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Effects of windthrow on a *Eucalyptus delegatensis* (Myrtaceae) stand and early understorey succession at Snowy River National Park, Victoria

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Effects of windthrow on a *Eucalyptus delegatensis* (Myrtaceae) stand and early understorey succession at Snowy River National Park, Victoria,

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Cover Photos: Effects of windthrow on a *Eucalyptus delegatensis* at Snowy River National Park. Photo by S. K. Florentine.

Abstract

The June 1998 a severe windstorm at Snowy River National Park near Mt. Gelantipy caused severe damage to a stand of *Eucalyptus delegatensis*. Little is known about the impact of windthrow on *E. delegatensis* and subsequent seedling recruitment. This study was undertaken 4.5 years later to examine (i) the windthrow damage on *E. delegatensis* and the understorey *Acacia dealbata* (type of damage, diameter class distribution), (ii) the influence of tree size (diameter at breast height, 1.3m) on pattern of tree damage (snapped/uprooted/ snapped and resprouting) (iii) undergrowth in the windthrow area compared with control plots, (iv) species composition of soil stored seed bank in windthrow damaged plots and control plots. Eleven (25 x 25 m^2) plots within damaged areas and five plots within undamaged (control) were selected for study. Tree diameter at 1.3 from the rooting point and type of damage (snapped, uprooted, snapped resprouted, snapped dead) were recorded. To examine seedling recruitment, each 25 x 25 m^2 plot was further divided into 1 x 1 m^2 sub-plots. Within each sub plot, all *E. delegatensis* seedlings and their diameters were recorded. Soil seed bank species composition was examined by taking 88 and 40 soil samples from windthrow and control sites respectively. Soil samples were placed in punnets and new recruits were counted and identified. This study showed that, high winds toppled virtually all trees regardless of size and species damaging 99% of *E. delegatensis*. Seedling recruitment was 49 ha^{-1} for the canopy species *E. delegatensis* and 2,210 ha^{-1} for the sub-canopy species *A. dealbata*. No *E. delegatensis* or *A. dealbata* seedlings were recorded in the control plots. In the soil seed bank study five species were recovered from soil samples collected from the control and six from the windthrow damaged sites. The canopy species *E. delegatensis* recruited only from the windthrow site. The exotic *Rubus fruticosus* was found to be colonizing the windthrow site, but was not present in the control site. Results show that *E. delegatensis* recruitment is very poor in the damaged area and species colonizing within the windthrow damaged area were light-demanding or early succession species. It is proposed that seedling recruitment in the winthrow sites be promoted by burning the site and broadcasting *E. delegatensis* seed.

Introduction

Wind is one of the primary natural disturbances in terrestrial ecosystems and has strong ecological impacts on forest communities (Stephens 1956; Schaetzl *et al*. 1989; Clinton & Backer 2000). Generally larger dominant canopy trees are most affected by this natural disturbance (Ulanova 2000). Barden (1981) reported that windthrow created approximately 97% of canopy gap in a mature mixed-mesophytic forest. In another study Clinton *et al*. (1993) found windthrow killed 11% of mixed hardwood forest trees. The impacts can be varied, but generally uprooting or tree fall is the major disturbance. This process may change the soil physical environment, exposing soil stored seeds (Putz & Appanah 1987) and create a new pit and mound topography (Clinton & Baker 1999). These changes may modify the microenvironment (Collins *et al*. 1985) and hence affect recruitment of species (Collins & Pickett 1982).

Once canopy trees are damaged, seedling recruitment and species composition are essential. Yamamoto (1961) and Ulanova (2000) suggested that the size of windthrow patch and time are two major factors determining the seedling recruitment and species composition. Regrowth may occur in three major ways: soil stored seed bank, plants established prior to windthrow and lateral growth of branches from surviving trees (Collins *et al*. 1985). Removal of canopy strata by heavy wind action may change soil temperature. Once the canopy layer has been reduced, a changed microenvironment enables light demanding species to colonize, especially small size species (Bonan & Shugart 1989). The reduced canopy will also help exotic specie to colonize. Moreover, these early colonizer species will decrease with time following disturbance. Ulanova (2000) found that early colonizers decreased from 55% in 1- 5 years to 10% in an old uprooting site.

The June 1998 wind damage investigated here occurred in the form of a severe windstorm in the Snowy River National Park (SRNP) near Mt. Gelantipy, in east Victoria. Little is known about windthrow impacts on *E. delegatensis* stands and subsequent seedling recruitment. The major objectives of this post windthrow study were to examine (i) the windthrow damage on *E. delegatensis* and understorey tree *Acacia dealbata* (type of damage, diameter class distribution), (ii) the influence of tree size (diameter at breast height 1.3m) on pattern of tree damage (snapped/uprooted/snapped and resprouting) (iii) undergrowth in the windthrow area compared with control plots, (iv) species composition of soil stored seed bank in windthrow and control plots.

Method

Study Site

Snowy River National Park (SRNP) is located in Far East Gippsland and covers approximately 98,700ha. SRNP is situated adjacent to the Alpine National Park, which gives additional protection to part of SRNP. This park is listed in Category II by the IUCN and managed mainly for conservation and recreation. SRNP has 13 vegetation communities and approximately 900 native species, 61 of them listed as threatened. Similarly, over 250 native fauna species have been recorded, 22 of them threatened in Victoria. Some areas of SRNP have been disturbed through past land use including, grazing, and mining (Anon 1995). The study site is located at Mt. Gelantipy, which is approximately 1200m a.s.l. (Figure 1 & 6A). This part of SRNP is dominated by *E. delegatensis* (Alpine Ash) with sub canopy species *A. dealbata*. The area was affected by high winds during June 1998 and this study was carried out between June and November 2002.

Sampling technique

Sample plots (25 x 25 m^2) were selected randomly within the windthrow area and within the undamaged area located approximately 300m from the windthrow site. The Northeast corner of each plot was marked with a numbered metal tag and spray marker. The diameter at breast height (1.3 m) was recorded for all trees found within the plot. In addition the type of damage: snapped, up rooted, snapped resprouted, and snapped dead were recorded.

Seedling study

Each 25 x 25 m^2 plot was further divided into twenty-five 1 x 1 m^2 sub plots. Within each sub-plot seedling were counted and identified. All *E. delegatensis* seedling diameters were measured at 10 cm from the soil surface using a diameter tape.

Soil seed bank

A total of 88 and 40 (n = 5, from each control and windthrow plot) samples from windthrow and control sites respectively were collected. Sampling was achieved by throwing a 10cm^2 quadrat around each collection area and removing soil with a small trowel to a depth of 10 cm. Samples were placed in separate labeled bags and transported to University Ballarat and stored in a glass house (20 – 25 $^{\circ}$C) until used.

Soil was thoroughly mixed within the bag to ensure a uniform distribution between seeds and soil. Punnets (8.5x14.0x5.5 cm) were lined with paper towel and filled with soil samples. Punnets were individually labeled with the sample number and placed into large trays (28.0x 44.0x5.5 cm) and then placed on benches in a shade house. Trays were watered twice a day with an automatic sprinkling system. The germinable seed bank was considered as the number of seeds that germinated under favourable water and temperature conditions within 90 days (Bertiller 1996). This measure provides an estimation of the immediately germinable seed bank.

Statistical analysis

Data were analysed using the Super ANOVA software program (Abacus Concepts, Berkeley, California) for obtaining two-way ANOVA and all pairwise multiple comparison procedures. Residual plots of each ANOVA were obtained to examine homogeneity of the variance.

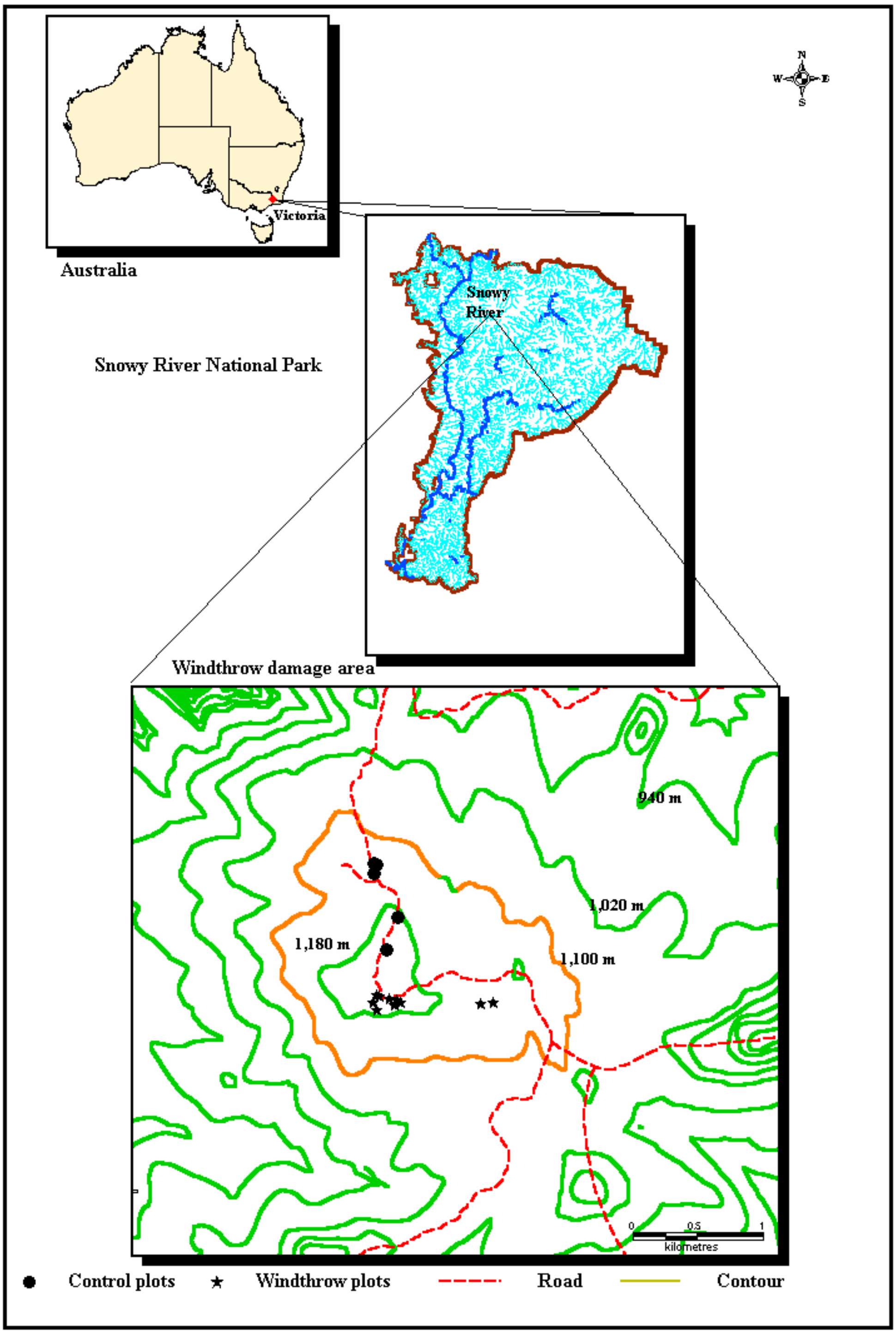

Figure 1: Location of control (") and windthrow damaged site (#) in the Snowy River National Park.

Results

In the windthrow site a total of 1,073 ha^{-1} trees were measured of which 91% (980 ha^{-1}) were *E. delegatensis* (Figure 6B) and 9% (93ha^{-1}) *A. dealbata*. Fifty five percent of *E. delegatensis* trees were snapped and dead, and 37% were uprooted. Only 6.8% of snapped trees had re-sprouted. Of the snapped and dead trees, 70 and 30% were *E. delegatensis* and *A. dealbata* respectively. The vast majority (95%) of uprooted trees were *E. delegatensis* (Figure 6C). Diameter class distribution shows that 78% of uprooted trees were > 30 cm in diameter, and 98% of snapped and dead trees were <30 cm in diameter (Figure 2A & B).

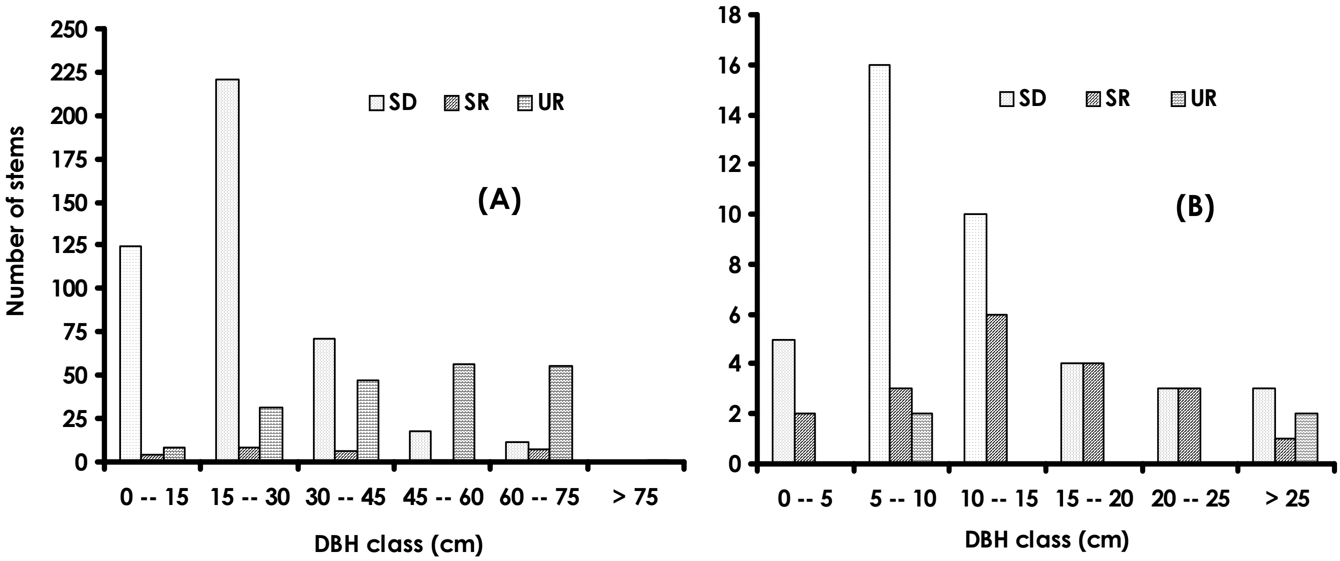

Figure 2: Diameter class distribution of *E. delegatensis* (**A**) and *A. dealbata* (**B**) trees found in the windthrow site. **SD** = Snapped & Dead; **SR** = Snapped & Resproted and **URD** = Up rooted.

One-way analysis was performed on the diameter of the snapped dead, snapped resprouted and uprooted trees. Results show that there is significant difference (P< 0.0001; F 177.88) in their diameter range. Trees with the larger diameter were uprooted, and followed by medium size diameter class trees were snapped resprouted and snapped and dead trees have smaller diameter (Figure 3).

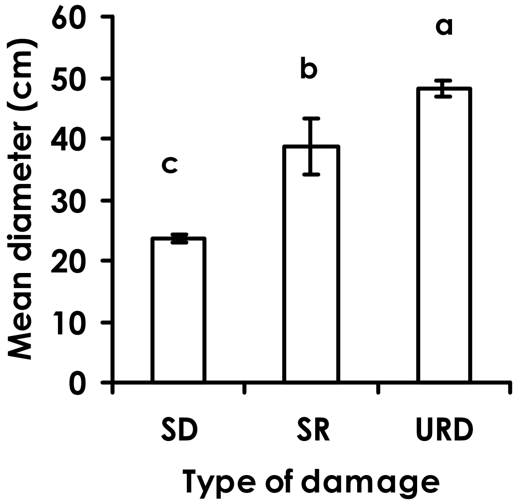

Figure 3: Mean diameter of *E. delegatensis* trees found in the windthrow plots. **SD** = Snapped dead; **SR** = Snapped Resprouted & **URD** = Uprooted Dead. Vertical bars indicate standard errors. Different letters indicate means are significantly different.

In control plots eleven species belonging to six families were found growing along with the canopy species *E. delegatensis*. The species diversity within the windthrow plots was higher with a total of 19 species from 15 families (Table 1). *E. delegatensis* seedlings were found to have recruited in the windthrow plots (49 ha^{-1}) (figure 6D). In contrast no *E. delegatensis* seedlings were recruited in the control plots. The mean diameter of those seedlings was 2.06 ± 0.55 cm. Ninety one percent of them were in the 1-2 cm diameter class. Sub-canopy species *A. dealbata* recruited (2,210 ha^{-1}) in the windthrow plots. None were recorded in the control plots (Figure 4).

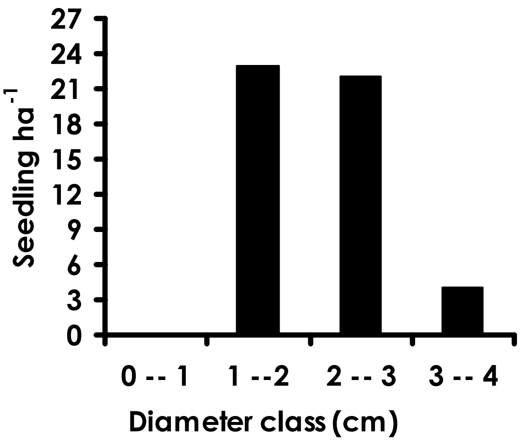

Figure 4: Stem diameter frequency class distribution of *E. delegatensis* seedlings recruited after windthrow occurred in June 1998. Seedling study was carried out November 2002.

Five species seedlings were recovered from soil samples collected from the control and six species seedlings recorded from the windthrow damaged sites respectively. The canopy species *E. delegatensis* (0.22 ha^{-1}) recruited only at the windthrow site (Figure 5).

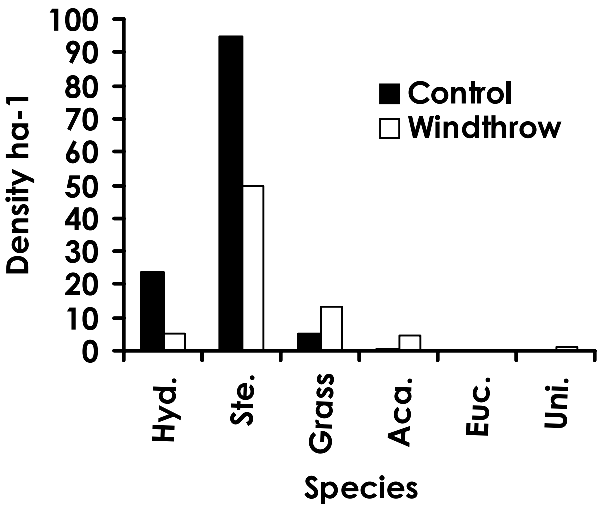

Figure 5: Density (ha^{-1}) and species recruited from the of soil seed bank. Hyd. = *Hydrocotyle* spp., Ste. = *Stellaria flaccida*, Aca. = *A. dealbata*, Euc. = *E. delegatensis*, Uni. = Unidentified.

Although the sub-canopy species *A. dealbata* recruited in both the control and windthrow sites, seedling density of *A. dealbata* seedlings recruited from the windthrow site (4 m^{-2}) was higher that that of control site (0.5 m^{-2}). In both control and windthrow sites the most frequent ground cover species was *Stellaria flaccida* (Caryophyllaceae) (Figure 6F).

Discussion

The 1998 windthrow had a devastating impact on the *E. delegatensis* stands at SRNP. Results show that high wind speeds toppled the trees regardless of size and species and damage 99% of *E. delegatensis*. Damage type varied with dbh (Figure 2). Of 674 trees recorded, only 0.6% escaped windthrow damage. Characteristics of the trees that might influence windthrow include size and species (Webb 1988), root depth (Fowells 1965) trunk tapering (King 1986), wood quality and flexibility (Putz *et al*. 1983) and prior wind stress (Mergen 1954). The damage occurred in the highest part of the Snowy River National Park near Mt. Gelantipy and possibly a combination of shallow soil, tall and older trees fully exposed on an open slope rendered this site particularly susceptible to windthrow. Treefall direction in all plots indicates that winds were from the southeast.

Table 1: Species recruited and density (ha^{-1}) (except *E. delegatensis* and *A. dealbata*) in the control and windthrow plots.

Species	Family	Life form	Height (m)	Density (ha^{-1})	
				Control	Winthrow
Bedfordia arborescens Hochr.	Asteraceae	Tall shrub	3-7	118	Ab
Cassinia aculeata (Labill.) R.Br.	Asteraceae	Shrub	2-3	12	312
Clematis aristata Ker Gawl. f. aristata	Ranunculaceae	Climber	NA	Ab	NA
Coprosma hirtella Labill.	Rubiaceae	Shrub	1-2	51	306
Coprosma quadrifida (Labill.) B.L.Rob.	Rubiaceae	Shrub	2-4	25	222
Cyathea sp.	Cyatheaceae	Fern	1-2	73	258
Dianella revoluta R.Br.	Phormiaceae	Grass	-	6	129
Elaeocarpus holopetalus F.Muell.	Elaeocarpaceae	Tree	5-16	Ab	123
Olearia argophylla (Labill.) Benth.	Asteraceae	Tall shrub/small tree	3-8	38	138
Olearia lirata (Sims) Hutch.	Asteraceae	Shrub	1-2	Ab	29
Polyscias sambucifolia (DC.) Harms	Araliaceae	Shrub/small tree	1-6	Ab	97
Pomaderris aspera DC.	Rhamnaceae	Shrub/slender tree	3-8	48	119
Prostanthera lasianthos Labill.	Lamiaceae	Shrub/small tree	2-8	Ab	325
Rorippa dictyosperma (Hook.) L.A.S.Johnson	Brassicaceae	Herb		Ab	34
Rubus fruticosus L.	Rosaceae	Prickly climber	NA	Ab	NA
Stellaria flaccida Hook.	Caryophyllaceae	Herb	NA	Ab	NA
Tasmannia lanceolata (Poir.) A.C.Sm.	Winteraceae	Shrub	2-3	41	93
Xerochrysum bracteatum (Vent.) Tzvelev	Asteraceae	Shrub	2-4	Ab	173
Grass sp. i (unidentified)	-	Grass	NA	48	142
Grass sp. ii (unidentified)	-	Grass	NA	25	119

NA = Not applicable, Ab= Absent

Peterson and Pickett (1991) pointed out the importance of snapped trees. These trees may resprout and gain some advantage in regrowth over seedlings. The crown of resprouts may contribute canopy cover and provide some suitable microclimate for tree seedlings to germinate. Grose (1957) found that higher percentage of *E. delegatensis* seeds germinated at 4.4 °C. If that is the case, two important question need to be answered: (i) will the resprouting canopy trees provide suitable soil temperature for *E. delegatensis* seeds to germinate? (ii) are enough *E. delegatensis* seeds stored in the soil seed bank? Firstly, the windthrow damage survey shows that only a small percentage (3.8%) of snapped *E. delegatensis* trees had resprouted (Figure 6E). The canopy developing from the resprouting trees is unlikely to provide a suitable temperature/microclimate for *E. delegatensis* seeds to germinate. This is demonstrated fact that the tree fern, *Cyathea* sp. was damaged by too much sunlight (Figure 6E). Further, these resprouting trees are fully exposed and prone to heavy wind making it unlikely that they will withstand the next windthrow.

Analysis of the diameter of snapped dead, snapped resprouted and uprooted trees. Showed that medium size (38.62 ± 4.5) trees are more likely to resprout than smaller (23.67 ± 0.62) or larger (48.06 ± 18.23) diameter classed. Larger diameter trees are more likely to be uprooted than that of smaller diameter. This is likely to be because, under stressed conditions, larger trees tend to loose or exceed the soil shear strength (i.e. soil ability to resist torsional forces) (Putz *et al*. 1983).

All species colonizating in the windthrow site are native to the study area except *Rubus fruticosus*. Apparent lack of *E. delegatensis* seedlings within the damaged can be attributed to several factors: firstly, microclimate in the windthrow site may not be suitable for germination of *E. delegatensis* seeds. Secondly seeds of *E. delegatensis* may have disseminated into this windthrow sites, but the thick cover of early colonizing species across site, may have prevented the seed from reaching the soil (Figure 6F). Finally the soil seed bank study suggests that a low number of *E. delegatensis* seeds were stored in the soil. The latter seems the most likely reason for lack of *E. delegatensis* recruitment.

The exotic *R. fruticosus* was found to be colonizing only in plots located close to the track (plot 1 & 2). Seeds of *R. fruticosus* may have been brought in and deposited in the soil during track maintenance and are slowly invading the gaps. Immediate control measures should be taken to prevent further infestation.

Windthrow hazard depends upon several biotic and abiotic factors including climate, topography, soil and stand characteristics (Ruel 2000). If we superimpose the factors such as topography and stand characters of Mt. Gelantipy, (1200m a.s.l.), on the Ruel (2000) windthrow hazards factors, we find that this site is susceptible to windthrow. A major issue is how windthrow risk and impacts on similar stands can be reduced. Studies have shown that silvicultural operations can minimize windthrow effects (Oke 1987). However, thinning would also increase wind penetration into the stand and could increase the damage for some years after the silvicultural operations (Cremer *et al*. 1982; Gardiner *et al*. 1997). Therefore selection of trees to be removed is vital to this operation and techniques selection for trees are yet to be assessed. Different silvicultural techniques should be studied to minimize the effects of windthrow on the *E. delegatensis* stands. Ruel (2000)

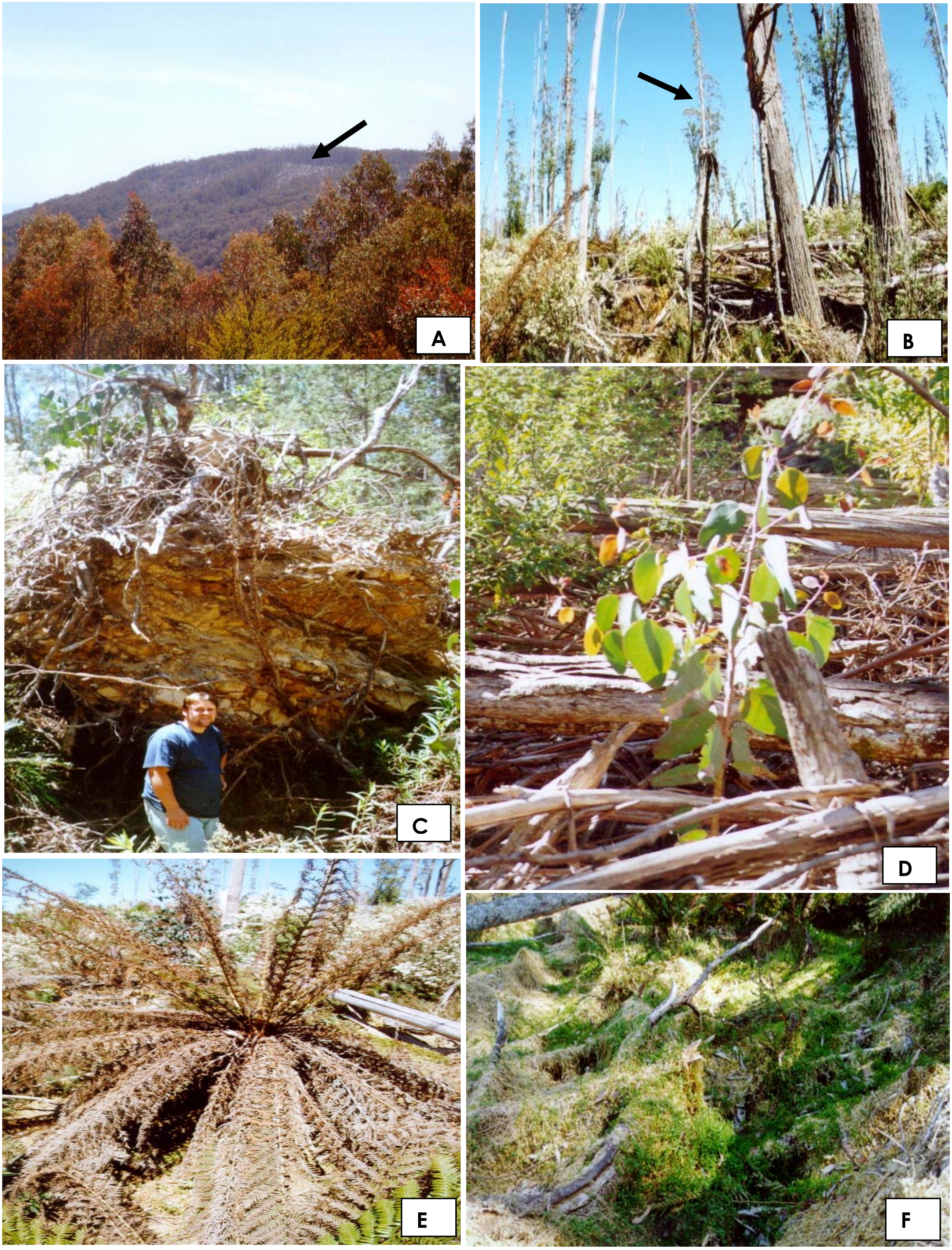

Figure 6: Photos of 1997 windthrow in the Snowy River National Park. A] Arrow indicates the clear patch of the windthrow study site, B] windthrow damage with some trees starting to resprout, C] Uprooted *E. delegatensis*, D] *E. delegatensis* seedlings recruited in the windthrow site, E] Tree fern *Cyathea* sp. damaged by too much sunlight and F] Prolific growth of the native herb *Stellaria flaccida* in the windthrow site.

suggested, that the impact of silvicultural operations on stands is likely to be insignificant compared with natural windthrow.

As a result of low numbers of *E. delegatensis* seedlings, and weed invasion into the area this will not develop into a healthy *E. delegatensis* stand. Further, although large numbers of trees are present adjacent to the damaged site, viable seed supply from those trees has not been determined. Even if seeds are supplied from the adjoining stand, seeds may not reach the soil surface, as the ground is covered with thick layer of litter and a significant part of the ground is also coved with weed species. The better way to encourage *E. delegatensis* seedling recruitment in the winthrow sites is to burn the site and broadcast *E. delegatensis* seed.

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