FIRE AND THE PERSISTENCE OF TUART WOODLANDS

by

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I declare that the work in this thesis is my own account of my research and contains as its main content work that has not been submitted for a degree at any tertiary education institution.

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ABSTRACT

Tall tuart (*Eucalyptus gomphocephala*) trees are a defining element of the landscape of Perth and the coastal plain to the north and south. However, with the health of some tuart stands deteriorating, most notably at Yalgorup south of Perth, concerns are heightening that the already fragmented tuart ecosystem will continue to contract, leaving a cultural and ecological scar in the landscape. Like many other eucalypt ecosystems, tuart woodlands have had a long association with fire and are believed to have been frequently burnt by the Aborigines prior to European settlement. Today, fragmentation and European land management practices have led to a lower frequency of fire across most remaining woodlands, but also episodes of intense fire at shorter intervals in some areas. Individual fire events as well as fire regimes have the potential to shape the structure, composition and extent of ecosystems, and eucalypt ecosystems are no different. Thus, the impact of fire and fire regimes on tuart health and regeneration was investigated in this study.

A survey of the woodlands at Yalgorup revealed tuart decline was present across a range of sites with contrasting fire histories. Tuart health was poorest at the longest unburnt site (35 years) and the site burnt by frequent wildfire (three fires in 13 years), suggesting these extreme fire regimes had played a role in the decline. Nevertheless, low ratings of tree health at sites burnt approximately once per decade, point to factors other than fire playing a role in the decline of tuart at Yalgorup. The tuart populations at Yalgorup were dominated by individuals in larger size-classes and there was a significant negative relationship between tree size and the probability of tree mortality. In one stand in Yalgorup National Park, 38 % of the tuart saplings/trees had died. It follows that the regeneration and development of tuart seedlings into adults will need to occur within the next one to two decades if these woodlands are to persist. Seedling counts confirmed that tuart regeneration was virtually absent in unburnt areas, as is common with eucalypt species. Interpretations of size-class distributions suggested controlled burning contributed little to recruitment, whereas in areas subject to wildfire outside Yalgorup, tuart had regenerated in abundance such that size-class distributions were skewed towards the smaller size-classes. A repeat survey of plots established in 1976 supported anecdotal reports that the mid-storey tree peppermint (*Agonis flexuosa*) was increasing in density and height in Yalgorup. The skew towards the smallest size-class within peppermint populations at Yalgorup and the presence of seedlings (> 200

seedlings ha^{-1}) within areas not recently burnt (at least four years since fire) brought into focus the differing mode of regeneration for this species in comparison to tuart. In further contrast to tuart, mature peppermints were in good health with no dead trees reported in the population surveys. A possible role for competition in tuart decline was highlighted by significant negative correlation between peppermint density and tuart health. Together, these results suggest that a general drift from tuart woodland to peppermint forest appears entrenched.

Comparative studies of the bark thickness, fire response and resprouting behaviour of tuart and peppermint illustrated the capacity of individuals of both species to persist with recurrent fire. As adults or juveniles, tuart and peppermint resprouted following complete canopy scorch, and often from crown branches: an ability not uncommon for co-occurring tree species and shrubs in this environment. Survival was between 75 and 100 % for fully-scorched tuarts in size-classes ranging from small saplings to trees across six sites. From the small sample of peppermints available for comparison, seedlings and small saplings appeared to be more vulnerable to mortality by fire; only 45 % of individuals with a diameter at breast height $\leq$ 1 cm survived following complete canopy scorch from a controlled burn. With thicker bark, a reliance on stem epicormic buds rather than a lignotuber for resprouting and a greater capacity for height growth, the fire resistance and post-fire recovery of tuart would be expected to differ from that for peppermint. Opportunities for managers to exploit these differences in their burning prescriptions so as to address the drift from tuart to peppermint dominance were outlined. In addition, results indicating a positive response in canopy condition for tuarts with < 10 % canopy scorch following a controlled burn imply that tuart vigour may benefit more immediately from fire. But, observations also revealed that spikes in intensity within controlled burns can damage large unhealthy trees and thereby accelerate the decline process. Thus, the application of fire to declining tuart stands needs to be conducted skillfully.

Patterns of growth and survival for tuart and peppermint seedlings were linked to the contrasting ability of the species to establish at burnt and unburnt sites. The purported importance of ashbeds in tuart establishment was demonstrated; at the end of summer (February) at a recently burnt site (Golden Bay), the mean height of tuart seedlings on ashbeds was three times that for those off ashbeds, and the survival rate on and off the ashbeds was 35 % and 15 %, respectively. Therefore, while important, tuart seedlings

were not dependent on ashbeds in this instance. The hardy nature of peppermint seedlings when compared to tuart was illustrated when the species were planted in an unburnt area of tuart-peppermint woodland at Yalgorup; nine months after planting, 38 % of the peppermint seedlings survived while only 9 % of the tuart survived. Most of the mortality was linked with the summer-drought period and it was suspected that peppermint seedlings were more drought tolerant. A complementary glasshouse experiment showed that tuart had a greater shoot:root ratio than peppermint, which may be one factor in the greater sensitivity of this species to drought. Further, this experiment revealed that with an increase in nutrient supply, the proportional increment in rooting depth for tuart (1.6 times) was significantly greater than for peppermint (0.3 times). An increased availability of nutrients in ashbeds following fire, particularly for phosphorous, was measured within tuart woodland. Therefore, it was inferred that the availability of nutrients was a critical factor increasing the growth, rooting depth and consequently the greater survival of tuarts on ashbeds. Overall, tuart was concluded to share the *Competitor* strategy (after Grime) in common with many other eucalypts: rapid growth and the attainment of a large size. On the other hand, peppermint exhibits some of the traits of the *Stress Tolerator* strategy (after Grime): low minimum resource requirements for growth and survival.

The consequence of the increasing cover of peppermint on tuart establishment was explored in field experiments with planted tuart seedlings. No significant impact on seedling growth or survival was observed. There was a declining trend in the seedling growth rates under the high compared to the low peppermint density treatments as the second summer of the experiment was approached, although a statistical difference could not be shown. Peppermint density also had no significant influence on damage to the seedlings from insect attack or the foliar pathogen *Mycosphaerella cryptica*. Overall, insects and *M. cryptica* had only an incidental impact on the seedlings: the mean level of canopy damage per affected seedling was < 10 % for either of these two damage agents. Soil type, specifically whether growth occurred on an ashbed was demonstrated to be the most important factor in tuart growth and survival in the 18 months following planting. Although survival was superior on ashbeds (88 %), mean survival was > 50 % in unburnt soil 18 months after planting indicating the potential for restorative plantings to occur in some woodlands between fires.

Tuart decline, and the role of altered fire regimes in the decline is complex and further avenues of research were emphasized. Nevertheless, the findings of this and other studies are sufficient to enable purposeful actions to conserve and restore tuart woodlands; recommendations regarding the application of fire with a view to these goals are presented in the final discussion.

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DEFINITIONS

Adult (plant)	Having produced flower buds ie. reached maturity.
Ashbed	Where combustion results in soil heating to depth (several centimeters) as well as ash deposition (several millimeters). Usually corresponds with patches where coarse fuels (for example, fallen tree branches) combust ie. where burn-out times are extended.
Burn-out time	Period of combustion (McArthur and Cheney 1966).
Canopy	**a)** Total foliage on a plant or **b)** The upper layer of foliage of the vegetation.
Canopy area (CA) rating	A scoring system for tree canopy area used in this thesis and based on Grimes (1978).
Canopy health (CH) rating	A scoring system for tree canopy health used in this thesis and based on Grimes (1978).
Crown	Spreading branches in upper zone of stem.
Decline	**a)** Long-term loss (years) of leaf area from a crown (tree scale), and/or **b)** a canopy (stand scale) and/or **c)** the loss of a species from the stand through a failure to regenerate (ecological drift).
Diameter at breast height (DBH) over bark (DBHOB)	Diameter at approximately 1.5 m above ground level.
Department of Environment and Conservation (DEC)	The Department of Conservation and Land Management until 2006.
Department of Conservation and Land Management (DCLM)	Changed to the Department of Environment and Conservation in 2006.
Dieback	Refers to “b” in “Decline”.
Establishment (seedlings)	The period from germination to approximately the end of one growth season (Bullock 2000).

Fire intensity	Standard descriptor for comparison between fires. Represents the energy release at the flaming front of a fire measured as kW m^{-1} but often qualitatively described as low, medium etc.
Fire severity	The degree of heating sustained by the soil and vegetation during a fire. Relates to the quantity of fuel combusted.
Fire regime	A description of fire types (intensity, severity, season etc.) within time (frequency) and space (burn extent and patchiness) (see Gill 1975). Simplest descriptions consist of intensity class x average fire return interval.
Forest	**a)** General: vegetation dominated by trees where the potential canopy cover is > 20 % (Department of Agriculture, Forestry and Fisheries 2003). Therefore technically includes some woodlands. **b)** Technical: Foliage projected cover of trees is > 30 % (Specht 1970).
Germinants	The period of seedling development following germination and prior to the formation of true leaves.
Regeneration	**a)** Seedling development from seed and/or **b)** new stems arising from the plant base or below. In this thesis regeneration refers to "a" only unless otherwise stated.
Recruitment	The completed progression from germination to adult. In this thesis the term refers only to the process beginning with seedling regeneration, not vegetative regeneration.
Safe site	A location within a site that can support survival and growth sufficient for a seedling to reach adulthood (ie. be recruited).
Sapling	For tree species: height above 1.5 m and yet to reach maturity.
Seedlings	For tree species: height below 1.5 m and includes germinants.
Unburnt (site)	A site that has not been burnt for several years or longer.