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Short Communication

Impact of wildfire on interdune ecology and sediments: An example from the Simpson Desert, Australia

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ABSTRACT

The stability of many sand dunes and their interdunes is dependent on vegetation and surface crust cover. When this cover is removed, the sand can be activated and fine sediments deflated making the dunefields into sources of dust. This paper reports the impact of devegetation by wildfire on an interdune in the Simpson Desert, Australia. The fire occurred in 2001 and six years after the event pronounced differences between a pair of burnt and unburnt sites was clearly discernible. The variables examined included vegetation assemblage, cyanobacteria abundance and sediment aggregation, particle-size distribution and colour; but whether they apply to all such situations is uncertain. Rate of recovery has been slow and the differences are likely to have been sustained by a combination of negative feedback processes and climate.

Until recently, global dunefields have not been recognized as significant dust sources because they have a low fines (<100 μm) content, and often have a vegetation cover which stabilizes the surface and reduces aeolian activity by increasing surface roughness; reducing near surface wind velocities and promoting sediment deposition (Wiggs et al., 1994; Hesse and Simpson, 2006). In addition, biological soil crusts can play an important role in dune stabilization (Belnap, 2001) through physical binding of sediment with their filaments or via the excretion of polysaccharides which act as a glue (Belnap, 2001). Such crusts are often capable of surviving drought conditions, continuing to stabilize dune surfaces (Eldridge, 2001) even when vascular plant cover declines.

Dust emissions from semi-stabilized dune areas can however be significant if they are reactivated by climate change or vegetation removal due to fire or grazing pressure – for example, Bullard et al. (2008), and McGowan and Clark (2008) have documented dust storms in Australia where the sediment source can clearly be traced to firescars in dunefields. The associated decrease in surface roughness and threshold wind velocity increases potential wind erosion (Wiggs et al., 1994) and saltating grains promote the entrainment of any fines in the dune sediment (resident fines). Saltation activity can also generate new dust-sized particles by abrasion and/or the removal of clay coatings on the grain surfaces (Bullard and White, 2005) but these will rapidly be removed. Dune geomorphology can also be modified following devegetation, for example the dune may become taller and steeper, be reworked into smaller dunes, or become reoriented to reflect a wider range of wind speeds (Hesse and Simpson, 2006).

This paper focuses on the impact of fire on the interdune ecology and sedimentology of one interdune. It is unclear how rapidly vegetation and crust cover can re-establish in a dunefield once devegetated by fire, but the effects are known to last from one or two years to over ten years (Wiggs et al., 1994; Eldridge, 2001). Rate of recovery is likely to be determined by a combination of burn severity, soil type and climate, as it is in most environments, but in dunefields aeolian activity and position on the dune (erosional, depositional or stable locations) are also important (Lesica and Cooper, 1999). Once a sand surface has been reactivated, it becomes hostile to vegetation and crust redevelopment because many species have a low tolerance for mobile surfaces (Kadmon and Leschner, 1995) and deflation of the fine fraction will significantly reduce the moisture-holding capacity of the soil. In addition, the impact of dune topography on airflow and sediment transport

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means that dune crests are usually less stable than interdunes, so the latter will support more rapid ecological recovery. This idea is supported by Wiggs (2006) who found that vegetation renewal in interdunes was twice as rapid as those in crestal regions.

This difference in aeolian activity with position means that dune crests typically contain less fine material, whilst interdunes contain more, and hence interdunes may be more important dust sources immediately post-fire. For example, in the southwest Kalahari dunefield, the proportion of dust-sized particles in interdunes can be up to 7% whilst dune crests only contain 1–3% fines (Livingstone et al., 1999). Dust production by abrasion and coating removal will continue while the surface is active, and long-term retention of dust particles in the dune surface layers is only likely to take place once vegetation cover has re-stabilized the surface. In comparison to an unburnt dune, therefore, a dune recently devegetated by fire would be expected to have less vegetation and biological crust cover, potentially a different vegetation structure given that annuals and perennials recolonise at different rates, and to contain less fine sediment having lost dust-sized material through deflation. These feedback processes are summarized in Fig. 1 and mean that although dune activation occurs rapidly post-fire, re-stabilization through recovery of both ecology and sedimentology may be a much longer processes. Fire can also have an impact on sediment colour, causing particles to redden by dehydrating the hydrated iron oxides in dune sand grain coatings (Jacobberger-Jellison, 1994).

Despite these expected physical changes there is a notable paucity of literature exploring the effects that fire has on interactions among dune ecology, sedimentology and geomorphology. Dunefield responses to vegetation change stimulated by climate change have been studied and modeled (Bullard et al., 1997; Hugenholtz and Wolfe, 2005), but responses to the impacts of fire are typically limited to the post-fire response of vegetation (Winkworth, 1967; Letnic, 2003) or sediment mass collected downwind of burnt areas (Sankey et al., 2009) and most field studies take place within two years of the event.

This short communication reports the results of a field study to quantify the ecological and sediment characteristics of one unburnt and burnt site in the Simpson Desert, Australia, six years post-fire, to explore whether any of the expected differences persist. As the sites represent subsamples within the same interdune the findings cannot be extrapolated to all interdunes, however the results should be viewed as providing preliminary data and a conceptual context in which future work should follow. The dunefield is dominated by partially-vegetated linear dunes and natural fires typically occur following dry electrical storms in the austral summer (Griffin et al., 1983). Wildfires are common throughout central Australia wherever the spinifex grass community exists, with Winkworth (1967) suggesting that at any one time 80% of the dune field vegetation communities within the Northern Territory are rejuvenating following fires or in a degenerative state due to lack of moisture. Fire return interval varies, but can be as short as 3–10 years (Griffin et al., 1983). Fires in the arid zone are more common and more widespread in years following above-average rainfall which increases vegetation fuel loadings; conversely, drought periods tend to be associated with less frequency and smaller fires (Turner et al., 2008).

Fires leave clear 'scar' marks that are visible on satellite imagery and aerial photographs (Fig. 2). The site chosen (25°18′23″S, 137°56′2″E) covers an area of 2807 km^2 and is known to have burnt prior to 1984 with the most recent fire affecting the area in 2001. Fieldwork was conducted in May 2007 – six years after the last burn. Given the importance of interdunes as relatively stable environments and stores of dust-sized material, sampling focused on two randomly assigned 40 m long west-east oriented transects across the same south-north oriented interdune (Fig. 2). The northern-most was located entirely within the area burnt in 2001; the transect 1.3 km to the south was located within an area that satellite imagery indicates has not burnt since at least 1984. Due to the proximity of the transects, it was assumed that the two locations had common vegetation and sediment characteristics before the fire and experience the same climate conditions. Soils comprise deep and infertile red siliceous sands.

In the field, vascular plants and cyanobacteria percent cover were calculated using a 1 m^2 quadrat placed at 5 m intervals ($n = 9$ at each site). Any vascular plants present were identified and recorded as either annual or perennial. Surface soil samples (0–20 mm depth) were taken at the same intervals and indicators of aeolian activity were noted (aeolian sand ripples, slipfaces). In the laboratory, cyanobacteria abundance was estimated through in-vitro incubation and light microscopy. For this, the soil samples were kept in an incubation chamber, hydrated with deionised water for 3 days, exposed to 12-h light and kept at 20 °C. Searching for cyanobacteria filaments occurred across seven fields of view

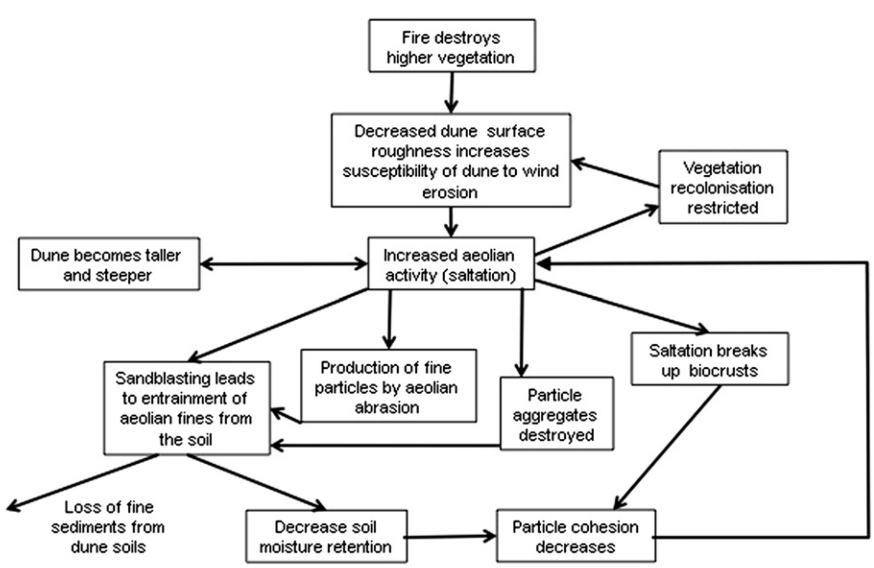

Fig. 1. Feedback model to illustrate processes leading to post-fire increased dune activity and destabilization.