12

The Impact of Severe Frost

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Introduction

The enormous wildfires of 1981 in Wyperfeld National Park in northwestern Victoria were followed in 1982 by the most severe frosts ever recorded in the region, and a major drought (see Tables 12.1 and 12.2). The annual rainfall (108 mm) was 30% of the annual average (351 mm). Rainfall data collected at the Ranger's residence show that from July 1982 to February 1983, no month had more than 10 mm and that the total rainfall in this period was only 30.5 mm. Data for the nearby town of Rainbow show 1982 as the lowest rainfall since records began in 1901, with 29 mm in the same period. Temperature data for the Park, which date back to 1959, show that, although winter frosts are common in this region, nothing of this severity had been previously recorded in the Park. Data for Ouyen, where temperature records have been kept since the early 1900's, suggest that frosts of this severity may be very rare.

The impact on the vegetation was remarkable: thousands of hectares of heathland and mallee scrublands, especially in the interdune swales, were devastated. Of the woody shrubs and tree species, few escaped unscathed, a notable exception being populations of the scrub pine (*Callitris verrucosa*). which showed no evidence of damage even in swales. Subsequent work by Coleman (1986) established that a screen temperature of -8°C at the Ranger's residence (Table 12.1) corresponded to an interdune swale temperature of at least -13°C. The closely related slender cypress pine, (*C. preissii*), showed severe scorch on some lower dune slopes and swale sites, and many young trees, up to 10 years old, died. Isolated large individuals of buloke (*Casuarina luehmannii*) in the Lake Albacutya region were totally scorched and appeared dead in 1983. All of these trees subsequently recovered by sprouting from epicormic shoots and have since flowered and set seeds on the sprout shoots (1987).

Casuarina muellerana was severely affected, even on dune crests where many other sensitive species have survived. *C. paludosa* and *C. pusilla* showed variable but often serious damage; partly scorched bushes have begun to regrow. The desert cherry (*Exocarpos sparteus*) a classical 'fireweed' and a root parasite on mallee eucalypts, was totally eliminated in frost-affected areas from

Table 12.1 Minimum Temperatures (°C: Screen Data) at Wyperfeld Ranger's Residence.

	June 1982						July 1982							
Date	4	5	6	7	8	9	15	16	17	18	19	20	21	22
Temperature	-5.0	-8.0	-8.0	-7.0	-6.0	-5.0	-1.0	-5.0	-7.0	-1.0	+3.0	-6.0	-8.0	-6.0

Table 12.2 Monthly Rainfall Records (mm) at Wyperfeld Ranger's Residence

	J	F	M	A	M	J	J	A	S	O	N	D	Total
1982	14.6	13.5	12.0	12.0	14.4	17.3	4.3	9.9	5.2	2.1	1.2	2.0	108.5
1983	5.8	0	99.5	21.7	35.0	21.2	35.4	59.8	53.6	57.4	21.1	55.0	465.5

all swale sites and from lower dune slopes. *Melaleuca lanceolata* was severely damaged in swale and lower dune sites but the majority have recovered by shoots from the lower regions of the trunk. Many adults of *Pittosporum phillyreoides* showed a pronounced scorch of leaves and loss of young twigs and deterioration has continued until the present. A similar induction of decline and loss of tree vigour are apparent in frost-scorched crowns of adult *Eucalyptus camaldulensis*. Along the Oulet Creek system, the frosts induced leaf scorch ingthis species, often extending to a height of 9-12 m. Such scorched regions of the crown usually have produced sprout shoots but photographic monitoring of the fate of these partially-scorched crowns shows a serious loss of vigour, which has exacerbated the effects of interference with the natural flood regimen of Outlet Creek (see Land Conservation Council 1987).

This chapter reports the results of observations taken from permanent transects and quadrats established in 1984 and 1985 in Wyperfeld National Park.

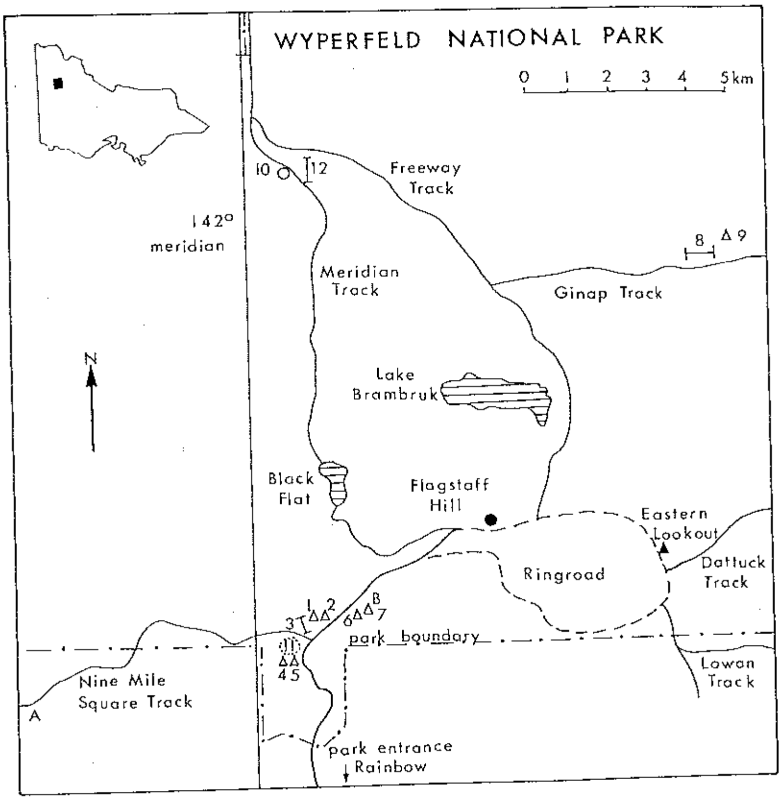

Figure 12.1 Map of part of Wyperfeld National Park showing tracks and study sites. Δ *Leptospermum coriaceum* sites assessed for post-frost regrowth (sites 1, 2, 4, 5, 6, 7, 9). ⊢⊣ Transects used to study seedlings induced by frost (site 3), by fire in January 1981 (site 8) and by the January 1985 fire in a region affected by mild frost (site 12). **o** Frost-killed *Banksia ornata* site, burnt by fire in January 85 (site 10). ⁞ Area used to measure frequency of seedling eucalypts beneath eucalypts showing varying degress of frost damage (site 11). A, *Casuarina/Banksia* site and, B, *Leptospermum* site, used to monitor long-term effects of frost in these two heathlands (see Tables 12.3 and 12.4).

Field Sites

In April of 1984, fixed quadrats were established at two sites, one on Nine Mile Square Track in a *Casuarina/Banksia* heathland, the other near the entrance road in a *Leptospermum* heathland (see Sites A & B, Fig. 12.1). These were monitored again in August 1984 and June 1986 to provide an insight into the long-term effects of the frost/drought combination on *Eucalyptus incrassata, E. dumosa, E. foecunda, Banksia ornata,* and *Leptospermum coriaceum* (O'Brien *et al.* 1986). At each site three 10 m x 10 m quadrats were established, one each in patches showing no apparent damage, medium damage and severe damage.

In January of 1985, a large wildfire burnt the northern section of the Outlet Creek system, including large areas of frost-killed *Banksia ornata/Leptospermum coriaceum* heathland, and stands of *Callitris preissii* and *C. verrucosa* (Fig. 12.1). Two short belt transects and a large fixed quadrat (5 m x 150 m) were placed in this area in 1985, to measure post-fire recovery.

Individual Species Response

At each site three 10 m x 10 m quadrats were established, one each in patches showing no apparent damage, medium damage and severe damage. A number of perennial species were eliminated (Table 12.3) from Sites A and B in the frost affected quadrats, but survived in the apparently unaffected quadrats. This suggests that it really was the frost, rather than the associated drought, which was responsible for this elimination. In contrast, some species (*Goodenia robusta, Schoenus breviculmis*) also disappeared from the quadrats which appeared undamaged by frost in April 1984. Perhaps such species suffered more from the severity of the 1982/83 drought. *Banksia ornata* adults were killed in the frost-affected quadrats, and no seedlings were observed in those quadrats (4 seedlings were present at site A in the undamaged quadrat). An extensive search of *ca* 2 ha of frost-killed *B. ornata* in August of 1984 in the Site A region failed to find any seedlings, even though large numbers of cones containing seed were present on the ground. Some of the frost-killed follicles had opened (about 10%), but the majority were still closed. Damage sustained by *Triodia irritans* varied

Table 12.3 Perennial species that have failed to regenerate after frost damage in fixed quadrats by June 1986 (Anderson and O'Brien, unpublished).

Site A ***Casuarina/Banksia* Heathland**	**Site B** ***Leptospermum coriaceum* Heathland**
Banksia ornata	*Banksia ornata*
Triodia irritans[1]	*Triodia irritans*[1]
Hibbertia stricta	*Hibbertia stricta*
Baeckea ericaea	*Hibbertia virgata*
Casuarina muellerana	*Goodenia robusta*[4]
Micromyrtus ciliata	*Micromyrtus ciliata*
Spyridium subochreatum	*Neurachne alopecuroidea*
Pimelea octophylla	*Cassytha pubescens*[3]
Phyllota pleurandroides	*Brachyloma daphnoides*[2]
Cryptandra tomentosa	*Danthonia caespitosa*[4]
Schoenus breviculmis[4]	*Billardiera cymosa*
Lomandra glauca[4]	*Scleranthus minusculus*
Stipa semibarbata[5]	*Oxalis corniculata*
	Chondrilla juncea
	Thysanotus pattersonii
	Tricoryne elatior

1 Surviving plants show poor growth and foliar death.
2 Single plant.
3 Parasitic liane.
4 Also disappeared from quadrat assessed as undamaged in April 1984.
5 See also Table 12.4, Site B.

Table 12.4 Perennial species either resistant to frost or showing good recovery after frost damage (as at June 1986: Anderson and O'Brien, unpublished).

Site A ***Casuarina/Banksia* Heathland**	**Site B** ***Leptospermum coriaceum* Heathland**
Leptospermum coriaceum	*Leptospermum coriaceum*
Lomandra leucocephala	*Stipa variabilis*[1]
Lomandra juncea	*Stipa semibarbata*[2]
Lepidosperma carphoides	*Aotus ericoides*
Lepidosperma viscidum	*Wahlenbergia stricta*
Callitris verrucosa	*Vittadinia triloba var. dissecta*
Grevillea pterosperma	*Helichrysum leucopsideum*
Hibbertia virgata	
Casuarina pusilla	
Casuarina paludosa	
Comesperma scoparium	
Calytrix tetragona	
Lepidobolus drapetocoleus	
Aotus ericoides	
Hybanthus floribundus	
Cryptandra leucophracta	
Kunzea pomifera	
Leucopogon rufus	
Astroloma conostephioides	
Brachyloma ericoides	
Neurachne alopecuroidea	
Hakea muellerana	
Clematis microphylla	

1 Cover drastically reduced from > 75% to < 25%
2 See also Table 12.3, Site A.

between Site A and B. All frost-damaged plants at Site B died back almost completely and no regeneration is evident (1988). At Site A, some chlorotic and necrotic shoots persist, but no new growth has been initiated.

Many species were either resistant or have shown good recovery since (Table 12.4). Some species (e.g. *Stipa variabilis*) have undergone very significant reductions in cover. The following discussion details the frost regeneration patterns of some of the dominant woody perennials.

Banksia ornata Cheal *et al.* (1979) list *Banksia ornata* as an obligate seed regenerator, as shown by the wealth of seedling establishment after the 1959 fire and by the absence of coppice shoots on either burned or frost-killed adults. However, examination of large stands of frost-killed banksias in 1984 and 1985 revealed very few seedlings. Cones were collected in 1985 along Nine Mile Square Track from adults either killed by frost or from undamaged bushes flowering at the time. The viability of seed from frost-killed plants was high (mean 84%) but significantly lower (analysis of variance, $p < 0.001$) than seeds collected from surviving plants (mean 91%).

The 1985 wildfire burnt a large stand of frost-killed adult *Banksia ornata* but seedling establishment afterwards was very poor. Since *B. ornata* normally regenerates vigorously from seed after a fire (Gill 1976, 1981), it is not known why the large viable reserves of seed in the frost-killed cones failed to germinate after the wildfire of 1985. Further work is needed to understand why the events of 1982/3 have induced a massive reduction of this species from swale sites and lower dune slopes in the Park.

Surviving adults are now located only on dune crests and upper dune slopes above the level affected by the frosts. Wyperfeld normally experiences 5-15 frost days per year, as measured at the Ranger's residence. In 1982, this figure was

35, including the two extended periods of nearly a week shown in Table 12.1.

Field experiments were done to expose *Banksia ornata* shoots to repeated cycles of freezing and thawing (O'Brien *et al.* 1986). The results showed that adult foliage was remarkably resistant to repeated freezing and thawing, even at temperatures of -20°C. Five cycles were necessary before a sudden collapse of the tissues occurred. Seedling tissues were even more resistant, surviving seven successive cycles in agreement with field observations. Tissues from the swale survivor did not behave differently from those of the plant from the dune crest. Presumably the exceptional winter of 1982 was more than this normally frost-hardy plant could tolerate. There is also the possibility that the severe frosting weakened the resistance of adults to the ensuing drought.

Leptospermum coriaceum Above-ground parts of this species suffered massive injury. Cheal *et al.* (1979) classified the post-fire responses of this species as a facultative root resprouter. The survival of basal regrowth (from the parent stem) and root-sucker regrowth were assessed in 1985 at seven sites, with severe frost damage. Plants without coppice on the main stems appeared to be dead and were recorded as 'basal coppice absent'. Open fruit capsules were also observed on frosted foliage and seedling numbers were counted in a 30 m x 30 m quadrat, randomly placed in each site. A short belt transect was placed in February 1985 at a site with frost-killed *Leptospermum coriaceum* to assess seedling establishment after a fire in January 1985.

It was found that 1 232 adults counted in the seven sites, an average of 31% failed to regrow in the three years 1982-85 (see O'Brien *et al.* 1986). Bark survival at ground level was checked in 5% of stems but none was found alive. There was very high between-site variation in the reponse though the cause of this variability is not known. It may well prove to be related to variation in soil moisture (see Adams 1985).

Vegetative recovery by *Leptospermum coriaceum* was generally satisfactory, even though some sites lost the majority of their above-ground shoots. Seedling numbers, however, were low and variable. Furthermore, no seedlings were found in 1985. Attempts to germinate seed released at room temperature from apparently healthy capsules of *Leptospermum* on unfrosted plants were unsuccessful, either on filter paper or in soil mixes, though the tetrazolium test revealed good viability. Capsules were harvested from apparently unfrosted plants, and subjected to two freezing treatments (frozen once, and frozen twice over two days at -20°C for 8 hours).

All freezing treatments reduced viability compared with unfrozen controls, though the effect varied according to the location of seed sources. This reduced viability may be a factor underlying the poor seedling input into the frost-killed sites.

Shoots of *Leptospermum coriaceum* were also removed from field grown plants and given experimental freezing treatments similar to those employed on *Banksia ornata*. All adult tissues showed significant cell death after just two freezing treatments, with tissues from swale plants being slightly more sensitive than those taken from dune crests. Tissues from root suckers took longer to die than other sources of adult foliage, independent of their site of origin.

It is difficult to assess the impact of the ensuing drought of 1982 on this species, especially in regard to the death of very large, frosted adults with stems 12 cm in diameter. There is need to study the water relations of frost-killed foliage under field conditions and the role of pathogens, or facultative pathogens, in the post-frost death of large shoots because large bushes separated by many metres turn out to be ramets of clones interconnected by horizontal roots up to 3 cm in diameter.

Despite the fact that severe frost appears to have the capacity to reduce viability of seeds in capsules, and hence restrict recovery by seedling establishment, the regenerative capacity of this species is such that its distribution in Wyperfeld in unlikely to be altered drastically as a result of the 1982/3 season.

An unusual aspect of the frost injury in stands of *Leptospermum coriaceum* was the effect noticed at track margins. Here, those parts of a bush which faced the track were often uninjured, whereas the rest of the bush may have been killed to ground level. No explanation of this phenomenon is available but it is clear that the radiation fluxes and temperature gradients during frosting can vary sharply over quite short distances and can be profoundly affected by man-made influences such as tracks.

Mallee Eucalypts Although some trees were killed outright, the majority regrew from coppice shoots. In severely affected trees, the coppice emanated from the lignotuber but in less severely affected trees epicormic regrowth was present on stems. As with *Leptospermum coriaceum*, some trees that had coppiced suffered a secondary round of death, losing all or part of their coppice shoots.

Preliminary observations showed that seedlings were rare and it was decided to examine the effects of experimental freezing treatments on seed germination. Capsules of *Eucalyptus incrassata, E. dumosa* and *E. foecunda* were collected from long unburnt stands showing no evidence of frost damage. Seeds were extracted and trials yielded reasonable germination in all species (*E. incrassata* 93%, *E. dumosa* 97% and *E. foecunda* 58%, 33%, 77%). Subsequent germination tests of *E. foecunda* in a varying light climate and atfluctuating temperatures gave higher results (94%).

Seeds were exposed to temperatures of -20°C. Repeated, long exposures (7 x 4 hours) reduced germination of imbibed seeds compared with less severe treatments. *Eucalyptus foecunda* was less affected than the other two species (see O'Brien *et al.* 1986).

These results suggest that in these eucalypts, the seed reserve stored in the capsules is quite safe even from very severe freezing conditions and that shed seeds are also resistant unless they are exposed to severe frost during germination. However, only 6 seedlings, 3 of *Eucalyptus foecunda* and 3 of *E. incrassata*, were found in a 400 m transect (2 m wide) in a frost affected eucalypt stand. In another transect (200 m x 2 m) which passed through a stand of vegetation burnt in the summer of 1981/2, prior to the frost, there were 169 seedlings of *E. foecunda*, but it is not known exactly when these germinated. They may have been induced by the low but regular monthly rainfalls from January 1982 to June 1982 (average 14 mm/month) or more likely they are the result of the drought breaking rains of March 1983 (99.5 mm).

The last 200m of the same transect passed through a long-unburnt stand suffering from mild frost damage. No seedlings were present in that part of the transect. A study of the distribution of seedlings beneath isolated trees, frosted to varying degrees of severity, was also made. All seedlings were found in areas with no litter layer. There was no obvious relationship between seedling density and degree of frost damage experienced by each putative parent tree.

It is not known why seedling establishment was so poor after the frosts, nor why the few seedlings that did occur were largely in regions outside the litter layer. Perhaps frost-kill in winter does not generate the massive seed release that follows summer fires. Capsules frozen in laboratory experiments released their seeds in a few days at 30°C, but capsule behaviour after field freezing has yet to be studied. Frost-killed litter may be inimical to germination, either because of its allelopathic effects, or because it is difficult to wet (J.C Noble, pers. comm.).

There is little doubt that seeds which lie on the surface and are not buried quickly, will be depleted by seed harvesting ants (Wellington & Noble 1985a, b). It is also possible that the protracted periods of very low temperatures experienced in 1982, and the gap between the two severe periods of low temperature, caught seeds on the surface in a partially-germinated state, with fatal results. The presence of a few seedlings in bare areas may be due to an increased chance of seed burial in that micro-site. It is not surprising that seedling establishment after a severe winter frost and prolonged drought is different from that found in long unburnt mallee or after summer fires followed by autumn rains. The strong vegetative response of the mallee eucalypts to frost injury, although accompanied by the loss of a proportion of adults, ensured that the three species did not suffer a serious change in distribution.

Conclusion

The mallee region of Victoria contains a large number of plant communities distributed in a mosaic pattern (see LCC 1987). The composition of some of these communities is clearly influenced by soil factors such as salinity. However, in the majority of cases it is not clear what aspects of plant adaptation and local environment have influenced the distribution and development of these communities (see also Adams 1985). Much attention has been given to fire and drought as causal factors in this semi-arid region. The impacts of other catastrophic disturbances on plant communities like the frosts of 1982/3 have not received equivalent attention.

In this region of low relief, differences in elevation also have dramatic impacts on night

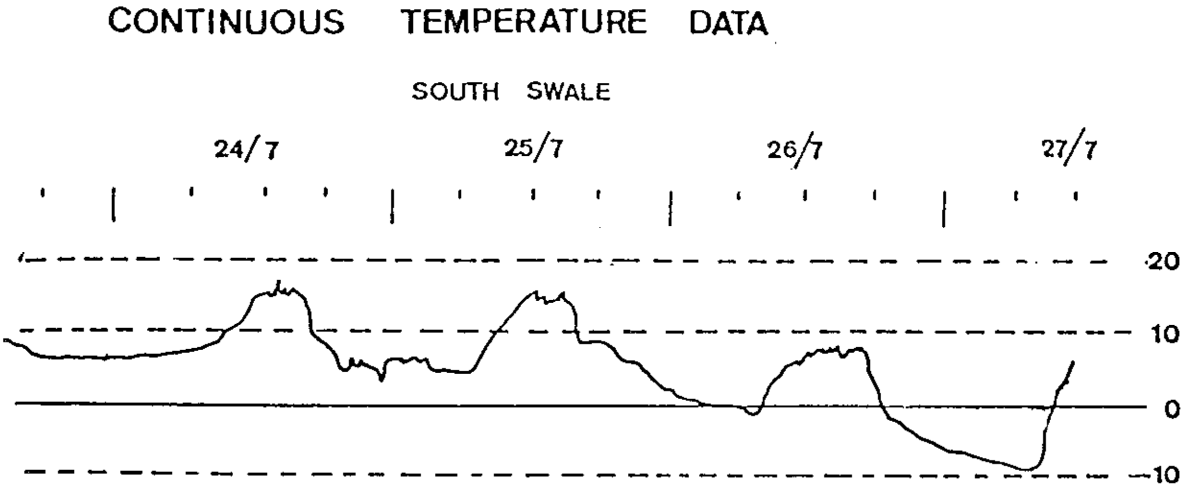

Figure 12.2 Continuous temperature recordings from a swale site close to the southern entrance of Nine Mile Square Track from 24 July 1986 to 27 July 1986. The temperature fell to -8ºC and stayed below freezing for 14 hours.

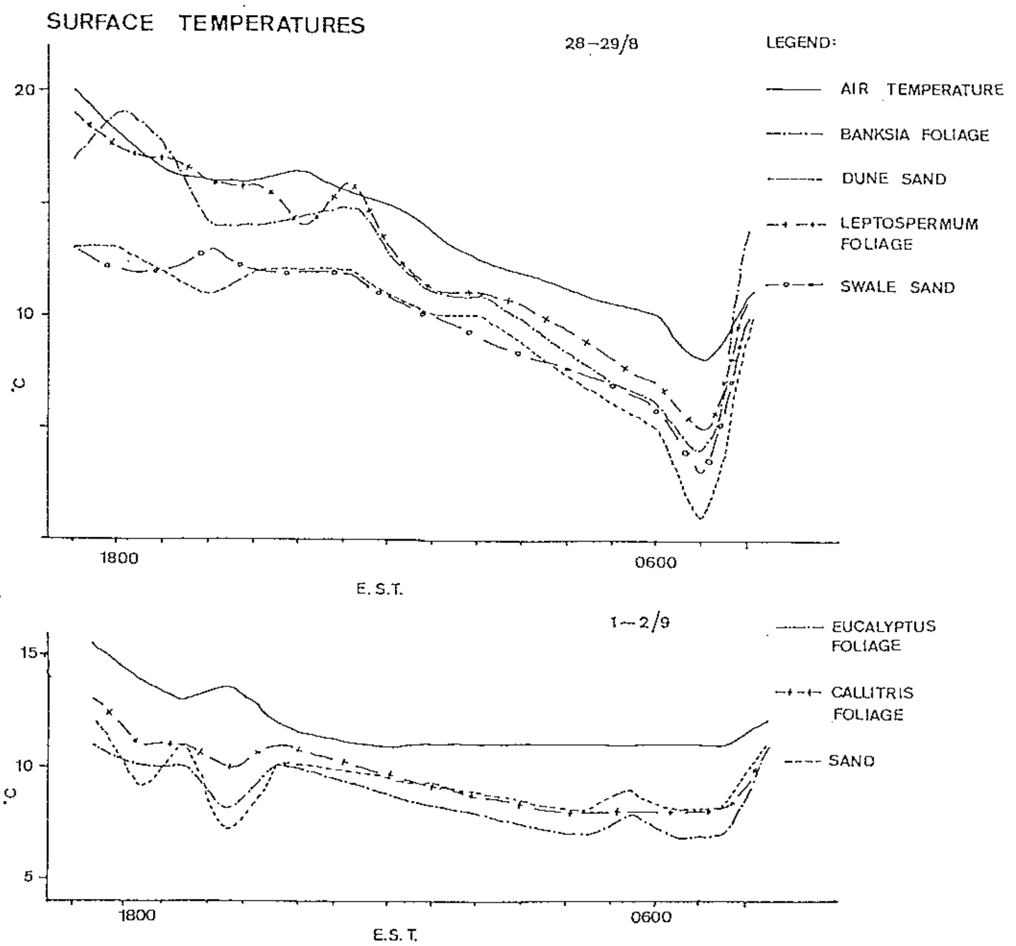

Figure 12.3 Recordings of the air temperatures and surface temperatures of the surface of various foliages and soils in the same swale in Fig. 12.2 but for the nights of 28-29 August 1986 and 1-2 September 1986. In both cases the foliage temperatures fell substantially below that of the ambient air (measured 1m above ground) and remained closer to that of the colder soil surface until sunrise (Fig.12.2 & 12.3 after Coleman 1986).

temperatures in the swales and lower dune slopes. Coleman (1986) has shown that swale temperatures on nights of severe frosts are about the same as minimum winter temperatures in sub-alpine areas of Victoria (Williams 1987). On July 26/27, 1985, Coleman measured the swale temperature for a 48 hour period revealing a minimum of -8°C in the swale (Fig. 12.2). The temperature was also found to remain below freezing for 14 hours. After sunset the air temperature begins to drop, and the temperature of the foliage stays well below that of the ambient air, closer to that of the much colder surface of the soil (Fig. 12.3). Future physiological studies of plants growing in this environment, and ecological models of their behaviour, must take this into account.

The events of 1982/3 have not been common in this region in the last 90 years, but they certainly illustrate the effects such a climatic event can have across a broad suite of species (see Table 12.3), and how a single event can affect the distribution of some species (e.g. *Banksia ornata* and *Exocarpos sparteus*). Severe conditions may limit the distribution of such species over long periods of time, similar perhaps to the influences of frost on distributions of eucalypts in sub-alpine Tasmania (Davidson & Reid 1985), and on closed heathland in sub-alpine Victoria (Williams 1987). It can be assumed that the late Pleistocene/Holocene climate in this region has involved many oscillating cycles of greater and lesser aridity, producing over the millenia, a large number of events equal, or greater, in severity to those seen in 1982/3.

Any effects of frosts such as those experienced in 1982 may now have much more serious consequences for nature conservation, because of the dramatic reductions in the range of most species that have followed the actions of man (e.g. clearing and salinity). Managers of reserves and other areas of natural vegetation may be forced to consider the options available for rehabilitation of damaged vegetation if catastrophic disturbances of this kind threaten the existence of species in remnants of the mallee.

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