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Fallen logs as sources of patchiness in chenopod shrublands of South Australia

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A B S T R A C T

While numerous studies focus on heterogeneity created by living plants and animal diggings in arid lands, little information exists on the pattern and role of heterogeneity created by large woody debris. We studied soil nutrient content, volumetric water content, and vegetation associated with the presence of logs in sites subject to different grazing intensity in a chenopod shrubland of South Australia. Soil volumetric water content was lower close to logs, and the soil there dried faster after rains. Organic carbon was higher, but available phosphorus was lower in soil associated with logs. We documented greater seedling emergence, species richness and diversity, and greater annual plant biomass next to logs. Our results were similar in the sites with high and low grazing pressure, the latter having higher numbers of seeds and species in the germinable soil seed bank. Logs in this system create patches that differ in properties from other patches in the system (i.e. those created by perennial plants, depressions, or diggings). Logs constitute a unique microenvironment which affects the plant community structure and may enhance the diversity of the system, and should be considered in management schemes.

1. Introduction

The distribution of water, nutrients and seeds in arid land ecosystems is highly heterogeneous and this is reflected in small scale heterogeneity in the plant community structure and function (Tongway and Ludwig, 2005). These systems typically contain patches with high resource availability within a matrix of very low resource availability overall (Noy-Meir, 1973; 1981). Studies of the arid lands around the world have found fertile patches associated with animal diggings (James et al. 2009), succulent plants (Stock et al. 1999), shrubs (Facelli and Temby, 2002), long lived trees (Facelli and Brock, 2000) and fallen logs (Pettit and Naiman, 2005). The variety of systems included in these studies and the diversity of patchiness found indicate that resource heterogeneity is a universal characteristic of arid lands when they are highly functional. In addition, they are critical determinants of ecosystem functions, such as resource dynamics, productivity and diversity maintenance (Aguiar and Sala, 1999). However, specific details of the arrangement, distribution, size and longevity of patches depends on the intensity and rate of accretion processes occurring around different plant species and other patch-forming entities. The properties of patches may vary widely from system to system, and even within a system, and these changes should have functional importance. While in some patches accumulation of water, nutrients and seeds may be enhanced, in some arid systems the extent and intensity of these effects may vary for the different variables. This difference in patch composition may be a key determinant of the structure of arid land plant communities.

The presence of patchiness is central to plant community dynamics in arid lands. Seedling establishment and survival is usually poor in open spaces, while fertile areas associated with larger plants or micro depressions provide safe sites for seedling establishment (Maestre et al. 2003). The higher emergence rate in enriched patches is most likely due to a combination of the more favorable microclimate and soil conditions (Hastwell and Facelli, 2003), and to the higher resource and seed availability in these patches than in open areas (Facelli and Brock, 2000; Osem et al. 2007). However, just as resources accrete differently around different patches, the properties of patches also vary the size and composition of the seed bank. Specific characters of the various structures that create patches, such as mound heights and differences in branching structure, can affect the ability to trap both resources and seeds (De Soyza et al. 1997). Importantly, this patchiness is a dynamic property of the system.

Abbreviations: VWC, volumetric water content.

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Presently most arid lands are heavily degraded by high densities of introduced grazers (Dregne, 2002), and a prominent feature of this degradation is the destruction of spatial heterogeneity (Lin et al. 2010) through the disruption of transport and accumulation processes (Tongway and Ludwig, 2005). Grazing eliminates features of the landscape that retain water, nutrients and seeds (Emmerson et al. 2012; Landsberg et al. 2003), while erosion dissipates the resources accumulated in patches and lowers the number of fertile patches (Sparrow et al. 2003). In the absence of accumulation patches, or of features able to build them up, vegetation may not recover as soil seed reserves are severely compromised and safe sites scarce (Kinloch and Friedel, 2005b). Degradation by introduced grazers is a result of cumulative impacts of grazing on ecological processes and management by landowners can vary such impacts (Andrew, 1988). The reintroduction of structures such as logs or branches on the surface may mitigate these negative effects or even help the recovery of the system.

Dead plant material has indeed been used in arid landscapes as a tool for rehabilitation in both grazed and ungrazed areas. For example, piles of Mulga branches placed on bare slopes of New South Wales arid lands dramatically increased soil nutrients, and increased water infiltration ten-fold (Tongway and Ludwig, 1996). Plant number and biomass are also enhanced by the presence of logs and branches (Ludwig and Tongway, 1996; Tongway et al. 1989). However, the study of the ecological effects of fallen logs in Australian arid lands has thus far been limited to a few combinations of vegetation types and landscapes (Ludwig and Tongway, 1996; Tongway and Ludwig, 1996; Tongway et al. 1989). Different combinations of land features, vegetation structure and the size and shape of logs may result in very different outcomes. The mulga branches used by Tongway and Ludwig (1996) may have effects that depend on their typical size and branching patterns. Extending the study to other systems is then necessary to further develop this conceptual framework.

The objectives of this study were to establish how logs create spatial heterogeneity in grazed chenopod shrublands of South Australia. We concentrated on the differences in soil nutrients, soil water content, soil seed bank, and plant growth between microsites next to logs and nearby open spaces. We conducted the research in two sections of a single paddock subject to different grazing intensities. The specific questions we addressed were: a) are there any changes in the soil characters associated with the presence of logs?, b) are there any changes in soil seed bank, establishment and plant growth associated with the presence of logs?, c) are there any changes in seedling establishment and growth associated with the presence of logs introduced to open spaces over a short time period?, and d) if there are differences in those variables, are they affected by grazing intensity?

2. Materials and methods

2.1. Study site

Our study was conducted at Middleback Field Research Centre, 16 km North West from Whyalla, South Australia (32°57′S, 137°24′E). The climate of the area is arid, with average yearly rainfall around 250 mm. Interannual variability of rainfall is characteristic of our site, with records varying from 146.8 mm to 510.3 mm over the years. Total rainfall for 2010 was 345.8 mm, which is above average, but not atypical for this area. Rainfall is concentrated in the winter months (June–August) which drives the growth of a diverse annual plant community. The soils are predominantly brown calcareous earths with clay-loam texture, and calcium carbonate accumulated at variable depths. The pH is slightly alkaline, and nutrient availability is generally low (Crocker, 1946). The vegetation at the study site is open woodland dominated by *Acacia papyrocarpa* Benth. with chenopod understorey; *Atriplex vesicaria* Heward ex Benth., *Maireana pyramidata* (Benth.) Paul G. Wilson and *Maireana sedifolia* (F. Muell.) Paul G. Wilson dominate the understorey (Facelli and Brock, 2000). A large number of annual plant species, both native and introduced can be found, and the guild is presently dominated by *Carrichtera annua* (L. Aschers.), an introduced plant from the Mediterranean (Facelli et al. 2005). Fallen logs are abundantly scattered throughout the landscape.

2.2. Site selection

The Purpunda Paddock is extensively affected by sheep and feral rabbit grazing, with a strong grazing gradient radiating from a single watering point. The paddock is 1440 ha and has been continually stocked with approximately 250 sheep since 1966 (Heshmatti et al. 2002). The greatest degradation occurs within 300 m of the watering point, while less degradation is found 1000 m from the watering point, as sheep infrequently travel beyond this distance, and when they do, they are present at low densities. We selected this paddock due to the strong grazing gradient but otherwise homogeneous environment, as well as the abundance of fallen logs. Our study was conducted between 10 May 2010 and 3 Sep 2010, encompassing most of the growing season.

Existing fallen logs (pieces of wood, 3–5 m long and at least 20 cm diameter, henceforth referred to simply as “logs”) were located in the paddock to assess their patch forming properties. Five logs were located in the field at 300 m and five at 1000 m from the watering point. We selected logs to be comparable: they had very simple structure, few or no branches and were intact or presented little or no sign of decay. As logs in a similar system are known to persist for at least 75 years (Sinclair, 2004), it is difficult to know their age, but as there presented little decay, it can be presumed that they are relatively young. The open space sites we chose were as close to each log as possible, but leaving a minimum 3 m distance from logs and away from any other living or dead plants.

2.3. Soil properties

To assess if the presence of logs modify soil properties we collected two soil samples (5 cm deep and 9 cm diameter) from the immediate vicinity of three of the logs and from their corresponding open space sites, at both distances from the watering point. As slope was negligible, the side of the log used was chosen at random. The two soil samples from each individual site were combined as a composite sample (1272 cm^3 soil for each site) and sent to CSBP soil and plant laboratory (Western Australia) for analyses of soil organic carbon, total nitrogen, available phosphorus and available potassium.

We assessed soil water dynamics by measuring volumetric water content (VWC). We deployed Em5b$^{(R)}$ data loggers with ECH2O EC-10 sensors (Decagon Devices, Washington USA) inserted into the ground to a depth of 10 cm (where most roots of annual plants grow (Harris and Facelli, 2003) in the immediate vicinity of both logs and at adjacent open space sites. Four log replicates and their adjacent open spaces were measured at both 300 m and 1000 m from the watering point. The data loggers measured VWC hourly over a period of 84 days, from 10 Jun until 31 Aug 2010. To compare microsites next to logs and open spaces we analyzed soil water content and the rate of water loss after two typical rainfall events; the first event occurred on 25 Jun 2010 with 7.8 mm of rain and drying for 14 days, the second event occurred on 19 Jul 2010 with 6.7 mm of rain and drying for 9 days. Data were analyzed using log transformed values to linearize the trend.