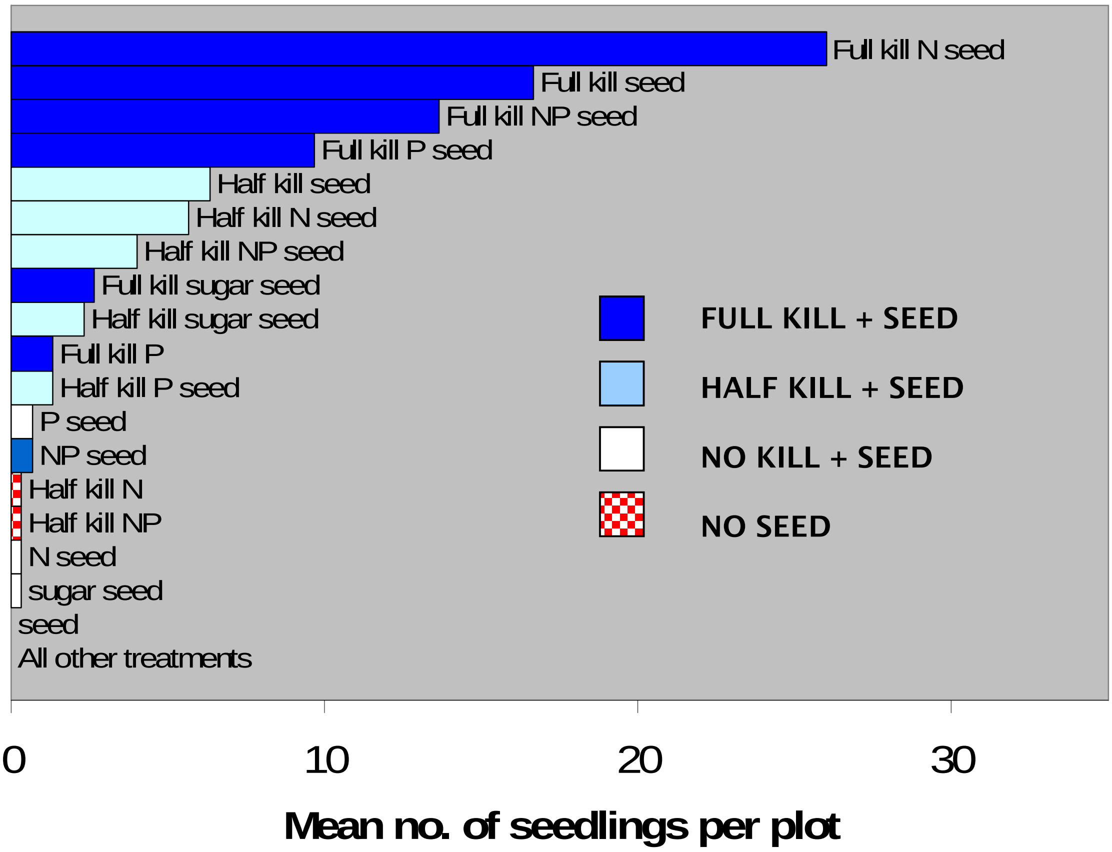

Figure 1. Mean number of *N. neesiana* juvenile plants 5 months after treatment in the seed inundation and disturbance field experiment.

Table 1. Effect of disturbance treatments on establishment of *N. neesiana*.

Effect of Kill and Sugar, 5 months after treatment
Transformed: long (number of *N. neesiana* seedlings +1)

Treatment	Full kill	Half kill	No kill	P value
No sugar	1.10	0.61	0.11	8.2 x 10-7 kill main effect
Sugar	0.40	0.38	0.10	0.022 sugar main effect

Effect of added N and P, 5 months after treatment
Transformed: log (number of *N. neesiana* seedlings +1)

Treatment	No	Yes	SED	P value
Nitrogen	0.56	0.65	0.115	0.42
Phosphorus	0.65	0.55	0.115	0.38

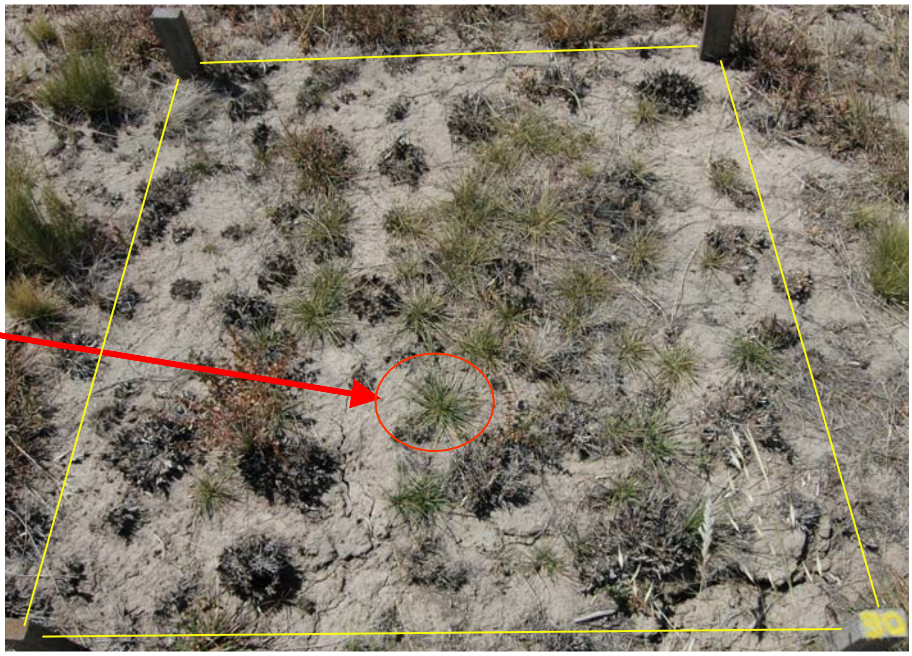

Figure 2. *N. neesiana* establishment on 'full kill' plot after 6 months (January 2008). *N. neesiana* has established mainly in the centre of the plot.

Clearly disturbance involving killing of the existing dominant grasses greatly facilitates invasion and intact swards are highly resistant to invasion. These results demonstrate that *N. neesiana* invasions may be largely the consequence of prior losses of diversity and suggest that the plant functions in the system as an analogue for a dominant native grass. However, once established, it may still cause biodiversity changes – these effects are intended to be assessed by other components of the project.

2. *N. neesiana* lifecycle

The seed inundation experiment has shown that seeds which germinate in spring can grow into mature plants by the following spring: most plants flower and produce panicle seeds before they are 12 months old.

3. Invasion of senescent *Themeda triandra* swards

Without repeated biomass reduction (e.g. by fire or grazing), highly productive *Themeda triandra* stands become extremely dense, with a very high proportion of dead foliage. Plants in these stands eventually senesce and die, releasing a pulse of nutrients into the soil. Pin transect sampling has been undertaken in stands of senescent *T. triandra* in the ACT (Figure 3) and Victoria to investigate the correlation between the degree of senescence and the amount of *N. neesiana*. A pin transect involves placing a fine rod (the 'pin') vertically through the grass sward at intervals and recording the number of touches on the pin by each plant species, live or dead. Highly significant positive correlations have been found between the presence of *N. neesiana* and a higher proportion of dead *T. triandra* foliage (Figures 5 and 6).

N. neesiana establishes around the bases of and between tussocks of senescent but still living *T. triandra* and in the thatch of dead leaves after *T. triandra* tussocks have died (Fig. 4). Areas of *T. triandra* with a higher proportion of live foliage are significantly less invaded (Figs. 5 & 6). Observations indicate that frontal or mosaic invasion occurs wherever senescent *T. triandra* is under propagule pressure from *N. neesiana*.

These results reinforce the finding that appropriate biomass reduction management of native grassland dominated by *T. triandra* is required to limit *N. neesiana* invasion and loss of biodiversity.

Figure 3. Chilean needle grass invasion front in senescent *Themeda triandra*, Dudley Street Grassland, ACT.

Figure 4. *N. neesiana* juvenile plants establish in thatch of dead *Themeda*.

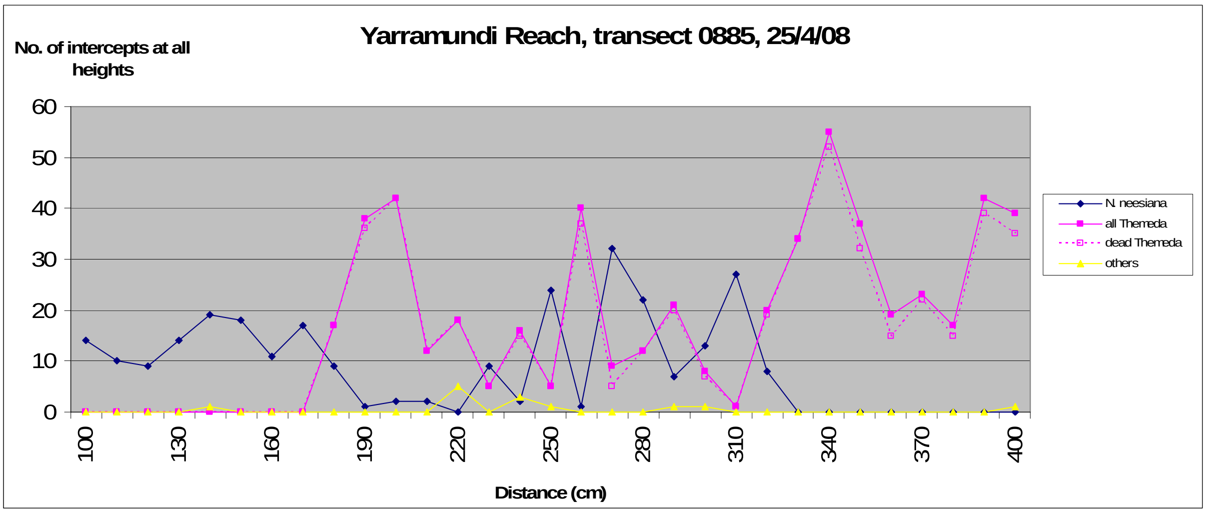

Figure 5. Pin transect across an *N. neesiana* invasion front at Yarramundi Reach grassland, ACT. The number of vegetation intercepts on a vertical 'pin' were counted at 10 cm intervals across the invasion front. Uninvaded *Themeda triandra* had consistently higher proportions of living leaves.

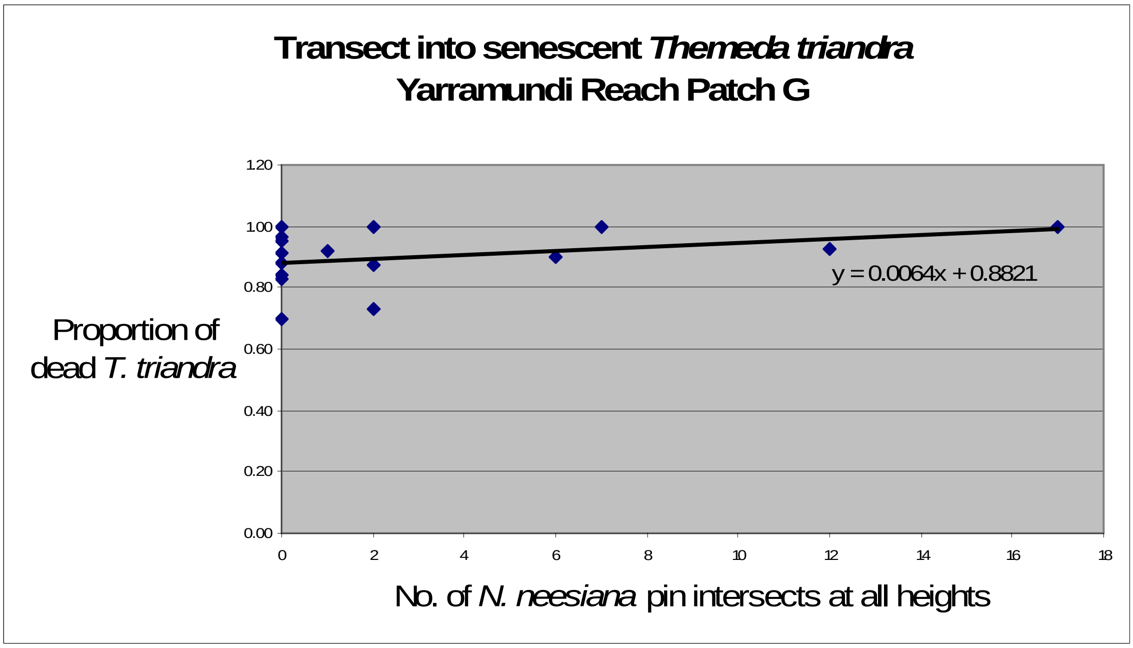

Figure 6. Typically, areas of more senescent *Themeda triandra* are more heavily invaded by *N. neesiana* than less senescent areas.

3. Laverton North pipeline study

Investigations have been undertaken at Laverton North Grassland to attempt to determine the effects of the installation of an oxygen pipeline in 1991 and subsequent management on the invasion of *N. neesiana* and the consequent effects on vascular plant diversity. The plant composition in the pipeline zone was assessed by other workers prior to, and in the years immediately after installation of the pipeline.

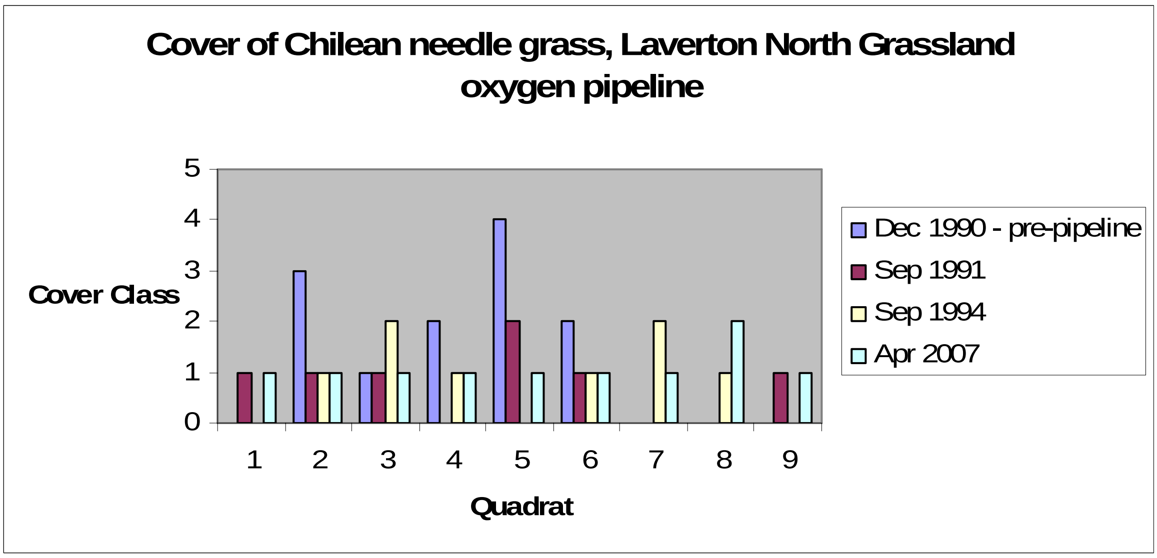

Figure 7. Cover of *N. neesiana* in matched quadrats in the pipeline zone before, immediately after and 16 years after pipeline installation.

In 2007 *N. neesiana* was more widespread than at any previous period, being present in for the first time in all quadrats, but never with more than 20% cover (Figure 7) and usually with less than 5% cover. It was present with lower cover than in previous years in six quadrats, with higher cover in only 1 quadrat. Cover values in 4 quadrats were lower than before pipeline installation.

Species frequency and cover was assessed in January 2008 in large (5 x 2 m) quadrats in three zones: within the Grassland Reserve (managed by burning), along the pipeline reservation and in an unmanaged zone immediately to the west. Analysis of the data indicates the highest *N. neesiana* cover in the pipeline zone, followed by the unmanaged zone, with much less cover in the Reserve. However these differences were not statistically significant. The pipeline zone contained significantly fewer native species and total species than the other zones, very little *Themeda* or native forbs, much more *Avena* spp. (Wild Oats) and ephemeral exotic grasses, and a much higher cover of grass litter.

Interpretation of these results is complicated: attempts to re-establish *Themeda* in the pipeline zone failed; native vegetation was destroyed along the pipeline and has largely failed to recolonise; subsequent management has perpetuated the dominance of annual grasses; and *N. neesiana* presence in the pipeline zone, while still high, has probably been reduced by infrequent spraying.

This component of the study enables good quantification of the effects of differing management regimes on the interaction between plant biodiversity and *N. neesiana.*

4. Comparative vascular plant diversity of *N. neesiana* patches and adjacent native grassland

To date results have been obtained from large numbers of patches at three sites: Laverton North Grassland, Vic., and Yarramundi Reach and Crace grasslands in the ACT. The former two sites are considered to be comparatively degraded grasslands, while Crace is better preserved with higher native plant diversity. Ideally the impact of *N. neesiana* needs to be assessed in high quality grassland remnants, but practically it has proved difficult to find rich remnants that have sufficient *N. neesiana* to enable replication of the work undertaken in the degraded grasslands.

Data from these grasslands (Figures 7-9) shows that areas within *N. neesiana* patches have lower total vascular plant diversity than those outside of patches and lower native plant diversity. Transitional zones (patch edges) had similar diversity to areas outside the patches.

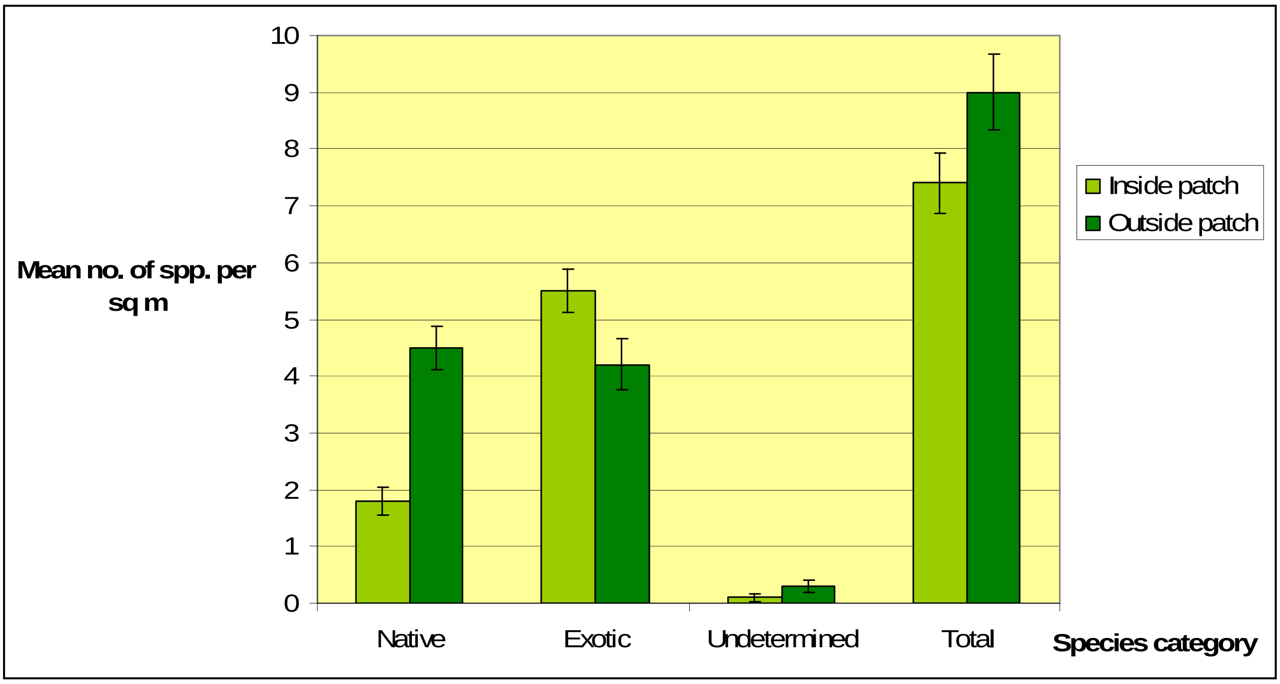

Figure 7. Mean number of vascular plant species per square metre inside and outside patches of *Nassella neesiana* at Yarramundi Reach, ACT.

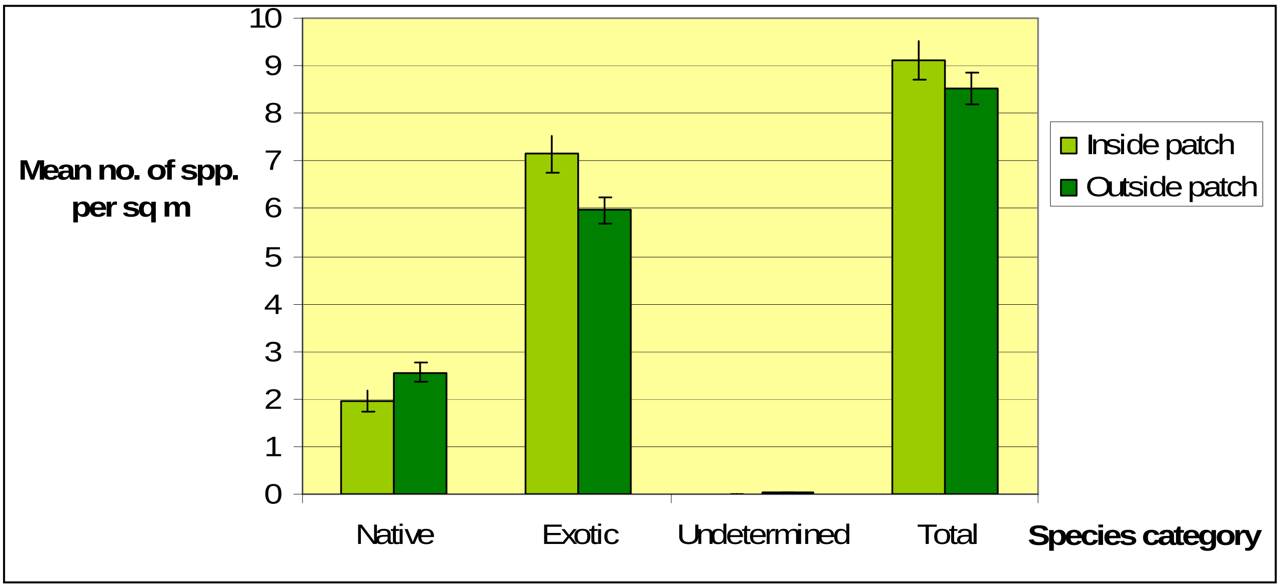

Figure 8. Mean number of vascular plant species per square metre inside and outside patches of *Nassella neesiana* at Laverton North Grassland, Vic.

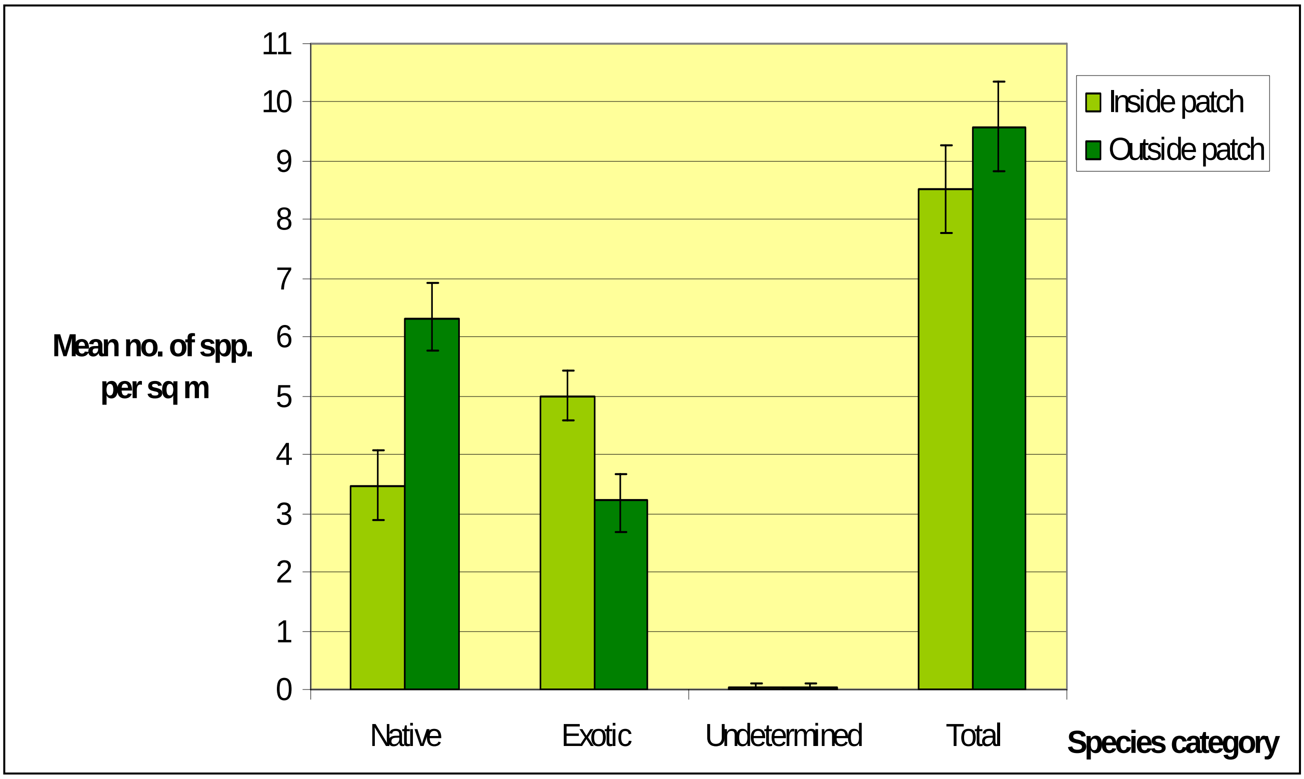

Figure 9. Mean number of vascular plant species per square metre inside and outside patches of *Nassella neesiana* at Crace Grassland Reserve, ACT.

Native plant species diversity per unit area decreases inside *N. neesiana* patches as the patch size increases (Figure 10). Extrapolation using the established relationship indicates that a patch of 1400 square metres would have an average of zero native plant species per square metre. This is not to say that larger patches contain fewer native species overall – the increased size of the patch may compensate for the generally lower native biodiversity per unit area.

Larger patches might be older than small patches, i.e. small patches might be expected to gradually expand through time. If they are, native diversity loss continues to increase after the initial invasion. Examination of historical aerial photographs is to be undertaken to attempt to establish a relationship between patch size and patch age.

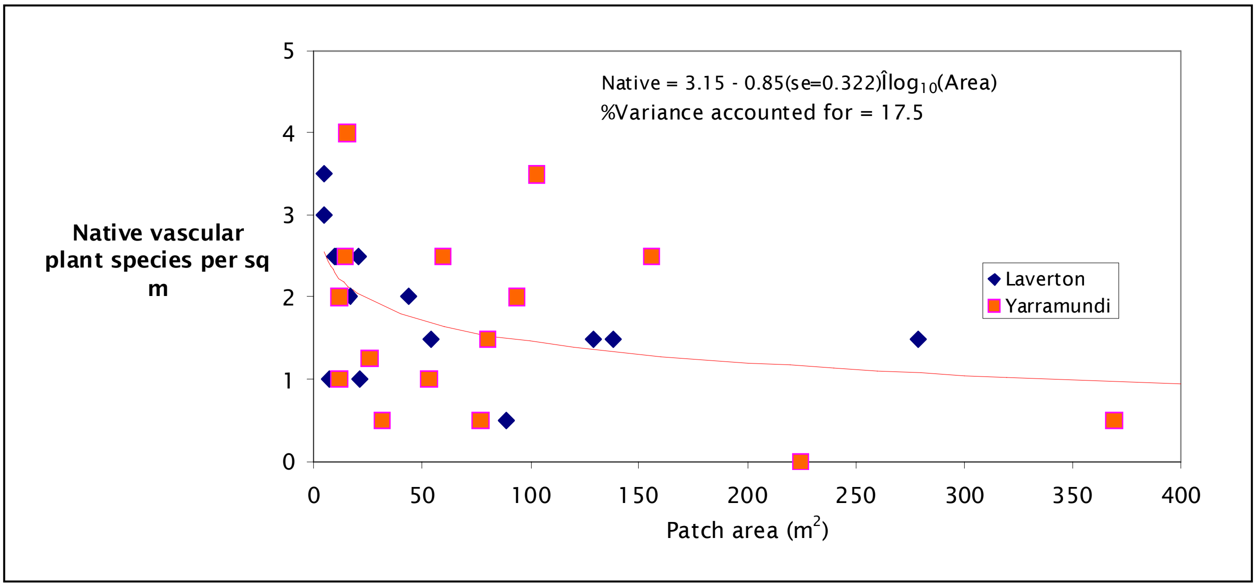

Figure 10. Relationship between *N. neesiana* patch size and native plant species diversity for Laverton North and Yarramundi Reach grasslands.

5. Comparative invertebrate biodiversity of *N. neesiana* patches and adjacent native grassland

Sets of pitfall trap, sweep net and direct search samples have been assembled and are in various stages of processing. Major progress has been made on the identification of taxa within the samples. Identifications have been undertaken at the Museum of Victoria and Victorian Agricultural Insect Collection (DPI) and using literature keys. A small number of species have been identified by specialists. No analysis has so far been undertaken and no clear trends are apparent. It is intended that subsets of the samples, involving selected major taxa, will be analysed in the most detail. Taxa chosen for more intensive investigation include ants, leafhoppers and beetles.

6. Invertebrate use of *N. neesiana*

As expected, it has been found that *N. neesiana* supports a substantial suite of polyphagous grass-eating native invertebrates including grasshoppers (Acrididae), various bugs (Hemiptera), a beetle stem borer, a range of leaf eating moths and a number of amycterine weevils. Grasshopper damage to seedlings has been observed to cause some mortality, but no other substantial damage has been observed. No organisms have been detected that damage seed on the plant.

A species of *Pheidole* ant has been found to harvest a high proportion of fallen *N. neesiana* seeds in Melbourne grasslands, along with a high proportion of all other grass seeds (Figures 11 and 12). The seeds are delivered to the nest, the nutritive part removed and the remains of the seed (lemma and awn fragments) are deposited outside the nest in prominent refuse heaps. Ant predation of seed may explain the much smaller size of *N. neesiana* seed banks in these grasslands than reported in New England and New Zealand pastures. Seed harvesting ants are doubtless partly responsible for the low numbers and very short life of most native plant seeds in the soil seed bank of south-eastern Australian grasslands.

A comparison of the invertebrate faunas of *N. neesiana* and *Themeda triandra* is an expected outcome of the project.

Figure 11. *Pheidole* sp. carrying seed of *N. neesiana*.

Figure 12. *Pheidole* foraging trail – ants carrying seeds of *Nassella trichotoma*, *T. triandra* and *Romulea rosea*.

7. Mechanisms of impact

The pattern of *N. neesiana* seedling establishment (mainly in the central part of 'full kill' plots) in the 'seed inundation and disturbance' field experiment suggests that competition for water is important in enabling establishment. Results from the patch floristics studies show that larger *N. neesiana* patches have reduced native plant diversity compared with small patches. If large patches are the result of the expansion of small patches over time, large patches are older, and their reduced native diversity is likely the result of cumulative losses over time. Resource competition is a likely explanation for such continuing decline.

An attempt is being made to test the hypothesis that *N. neesiana* causes impact on the majority of native plant species by depleting soil water during the spring growing period. The dominant native grass in many temperate south-eastern Australian grasslands is the C4 ('summer growing') *T. triandra*, which presumably does not compete strongly for soil water when the major flush of native species occurs in the spring. In contrast, *N. neesiana* is a C3 ('spring growing') grass, so presumably competes directly for water with the native spring growing species.

Measurements of soil moisture content in ACT grasslands indicate that soils occupied by *N. neesiana* are drier in spring than those occupied by immediately adjacent *T. triandra*. Good evidence for the hypothesis requires a reversal of this situation in the summer.

Depletion of soil water by *N. neesiana* prior to the growing period of *T. triandra* would presumably negatively effect its growth, fecundity and survival, and may plausibly be a contributory factor to *T. triandra* senescence; i.e. *N. neesiana* presence may establish a positive feedback cycle that accelerates senescence and enables patch expansion.

8. Historical analysis of invasions

Sets of historical aerial photographs have been obtained for a number of grasslands with major *N. neesiana* infestations. These are intended to be used to evaluate the time-course of the invasions and if possible to estimate rates of spread and patch expansion. 'Ground-truthing' of some areas of these grasslands has been undertaken to assess current *N. neesiana* distribution. Photographs of Laverton North Grassland show historical disturbances that correlate closely with current *N. neesiana* patches. Detailed evaluation of these disturbances including what is known from the written record is expected to add substantially to the understanding of the invasion process.

8. Inventory studies

Annotated lists of taxa detected at each grassland site are being compiled as time permits, and where possible synthesised with information recorded in the literature. These are mainly focused on the invertebrates, since the vascular plants and vertebrates are much better known, but include all taxa that are identified in project work. Details of each pertinent observation of a species are compiled e.g. on abundance, food plants or behaviour. A range of rare taxa have been detected e.g. *Antitrogus carnei* Britton (Scarabaeidae: Melolonthinae: Melolonthini), a large beetle, 16-18 mm long, with a black head and pronotum and reddish brown elytra, collected at Laverton North Grassland, appears to have been previously known from only a few records in Canberra and four males collected in January 1971 at Yea, Victoria.

Summary

Findings to date:

1. *N. neesiana* presence has been correlated with reduced diversity of native plant species and increased diversity of exotic plant species (i.e. other weeds). *N. neesiana* patches may be expected to have an average of c. 0-3 fewer native plant species per square metre than immediately adjacent uninvaded areas.
2. The number of native plant species per square metre in *N. neesiana* patches declines as patch size increases, suggesting that diversity losses accumulate over years.
3. *N. neesiana* seedlings do not establish and survive in areas of intact native grassland but establish well in areas where the existing dominant perennial grass is killed.
4. Addition of fertilisers (nitrogen and phosphorus) did not aid seedling establishment, in the experimental grassland, but immobilisation of nutrients (using sugar) in areas where the native grass has been killed, suppressed seedling establishment.
5. *N. neesiana* presence is higher in stands of *Themeda triandra* that have senesced due to inappropriate management than in healthy stands – the weed invades as the dominant native grass dies.
6. Overall, the results suggest that *N. neesiana* invasion is commonly a consequence of previous loss of plant diversity due to disturbance that causes death of the dominant native grasses or due to inappropriate management that leads to senescence dieback of *T. trianda*. Reduced native plant diversity in *N. neesiana* patches may often precede and enable *N. neesiana* invasion.
7. Further loss of native diversity within *N. neesiana* patches due to competitive effects of the grass may occur over time as the size (and age?) of the patch increases. However patch size expansion may be caused by further disturbance, particularly continued senescence of *T. triandra*. Larger patches may possibly occur in areas where there was less initial resistance to invasion, and such areas could be expected to already have lower native plant diversity.
8. Numerous species of generalist herbivores utilise *N. neesiana* for food – and it possibly preferred over native grasses in some cases.
9. Invasions can be halted and stabilised by appropriate grassland management.

Publications

Faithfull, I. (2007) Impact of Chilean needle grass on biodiversity in Australian native grasslands. Chilean needle grass Research Update. Pp. 7-13 in *Chilean Needle Grass Field Day Fact Sheets Research Update*, compiled by C. Grech, I. Faithfull & D. McLaren, Department of Primary Industries, Attwood, November 2007, 32 pp. www.weeds.org.au/WoNS/Chileanneedlegrass/docs/86_Field_Day_Research_Update_2007.pdf

Faithfull, I., Hocking, C. and McLaren, D.A. (2008) An investigation of the effects of disturbance on the establishment of *Nassella neesiana* (Trin. & Rupr.) Barkworth (Poaceae) in an Australian native grassland. *Proceedings of the 16th Australian Weeds Conference*, eds. R.D. van Klinken, V.A. Osten, F.D. Panetta and J.C. Scanlan (Queensland Weeds Society, Brisbane), pp. 202-204.

Faithfull, I., Hocking, C. and McLaren, D.A. (2008) A preliminary assessment of the composition and cover of vascular plants associated with patches of *Nassella neesiana* (Trin. & Rupr.) Barkworth (Poaceae) in Australian native grassland. *Proceedings of the 16th Australian Weeds Conference*, eds. R.D. van Klinken, V.A. Osten, F.D. Panetta and J.C. Scanlan (Queensland Weeds Society, Brisbane), pp. 206-208.

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