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THE POTENTIAL FOR COASTAL DUNE DE-STABILISATION FOLLOWING 2015/16 WILDFIRES NEAR ESPERANCE, WA

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Cover: Burnt dunes near Lake Quallilup, WA – Photo: Samuel Shumack

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ABSTRACT

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This study investigates the potential for long term change in the coastal landscape following wildfires. Under certain conditions it is possible for coastal dunes to shift from stable to active and vice versa. The removal of vegetation via disturbance (natural or human) is one possible trigger for the transition from stable to active (destabilisation). Fire has been proposed as a disturbance which is likely to destabilise dunes, however this has not been well studied. The aim of this project is to assess the immediate aftermath of fires on two dune areas near Esperance, WA (behind Quallilup Beach to the west, and Wylie Beach to the east), and then to monitor the geomorphic response of the dunes, interpreting this with regard to a range of potentially influential factors (meteorological and ecological). The key themes thus far are that re-sprouting plants at Wylie Beach indicate a reasonable likelihood of vegetation recovery and the dunes remaining stable. However, full recovery may hinge on appropriate conditions for continued plant regrowth. The future Quallilup less clear, due to the potential decrease in regrowth after a more intense burn. It is feasible that prolonged exposure of the surface to strong winds in the absence of vegetation recovery may eventually wear through the protective crusting and destabilise the dunes.

BACKGROUND

During the Western Australian fire season of 2015/16, two fires burned large areas of coastline near Esperance, WA. On 15 November 2015 a lightning strike sparked a fire approximately 13 km to the east of Esperance, near Mullet lakes, WA. Over several days approximately 14240 ha of land burned with moderate intensity (within Mullet Lakes Nature Reserve, other unmanaged reserve area and some rural properties) behind Wylie beach between Esperance and Cape le Grande, WA (Fig. 1). No lives were lost and, aside from some cleared land, the fire was largely confined to uninhabited areas covered with coastal heath.

On 04 January 2016, a second fire sparked by lightning burned 13500 ha from 10 km west of Esperance (near Pink Lake, WA) through unmanaged reserve and National Park land across approximately 35 km of coastline towards Lake Quallilup, WA. This fire had a comparatively high intensity. Once again, damage to urban and agricultural land was negligible and the fire was contained within coastal heath vegetation (Fig. 1).

Both fires burned over areas of what can be termed 'stabilised sand dunes' (areas of wind-blown sand now covered by soil and vegetation) (Arens et al., 2007). As can be seen in figure one amidst the areas of burned vegetated sand dunes, there are large patches of mobile or bare sand dunes with no vegetation. This research is primarily concerned with investigating the potential for much of the burned landscape to eventually transition from vegetated dunes to perpetually bare, shifting sand owing to the disturbance. Such an occurrence may further threaten nearby properties and see a reduction in local habitat for flora and fauna.

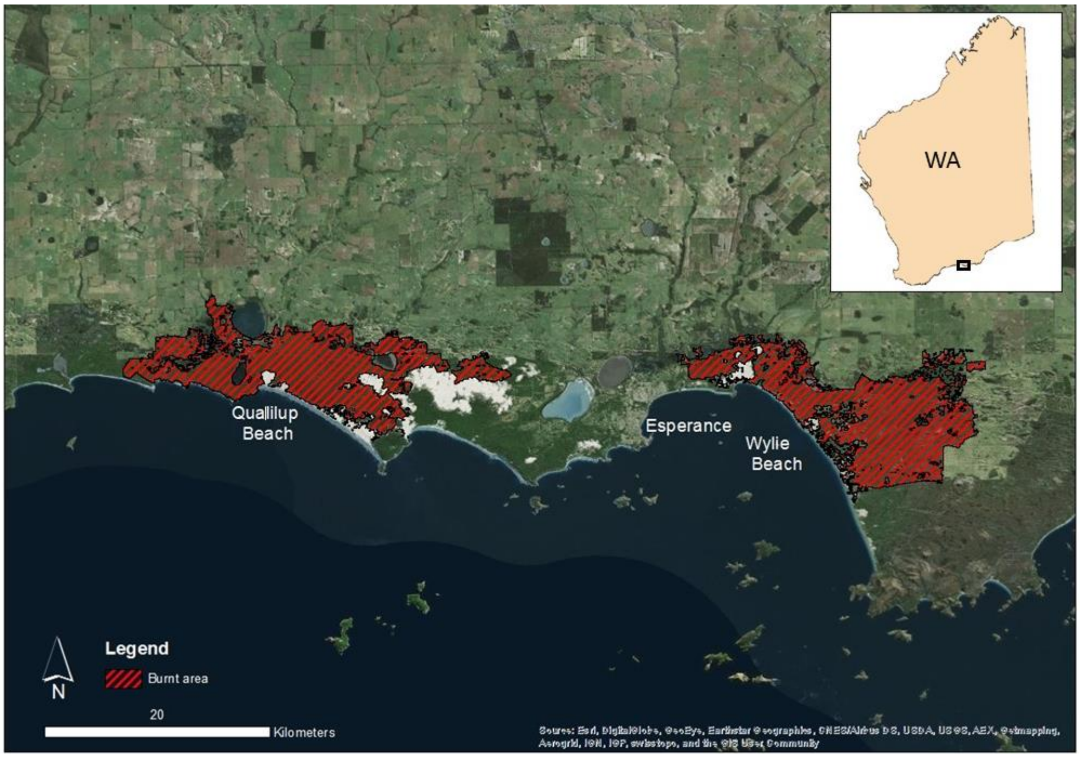


FIGURE 1: REGIONAL MAP OF THE ESPERANCE AREA SHOWING RELEVANT FIRE BOUNDARIES NEAR QUALLILUP BEACH AND WYLIE BEACH

CURRENT KNOWLEDGE AND RESEARCH OBJECTIVES

Coastal sand dunes are complex environments. They exist in a range of states between mobile, with abundant sand movement by wind (aeolian activity), and stable, with a protective covering (vegetation, soil etc.) limiting sand movement (Arens et al., 2007). Under certain conditions it is possible for coastal dunes to shift from stable to active and vice versa (Hesp, 2013, Barchyn and Hugenholtz, 2013). Such destabilisations and the associated sand drift can be natural, but also can be a threat to farms and urban areas. However, these processes and their necessary conditions have not been comprehensively studied (Hesp, 2013). The removal of vegetation via disturbance (natural or human) is one possible trigger for the transition from stable to active (de-stabilisation) (Barchyn and Hugenholtz, 2013). Which types of disturbance (e.g. fire) and what magnitude is necessary to destabilise a dune is not well understood (Barchyn and Hugenholtz, 2013).

It is speculated that fire is a disturbance on coastal dunes which may lead to destabilisation following the reduction of vegetation cover (Rust and Illenberger, 1996, Hesp, 2013, Yizhaq et al., 2013, Catto, 2002). The documented evidence of this process in a coastal setting is limited to scattered charcoal fragments within dunes, possibly associated with times of dune mobility (Gaigalas and Padzur, 2008, Catto et al., 2002). More often cited in support of this speculation is a body of literature describing destabilisation following fires through the Holocene (the past ~10,000 years) in sub-arctic pine forested dunes interpreted from the stratigraphy of well-defined charcoal layers within dunes in Canada and Finland (Matthews and Seppala, 2014, Carcaillet et al., 2006, Kayhko et al., 1999, Seppala, 1995, Filion et al., 1991, Filion, 1987, Filion, 1984). These are not usually coastal settings, and typically the dunes were only destabilised after fires when the climate is particularly cold and dry (Filion, 1984, Matthews and Seppala, 2014). Contemporary studies of post-fire susceptibility to wind erosion are limited to the use of satellite imagery to measure vegetative cover on desert dunes (Levin et al., 2012), and a handful of field surveys (only one of which, Vermeire et al. (2005), was on sand dunes) (Ravi et al., 2012, Stout, 2012, Sankey et al., 2009, Whicker et al., 2006). These surveys all show an increase in aeolian activity following fires (Ravi et al., 2012, Stout, 2012, Sankey et al., 2009, Whicker et al., 2006). However, unlike the studies from Canada and Finland, they do not show destabilisation, rather, with the exception of Whicker et al. (2006), vegetation mostly recovered within the study periods. For land managers in regions such as the southern coast of Australia, what is lacking is a study showing the potential for fires on coastal dunes in temperate regions to trigger destabilisation (blowouts etc.).

The coastal regions near Esperance, WA, exhibit large areas of dunes which have been active since before the recent fires (see Figure 1).

Therefore, local conditions clearly allow aeolian activity to persist a large scale. Given the theoretical possibility of future dune destabilisation, the recent fires provide an opportunity to test the role of fire in this process. With this information one could better interpret the origin of existing transgressive dunes, and also better predict the results of burning (prescribed or wildfire) in coastal regions. The aim of this project is to assess the immediate aftermath of fires on two dune areas near Esperance, WA, and then to monitor the geomorphic response of the dunes, interpreting this with regard to a range of potentially influential factors (meteorological and ecological).

METHODS

Our field study approach was to a) characterise vegetation in terms of size and coverage, and in terms of protective characteristics (e.g. living or dead); b) assess the abundance other ground protection (e.g. litter, crust etc.); c) record any evidence of recent sand movement by wind (e.g. ripples, loose sand etc.); d) characterise the burn severity at each site; and e) characterise wind flow through study sites in terms of shear velocity and the influence of surface roughness elements (Fig. 4;5).

From 10-15 February 2016, assessment was carried out along four separate transects shown in Figure 2. At Quallilup Beach we ran one transect across an area of previously vegetated dune burned with a high intensity, and one transect across a currently bare, active dune (Fig. 2). At Wylie Beach we ran one transect across an area burned with moderate intensity, and one along a remnant patch of unburned dune with heath vegetation (Fig. 2). Anemometers were set up at four heights ranging from 5 cm to 210 cm at chosen sites covering a range of dune morphological units (e.g. foredune, swale, stoss slope and dune crest) as well as on the beach (Fig. 5). At each anemometer site we conducted a point survey of vegetation, other significant protective ground cover, and signs of aeolian activity. With the anemometer site at the centre, each survey covered 20 m along the main transect (Fig. 3). Perpendicular transects covering 8 m (data was recorded at 1 m intervals) taken every 5 m along the main line (Fig. 3). As well as a point survey, at each point along the central transect was characterised in terms of burn severity. Burn severity is a measure of biological, physical and chemical change after a fire (Díaz-Delgado et al., 2003). In this study we focus on the physical and biological aspects. Following after Diaz-Delgado et al. (2003), we placed each point in one of the following categories (adapted to suit our study site):

0. Not burned
1. Ground fire
2. Canopy partially green
3. Burned trees with remnant burned leaves
4. Burned trees with fine branches across all of the trunk
5. Burned trees with fine branches only near the top of the trunk
6. Burned trees with no fine branches
7. Burned trees with only a trunk
8. Burned trees with only a stump

The data described above was necessary to collect within a short time after the incidents to ensure proper interpretation of any landscape transformations which may occur in the coming months. Without having done comprehensive data analysis as yet, the 'Initial Themes' section of this report will focus on a couple of key observations made in the field.

Nevertheless, the intended analysis approaches and additional supplementary data collection are outlined below.

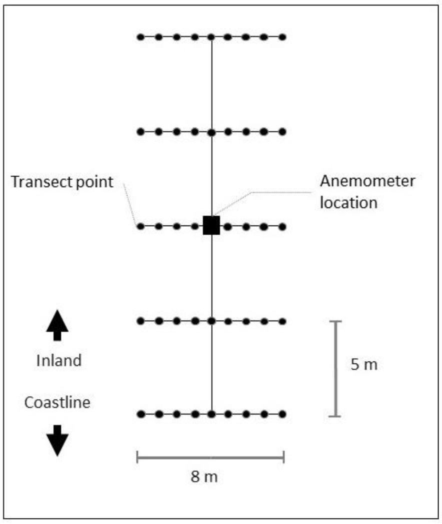
In analysing this data, comparisons will be made between burned areas of different severities, un-burned, and bare areas. In particular we intend to compare and/or examine:

- The amount to which vegetation (e.g. burned and un-burned) influences the wind over the surface and provides protection.
- Levels of recent aeolian activity.
- The amount to which protective elements such as soil crusts and litter are capable of limiting aeolian activity even in the absence of vegetation.
- Dominant vegetation types and their associated fire-recovery strategies.
- The rate of re-sprouting for the burned areas of different severities.

Supplementary data:

- Samples of surface sediment were collected in the field, with the intention of analysing sediment characteristics and estimating the potential for wind erosion.
- Follow up images of post-fire vegetation recovery (subject to activities of contacts made in Esperance) will aid in understanding the rates of vegetation recovery at different sites
- Aerial drone images for accurate vegetation coverage assessment and also for 3D model production (useful in accounting for topographic influence when interpreting wind data).
- Satellite remote sensing images will be used to monitor vegetation recovery and the amount of bare sand in the study region.
- The ongoing monitoring with satellite imagery will interpreted with the aid of acquired meteorological data considered potentially influential. This includes wind, precipitation, and temperature.

FIGURE 2: REGIONAL MAP SHOWING TRANSECT LOCATIONS Q1 AND Q2 AT QUALLILUP BEACH (LEFT) AND W1 AND W1 AT WYLIE BEACH (RIGHT) NOTE: THE BACKGROUND IMAGES (SOURCED FROM GOOGLE EARTH (TOP) AND ESRI (BOTTOM LEFT & RIGHT)) WERE TAKEN BEFORE THE FIRES



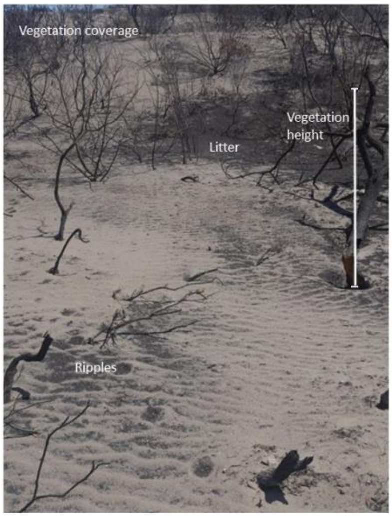


FIGURE 2 (ABOVE, LEFT): SCHEMATIC REPRESENTATION OF THE SURVEY TRANSECT POINTS SHOWN FROM BIRDS EYE VIEW RELATIVE TO THE CENTRAL ANEMOMETER STAFF LOCATION

FIGURE 4 (ABOVE, RIGHT): PHOTO TAKEN NEAR LAKE QUALLILUP, WA, LABELLED WITH EXAMPLES OF FEATURES WHICH WERE SURVEYED AFTER THE FIRE. PHOTO © PAUL HESSE

FIGURE 5 (LEFT): EXAMPLE OF ANEMOMETERS SET UP FOR WIND MEASUREMENTS ON WYLIE BEACH, WA. PHOTO © SAMUEL SHUMACK

INITIAL THEMES

Before reporting our initial themes, it is important to clarify two points. Firstly, the study site at Quallilup Beach was burned more recently (January 2016) than was the study site at Wylie Beach (November 2015). And secondly, personal communication with members of the Department of Parks and Wildlife (D.P.A.W) Western Australia, as well as our own observations, indicate that the area near Quallilup Beach burned with a higher intensity than did the area near Wylie Beach.

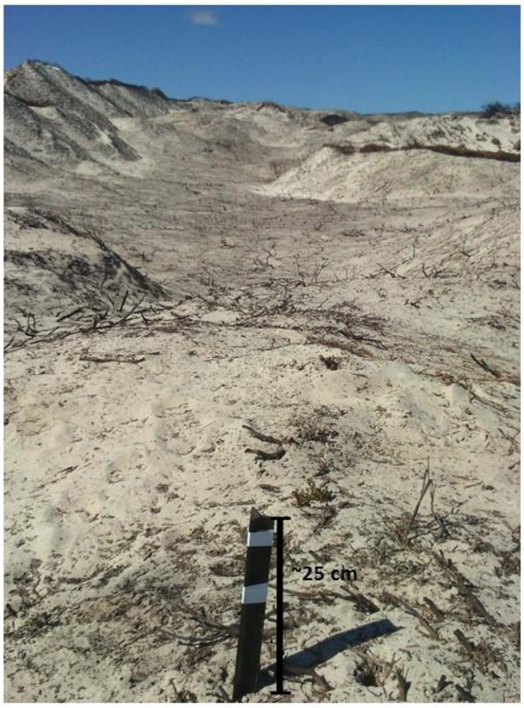


FIGURE 6: PHOTOS SHOWING MODERATELY BURNED SITE AT WYLIE BEACH (LEFT) WITH SOME RE-SPROUTING, AND A SEVERELY BURNED SITE AT QUALLILUP BEACH (RIGHT) WITH FEWER REMAINING TRUNKS AND FEWER RE-SPROUTING PLANTS. PHOTOS © SAMUEL SHUMACK

The initial themes of this study can be summarised as follows:

- Some aeolian activity is evident at both burn sites.
- Very little, if any, aeolian activity is occurring at the unburned site at Wylie Beach.
- The more severe burn at Quallilup Beach coincides with decrease in apparent reduction in vegetation cover and increase in sand movement compared with the moderate intensity burn at Wylie Beach (Fig. 6).
- Neither burned site is as abundant in apparent sand movement as the currently active dune at Quallilup Beach.

- The Burned transect at Wylie Beach exhibits higher re-sprouting plant numbers than that of Quallilup (Fig. 6). It is unclear whether this is merely a function of time, or whether the difference in burn severity has played a role.

- While some amount of shifting sand is apparent at both burned sites, the surface as yet has not been significantly disturbed by erosion and no blowouts have formed at either site.

- Re-sprouting plants suggest Wylie Beach appears on the road to recovery (in terms of surface cover, not necessarily healthy biodiversity, this is not our present concern).

- The continuation of this process may, however, hinge on the persistence of appropriate meteorological conditions for minimal sand movement and continued plant recovery.

- The future Quallilup Beach is less clear, owing to the potential decrease in regrowth after the more intense burn. It seems feasible that prolonged exposure of the surface to strong winds in the absence of vegetation recovery may eventually wear through the protective crusting and destabilise the dune forms. Ongoing monitoring will hopefully shed light on this.

FUTURE USE OF OUTCOMES

Thanks to the funding provided by the BNHCRC, our hope is that the outcomes of this study will be useful for land managers in Australia and elsewhere around the world.

Specific uses are likely to include better understanding the level of risk associated with prescribed burning on sand dune areas (typically considered to be 'susceptible') in terms of potential land degradation. And also possibly helping managers target specific sites for ecosystem rehabilitation after fires.

Furthermore, the study will contribute to our scientific understanding of the role of fire in initiating many of the transgressive dune areas that can be seen on the Australian coastline. And it will contribute to the broader scientific understanding of how landscapes evolve through time in response to climatic and disturbance-related drivers.

CONCLUSIONS

The aim of this project has been to assess and then monitor the geomorphic response of dune areas near Esperance, WA after recent fires and interpret this with regard to a range of potentially influential factors (meteorological and ecological). The key initial themes thus far are that re-sprouting plants at Wylie Beach suggest it is likely to recover its vegetation covering and remain stable. However, full recovery may hinge on the persistence of adequately low winds and sufficient rainfall. The future Quallilup Beach not as clear due to the potential decrease in plant regrowth after the more intense burn. There may be a possibility that prolonged exposure of the surface to strong winds in the absence of vegetation recovery will eventually wear through the protective crusting and destabilise the dunes. Analysis of survey data and wind data collected soon after the fires will provide essential insight in understanding any landscape transformations which are observed during the monitoring over the coming months.

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