Eragrostis curvula effects on above and below-ground plant species richness and diversity

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Key words: soil seed bank; invasive perennial grass; species richness; species diversity

Abstract

Monitoring and managing the soil seed bank is fundamental to land management as it constitutes the future generations of invasive plant communities. Invasive plants have traits that result in high recruitment through increased seed generation, short seed dormancy and phenotypic plasticity. Furthermore, invasive plants with growth forms that inhibit the growth and recruitment of other species can lead to monocultures and associated reduction in above-ground biodiversity, potentially negatively impacting the soil seed bank diversity and ecosystem functions and services. *Eragrostis curvula* is one such species that has many of these invasive traits, including high propagule generation, and can exclude plant species from establishing in the above-ground population, thus negatively impacting above-ground biodiversity, as measured by species richness and Shannon diversity index. However, our findings suggest it has not significantly impacted the soil seed bank species diversity or richness across eight sites within the Snowy Monaro region when competition is removed as a limiting factor. Our findings provide valuable information on a path to invasive plant species management. If *E. curvula* above-ground biomass is controlled, other species dormant in the soil seed bank may recruit in the ecosystem, provided they remain viable in the soil seed bank. However, to date, our research has not investigated the species composition of these sites in detail. With such a high density of potentially germinating seeds in a soil seed bank and the adverse effects the species can have on the above-ground species diversity and richness, *E. curvula* needs integrated management to mitigate its spread and ecosystem and economic impact.

Introduction

The impact of invasive plants on species richness and diversity is well established in the literature, with examples of disturbance regime changes and superior competition due to enemy release or resource use efficiency and phenotypic plasticity all potentially contributing to decreased biodiversity (Briske, Fuhlendorf, & Smeins, 2005; Catford et al., 2016; Catford, Jansson, & Nilsson, 2009; Vitousek, 1990). Further, it has been established that genetic, species and functional diversity reductions can adversely affect ecosystem function and services by lowering primary production, nutrient and water cycles and pollination (Cardinale et al., 2012; Hooper et al., 2005). Therefore, landscapes with severe invasive species infestations should be assessed for the impact on biodiversity and managed towards natural recovery to maximise economic, ecological and social good.

The inherent native soil seed bank present at an invaded site plays a vital role in facilitating the natural recovery following invasive species management (Fourie, 2008). However, an issue when managing invasive species is re-infestation or infestation by another undesirable species present in the soil seed bank or through vegetative reproduction (Buckley, Bolker, & Rees, 2007). In order to make informed decisions regarding invasive plant management, it can be helpful first to understand the underlying soil seed bank richness and diversity.

Methods

The extent of the study area covers the New South Wales Local Government Area of the Snowy Monaro Regional Council (hereafter SMRC), which has an approximate area of 1,516,000 hectares (top: -35.579312, right: 149.602741, bottom: -37.262980, left: 148.200678).

Ten randomly placed 1 x 1-metre quadrats were placed at each site, with three sites per property and eight properties surveyed across the SMRC, resulting in 24 sites total. Each quadrat was split into a grid formation with equal spacing of 33.3cm. Sixteen soil samples were taken in each quadrat at the interception of the grid and amalgamated into a single sample. The soil sample size was a core of eight cm deep and a diameter of five cm taken with a hand auger. Soil samples were stored at 4 degrees Celsius until established in a greenhouse experiment. In addition to soil samples being taken, a vegetation survey was conducted within each quadrat, with species identity and cover estimate recorded of above-ground biomass, the outcome here referred to as above-ground species richness and diversity.

The germination of the soil seed bank, the outcome here referred to as below-ground species richness and diversity, was conducted in a temperature-controlled glasshouse with a day-night cycle of 16-8 hours, with day temperature set to 25°C and night temperature set to 15°C. Two-hundred and twenty-six 30x22cm germination trays were used in this experiment, with each tray containing a subset of the soil collected in the field. In each germination tray, approximately 3cm of coir garden soil was placed at the bottom of the tray to retain water and prevent soil loss, and a one-centimetre layer of the sampled soil from each quadrat was laid on top of the coir and randomly placed in the glasshouse. Daily observations were made for the first two weeks of the glasshouse experiment to record any early germination with daily watering or as needed. Following the two weeks, observations were recorded three times a week for the duration of the experiment, three months. If a species could not be identified as a seedling, it was transplanted to a pot until an identification could be made.

Analysis

Generalised linear mixed effect models (GLMM) using a poisson distribution were used to analyse the data with *E. curvula* proportional covers set as the predictor variable and species richness or Shannon-Wiener diversity index as the response variables for above and below-ground data, resulting in four full GLMM. For each GLMM, a random variable of “Farm site” was used, corresponding to each site surveyed. The full and null models were compared with ANOVA using the Akaike Information Criterion (AIC) derived from the models to determine if the effect of the predictor variable was more influential on the response than the mean, with the model with the lower AIC value explaining more of the variation in the model, thus assessing model fit. Bayesian Information Criterion BIC, log-likelihood value and deviance were also used to assess model fit.

Results and Discussion

Fifty-six species were recorded in the soil seed bank experiment. 29% of the species recorded in the experiment could not be identified to a species level but were considered morphologically distinct from other species. Our results suggest that above-ground species richness and diversity are negatively correlated with the proportional cover of *E. curvula*, with a more pronounced effect on species diversity as measured by the Shannon–Wiener diversity index. However, no correlation was observed between below-ground species richness or diversity and *E. curvula* (**Table 1**).

Table 1 *Eragrostis curvula* interaction with above and below-ground species richness and diversity. The * indicates a significant difference between the null and the full model as determined by analysis of variance run on the AIC values.

			AIC	**BIC**	**logLik**	**deviance**
Above- ground	Richness	Null model	728.5	734.4	-362.3	724.5
		Full model*	710.8	719.7	-352.4	704.8
	Diversity	Null model	41.7	50.5	-17.8	35.7
		Full model*	-83.5	-71.7	45.8	-91.5
Below-Ground	Richness	Null model	592.6	601.4	-293.3	586.6
		Full model	593.9	605.6	-292.9	585.9
	Diversity	Null model	151.5	163.3	-71.8	143.5
		Full model	152.7	167.4	-71.3	142.7

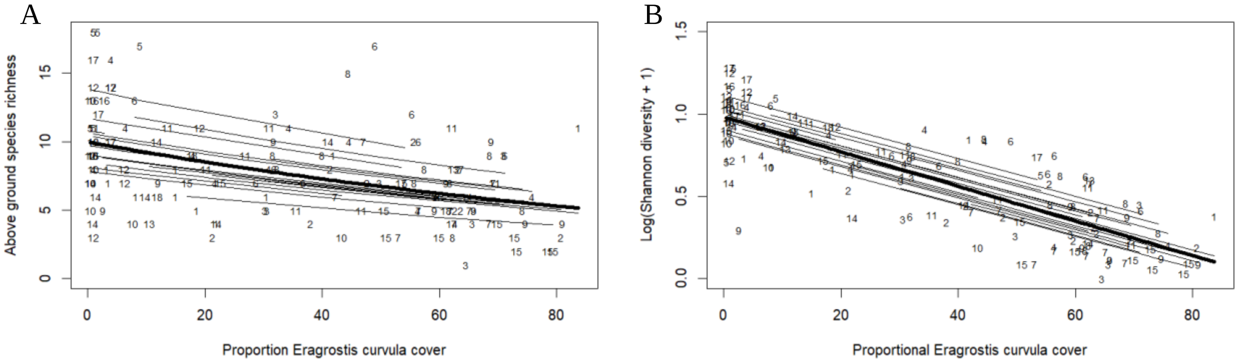

Figure 1 Relationship of the proportion of *Eragrostis curvula* proportional cover and above-ground species richness (A) and log above-ground species Shannon–Wiener diversity index (B). The numbers in each plot correspond to different sites used in this experiment. The bold lines show the model fit with a generalised linear model fit using a poisson distribution, while the thinner lines show the generalised linear mixed effect model using a poisson distribution to illustrate the variation among sites.

Invasive plant species treatment

The inherent native soil seed bank present at an invaded site plays a vital role in facilitating the natural recovery following invasive species management (Fourie, 2008). However, an issue when managing invasive species is re-infestation or infestation of another undesirable species present in the soil seed bank or through vegetative means (Buckley et al., 2007). Our research shows that regardless of *E. curvula* proportional cover, below-ground species richness and species diversity are not affected. Fourie (2008) observed similar soil seed bank dynamics in the invaded grassy fynbos of South Africa where despite 30 years of established invasion of *Acacia longifolia,* the soil seed bank still had “diverse and viable soil seed bank with relatively high seed densities”. Records of *E. curvula* present within the study region date to 1948, indicating that certain areas may have been invaded for as long as 70 years (Leigh & Davidson, 1968).

Impacts of invasive plant species on species richness and diversity

Here we see that as *E. curvula* proportional cover increases, above-ground species richness and diversity decrease. This negative correlation is most pronounced in the relationship between above-ground species diversity and *E. curvula* proportional cover. This is partly a result of *E. curvula’s* ability to produce dense biomass that can act as a barrier to light, making light a limiting resource for other co-existing species (Firn, House, & Buckley, 2010; Johnston, 1989; Mynhardt, Vanrooyen, & Theron, 1994). This effect is exacerbated by the early growth traits of *E. curvula*, as it will germinate earlier and grow faster than many native and non-native co-existing species (Firn et al., 2010; Han, Buckley, & Firn, 2012; Roberts, Florentine, van Etten, & Turville, 2021). Ghebrehiwot, Aremu, and Van Staden (2014) offer an alternate explanation that may work in tandem with light limitation in the form of allelopathy. Ghebrehiwot et al. (2014) suggest that *E. curvula* can inhibit the growth of other species through chemical compounds in its leaves, leading to *E. curvula* not only being the dominant species but also restricting the recruitment of other species.

Schlierenzauer, Risch, Schütz, and Firn (2021) present similar findings to our observations, where they observe that presence of *E. curvula* resulted in significantly different plant species compositions compared to similar sites lacking *E. curvula*. Schlierenzauer et al. (2021) observed different plant species compositions and lower species richness and forb diversity on both sites, dominated by *E. curvula* and co-dominated by the native *Themeda triandra*. Schlierenzauer et al. (2021) suggest grazing herbivores as a potential driver of the observed species composition difference, where herbivores will selectively graze the more palatable species, leaving the less palatable *E. curvula* relatively less consumed (Firn et al., 2010). As *E. curvula* is not a preferred grazing species, less biomass will be removed, further supporting the hypothesis that light limitation is one of the main driving factors leading to lower species richness and diversity at sites dominated by *E. curvula* (Borer et al., 2014; Schlierenzauer et al., 2021).

Conclusions

Soil seed bank studies are fraught with limitations due to the complex spatial distribution of seeds in the soil, required germination cues such as heat, smoke and disturbance, and germination timing of different species (Baskin, Baskin, Baskin, & Baskin, 2014). Furthermore, soil seed bank studies are a snapshot of a dynamic system with soil seed banks being in a state of flux with species compositions being dependent on the time of sampling (Fourie, 2008). Regardless, value can still be obtained from soil seed bank research as it allows insight into managing invaded systems. Our research indicates that *E. curvula* has a negative impact on both plant species richness and diversity. However, this negative impact does not appear to extend to below-ground plant species richness and diversity. We suggest that recovery of these invaded systems may be feasible if the biomass of *E. curvula* invaded sites is controlled. If the biomass is controlled, as the natural recruitment of propagules in the soil seed bank occurs, this may act as enough competition to shift the above-ground species composition from an invaded state to a native state (Han et al., 2012). It is vital to note that here we have not separated species into functional groups or classes of native and non-native. Therefore, further research is needed on the specific impacts of *E. curvula* on functional diversity and native and non-native species richness and diversity.

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