Germination, competition and climate: Plant interactions and the formation of novel annual plant communities

Introduction

Broad scale processes such as climate change and landscape transformation affect local environments and therefore local communities. Changed environmental conditions coupled with the introduction of exotic species lead to collections of new species that do not normally live together. Little is known about how these “new” or “novel” communities form, or how they function. Are the new exotic arrivals able to coexist with the current residents, or do they eventually outcompete and exclude the current native occupants? How are these competitive dynamics likely to shift under a climate-warming scenario?

In order to study novel community dynamics, I chose to use annual plant species found within the bio-diverse South-west region of Western Australia (WA). This region has undergone extensive landscape transformation. The combination of land clearing for agricultural crops such as wheat, along with application of fertilisers, and the introduction of exotic pasture has led to a heavily fragmented environment with many exotic invaders. Only 2 – 3% of native vegetation remains in a patches of remnant woodland, and many of these remnant patches already show signs of novel community formation.

South-west WA experiences a Mediterranean climate, with cool wet winters and hot dry summers, and water availability is a major limiting factor. Given the harsh summer conditions, most annual plants within this system survive by germinating in cool wet conditions. To ensure seedlings emerge at this time, many native species possess adaptive early life history strategies such as seed dormancy and germination cueing. New arrivals into this system however, may employ other life history strategies such as no dormancy or germination cueing, or may be superior at securing limited water resources. For this reason, it may be difficult to predict how these new residents affect the competitive dynamics and thereby shift community structure within these plant communities.

Climate change predictions include raised temperatures and increased rainfall variability for the South-west WA region. Because many native plants rely on cool wet conditions as cues for germination, shifts in these environmental conditions may affect the timing and abundance of seedling emergence, potentially affecting how they compete with introduced exotic species. Currently, native and exotic species coexist within the remnant patches in South-west WA; however, is this relationship likely to change when the climate warms and rainfall becomes less predictable?

Methods

Using a guild of annual plants associated with York gum (*Eucalyptus loxophleba* subsp. *loxophleba*) woodlands from the Perenjori region in South-west WA, I investigated whether temperature and water availability interact with germination cues and competitive ability to shift community dynamics among native and exotic plants. In order to test these interactions, I conducted my experiments in two parts. First, I aimed to establish what the temperature and smoke mediated germination cues are for both native and exotic species within these communities. I conducted germination trials using seed from 29 species (nine exotic and 20 native). Results from early trials suggested that many of these seeds were dormant, so in order to alleviate dormancy, I pre-treated all seed with two weeks dry after ripening (DAR) at 40°C. In order to test for specific germination cues, I placed seeds into factorial combinations of temperature and smoke treatments. Treatments consisted of one of three constant temperatures (7°C (cool), 14°C (warm) and 25°C(hot)) and one of two smoke treatments (smoke (S) or non-smoke (NS)).

For the second part of my study, I chose one native, *Podotheca gnaphalioides* (Asteraceae), and two exotic, *Bromus rubens* (Poaceae) and *Hypochaeris glabra* (Asteraceae) annual plant species for my competition experiment. These species currently grow together within the York gum annual flora in South-west WA. I grew plants in factorial combinations of species mixture (monoculture, two and three species), emergence time (early or concurrent) and water treatment (wet or drought) to determine the effect of competition on biomass for each species. As a control, I grew five individuals from each species free of competition in good conditions. I grew all other species mixtures at a density of one plant per square centimetre to ensure plants were competing for limited resources.

Because *P. gnaphalioides* preferred to germinate in warm conditions but also germinated in hot conditions, while *H. glabra* had no specific temperature preference and *B. rubens* preferred hot temperatures, I simulated seedling emergence time to test whether early emergence of the native improved its survival when competing with potentially stronger exotic competitors. In the early emergence treatments, the native (*P. gnaphalioides*) had a two-week head start on other species, simulating early emergence of natives in warm conditions while hot cued exotic species emerge later. Concurrent emergence simulated hotter conditions where hot cued exotic species emerge at the same time as the natives that can also germinate in hot conditions.

After all seedlings were established, I applied water treatments to simulate increased rainfall variability expected under a climate change scenario. All combinations of competitive species mixtures and timing of seedling emergence received either wet (30mL water every two days) or drought (30mL water every eight days) treatments to test survival of both exotic and native species under reduced water availability. I applied water treatments for seven weeks; however, due to time constraints for the completion of my honours project, I had to finish my competition experiment at this time. My experiment ran for a total of 12 weeks, and plants did not reach reproductive maturity. Although I could not measure number of survivors or reproductive output, I did measure the mean biomass per individual within each pot (mg/plant). Although not an ideal measure of plant success, plant biomass indicated the presence of strong competition because all plants grown under competitive conditions were significantly smaller than the individual control plants grown free of competition. Therefore, the results of my study were representative of competitive interactions at the early, rather than later stages of plant growth.

Results

Germination trials: Despite the application of DAR, only 15 of the 29 species tested germinated to statistically significant amounts. My results suggest that most native and exotic species found in the York gum annual communities from the Perenjori region exhibit some form of germination delaying mechanism such as seed dormancy or germination cue, however seed dormancy was not specifically investigated. For the species that germinated significantly, I found no overall distinct pattern in germination cue preference. Two exotic and two native species showed no particular germination temperature cue, germinating equally well across all temperature treatments. Many species, however, preferred to germinate at 14°C and 25°C, and across at least two temperature treatments. Two native species preferred cool to warm temperatures, and did not germinate at hot temperatures. Contrary to the findings of other studies from South-west WA, smoke promoted the germination of only one native species (*Rhodanthe manglesii*) at 7°C, but inhibited the germination of three exotic and three native species. Such variability in germination strategy may buffer some of these species against small shifts in climate warming, but others that prefer cool temperatures are likely to experience negative impacts. Under a warmer climate, some species may no longer get a head start, and may germinate concurrently with non-cued exotic species, or species with cool temperature preferences may germinate in lower numbers.

Competition experiment: All species within the high-density monoculture, two and three species mixtures experienced competition, because all plants were smaller in mean biomass per individual. The mean biomass per plant of *P. gnapahlioides* was unaffected by the presence of the non-grass exotic, *H. glabra*, but was significantly affected below ground when competing with the exotic grass, *B. rubens*. The presence of *H. glabra* within a species mixture had no effect on either *P. gnapahlioides* or *B. rubens*, but was the most heavily affected by these two species. The three species competitive mixture showed some amelioration of the negative effects of other species. There was no evidence to suggest this effect was due to either direct or indirect facilitation. However, one explanation is the release of competitive effects by increased diversity. The density of plants within each pot was largely consistent across treatments, but the relative number of each species within pots differed. Therefore, it is likely that greater diversity within the three species mixtures was sufficient to release individuals from the negative effects of either (or both) intra and interspecific competition. In this way, neighbour identity along with density dependence may play a major role in structuring the York gum annual plant communities.

Most importantly, my results show that *P. gnaphalioides* suppressed both exotic species to varying degrees when it emerged first, and had a two-week's head start. Because *P. gnaphalioides* itself was only affected below-ground by the exotic grass, but unaffected above-ground by either exotic, regardless of whether it had emerged first or not, suggests that regardless of competitive neighbour identity, this native species may be able to persist even if it emerges concurrently with other exotic species.

Conclusions and future directions

Collectively, my results suggest that native species within the York gum annual plant communities may be able to coexist regardless of seedling emergence time, and that some exotic species may be suppressed by intense competition with the natives. However, as the climate warms, species whose optimal germination temperature preferences lay within the cool to warm range may germinate at lower abundances, causing a shift towards a greater abundance of warm to hot temperature cued species within this system. I suggest that future studies repeat this experiment for the full lifecycle of these annual plants to determine how competitive dynamics change at the later stages of competition, measuring other indicators of plant success such as survival and fecundity. Experiments using a higher diversity treatment may also help to tease apart whether neighbour identity is a factor that releases individuals from the impact of intra or interspecific competition. Also of interest would be the shifts in competitive ability of native annuals under scenarios where exotic species emerged first, which may occur if exotic species have a faster rate of germination in hotter conditions.