

## THE BIOLOGY OF TUART

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### ABSTRACT

The biology of Tuart has received little attention. Existing known studies, including work by the authors, are used to look at aspects of Tuart's reproductive biology, phenology, seed bank dynamics and seedling recruitment, as well as the effects of fragmentation and fire on Tuart populations.

The studies of Tuart's reproductive biology and phenology have found that flowering occurs from January to April with reports of mass flowering occurring every five to eight years and patchy flowering occurring intermittently. Seed production and supply in Tuart may show considerable temporal variation. A diverse array of insects and birds are most likely to be involved in pollination of Tuart.

Research currently on the seed bank dynamics of Tuart has observed that on average four seeds are stored in each woody fruit for up to two seasons. As a consequence, seed storage in the canopy may be high when heavy flowering seasons occur. Seeds are normally slowly released from the canopy, but can also be released *en masse* following disturbances such as fire. Tuart seed is susceptible to predation by ants that can remove a large proportion of seed in the soil quickly and hence, Tuart seeds do not form a long-lived soil seed reserve. Seeds have high viability (86%) and no innate dormancy. Mass recruitment of seedlings following fire occurs as the seeds swamp the predators.

Fragmentation and changed disturbance regimes are affecting many remnant Tuart woodlands, transforming community structure and species composition. There is evidence to suggest that Tuart is declining in urban remnants. Tuart flowering is patchy, in time and space, and therefore the size of the canopy seed store may vary considerably between years. Studies in remnants indicate that it takes some time for a Tuart population recovering from fire to become reproductive. If a fire occurs before this time, it is unlikely that adult trees will have a canopy seed store available for synchronous seed release following a fire to establish new trees. Mature Tuarts are regularly killed by fire when the fire breaches the bark and establishes in the wood. It is also been suggested that in urban remnants the abundance of naturally occurring wood boring insects may have increased as a consequence of their natural predators declining in numbers. This increased abundance of wood boring insects may be causing increased mortality in Tuart populations. Similar suggestions have been advanced for pathogenic fungi, such as *Armillaria*.

Some suggestions for future investigations to improve knowledge to aid in the management of Tuart in remnants are listed.

### INTRODUCTION

*Eucalyptus gomphocephala* (Tuart) is most commonly a medium to tall tree endemic to the Swan Coastal Plain in south-western Australia. It occurs more or less continuously in a narrow coastal belt of sand dunes and sub-coastal plains between Jurien and the Sabina River (Keighery *et al.* Map 1 this publication).

Throughout this region Tuart communities have been extensively cleared for urban and agricultural development. Nowhere is this more evident than in the rapidly expanding northern and southern corridors of the Perth Metropolitan Region, and in the growing regional centres of Mandurah and Bunbury where Tuart communities are being increasingly fragmented into isolated remnants. Within this region there is a growing interest amongst individuals, community groups and government agencies, in the ecology, conservation and management of Tuart communities. Currently, information about the biology of Tuart is spread across disparate sources and, as a consequence, our knowledge is difficult to assess and our ability to answer questions regarding its conservation management is limited. This chapter aims to go some way towards overcoming this problem by providing an overview of what is currently known about the biology of Tuart. The chapter draws on the available literature and on studies by the authors, and highlights shortcomings in knowledge regarding Tuart populations.

## **ETYMOLOGY, TAXONOMIC STATUS AND LIFEFORM**

The common name, Tuart, is derived from one of the many Nyoongar names for the species which include duart, moorun, mouarn and toart (Bennett 1993). The species is less commonly known as White Gum in reference to its bleached grey-white typically box like bark and is the source for the Perth suburb name White Gum Valley. The first scientific description of Tuart was undertaken by the Swiss botanist Augustin Pyramus de Candolle in 1828 who classified and named the plant *Eucalyptus gomphocephala* from the Greek words *gomphos* (club) and *kephale* (head), in reference to the species' club headed flower bud (Figure 1). Tuart belongs to the largest *Eucalyptus* sub-genus *Symphyomyrtus* but is taxonomically very distinct, having no known close relatives and thus forming a monospecific section (Brooker and Kleinig 1990). Tuart most commonly occurs as a medium to tall tree and is a dominant in tall woodlands and woodlands but also occurs as a smaller tree, in heath, at the northern end of its distribution (Beard 1990) and as a mallee in several locations (Coates *et al.* and Keighery *et al.* this publication).

## **FACTORS AFFECTING THE DISTRIBUTION AND ABUNDANCE OF TUART**

### **Climate and Geomorphology**

The distribution and abundance of Tuart may be understood in terms of its interactions with the physical environment, other organisms and its resilience or ability to recover from disturbance. At the very broadest landscape scale, the distribution of Tuart is affected by climatic gradients and geomorphological soil patterns and its physiological limits. In this section we review existing information on the physical environment where the species has been recorded.

The climate throughout Tuart's distribution is Dry Warm Mediterranean to Warm Mediterranean with rain falling predominantly in the winter months between May and October (Beard 1990). The average annual rainfall increases and temperature and the number of dry summer months decreases along a north-south climatic gradient. Average annual rainfall, the maximum number of dry summer months, and the temperature range at the northern end of Tuart's distribution near Jurien Bay are: 567 mm; 5 months; and -1.0° to 45.2°C. At the southern end near Busselton the measurements are: 822 mm; 6 months; and 0.4° to 39.1°C (Bureau of Meteorology 1999). Not surprisingly, Tuart community physiognomy appears to be related to climate, with trees reaching their greatest height (and stature) forming Tall Woodlands at the southernmost end of the species' distribution where rainfall is highest (Beard 1990).

Geomorphology and soils also play an important determining role in Tuart's distribution. Tuart is most commonly found on the æolian derived Spearwood Dune System on the coastal limestone derived Cottesloe and Karrakatta soil units. Soils in these units are sandy, coarse and well drained with a high percentage of calcium carbonate (Semeniuk and Glassford 1989, McArthur 1991). Tuart is one of the few eucalypts adapted to these highly calcareous alkaline soils (Eldridge *et al.* 1994, Gibson *et al.* this publication). However, Tuart is also recorded on the younger Quindalup Dune System occasionally further inland on riverflats (Fox and Curry 1979, Beard 1989, Boland *et al.* 1984 and in this publication Coates *et al.*, Keighery *et al.* and Gibson *et al.*). These outlying populations may provide interesting insights into the evolutionary history and biogeography of Tuart.

### **Demographic Processes – Biological Interactions and the Effects of Fire**

At the broadest regional scale, climate and geomorphological soil patterns interact with Tuart's physiological limits to determine the potential range of the species. At a more localized scale, within this range the distribution and abundance of individuals is affected by the demographic processes of dispersal, seedling recruitment (births) and plant mortality (deaths). This is best illustrated by considering Tuart's life cycle. For seedling recruitment to occur, trees have to flower, and flowers have to be pollinated and set and disperse viable seed; the seed then has to escape predation so that it can be incorporated into a soil seed bank where it must persist until the right conditions stimulate germination; the young plant then has to survive and grow to reproductive maturity (Harper 1977). The movement of individuals through this life-cycle is affected by biological interactions (e.g. pollination, seed predation and herbivory), stochastic processes (e.g. rainfall variability) and catastrophic events (e.g. fire). In this section we review the available information and studies currently being undertaken by the authors on the above processes within the context of Tuart's lifecycle.

### ***Floral Biology and Pattern of Flowering***

Beyond general descriptions of bud and flower morphology, only one comprehensive study of Tuart's reproductive biology and phenology has been undertaken. Inflorescences are produced from the current season's shoots in the outer canopy and develop laterally in leaf axils as unbranched clusters of up to seven buds which are mushroom shaped, sessile and of size 1.4-2.3 cm x 0.8-1.5 cm (Boland *et al.* 1984, Brooker and Kleinig 1990) (Figure 1). Flower buds are susceptible to predation by the Tuart Bud Weevil (*Haplonyx tibialis* Curculionidae) which lays an egg inside the flower bud before cutting the bud off partially or completely. The larvae then feed on the top part of the bud for four months before pupating and cutting their way out through the base (Fox and Curry 1979). The effects of the Tuart Bud Weevil have been reported since at least 1880 (Fox and Curry 1979).

Tuart has a typical eucalypt flower with creamy white filaments that are splayed upwards and outwards from the rim of the hypanthium, forming a flat topped array 1.3-2.7 cm in diameter and exposing a nectar producing disc. Across Tuart's range flowering has been recorded from January to April (Marchant *et al.* 1987, Brooker and Kleinig 1990, Ruthrof 2001), with reports of mass flowering occurring in populations every five to eight years and patchy flowering occurring intermittently (Keene and Cracknell 1972, Kay 1985). Similar patterns of mass flowering have been observed in other temperate eucalypts. For example, Ashton (1975) found in *Eucalyptus regnans* that during poor flowering years some trees flowered, but others did not and attributed this to individuals having their own cycle of bud production. Heavy flowering years occurred when there was a coincidence of phases between individuals. As a consequence, seed production and supply in Tuart may show considerable temporal variation.

### ***Breeding System and Pollination Biology***

Previous to this publication (Coates *et al.*), no studies of Tuart's breeding system are known. The majority of eucalypts studied are hermaphroditic and protandrous with anthers dehiscing before the stigma becomes receptive, and have asynchronous flower development within the canopy (House 1997, Potts and Wiltshire 1997). As a consequence, flowers within and between inflorescences can be in the male or female phase and pollinators only need to move the relatively short distance between flowers which are in the male phase to flowers which are in the female phase within the same inflorescence or plant to effect pollination (House 1997). There is therefore ample opportunity for self pollination and indeed, to date, all eucalypts studied have a mixed mating system combining outcrossing and inbreeding (for reviews see Moran and Hopper 1987, Sampson *et al.* 1990, House 1997, Potts and Wiltshire 1997). On the balance of evidence from other eucalypts, it is highly probable that Tuart similarly has a mixed mating system with preferential outcrossing. Coates *et al.* (this publication) establishes that this indeed is the case with Tuart.

Similarly, there are no known comprehensive studies of Tuart's pollination biology but again there is much that can be inferred from studies of other species in the genus. In summary, eucalypts share the same basic floral structure but there is considerable variation between species in traits such as bud size, the number of flowers produced, flower and inflorescence size, filament colour, production and presentation of nectar, and flowering time (Pryor 1976, Griffin 1982, House 1997). This variation and associations of traits such as flower size and filament colour has led Sargent (1928), Pryor (1976), Ford *et al.* (1979) and Hopper and Moran (1981) to propose that floral traits evolved in the genus in response to the selective behaviour of different pollen vectors.

Ford *et al.* (1979), Hopper and Moran (1981) and Griffin (1982) have hypothesised that eucalypts which produce small, white or cream flowers (e.g. *Eucalyptus muelleriana* (Ireland and Griffin 1984); *Eucalyptus foecunda* and *Eucalyptus cylindrifolia* (Hawkeswood 1982); *Eucalyptus stellulata* (House 1997); and *Eucalyptus marginata* (Yates *et al.* 2002 submitted)) with low volumes of concentrated nectar grouped into large conflorescences attract many insects, and less frequently birds and mammals, whereas eucalypts which produce large flowers with yellow or red filaments (e.g. *Eucalyptus stoatei* (Hopper and Moran 1981); *Eucalyptus incrassata* (Bond and Brown 1979); *Eucalyptus rhodantha* (McNee 1995); and *Eucalyptus ramelliana* (Sampson *et al.* 1995)) and large volumes of dilute nectar attract fewer insects but larger, more active birds and mammals. These studies generally confirm the above hypothesis. On the basis of these studies it would be expected that Tuart is pollinated by insects and birds.

There are two records of two animal species visiting Tuart flowers, the Singing Honeyeater (*Lichenostomus virescens*) and Brown Honeyeater (*Lichmera indistincta*) (Brown *et al.* 1997). Recent studies of the floral visitors to Jarrah (*Eucalyptus marginata*) in a mixed Jarrah/Tuart woodland suggest that a diverse array of insects are involved in pollination of mass flowering white-flowered eucalypts (Yates *et al.* 2002 submitted). The study observed 84 insect species from five orders including: Hymenoptera (ants, bees and wasps); Diptera (flies); Coleoptera (beetles); Lepidoptera (moths and butterflies); and Blattadea (cockroaches). Studies of Tuart are likely to yield similar results and this is an area for further research.

### ***Seedbank Dynamics***

There are no known published studies describing the seed bank dynamics of Tuart. Research currently being undertaken has observed that on average four seeds, though this is variable, are stored in woody fruit for up to two consecutive flowering seasons (Ruthrof 2001). As a consequence, seed storage in the canopy may be high when heavy flowering seasons occur. Seeds are black, flattish to saucer shaped, often flanged, with a distinct reticulum and are 2-3 mm long.

Seeds are gradually released from the canopy seed store as a light seed rain throughout the year but particularly in the summer months (Ruthrof 2001). Similar patterns of seed fall have been observed in other temperate eucalypts (Cremer 1965, Andersen 1989, Yates *et al.* 1994, House 1997). Seeds are released from the canopy seed reserve in four ways:

1. when fruit dry out over summer months;
2. when branches subtending fruit die and capsules dry out;
3. when unopened fruit are blown from the canopy and dry out on the ground; and
4. when cockatoos and parrots feed on seeds and some escape predation and fall to the ground freely or in dissected fruit (Cremer 1965, Yates *et al.* 1994, Ruthrof 2001).

In a number of temperate eucalypts seeds can also be released from the canopy reserve *en masse* following disturbances such as fire (O'Dowd and Gill 1984, Burrows *et al.* 1990). This is also likely to be the case in Tuart which displays mass recruitment of seedlings following fire (see below).

Following dispersal from the canopy, seed on the soil surface is susceptible to predation. In temperate eucalypts the most commonly observed predators are ants (Ashton 1979, Andersen 1982, O'Dowd and Gill 1984, Abbott and van Huerck 1985, Wellington and Noble 1985b, Yates *et al.* 1995, Majer *et al.* 1997). Generally these studies have observed that seed predation occurs throughout the year, but is highest in the summer months when ants are most active. Studies undertaken have similarly observed that Tuart seed is also susceptible to predation by ants (Ruthrof 2001). In mixed Jarrah/Tuart woodland, ants removed 47% of Tuart seeds from seed baits (cafeterias) within 4 days. One species of ant, *Meranoplus* sp., was seen removing seed from a cafeteria and in a concurrent pitfall trapping study 8 granivorous ant genera were recorded. The most frequently trapped ants belonged to two genera, *Solenopsis* and *Iridomyrmex* (Ruthrof 2001).

Post-dispersal predation by ants clearly affects the number of seeds that enter the soil where they must persist until suitable conditions occur for germination. Studies of Tuart's soil seed bank dynamics currently being undertaken in mixed Jarrah/Tuart woodland have observed that Tuart seeds do not form a long lived soil seed reserve (Ruthrof 2001). When an artificial seed reserve was established, the number of seeds recovered declined with increasing exposure and most seeds had germinated within 6 months of the onset of winter rains (Ruthrof 2001). Similar observations have been made for a number of other temperate eucalypts (Yates *et al.* 1995).

### ***Germination, Establishment and Growth: the Regeneration Niche***

Studies on the germination physiology of seeds collected from Tuart in an urban remnant, Kings Park Bushland, have observed high viability (86%) and no innate dormancy (Ruthrof 2001). The studies observed that under laboratory conditions seeds did not respond to commonly reported external dormancy breaking stimuli such as smoke. Seeds germinated readily at temperatures ranging from 13° to 23°C, with maximum germination at 13°C (Ruthrof 2001). Investigations of germination under field conditions observed that seeds sown into mixed Jarrah/Tuart woodland unburnt for 2 and 10 years germinated with the onset of the winter rains, but seedlings failed to survive the first summer.

The information presented thus far suggests that Tuart shares life history characteristics with eucalypts that recruit seedlings following large scale disturbances such as fire (O'Dowd and Gill 1984, Wellington and Noble 1985a). These characteristics include: canopy seed stores (Grose 1957 and 1960, Christensen 1971, Ashton 1975, Cremer *et al.* 1978, Wellington and Noble 1985a, Davies and Myerscough 1991); heavy seed predation by ants (Ashton 1979, O'Dowd and Gill 1984, Andersen and Ashton 1985, Wellington and Noble 1985b); the absence of a persistent soil seed bank (Carol and Ashton 1965, Barbour and Lange 1967, Wellington and Noble 1985a); and

the failure of seedlings to establish during inter-fire periods (Wellington and Noble 1985a, Yates *et al.* 1996).

Indeed, recent studies both in an urban mixed Jarrah/Tuart woodland, Kings Park, and in relatively unfragmented woodland at the more southerly end of the Tuart's distribution, have observed mass recruitment of Tuart seedlings following fire (Ruthrof 2001). Widespread recruitment of Tuart seedlings in Kings Park was particularly evident following a fire in 1996. In the second winter after the fire there was an average of 52 seedlings in 5 m x 5 m quadrats with as many as 101 seedlings being recorded. The seedlings had relatively high growth rates and were, on average, 90 cm high with the tallest seedling being 215 cm.

Seedling recruitment following fire has been attributed to a number of interactions such as changes in seed dynamics and increased abundance of safe sites for germination and establishment (Wellington and Noble 1985a). It has been observed that fire induces a massive and synchronous release of all canopy stored seed (O'Dowd and Gill 1984, Andersen 1988, Burrows *et al.* 1990) which causes a temporary satiation of seed eating ants, resulting in lower rates of seed predation (O'Dowd and Gill 1984, Wellington and Noble 1985b, Andersen 1988) and the establishment of a temporary soil seed bank. However, fire also increases the abundance of safe sites for germination and establishment (O'Dowd and Gill 1984, Andersen 1987 and 1989) through its effects on soil physical, chemical and biological properties (Humphreys and Craig 1981, Walker *et al.* 1986). These changes influence seedling emergence, growth and survivorship (Pryor 1960 and 1963, Loneragan and Loneragan 1964) by increasing the availability of nutrients (Humphreys and Lambert 1965, Tomkins *et al.* 1991, Bauhus *et al.* 1993, Chambers and Attiwill 1994) and destroying the soil-litter complex of micro-organisms inhibitory to plant growth (Renbuss *et al.* 1973, Bell and Williams 1997); reducing competition, particularly in gaps created by the death of adult plants (Wellington and Noble 1985a) and removing the natural enemies of seedlings (Whelan and Main 1979, Whelan *et al.* 1980).

### ***Herbivory***

Like most eucalypts, Tuart provides a resource for a range of leaf eating and wood boring insects and there are a number of herbivores and parasites that can affect the growth of seedlings and adults. There are no known detailed studies of herbivory in Tuart beyond describing the most common herbivores. Fox and Curry (1979) have listed a number of these. Insects feeding on foliage include leaf eaters such as the Tuart Miner (*Nepticula* sp. Nepticulidae Lepidoptera) and sawfly larvae (*Perga* sp. Pergidae Hymenoptera) and leaf suckers like leaf hoppers (Eurymeliidae Membracidae Hemiptera), shield bugs (Pentatomidae Hemiptera), and lerps (Psyllidae Hemiptera) (Fox and Curry 1979). Wood boring insects include: Tuart Borer (*Phorocantha impavida* Cerambycidae Coleoptera); *Culama* sp. (Cossidae, Lepidoptera); Stem Girdler (*Cryptophasa unipunctata* Lepidoptera); and Pinhole Borer (*Attractocerus kreuslerae* Lymexylidae Coleoptera) (Fox and Curry 1979).

### **CONSERVATION ISSUES**

Large areas of Tuart woodland have been cleared for both urbanisation and agriculture throughout the species' range. Beard and Sprenger (1984) estimated that approximately 94% of Tuart woodlands and 90% of Tuart/Jarrah woodland have been cleared. More recently Hopkins *et al.* (1996) estimated that 90% of medium Tuart woodland, 96% of medium Tuart and Tuart/Jarrah woodland and 80% of medium open Tuart woodland have been cleared. Nowhere is this more evident than on the coastal strip which encompasses the rapidly growing areas of the greater Perth Metropolitan Region and Mandurah, which coincides with the central portion of Tuart's

distribution. In this area Tuart woodlands are fragmented and subjected to disturbance regimes which differ in type, frequency, intensity and scale to that experienced by woodlands prior to European settlement.

The impacts of fragmentation and changed disturbance regimes are affecting many remnant Tuart woodlands, transforming community structure and species composition; the least resilient species are declining in abundance, some species are showing no change and others, predominantly exotic species though not always, are increasing in abundance (Recher and Serventy 1991, Dixon *et al.* 1995). There is considerable anecdotal evidence, and some scientific evidence, to suggest that Tuart is one species which is declining in a number of urban woodland remnants. This trend is well documented at Star Swamp in the northern suburbs of Perth where Piggot (1994) measured decline in Tuart canopy cover from 30% in 1953 to 7% in 1988. Piggot suggested this decline was associated with weed invasion and increased frequency of fire, weakening adult trees and impacting on recruitment.

Indeed, there is evidence in urban Jarrah/Tuart woodland remnants such as the Kings Park Bushland that invasion by the exotic grass *Ehrharta calycina* (Perennial Veldtgrass) has increased the frequency and intensity of fires and established a cycle that promotes fire and further invasion, and caused decline of native species and localized extinction of fire sensitive species (Wycherley 1984, Dixon *et al.* 1995).

It is seemingly a paradox that Tuart, which relies predominantly on fire for recruitment of seedlings and is relatively thick barked and able to resprout from epicormic buds, is declining in remnants which are frequently burnt. There are several explanations for this. Firstly, Tuart flowering is patchy in time and space and therefore the size of the canopy seed store may vary considerably between years. As a consequence, there may be considerable variation in the potential for seedling recruitment following a fire. Secondly, studies currently being undertaken in an urban Jarrah/Tuart woodland remnant indicate that it takes some time for a Tuart population recovering from fire to become reproductive. Ruthrof (unpublished data) observed that 3 years after fire 13% of resprouting adult Tuarts had buds but none held fruit within their canopy, and ten years after fire 60% of adults had buds and 73% had fruit. The exact time needed for Tuart to recover from fire and produce enough seed to recruit seedlings is unknown but these results suggest that the minimum time is between 4 and 9 years and that after a decade a considerable part of the population was not reproductive. Consequently, if a fire occurs before this time, it is unlikely that adult trees will have a canopy seed store available for synchronous seed release following a fire. Finally, Tuart generally does not form a lignotuber and seedlings and juveniles are therefore killed by fire until they reach a stem diameter where the bark is thick enough to protect sensitive cambial tissue. The time taken for juveniles to reach a size where they have some fire resistance is unknown but Fox (1981) has suggested that some resistance occurs after 3 to 4 years. In addition, mature Tuarts are regularly killed by fire when the fire breaches the bark and establishes in the wood. The fire continues internally after the causal fire, eventually killing the tree.

Clearly, increases in the frequency of fire have the potential to cause decline in Tuart populations and all efforts should be made to reduce the incidence of fire in urban remnants by reducing the abundance of weeds like Perennial Veldtgrass and quickly responding to and containing fires when they do occur.

Fragmentation and changes in the intensity and frequency of disturbance can have a direct impact on the abundance of Tuart. They can also affect the abundance of organisms that Tuart interacts with. It has been suggested that in urban remnants the abundance of naturally occurring wood boring insects including Tuart Borer *Phoracantha impavida*, Stem Girdler *Cryptophasa unipunctata* (Lepidoptera) and the moth larvae *Culama* sp. (Cossidae) may have increased as a

consequence of their natural predators declining in numbers or becoming extinct (Fox 1981). For example, Carnaby's Cockatoo which feeds on the larvae of *P. impavida* and Grey Currawong which feeds on the adult borer have significantly declined or become locally extinct in many urban Tuart woodland remnants (John Dell pers. comm., Recher and Serventy 1991). Wood boring insects may cause considerable damage to Tuart, resulting in branch ring barking and even plant death. As a consequence, increased abundance of wood boring insects may be causing increased mortality in Tuart populations. Currently not enough is known about the factors which limit the distribution and abundance of wood boring insects and their relative abundances in disturbed urban woodland remnants and less disturbed relatively unfragmented Tuart woodlands. It is therefore difficult to assess whether the abundances of wood boring insects and rates of damage in disturbed urban remnants are within the range of what is observed in less disturbed relatively unfragmented Tuart woodlands. Clearly, determining the factors which limit the distribution and abundance of wood boring insects and documenting the spatial and temporal variation in their abundance would be fruitful areas for further research and provide important information for managing Tuart populations.

Fox (1981) has suggested that Tuart decline in some urban remnants may be due to increased rates of infection by fungi such as *Armillaria* and *Piptoporous*. Both fungi are regarded as secondary pathogens that invade weakened eucalypts (Palzer 1980). Evidence for fungal pathogens being a cause of decline is equivocal but it may be possible that increased frequency of fires in urban remnants has weakened trees and increased the amount of dead wood available for *Armillaria* and *Piptoporous* to invade. As with wood boring insects, there is little scientific data to determine whether rates of *Armillaria* have increased in urban remnants where Tuart is declining. Clearly this is an area worthy of further research.

It has been suggested that atmospheric pollution has had an adverse effect on Tuart populations (Seddon 1972, Chilcott 1992). Evidence for this is equivocal and must be viewed with caution as no long-term studies have been carried out on the direct impact of pollution on Tuart. Chilcott (1992) reported that the distribution of Tuart decline is generally restricted to urban areas and is worse in the Kwinana Industrial Area. General health increased with distance from the point of pollution. Chilcott (1992) concluded that the synergistic effect from the combination of SO<sub>2</sub> and NO<sub>x</sub> pollution was acting to damage Tuart. However, revegetation trials with irrigated Tuart seedlings conducted by Meney and Fox (1986) showed that Tuart seedling survival was high (100% survival rate) at a site within the Kwinana industrial belt. Meney and Fox (1986) concluded that water availability was a more important factor than air pollution in determining early Tuart survival.

## CONCLUSIONS

We have presented a brief review of what is currently known about the biology of Tuart. We have focused primarily on the ecological interactions which influence the distribution and abundance of the species; clearly there is still much to be learnt, in particular, how habitat fragmentation and disturbance influence the rates of these interactions. We suggest that the following avenues of research would be particularly useful:

- long term studies of reproductive phenology in both disturbed urban remnants and relatively undisturbed unfragmented woodlands;
- long term longitudinal monitoring of seedling cohorts and adult recovery following fire in both disturbed urban remnants and relatively undisturbed unfragmented woodlands;
- studies of the population dynamics and abundance of wood boring insects in both disturbed urban remnants and relatively undisturbed unfragmented woodlands;
- studies of Tuart pathology in both disturbed urban remnants and relatively undisturbed

- unfragmented woodlands; and
- the development of management techniques for increasing Tuart abundance in remnants where it has declined.

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#### **PERSONAL COMMUNICATIONS**

**Dell, John** Department of Environmental Protection (previously Western Australian Museum)

FIGURES

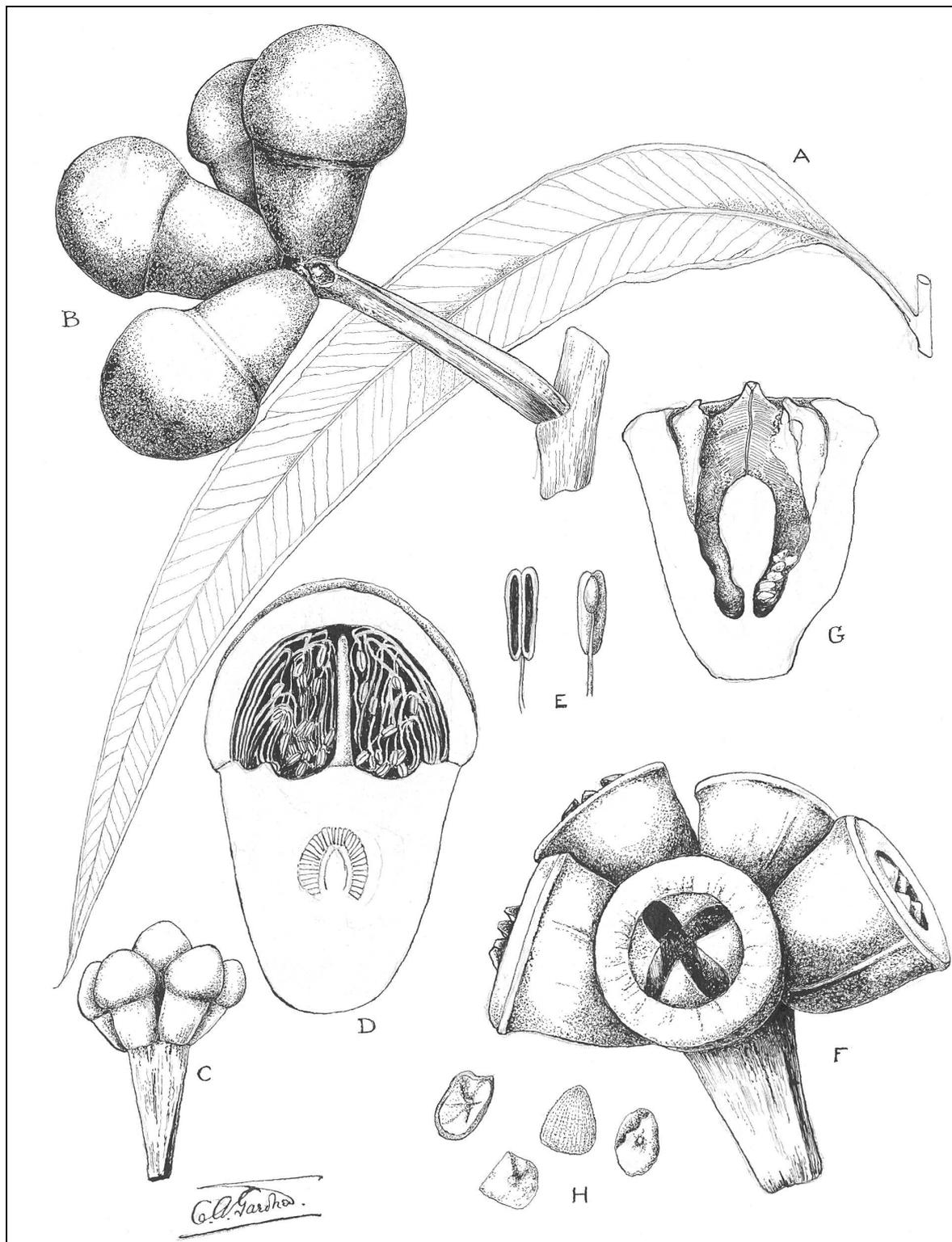


Figure 1. *Eucalyptus gomphocephala* A. Leaf; B. Buds (x 1.5); C. Buds (x 0.5); D. Section of flower bud (x 2); E. anthers (much enlarged); F. Fruits (x1); G. Section of fruit (slightly enlarged); H. Seeds (much magnified) (Gardner 1987). Reproduced from the original with the kind permission of the WA Herbarium.