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Longevity, growth and community ecology of invasive *Poa annua* across environmental gradients in the subantarctic

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Abstract

Poa annua is a cosmopolitan weed in turf grass. It is a widespread non-native species in the subantarctic and also occurs in the Antarctic Peninsula. It has highly variable morphology, longevity and reproductive capacity across both its invaded and native range. Little is known about the ecology of *P. annua* in the subantarctic, particularly its longevity, morphological variation across small spatial scales and competitive ability. We monitored individual *P. annua* plants on subantarctic Macquarie Island to assess their longevity; quantified morphology and biomass allocation across environmental gradients; and assessed community diversity indices in areas of varying *P. annua* density. We show that *P. annua* plants on Macquarie Island are perennial, and their morphology varies with elevation, animal disturbance and soil properties. At low altitude, coastal sites with high animal disturbance and deep, sandy soils, *P. annua* plants are larger and native plant diversity is low. Conversely, at high altitude sites *P. annua* plants are smaller and the diversity of native species is not reduced. This new information informs why *P. annua* is the most successful plant invader in the subantarctic and quantifies some key characteristics enabling an invasive species to function well beyond its natural range. Community ecology theory can also explain patterns in the ecology of *P. annua* on Macquarie Island.

Keywords: Alien; Antarctic region; Wintergrass; Weed; Perenniality

Introduction

Poa annua L. is a cosmopolitan weed (Heide, 2001). Its introduced range extends to the Arctic (Warwick, 1979), Antarctic Peninsula (Chwedorzewska et al., 2015) and subantarctic (Frenot et al., 2005; McGeoch, Shaw, Terauds, Lee, & Chown, 2015; Williams, Kristiansen, Shaw, Sindel, & Wilson, 2013) (Fig. 1). It is the only introduced plant with an established, reproducing population in the Antarctic (Chwedorzewska et al., 2015), and is the most widespread non-native plant in the subantarctic (McGeoch et al., 2015). The longevity, morphology and reproductive capacity of *P. annua* vary greatly across its secondary and native range, largely in response to environmental conditions (Soreng & Peterson, 2012; Warwick, 1979). *P. annua* plants in the Antarctic and subantarctic differ in their ecology from populations elsewhere (Galera, Chwedorzewska, & Wódkiewicz,

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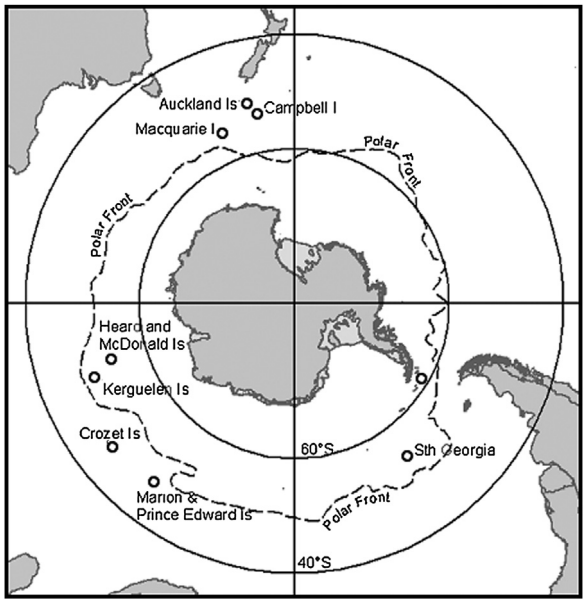

Fig. 1. Distribution of *Poa annua* on the main sub-Antarctic islands and the Antarctic Peninsula, as indicated by grey circles. Modified from Australian Antarctic Data Centre (2005).

2015). On subantarctic Macquarie Island, *P. annua* was accidentally introduced by seal hunters nearly 150 years ago. It is now widespread on the island, found from coastal tussock vegetation to the wind-swept feldmark (Selkirk, Seppelt, & Selkirk, 1990), and appears to differ considerably in its morphology and reproductive output.

The ecology and population dynamics of *P. annua* have been well studied in temperate turf grass where the species is a particular management problem (Beard, Rieke, Turgeon, & Vargas, 1978; Heide, 2001; Mitich, 1998; Wu, Till-Bottraud, & Torres, 1987). In turf grass systems, *P. annua* tolerates disturbance and nutrient enrichment (Beard et al., 1978; Heide, 2001), has very high seed bank densities (e.g. 210 000 seeds m^{-2}) (Lush, 1988) and competes with sown turf grass species (Beard et al., 1978). Some research on the ecology and population dynamics of *P. annua* has been undertaken in the subantarctic. *P. annua* is widespread in the subantarctic, occurring on all the major island groups and is highly tolerant of grazing by introduced herbivores, wildlife disturbance, nutrient enrichment and trampling (Bergstrom & Smith, 1990; Copson, 1984; Haussmann, Rudolph, Kalwij, & McIntyre, 2013; Scott & Kirkpatrick, 1994, 2013; Whinam, Fitzgerald, Visoiu, & Copson, 2014). It is also an early coloniser of bare ground, deglaciated areas and landslips (Frenot, Gloaguen, & Tréhen, 1997; Frenot, Gloaguen, Cannavacciuolo, & Bellido, 1998). Other aspects of the ecology of *P. annua*, such as longevity, morphology and competitive ability are less well understood. Given the variability seen in *P. annua* elsewhere, aspects of its ecology are likely to differ both between the subantarctic islands and within islands in response to differing environmental variables.

Longevity is an important and variable plant trait influencing population dynamics, often closely aligned with a plant's morphology. Field observations suggest there are annual and perennial populations of *P. annua* in the subantarctic (Frenot et al., 2005). Tussocks in the Antarctic have been observed to be perennial (Chwedorzewska et al., 2015), and the Macquarie Island populations have been suggested to be perennial (Ellis, Lee, & Calder, 1971; Selkirk et al., 1990). However, to the best of our knowledge, the longevity of individual *P. annua* plants in the subantarctic has never been quantified *in situ*.

The morphology of *P. annua* plants can vary both within the Antarctic and subantarctic region and is largely attributed to environmental factors. *P. annua* plants growing in the Antarctic (South Shetlands) and subantarctic Kerguelen and Crozet Islands are smaller and more compact due to the lower growing temperatures and wind and snow damage than those from Poland, a likely source location of the Antarctic *P. annua* population (Frenot & Gloaguen 1994; Galera et al., 2015). When *P. annua* plants sourced from different populations around the world (including subantarctic Macquarie Island) were grown under common garden conditions, plants maintained morphological differences in response to provenance, albeit for an unspecified time period (Ellis et al., 1971). Frenot et al. (1999) observed distinct morphological differences in *P. annua* between populations on subantarctic Kerguelen and Crozet. Although plants were similar in size, those from Kerguelen had higher reproductive fertility, possibly due to vertebrate enrichment (higher nitrogen and phosphorus) at the Kerguelen sites. Plants also differed in morphology within each archipelago in response to environmental factors such as soil particle size (Frenot et al., 1999). Whilst the aforementioned research shows there is variability in the morphology of *P. annua* across the Antarctic region, the variability in *P. annua* morphology across smaller spatial scales (i.e. between populations within an island) and the drivers of this variation (environmental correlates) requires more research.

The competitive ability of *P. annua* and its impacts on native plant communities in the subantarctic appear to vary between sites. Some studies show that while *P. annua* is an early coloniser of bare ground, it does not directly compete with native species but is outcompeted over time in established native vegetation (Scott and Kirkpatrick, 2008, 2013; Whinam et al., 2014). Other studies report that in the highly disturbed, nutrient-enriched areas around seal haul outs, *P. annua* forms low grasslands and dominates the native vegetation (Frenot, Gloaguen, Masse, & Lebouvier, 2001; Haussmann et al., 2013). Pot trials with *P. annua* collected from the Antarctic Peninsula, however, showed the species competes directly with native plants (Molina-Montenegro et al., 2012, 2016). Competitive ability therefore depends on specific environmental factors.

As the most widespread invasive plant species in the subantarctic region, it is important to understand the ecology of *P. annua* as this has implications for management, conservation and invasion biology in the region and informs invasive plant

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