Eucalypt flower production in the suburbs and bush: implications for the endangered Swift Parrot *Lathamus discolor*

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The endangered Swift Parrot *Lathamus discolor* breeds mostly in coastal south-eastern Tasmania, an area where urban development is common and the city of Hobart is situated. Hobart's suburbs are visited regularly by foraging Swift Parrots that nest in the surrounding forests. The reproductive success of Swift Parrots depends largely on the availability of the birds' major dietary items, the nectar and pollen of *Eucalyptus* trees. This study investigated the relative value of suburban trees and those in adjacent native forest in Hobart as food sources for Swift Parrots. To this end, we compared flower production between mature trees in suburban and bushland areas for the two species on which Swift Parrots predominantly forage while breeding; Tasmanian Blue Gum *Eucalyptus globulus* and Black Gum *E. ovata*. For both species, flower production over the past few years was greater for individual trees in the suburb than for those in the surrounding bushland. Hence, individual trees in the suburb probably provide more nectar and pollen than do those in the nearby bushland and are potentially important to the reproductive success of Swift Parrots. Our findings suggest that the relatively poor flowering in this peri-urban bushland may be the result of poorer health of trees in the bushland than in the suburb, particularly the greater fire damage and sparser canopies in the bushland trees. Further research is required to determine the frequency and intensity of fire in bushland that will promote the greatest flower production in *E. globulus* and *E. ovata*.

Key words: *Eucalyptus* flowering, Fire management, Threatened species management, Urban ecosystems.

INTRODUCTION

THE Swift Parrot *Lathamus discolor* is listed as an endangered species of Australia (Swift Parrot Recovery Team 2001; Saunders *et al.* 2007). It breeds only in Tasmania (Hindwood and Sharland 1963; Brown 1989; Brereton 1996), and forages largely on nectar and pollen of Tasmanian Blue Gum *Eucalyptus globulus* and Black Gum *E. ovata* at this time (Brown 1989; Brereton 1996, 1997; Gartrell *et al.* 2000; Gartrell and Jones 2001; Hingston *et al.* 2004a). Reproductive success depends strongly on the extent of flowering of *E. globulus*. Fewer Swift Parrot chicks are fledged during years of poor flowering of *E. globulus* (Brereton 1996). *Eucalyptus ovata* can provide an alternative source of nectar and pollen in years when the flowering of *E. globulus* is poor, and in early spring if the birds arrive in Tasmania before *E. globulus* is in full bloom (Brown 1989; Brereton 1996; Hingston 2007).

In search for food Swift Parrots are capable of using all sizes of eucalypt patches, including those of less than one hectare and isolated suburban trees (Brown 1989; Brereton 1996; Mallick *et al.* 2004; Saunders and Heinsohn 2008). Swift Parrots often forage in *E. globulus* and *E. ovata* in the outer Hobart suburb of Mt Nelson during spring (Brereton 1996, 1997; Gartrell 2001 p.26; Hingston 2002 p.160, 2007), and have nested in this area (Brown 1989; Brereton 1997). In some breeding seasons (e.g., 2002-03) 4–5% of the wild population of Swift Parrots has been observed foraging in Mt Nelson (Hingston 2007).

This study investigates the relative value of suburban trees and those in the extensive areas of intact native forest in Mt Nelson as foraging habitat for Swift Parrots. Specifically, we compare flower production between mature trees in suburban and bushland environments for *E. globulus* and *E. ovata*. We then explore whether these differences in flower production are related to variables associated with tree size (basal area and height), tree health (canopy density and fire damage), and microhabitat (aspect and slope).

METHODS

Tree selection

The study area encompassed most of the suburban areas in Mt Nelson, as well as adjacent areas of bushland. Within bushland areas, trees were selected from the following forest communities: 1) *E. pulchella/E. globulus/E. viminalis* grassy/shrubby dry sclerophyll forest; and 2) *E. globulus* wet sclerophyll forest.

Only large trees were included in the study because the Swift Parrot prefers to forage in larger eucalypts (Kennedy and Overs 2001; Brereton *et al.* 2004; Kennedy and Tzaros 2005). Larger eucalypts may constitute a more reliable food source for nectarivorous birds because they flower more frequently and/or intensely than do smaller trees (Wilson and Bennett 1999;

Kennedy and Tzaros 2005). Large trees were defined as having a basal area at breast height of at least 0.283 m², which equates to a single stem with a diameter of at least 60 cm. Basal area for any tree with multiple stems was defined as the total of all stems. Diameters were measured at 129.5 cm from the ground on the downhill side of the tree. Tree height was also measured, using an optical reading clinometer.

Data were collected from 261 randomly selected large trees, including 84 suburban trees (47 *E. globulus*, 37 *E. ovata*) and 177 bush trees (160 *E. globulus*, 17 *E. ovata*). Suburban trees were within 20 m of residential or commercial buildings, gardens, sports grounds, or paved surfaces. Such trees may have been planted or constituted remnants of the native bush and occurred as isolated trees or in small patches. Bush trees were found within natural vegetation, including residential blocks that resembled bush in their conditions and general setting.

Flower production in suburb and bush

Flower production was compared between suburban and bushland trees of each eucalypt species. Trees were assessed between early March and mid-April 2008, which was outside the usual flowering seasons of *E. globulus* and *E. ovata* (Williams and Potts 1996). As a result, the measurements of tree flowering, rather than being based on direct observations of the actual flowers, focused on opercula that had fallen from flowers and the abundance of seed capsules.

For the *E. globulus* trees, operculum counts were performed in three quadrats of 1 m × 1 m placed randomly beneath each tree. Based on these counts, mean numbers of opercula per square metre were calculated. Only fresh opercula, differentiated from older opercula by their brighter colour, were counted. Hence, these counts indicate the numbers of flowers produced in the previous flowering season (Pook *et al*. 1997). We did not attempt to count opercula of *E. ovata* because of concerns regarding possible differences between habitats in finding these smaller opercula (diameters: *E. ovata* 4–6 mm; *E. globulus* > 14 mm, Boland *et al*. 1984).

Because flowering intensity varies among years for *E. globulus* and *E. ovata* (Brown 1989; Brereton 1996), several years' data are needed to understand flowering trends. Such data can be obtained in a single count of capsules because most Tasmanian eucalypt species usually retain their capsules in the canopy for several years (Reid and Potts 1999). However, we counted capsules in the tree and on the ground, including floral receptacles that did not develop into mature capsules, because of possible

variation among trees in capsule development and retention (Hingston 2002). Capsule load for *E. globulus* and *E. ovata* was estimated visually from the ground by one of us (MP), with the aid of binoculars, and standardised for volume of canopy. For each species, the tree with the most capsules per volume of canopy was defined as having a capsule load of 100%. Capsule loads for all other conspecific trees were expressed as percentages of this density, according to the following categories: 0% = no capsules; 1 = < 10%; 2 = 10–40%; 3 = 40–70%; 4 = 70–100%.

Variables influencing flower production

We investigated the relationships of flower production and habitat (suburb or bush) with several variables associated with tree size or health, or microhabitat (basal area, height, canopy density, fire damage, ground slope, Moisture Index based on aspect). This was done to explore which of these variables contributed to any relationships between flower production and habitat. Firstly, we investigated whether these variables were related to the flower production of each eucalypt species. If a significant relationship was found, we then examined whether there was a relationship between the tree variables and habitat for each eucalypt species. If we found a significant relationship between a measure of flower production and a tree variable for the 207 *E. globulus* trees, we also tested whether this relationship persisted when the analysis was restricted to the 160 *E. globulus* trees in the bush.

Canopy density was estimated visually by one of us (MP) by subtracting the percentage of light coming through the canopy from a theoretical one hundred per cent of canopy cover (Walker and Hopkins 1990).

Fire damage was recorded by one of us (MP) using the following classification (Koch 2007): 0 = no evidence of fire; 1 = bark damage; 2 = wood exposed and damaged by fire; 3 = severe fire damage such as a bridge or large hollow in the base of the tree.

The ground slope at the tree location was measured in degrees with a clinometer. For trees with different inclines up- and down-slope, a mean of both figures was recorded.

Aspect for locations with some slope was measured in degrees in the field and later classified into five classes of Moisture Index (MI) (1 = north-west; 2 = west and north; 3 = south-west and north-east; 4 = south and east; 5 = south-east), following the aspect classes used by Jones (2004). These classes were used because the moisture is least on the north-west facing slopes as a result of northern aspects receiving more solar radiation in conjunction with the

prevailing dry north-westerly winds (Kirkpatrick and Nunez 1980).

Data analysis

Non-parametric tests were used to compare differences among and between groups because data were either categorical, or continuous with distributions that could not be transformed to meet the assumptions of normality and homogeneous variance. Hence, comparisons between suburban and bushland trees in measures of flower production or variables associated with other tree characteristics or microhabitat were made with Mann-Whitney U-tests. Comparisons in measures of flower production according to categorical variables that comprised more than two classes (fire damage, Moisture Index based on aspect) were made with Kruskal-Wallis tests. Analyses of the effects of continuous variables (basal area, height, canopy density, ground slope) on capsule production were made by using Kruskal-Wallis tests to compare medians of the variables among the five capsule load classes. Linear regression was used to compare associations between these continuous variables and the mean number of *E. globulus* opercula collected from three quadrats beneath trees. Minitab 15 for Windows was used for all analyses.

RESULTS

Flower production in suburb and bush

Our data indicate that trees in the suburb produced more flowers than those in the bush. There was a difference between habitats in the mean number of *E. globulus* opercula collected from three quadrats beneath trees (mean ± s.e. suburban 23.00 ± 4.40, bushland 1.78 ± 0.32, W = 7527.5, p < 0.0001). There were also more *E. globulus* capsules recorded for suburban than bushland trees (W = 6241.0, p < 0.0001) (Fig. 1a). Almost half (48.9%) of the *E. globulus* trees in the suburb had capsule loads of more than 40% of the maximum, a figure which was more than double that in the bush (20.6%) (Fig. 1a). This difference was even more pronounced for trees with capsule loads of more than 70% (Fig. 1a). In accordance with this, almost half (46.9%) of the *E. globulus* trees in the bush had capsule loads of less than 10%, a figure which was almost double that in the suburb (25.5%) (Fig. 1a). The number of capsules for trees of *E. ovata* was also greater in the suburb than in the bush (W = 1249.5, p < 0.0001) (Fig. 1b). The majority (59.5%) of *E. ovata* trees in the suburb had capsule loads of more than 70%, whereas none of those in the bush bore such heavy capsule loads (Fig. 1b). Correspondingly, most (58.9%) *E. ovata* trees in the bush had capsule loads of less than 40%, while this figure was only 10.8% for those in the suburb (Fig. 1b).
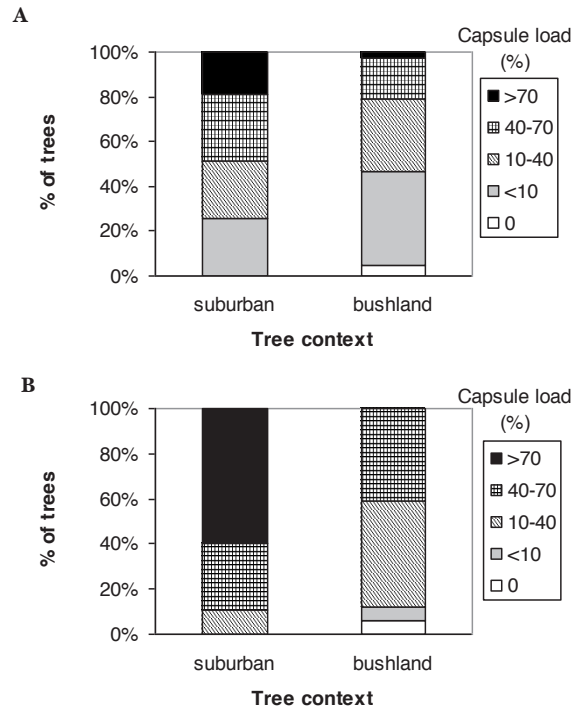

Fig. 1. Comparisons between suburban and bushland trees in levels of capsule production for a) *E. globulus* and b) *E. ovata*.

Variables influencing flower production

The size of tree had no apparent effect on flowering for large trees with basal area of at least 0.283 m². There was no association between the mean number of *E. globulus* opercula and tree basal area (r^2 = 1.6%) or height (r^2 = 1.7%). There were no differences among the five categories of capsule loads for *E. globulus* in tree basal area (H_4 = 2.08, p = 0.72) or height (H_4 = 4.26, p = 0.37). Similarly, the five categories of capsule loads for *E. ovata* did not differ in tree basal area (H_4 = 8.62, p = 0.071) or height (H_4 = 5.01, p = 0.29).

Although there was little association between canopy density and the numbers of opercula per square metre beneath *E. globulus* (r^2 = 4.5%), trees with denser canopies produced more capsules per volume of canopy and canopies were denser in suburban than in bushland trees. There was a difference in canopy density among the five capsule load classes for each species of eucalypt (*E. globulus* H_4 = 10.91, p = 0.028; *E. ovata* H_4 = 12.32, p = 0.015) (Fig. 2). Post hoc pair-wise tests revealed that *E. globulus* trees with capsule loads of > 70% had denser canopies than did trees with capsule loads of < 10% (Fig. 2). For *E. ovata*, trees with capsule loads of 10-40% had sparser canopies than did trees with more capsules (Fig. 2). Suburban trees had denser canopies than did their bushland counterparts for *E. globulus* (mean ± s.e. urban 65.21% ± 0.79%, bush 59.25% ± 0.86%, W = 6065.0, p = 0.0008) and *E. ovata* (mean ± s.e.
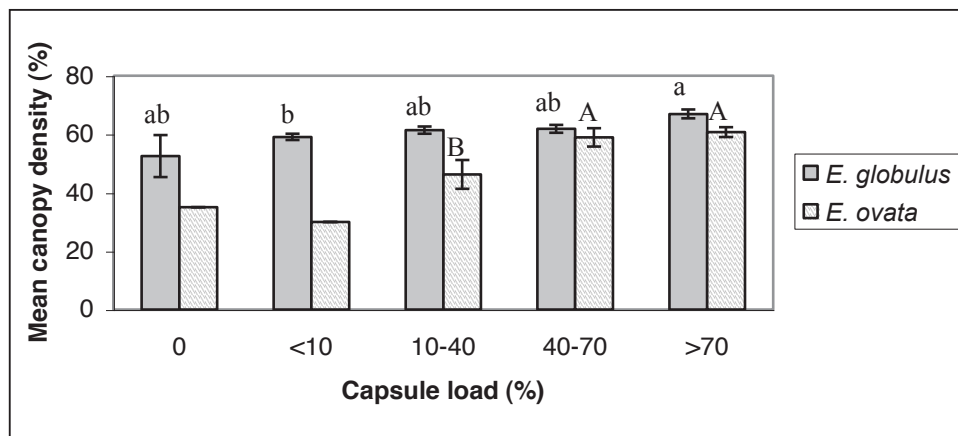
Fig. 2. Comparison of the mean canopy density and capsule load for *E. globulus* and *E. ovata*. Standard errors shown. Pair-wise differences between conspecifics in the capsule load classes are denoted by different letters. Capsule load classes of 0% and < 10% for *E. ovata* were excluded from the post hoc tests because of insufficient data.

urban 59.32% ± 1.78%, bush 48.24% ± 2.63%, W = 1143.0, p = 0.018). However, when the analysis was restricted to the 160 *E. globulus* in the bush, a difference in canopy density among the five capsule load classes was not found (H_4 = 2.74, p = 0.60).

Greater fire damage was associated with scant flower production, with this being more common in bushland than suburban trees. Differences were found among the four classes of fire damage in the mean number of opercula (H_3 = 31.73, p < 0.001) (Fig. 3) and capsule load (H_3 = 19.64, p < 0.001) (Fig. 4) for *E. globulus*. Post hoc pair-wise tests showed that *E. globulus* trees with no fire damage had more opercula and capsules than did trees in any of the classes with fire damage (Figs 3 & 4). Similarly, there was a difference in *E. ovata* capsule loads among trees with various levels of fire damage (H_3 = 11.62, p = 0.009), with capsule loads being greater for trees with no fire damage than for trees with any fire damage to

the wood (Fig. 5). Levels of fire damage were greater in bushland than suburban trees for *E. globulus* (W = 2456.5, p < 0.0001) and *E. ovata* (W = 840.5, p < 0.0001) (Fig. 6). However, when the analysis was restricted to the 160 *E. globulus* in the bush, there were no differences among the four classes of fire damage in the mean number of opercula (H_3 = 4.95, p = 0.18) or capsule load (H_3 = 5.84, p = 0.12).

Ground slope did not seem to influence flower production. There was no relationship between the number of *E. globulus* opercula and ground slope (r^2 = 3.4%). Moreover, no differences were found in ground slope among the various capsule load classes for *E. globulus* (H_4 = 2.64, p = 0.62) and *E. ovata* (H_4 = 4.55, p = 0.33).

Moisture Indices based on aspect had inconsistent associations with measures of flower production. There was a difference among the five Moisture Indices in the numbers of *E. globulus* opercula per square metre beneath the
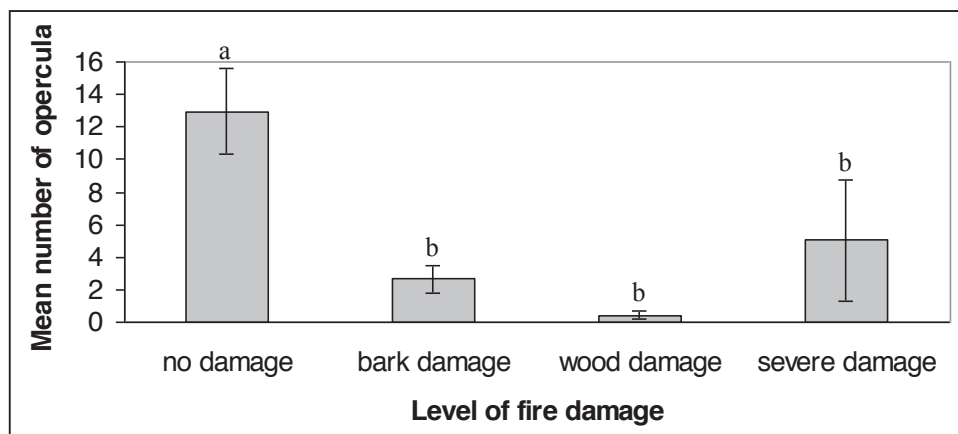

Fig. 3. Comparison of *E. globulus* mean opercula number per square metre and various levels of fire damage. Standard errors shown. Pair-wise differences between various levels of fire damage are denoted by different letters.
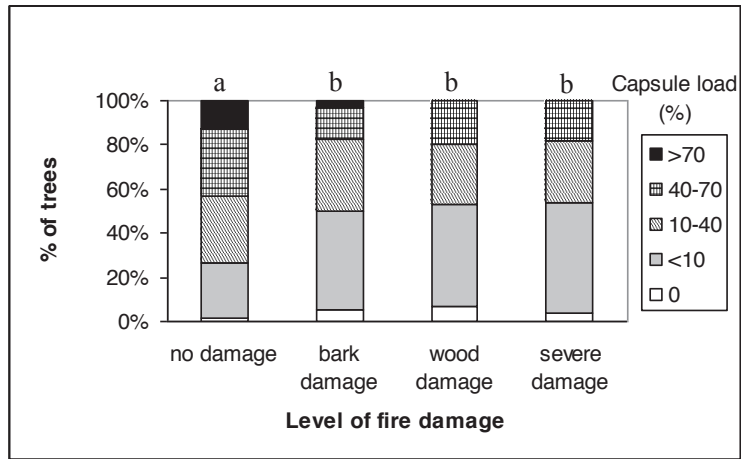
Fig. 4. Comparison of *E. globulus* capsule loads and various levels of fire damage. Pair-wise differences between various levels of fire damage are denoted by different letters.
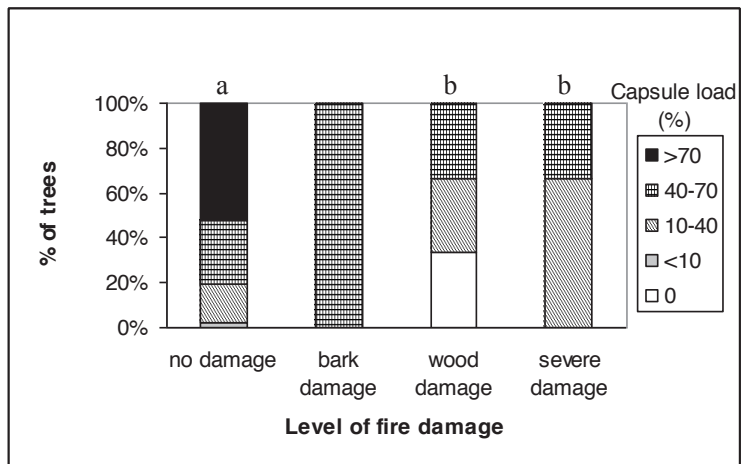

Fig. 5. Comparison of *E. ovata* capsule loads and various levels of fire damage. Pair-wise differences between various levels of fire damage are denoted by different letters. The "bark damage" class was excluded from the post hoc tests due to insufficient data.
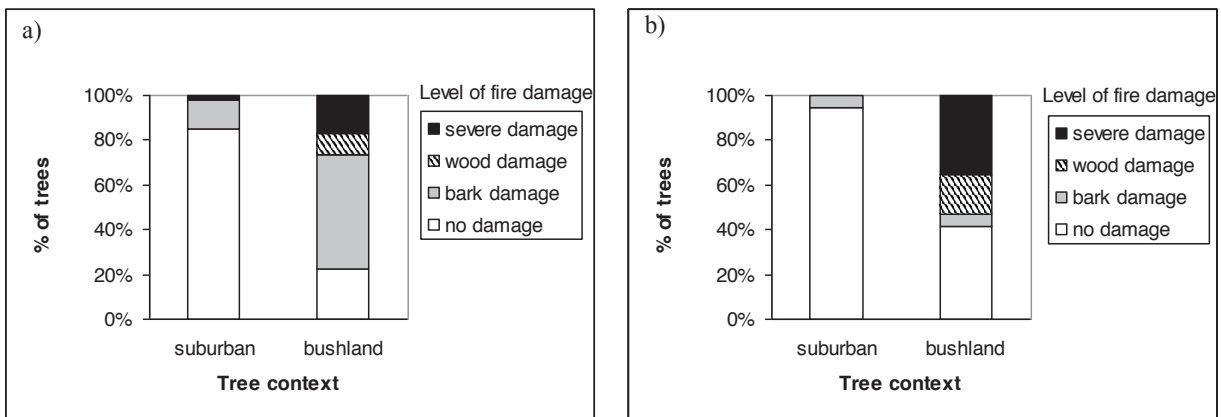

Fig. 6. Comparisons between suburban and bushland trees in levels of fire damage for a) *E. globulus* and b) *E. ovata*.
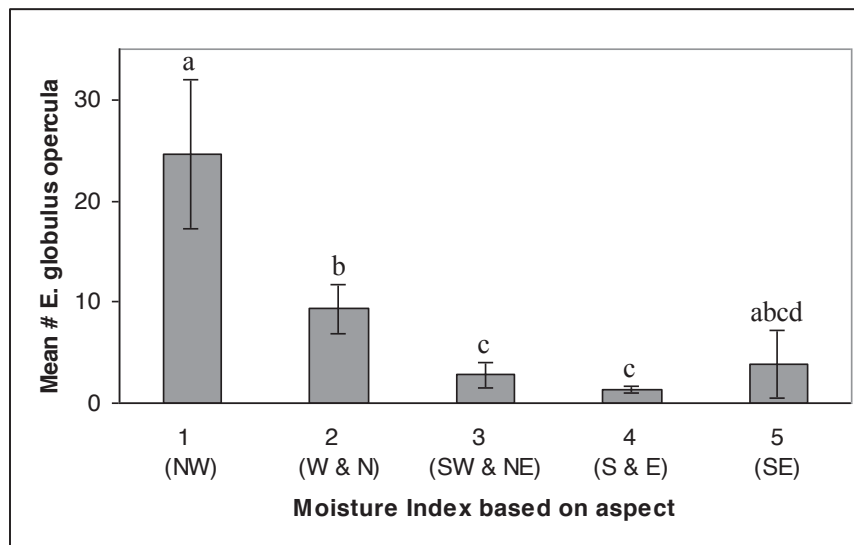
Fig. 7. Comparison of the mean number of opercula per square metre beneath trees of *E. globulus* and Moisture Indices based on aspect. Trees from sites with slopes of zero degrees were excluded from the analysis. Pair-wise differences between Moisture Indices are denoted by different letters.

trees (H_4 = 29.44, p < 0.001) (Fig. 7). Trees growing on a north-westerly aspect (MI = 1) had more opercula than trees on aspects with MI = 2-4 (Fig. 7). The numbers of opercula beneath trees with MI = 2 were also greater than those on aspects with MI = 3-4 (Fig. 7). Trees with MI = 5 did not differ from those with other Moisture Indices, but only five trees were sampled from a south-easterly aspect. Hence, the numbers of opercula appeared to be greater on drier aspects. In accordance with this, trees of *E. globulus* in the suburb occurred on drier aspects than those in the bushland (mean MI ± s.e. urban 2.19 ± 0.16, bush 2.99 ± 0.08, W = 3175.0, p < 0.0001). However, there were no differences in the capsule loads among the five Moisture Indices for *E. globulus* (H_4 = 2.77, p = 0.60) or *E. ovata* (H_4 = 2.38, p = 0.67). Moreover, when the analysis was restricted to the 160 *E. globulus* in the bush, there were no differences among the five Moisture Indices in the mean number of opercula (H_4 = 5.35, p = 0.25).

DISCUSSION

Flower production in suburb and bush

Individual large trees of *E. globulus* and *E. ovata* within 20 m of buildings, gardens, sports grounds, or paved surfaces, in Mt Nelson produced more flowers than did those in adjacent bushland. Hence, individual suburban trees are likely to provide more food for the many species of birds and insects that consume nectar and/or pollen from these two species (Hingston and Potts 1998, 2005; Hingston and McQuillan 2000; Hingston *et al.* 2004b) than do individual bushland trees. This supports the statement by Brereton (1997) that *E. globulus* trees on the edges of clearings produce more flowers than those in forests, as well as the view of Ozolins *et al.* (2001) who stated that the value of isolated trees exceeds their relative abundance in the landscape.

Variables influencing flower production

Flower production was associated with tree health (canopy density and fire damage), rather than tree size (basal area and height) or microhabitat (aspect and slope). Trees with denser canopies and no fire damage produced more flowers, and these healthy trees were typical of the suburban rather than bushland habitat. The better health of trees in the suburb may have been the result of people removing unhealthy trees near houses (Hingston and Piech 2011), protection of the suburb from fire, or greater availability of water, nutrients and sunlight in the suburb.

Our findings suggest that the greater fire damage to trees in the bushland than in the suburb contributed to the lower levels of flower production in the bushland. Trees of both species incurred more fire damage in the bushland than in the suburb, and all measures of flower production were greater for trees with no fire damage. Wildfires have occurred in our study area in 1967, 1982, 1995, 1998 and 2006, and fuel reduction burning has also been frequent since 2003 (S. Bresnehan, Hobart City Council Bushland Fire Officer, pers. comm.). Previous studies have found that canopy scorch from fires can lead to a loss of buds in some myrtaceous trees (Setterfield 1997; Law *et al.*

2000) and delay flowering for up to three years (Law *et al.* 2000). Repeated high intensity fires in northern Australia significantly reduced floral bud density in two species of *Eucalyptus* relative to repeated low intensity fires or an absence of fire (Setterfield 1997). Poor flowering after intense fires can result from trees allocating resources away from reproduction into vegetative recovery of damaged canopies (Reekie and Bazzaz 1987). However, we found no association between flower production and the amount of fire damage to the bark and wood of *E. globulus* trees in bushland. This is, perhaps, to be expected given that the amount of fire damage to the bark and wood of trees is unlikely to be directly related to the condition of the canopy in situations where the time since fire varies among trees.

Flower production was also related to canopy density. We found that, for both species, canopies were sparser in bushland than in suburban trees and sparser canopies produced lower densities of capsules. Sparser canopies in bushland areas could partly have been the result of greater fire damage. Canopy area was reduced significantly in two species of *Eucalyptus* in northern Australia after repeated intense fires (Setterfield 1997). However, *E. ovata* trees experiencing various levels of fire damage did not differ significantly in canopy density, and there was also little evidence of fire damage affecting canopy density in *E. globulus* (Piech 2008). This effect may, however, have been masked by differences among trees in time since fire. Canopies might also have been denser in suburban areas because of enhanced soil water and nutrients in gardens, and less competition for water, nutrients and sunlight from surrounding trees (Brereton *et al.* 2004; Mallick *et al.* 2004). Greater water availability may be important to flowering in these species, as flowering frequency in *E. tricarpa* was enhanced within 5 m of farm dams in Victoria (Wilson and Bennett 1999). Furthermore, a 10-year study found that total flower production in spring from myrtaceous tree species in northern New South Wales was greatest after abundant autumn rainfall (Law *et al.* 2000). However, we found that ground slope, which should influence soil moisture, did not affect flower production in *E. globulus* or *E. ovata*. Moreover, we found more *E. globulus* opercula beneath trees on drier aspects, suggesting that access to soil moisture was not important to flower production in spring 2007. However, suburban trees occurred more frequently on drier aspects than did bushland trees, so there is a possibility that drier aspects were associated with more soil moisture. It is also possible that the greater numbers of *E. globulus* opercula beneath trees on drier aspects was a response to more sunlight, supporting the notion that suburban trees produced more flowers because they received more solar radiation. This is supported by observations of more flowers on branches of *E. globulus* near the ground on the northern, than southern, halves of canopies (A. Hingston pers. obs.). However, the amount of solar radiation had little effect on levels of flower production in myrtaceous trees in northern New South Wales (Law *et al.* 2000).

Management implications

The apparent value of *E. globulus* and *E. ovata* in suburban situations as potential foraging habitat for Swift Parrots suggests that measures to maintain, or increase, their abundance in suburban areas in south-eastern Tasmania would benefit Swift Parrots. However, conservation priorities associated with Swift Parrot habitat are often outweighed by social and economic factors (Saunders *et al.* 2007), and the resultant loss of foraging habitat used during its breeding season is considered one of the major threats to the Swift Parrot (Brown 1989; Brereton 1996, 1997; Swift Parrot Recovery Team 2001). This threat is exacerbated by the lack of restrictions for clearing of native vegetation on private land in Tasmania, where the vast majority of *E. globulus* and *E. ovata* occur in the Swift Parrot's breeding range (Brereton 1996, 1997). A survey of Mt Nelson residents found that almost 30% of large *E. globulus* and *E. ovata* in the suburb were removed in the preceding 5-10 years, or would be removed in the near future (Hingston and Piech 2011). The most common reason given for the removal of these trees was their perceived threat to buildings from falling limbs or promotion of wildfire (Hingston and Piech 2011). The planting of these trees, as promoted in the Swift Parrot Recovery Plan (Brereton 1996; Swift Parrot Recovery Team 2001; Brereton *et al.* 2004), may be worthwhile in suburban areas where they do not pose a threat to buildings (Mallick *et al.* 2004).

We cannot say whether the relatively low levels of flower production in Mt Nelson's bushland are typical of all bushland situations. However, the positive associations between tree health and flower production suggest that changes to the management of Mt Nelson's bushland that promote tree health could increase food resources for Swift Parrots. Our findings, together with studies elsewhere (Setterfield 1997; Law *et al.* 2000), suggest that the intensity and frequency of fires could be the principal factors influencing eucalypt flower production in bushland.

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