Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (s266B)

Approved Conservation Advice (incorporating listing advice) for the Tuart (*Eucalyptus gomphocephala*) woodlands and forests of the Swan Coastal Plain ecological community

1. The Threatened Species Scientific Committee (the Committee) was established under the EPBC Act and has obligations to present advice to the Minister for the Environment (the Minister) in relation to the listing and conservation of threatened ecological communities, including under sections 189, 194N, 266B and 269AA of the EPBC Act.

2. The Threatened Species Scientific Committee conducted a listing assessment following the ecological community being placed on the 2016 Finalised Priority Assessment List.

3. The Committee provided its advice on the ‘Tuart (*Eucalyptus gomphocephala*) woodlands and forests of the Swan Coastal Plain’ ecological community to the Minister within a draft conservation advice in 2018. The Committee recommended that:
    - the ecological community merits listing as **critically endangered** under the EPBC Act; and
    - a recovery plan is not required for the ecological community at this time.

4. In 2019, the Minister accepted the Committee’s advice, and adopted this document as the approved conservation advice. The Minister amended the list of threatened ecological communities under section 184 of the EPBC Act to include the ‘Tuart (*Eucalyptus gomphocephala*) woodlands and forests of the Swan Coastal Plain’ ecological community in the critically endangered category.

5. A draft conservation advice for this ecological community was made available for expert and broader public comment for a minimum of 30 business days. The Committee and Minister had regard to all comment that was relevant to the consideration of the ecological community.

6. This approved conservation advice was based on the best available information at the time it was prepared; this includes scientific literature, advice from consultations, and existing plans, records or management prescriptions for this ecological community.

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1. CONSERVATION OBJECTIVE

To mitigate the risk of extinction of the Tuart (*Eucalyptus gomphocephala*) woodlands and forests of the Swan Coastal Plain ecological community, and help recover its biodiversity and function through protecting it from significant impacts as a Matter of National Environmental Significance under national environmental law, and by guiding implementation of management and recovery, consistent with the recommended priority conservation and research actions set out in this advice.

This conservation advice contains information relevant to the conservation objective by:

- describing the ecological community and where it can be found
- identifying the key threats to the ecological community
- presenting evidence (listing advice) to support the ecological community being listed as nationally threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act); and
- outlining the priority conservation and research actions that could stop decline and support recovery of the ecological community

The information used in this Conservation Advice was relevant as at the time this assessment was completed.

2. DESCRIPTION OF THE ECOLOGICAL COMMUNITY AND THE AREA IT INHABITS

2.1 Introduction and name of the ecological community

This section (Section 2) describes the assemblage of native species that characterises the ecological community throughout its range at the time of listing. It also describes some of the roles that these species play, vegetation structure, as well as some of the changes in species composition that have occurred over time. Due to natural variation, environmental factors and disturbance across the range of the ecological community, not all of these species are present at every site or patch of the ecological community. Often for this threatened ecological community, the absence of a species within a patch may be as a result of local extinction. Patches of the ecological community may also contain species not recorded in this Conservation Advice. Fuller lists of species are available in Appendix E. However, even those lists do not cover the total species of the ecological community across all occurrences. The number and identity of species recorded at a particular site is a function of sampling scale and effort. In general, the number of species recorded is likely to increase with the size of the site and there is a greater possibility of recording species that are rare in the landscape.

Species presence and relative abundance (including dominance) will vary from site to site as a function of environmental factors such as soil properties (chemical composition, texture, depth, drainage), topography, hydrology and through time as a function of disturbance (e.g. fire, logging, grazing), climate, and weather (e.g. flooding, drought, extreme heat or cold). This Section also describes the area that the ecological community inhabits and some key ecological processes, including the location, physical environment and other factors that help determine where the ecological community occurs in nature.

National ecological community listings typically aim to focus legal protection on areas that remain in at least moderate condition, and retain natural composition and ecological function to a certain degree. Section 3 of this Conservation Advice provides additional information to help identify areas of the ecological community that are considered a Matter of National Environmental Significance and so are protected under national environment law. This includes specifying diagnostic characteristics, a patch definition, sampling protocols, size and condition thresholds and further information to help identify patches and avoid significant adverse impacts to the protected ecological community.

The name of the ecological community is the **Tuart (*Eucalyptus gomphocephala*) woodlands and forests of the Swan Coastal Plain**, hereafter referred to as ‘Tuart woodlands and forests’, or ‘the ecological community’. The ecological community occurs as woodlands or forests or other structural forms where the primary defining feature is the presence of *Eucalyptus gomphocephala* (Tuart) trees in the uppermost canopy layer. The name of this tree species reflects one of its various Noongar names. The ecological community includes the assemblage of plants, animals and other organisms that occur in association with Tuart. The ecological community has a discontinuous distribution in the west of the Swan Coastal Plain, of southwest Western Australia.

2.2 Location and physical environment

The Tuart woodlands and forests occur on the Swan Coastal Plain in Western Australia, from Jurien, approximately 200 km north of Perth, to the Sabina River, near Busselton, 225 km south of Perth. The distribution was historically almost continuous from the Sabina River to Lancelin, with the woodlands and forests being most prominent in the southern part of the range. The ecological community further north, near Cervantes is more sparse and isolated, which is likely to have been a long-term characteristic. Additional outlying populations are located near the following rivers: Canning, Harvey, Moore, Murray, Serpentine and Swan (Keighery et al 2002; Tuart Response Group 2003). The ecological community is strongly associated with calcareous soils of the western part of the plain, including those very close to the coast. While it mainly occurs where soils are sandy and well drained, it can also occur in other areas such as on protected swales, saline and freshwater wetlands, close to river banks and on limestone slopes (Keighery et al 2002; Keighery 2002).

The distribution of the ecological community is inherently limited by the distribution of Tuart, as its defining species, although Tuart trees do also occur as a component of other vegetation communities, including the nationally-listed Banksia woodlands of the Swan Coastal Plain threatened ecological community (Department of the Environment and Energy 2016). These other vegetation communities are commonly found adjacent to the Tuart woodlands and forests and their distributions may overlap with the ecological community (Tuart Response Group 2004).

The ecological community occurs within the country of the *Noongar* nation (SWALSC 2016). The main distribution of the ecological community occurs within the IBRA (v7) Swan Coastal Plain bioregion (SWA), in the Perth Subregion (Department of the Environment, 2012). These areas fall within the Swan, Peel-Harvey, South West and Northern Agricultural Natural Resource Management regions as at May 2018 (Government of Western Australia, 2016a).

Local government areas known to contain the ecological community as at May 2018 include Bunbury, Busselton, Cambridge, Capel, Cockburn, Dandaragan, Dardanup, Fremantle, Gingin, Harvey, Joondalup, Kwinana, Mandurah, Murray, Nedlands, Rockingham, South Perth, Stirling, Wanneroo and Waroona.

2.2.1 Geology, landscape and soils

The ecological community occurs within the Perth Basin. The development of this sedimentary basin has formed the general landscape pattern of the Swan Coastal Plain which narrows from approximately 34 km wide in the north to 23 km wide in the south and comprises a series of features parallel to the coast (McPherson and Jones 2005). During the past 2.5 million years, both wind-blown and alluvial sediments have accumulated in these bands, resulting in the modern soils of the Swan Coastal Plain (Chalmers 1997 after Playford 1976).

Five main land features have been identified on the Swan Coastal Plain: Quindalup, Spearwood and Bassendean dune systems, the Pinjarra Plain, and the Ridge Hill Shelf. Tuart woodlands and forests are most commonly found on the Spearwood dune systems, also occurring on the Quindalup dune systems and in some places also found on the Bassendean dune systems. It also occurs in between the dunes in sheltered swales and on the margins of wetlands, as well as on the margins of rivers further inland, including some on very saline soils. Tuart is one of the few eucalypts known to be well adapted to calcareous alkaline soils (Gibson et al 2002; Ruthrof et al 2002), although it occasionally also occurs on the more acidic soils of the Bassendean dunes and Pinjarra Plain (Coates et al 2002).

The parallel dune systems were formed with fluctuations in sea level and they increase in age and decrease in pH with distance from the coast. Closest to the coast are the Quindalup dunes, which are lime and quartz beach sands that have blown into dunes and ridges (McPherson and Jones 2005). These are cream to white in colour. The dunes contain shells and other carbonate rich material, causing them to be strongly alkaline (pH 8-9). To the east of these are the Spearwood Dunes, which most commonly support the ecological community in its current distribution. Almost all of the Tuart woodlands mapped by the Tuart Response Group (2003) as having understorey with lowest visible disturbance occurred on Spearwood Dunes. The Cottesloe and Karrakatta soil units found on these dunes are white to pale yellow or yellowish brown sands that are coarse and well drained (Government of Western Australia 2000; Ruthrof et al 2002). The sands overlie the Tamala limestone, which outcrops to the west. This limestone also results in alkaline pH for these soils but they have less carbonate rich material than the Quindalup dunes. The Bassendean dunes are the oldest of the dune series. They are approximately 20 km wide and are gently undulating. They consist of deep quartz sands, with most carbonate material leached, and no underlying limestone, resulting in acidic soils. They are likely to have formed as shoreline deposits and coastal dunes during periods of high sea level (McPherson and Jones 2005). They support some areas of the ecological community but more commonly support Banksia dominated ecological communities (such as the nationally listed Banksia woodlands of the Swan Coastal Plain). At some locations, such as south of Bunbury, relationships between landscape elements such as the Spearwood and Bassendean dunes have been altered by the local history of erosion and re-deposition, and can be complex (Bischoff 2002).

From the Bassendean dunes the land falls to the Pinjarra Plain. This is a flat area of between 5 and 15 km wide covered by alluvial sediments brought by rivers and streams flowing from the Darling and Dandaragan plateau above (McPherson and Jones 2005). The Bassendean dunes are generally separated from the Pinjarra Plain, but in the south of the Swan Coastal Plain, along the eastern fringe of the Tuart Forest National Park, the dunes overly the Pinjarra

Plain (Keighery & Keighery, 2002). Further inland still is the Ridge Hill Shelf, which forms the foothills to the Darling Scarp plateau (Figure 1).

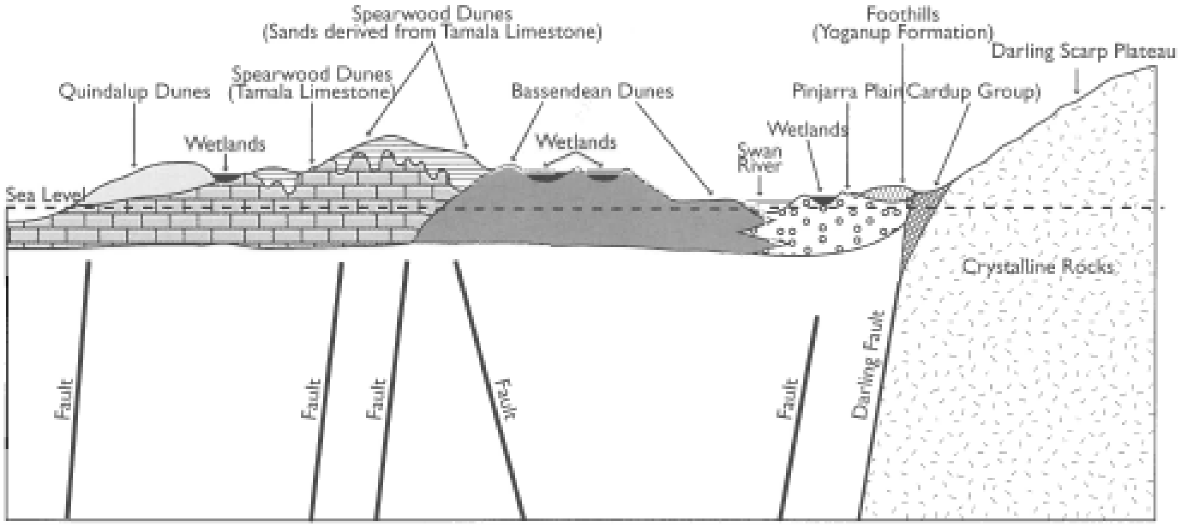

Figure 1. Landscape profile for the Swan Coastal Plain

The ecological community occurs mainly on the Spearwood and Quindalup dune systems, which are underlain by Tamala Limestone.

Reproduced in part from Government of Western Australia (2000) 'Bush Forever Part A' p.19

2.2.2 Groundwater hydrology

Across the Swan Coastal Plain the depth to groundwater varies, with the shallowest areas above several groundwater mounds, from which there is radial flow. In many parts of the Plain, depth to groundwater is relatively shallow. Wetlands occur where groundwater is very shallow, particularly in areas between dunes (Tuart Response Group 2002). Tuarts have complex physiology related to their access and use of water that varies seasonally, as both surface and groundwater availability responds strongly to rainfall (Franks et al 2007). As Tuart trees mature they develop deep roots and so are better able to extract groundwater seasonally. This use of water is described by Drake et al (2011) as 'opportunistic'. With declining rainfall in the region since the 1970s, the availability of both surface and groundwater is likely to be reducing, which may place stress on trees including Tuarts (Petrone et al 2010). This is likely to be compounded by water extraction for domestic, horticultural and industrial use. With changing groundwater levels, salinity may also change, for example with incursion from hyper-saline lakes, as well as the ocean (Forbes and Vogwill 2016). In some locations, particularly on estuarine soils located in sumplands, changed hydrology can also lead to the development of acid-sulphate soils (Singh et al 2012), limiting suitability for many plants.

2.2.3 Climate

The ecological community occurs throughout the latitudinal range of the Swan Coastal Plain, and as far north as Jurien Bay. The climate throughout this area is mediterranean, with warm to hot summers and temperate winters. Annual rainfall increases southwards, from approximately 536 mm in Jurien Bay to 709 mm in Busselton near the coast (Bureau of Meteorology 2016). It also increases towards the Darling Scarp. The majority of Tuart woodlands and forests with understorey with low visible disturbance occurs in the

700- 900 mm range (Tuart Response Group 2003). The rain is strongly seasonal, occurring predominantly in winter (Table 1). This seasonal climate predisposes the ecological communities in the region to summer fires but fire regimes are likely to have changed substantially since European occupation. The climate is also changing, with a substantial decrease in rainfall in recent decades (Hope et al 2015; also see Section C.6 Climate change).

Table 1. Mean annual rainfall for sites across the range of the ecological community

Source: Bureau of Meteorology

Weather station	Mean temperature (Degrees Celsius)	Mean rainfall (mm)
Jurien Bay (1981-2010)	February max 30.7 (warmest month) July max 19.4 (coolest month)	January 7.0 (annual low) July 116.1 (annual high) Annual 536.4
Perth Airport (1981-2010)	February max 32.1 (warmest) July max 18.1	January 7.8 (annual low) July 148.9 (annual high) Annual 725
Busselton (1998-2011)	January, February max 29.3 (warmest) July max 17.1 (coolest)	February 4 (annual low) July 40.8 (annual high) Annual 708.8

2.3 Vegetation

The following description of the vegetation generally relates to the less disturbed, or 'reference' condition, occurrences of the Tuart woodlands and forests. In many locations there has been substantial disturbance to the ecological community, which is also reflected in its current state: clearance, with fire history and management including grazing having had a strong influence on the current structural and floristic composition of the ecological community (Ruthrof et al 2002). Also see Section 3 IDENTIFYING AREAS OF TUART WOODLANDS AND FORESTS THAT ARE PROTECTED UNDER NATIONAL ENVIRONMENT LAW.

2.3.1 Variation across the ecological community

The primary defining feature is the presence of *Eucalyptus gomphocephala* (Tuart) in the uppermost canopy, although this may co-occur with various other tree species. The ecological community varies in structure, with variable height and canopy closure across its range. Thus it can occur in a variety of forms, most commonly open forest, woodland and open woodland, but can also include other forms including various mallee structural formations (NVIS Technical Working Group 2017). The Tuart trees themselves include multi-stemmed mallee that can be less than 10 m in height and single trunked trees in a range of heights, generally smaller in the northern part of the range, with large trees of up to 40 m in height, particularly in the southern part of the range (Florabank, undated; Figure **2**). Landscape position also influences the form and size of the trees (Keighery et al 2002). There may also be a substantial sub-canopy, for example dominated by *Agonis flexuosa* (Peppermint). The understorey is often relatively open, including many non-woody species from the Asteraceae, Cyperaceae, Restionaceae and Orchidaceae families as well as lilies.

The southwest of Western Australia is recognised as a global biodiversity hotspot (Myers et al 2000). It is recognised for its very high species richness and endemism of plants (Hopper and Gioia 2004). Notwithstanding this, the ecological community is typically less species rich and contains fewer endemics than some of the other ecological communities found nearby, for example, proteaceous woodlands and heaths. The local expression of the ecological community is influenced by geology, soil composition and drainage, rainfall, site history and current and historical management. There are strong differences between structure, species composition and richness of the ecological community on the various dune formations, reflecting differences in available soil nutrients. Where the ecological community occurs on Bassendean dunes, these sites typically have highest species richness. On Spearwood dunes, where the ecological community mostly occurs it has lower species richness, although there is greater structural diversity. Examples of the ecological community on Quindalup dunes are generally least rich in species, but composition may vary substantially between sites (Gibson et al 1994; Government of Western Australia 2000; Gibson et al 2002).

In surveys of 64 plots across the range of Tuart, one third of the species were recorded at only one location, indicating the high level of floristic variation between sites (Gibson et al 2002). Given the high variation in floristics across its range, some types of the Tuart woodlands and forests are particularly rare. Keighery (2002) documented the flora of Tuart woodlands at 12 locations, identifying 575 vascular plants, of which 414 were native species and 161 weeds. While most were common species of the Spearwood and Quindalup dunes, several species were largely confined to the Tuart woodlands and forests. The climate also varies across the range of the ecological community, with warmer and drier conditions in the north. This is reflected in changes in the species composition across its latitudinal range.

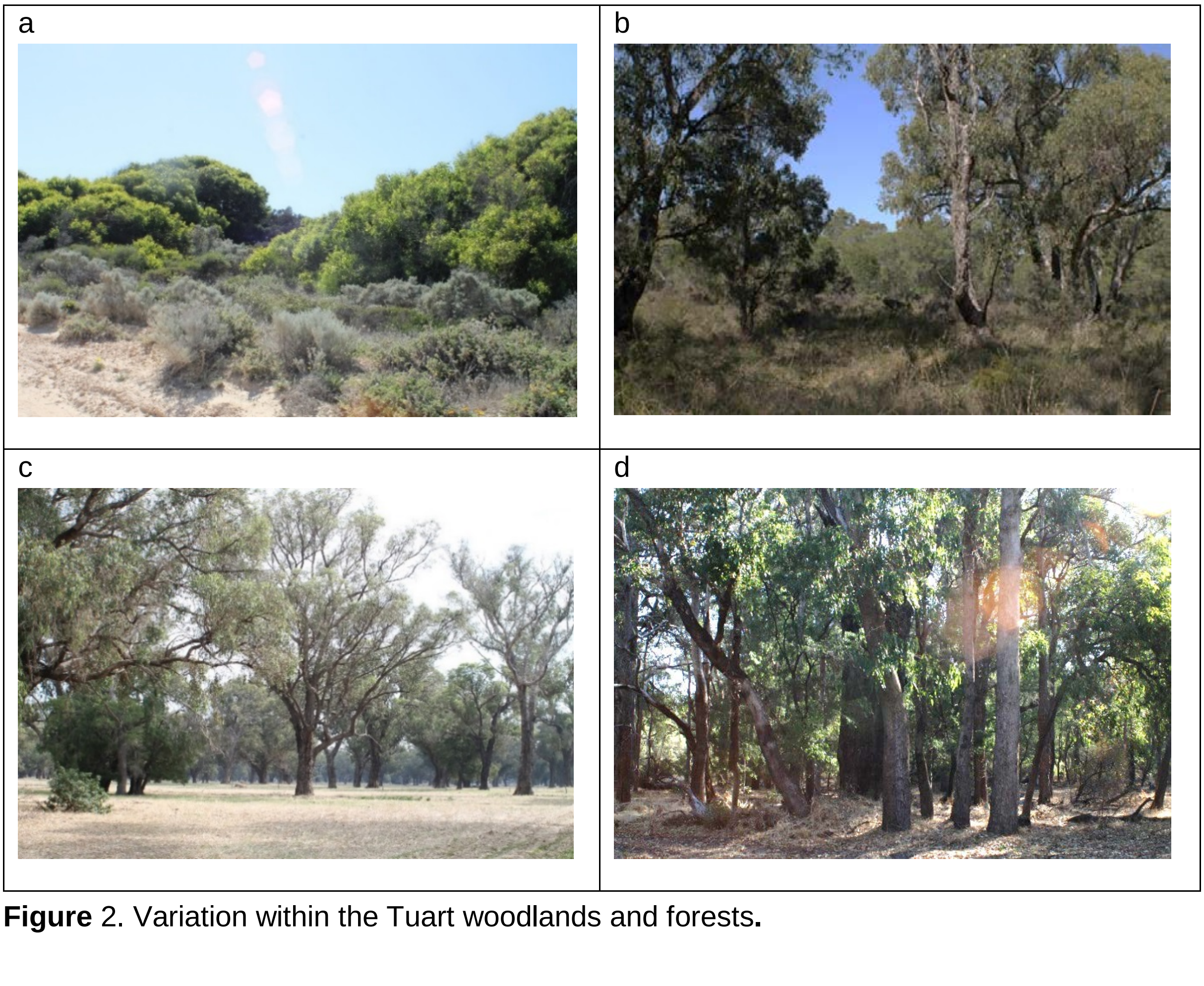

Figure 2. Variation within the Tuart woodlands and forests**.**

Examples of the expression of Tuart woodlands and forests across its range, reflecting natural variation and disturbance history: a) Guilderton, b) Lake Clifton, c) Myalup, d) Ludlow.

2.3.2 Tree canopy

Eucalyptus gomphocephala (Tuart) is generally the primary tree species defining the upper-most canopy. It is the largest tree species found on the Swan Coastal Plain and is endemic to the bioregion (Gibson et al 2002). Tree growth is dependent on conditions such as shelter, soil depth and water supply; Tuart trees are generally larger, in both girth and height, in the southern part of the range, where rainfall is highest, but also in sheltered and well-watered places in other parts of the range. Tuart is thought to be tolerant of salty winds (Florabank undated), but where trees are exposed to the maritime winds particularly on the Quindalup dunes, they may take a mallee form, for example, at Dalyellup (Keighery et al 2002), as well as at Guilderton. Tuart trees grow on a range of well drained soils, including sandy, loam, sandy loam, and sandy clay textures (Florabank undated). Like many other eucalypts, it is likely that Tuart hybridises with other *Eucalyptus* species when nearby (Coates et al 2002), so hybrid trees may form part of the ecological community.

Tuart co-occurs with most other canopy species on the Swan Coastal Plain, although these vary in their likelihood of co-occurrence. Other frequently occurring canopy or sub-canopy species include *Banksia attenuata* (Candlestick Banksia) and *Agonis flexuosa* (Peppermint). The former occurs across the latitudinal range of Tuart, while the latter is commonly present in the southern part of the range of the ecological community, but does not occur in its northern part (Gibson et al 2002). Tuart also occurs with *Eucalyptus marginata* (Jarrah), *Banksia grandis* (Bull Banksia) in the more southerly areas, *Melaleuca rhaphiophylla* (Swamp Paperbark) and occasionally *Banksia prionotes* (Acorn Banksia) in northern areas (Gibson et al 2002). It may also occur with *Banksia menziesii* (Firewood Banksia) in the central and northern part of the range. Heddle et al (1980) also identified co-occurrence with *Eucalyptus rudis* (Flooded Gum) and less commonly with *Corymbia calophylla* (Marri). It is very unlikely to occur with *Eucalyptus decipiens* (Redheart Moit) or *Melaleuca lanceolata* (Black Paperbark) (Gibson et al 2002).

Analysis of tree species distribution within the natural range of Tuart trees on the Swan Coastal Plain, considering various environmental characteristics, suggested that soil pH and phosphorus content were the best predictors of Tuart's distribution (Gibson et al 2002). Many of the soils or substrates with which Tuart is associated are alkaline due to high concentrations of calcium carbonate. In comparison with many other tree species of the region, Tuart is relatively tolerant to variation in soil characteristics and is able to grow in soils of various salinity levels and so grows in some locations where species more sensitive to these characteristics do not flourish. In some locations, such as some wetland areas, the occurrence of Tuart has been described as 'opportunistic'. As pH and phosphorus concentration increases moderately, the likelihood of Tuart and Peppermint occurrence increases, while likelihood of occurrence of *Banksia menziesii*, *B.attenuata*, *C. calophylla* and *E. marginata* decreases (Gibson et al 2002). This is likely to explain the frequent occurrence of Tuart on Spearwood dunes and dominance of other flora such as Banksia species on the more acidic and less nutrient rich Bassendean sands.

While descriptions of vegetation structure refer primarily to living vegetation, especially in landscapes subject to disturbances such as fire and 'Tuart decline', dead trees still contribute substantially to vegetation structure and habitat features. Dead trees provide vantage points for fauna, contribute to connectivity and may continue to provide hollows for up to 100 years after the tree's death (Gibbons and Lindenmayer 2002).

2.3.3 Understorey

There is substantial floristic and structural variation in the understorey of the ecological community. This variation is influenced by the latitude and associated climatic variation, in particular, rainfall. It is also influenced by geomorphic and soil differences associated corresponding with position in the landscape (for example, location on Quindalup or Spearwood dune systems) (Keighery 2002). The structure of the understorey may vary from being open, particularly on Quindalup dunes, to densely shrubby, or include a sub-canopy of smaller trees as noted in Section 2.3.1. The extent to which the understorey is grassy or shrubby may depend in part on impacts of fire and grazing and weed invasion. In some areas, particularly on either Quindalup or Spearwood dunes there may also be significant bare patches of sand (Government of Western Australia 2000).

Floristic analysis of 64 sites containing Tuart found that the taxa occurring across the greatest number of sites were *Hardenbergia comptoniana* (Native Wisteria), *Daucus glochidiatus* (Australian Carrot) and *Trachymene pilosa* (Native Parsnip). These surveys also found that one third of plant species occurred in only one site (Gibson et al 2002). Of the 575 vascular plant taxa recorded by Keighery (1999 cited in Keighery 2002), 59 were found in more than 70% of the survey sites. These two surveys demonstrate the high variability in understorey floristic composition between sites, as is typical for the region.

Some native plants can be identified as commonly associated with the ecological community in various parts of its distribution. For example, species characteristic of the northern part of the range are: *Chamelaucium uncinatum* (Geraldton Wax), *Labichea cassioides* and *Lechenaultia linarioides* (Yellow Leschenaultia). In the middle part of the range, *Spyridium globulosum* (Basket Bush) is common. Some that are associated with the southern part of the range of the ecological community include *Cheilanthes austrotenuifolia*, *Dichondra repens* (Kidney Weed) and *Lindsaea linearis* (Screw Fern) (Keighery 1999 cited in Keighery, 2002).

Other native plants identified by Keighery (2002) as common across the surveyed range of Tuart woodlands include:

Shrubs: *Acacia cyclops*, *A. cochlearis*, *A. pulchella*, *A. rostellifera*, *A. saligna, Adriana quadripartita, Banksia dallanneyi*, *B. sessilis, Gompholobium tomentosum, Hakea prostrata, Hibbertia hypericoides, Logania vaginalis, Melaleuca systena, Myoporum insulare Olearia axillaris*, *Phyllanthus calycinus*, *Rhagodia baccata*, *Thomasia cognata* and *Xanthorrhoea preissii*.

Climbers and vines: *Cassytha racemosa, Clematis linearifolia, Comesperma integerrimum Hardenbergia comptoniana, Kennedia prostrata,* and *Muehlenbeckia adpressa.*

Grasses: *Austrostipa elegantissima, A. flavescens* and *Microlaena stipoides*

Herbs (monocot):

Perennial lilioid herbs: *Acanthocarpus preissii, Dianella revoluta, Lomandra maritima, L. micrantha* and *Tricoryne elatior*

Annually renewed (geophytes) including orchids: *Acianthus reniformis, Caladenia latifolia. Corynotheca micrantha, Dichopogon capillipes, Thysanotus arenarius* and *T. patersonii*

Herbs (dicot)

Annually renewed from seed: *Crassula colorata, Daucus glochidiatus, Galium murale, Lobelia tenuior, and Parietaria debilis, Trachymene coerulea* and *T. pilosa*

Annually renewed (geophytes): *Oxalis perennans, Pelargonium littorale*

Perennial

Opercularia hispidula (Florabase, 1999)

Sedges

Perennial: *Carex thecata, Ficinia nodosa, Lepidosperma gladiatum, L. squamatum* and *Schoenus grandiflora*

Annually renewed from seed: *Isolepis marginata, Triglochin calcitrapa*

2.3.4 Cryptogams

While the fungi and other cryptogams (such as liverworts, hornworts) associated with the ecological community are not well known, they contribute substantially to its diversity and function. 479 species of fungi have been identified in Perth's Bold Park, which is predominantly Tuart woodlands and forests and Banksia woodland (Botanic Gardens and Parks Authority 2016a). Mycorrhizal fungi are particularly important in their associations in many plants, increasing the uptake of water and nutrients (Bougher 2009). Fungi are also an important food for fauna such as *Isoodon obesulus* (Quenda) and *Bettongia pencillata* (Woylie) (Valentine et al 2012).

2.4 Faunal components of the ecological community

Of the fauna occurring within the ecological community, some such as *Macropus fuliginosus* (Western Grey Kangaroo) are widely distributed while others, such as *Pseudocheirus occidentalis* (Western Ringtail Possum) have a specialised habitat niche. Data compiled from 12 Tuart woodland sites by Dell et al (2002 cited in Tuart Response Group 2004) identified 158 vertebrate species. The Tuart Response Group (2004) identified the importance of invertebrates in terrestrial ecosystems generally, but stated that for Tuart woodlands the invertebrate assemblages were poorly understood.

Much of the components of the assemblage of vertebrate fauna that may be found in Tuart woodlands and forests also use adjacent or nearby vegetation communities as habitat. Less is known about the invertebrate faunal assemblage although it is likely that a greater proportion would be endemic to the Tuart woodlands and forests than for vertebrate fauna.

2.4.1 Mammals

Sixteen non-volant mammal species have been recorded in Tuart woodlands, however, they have been substantially affected by changes to habitat resulting from clearing for agriculture, grazing and urbanisation across the Swan Coastal Plain. Mammals have been identified as the vertebrate group most impacted by these changes, which have caused marked declines or local extinction for many species, including important ecosystem engineers (Fleming et al 2013). Predation by cats and foxes continues to limit population recovery for many small to medium size mammals, while other factors such as climate change and disease may also be limiting (Abbott 2008). Within the Perth region most small mammals are regionally extinct (Hyder and Dell 2009).

Mammals likely to be present in the ecological community include macropods such as Western Grey Kangaroo, whose populations may have increased in some areas resulting in higher grazing pressure on the understorey. The Tuart woodlands and forests with Peppermint sub-canopy in the southern part of the ecological community's range remain particularly important for both Western Ringtail Possum (listed as 'Critically Endangered' in WA and nationally) and *Trichosurus vulpecula* (Brushtail Possum) (Dell et al 2002; Tuart Response Group 2004). The leaves of Peppermint are the primary food for Swan Coastal Plain populations of Western Ringtail Possum. Remaining populations of *Phascogale tapoatafa wambenger* (Southern Brush-tailed Phascogale, *wambenger*) are also concentrated in Tuart woodlands and forests, including Yalgorup National Park, with declines associated with the loss of woodland (Department of Conservation and Land Management 1995; Dell et al 2002). These three nocturnal species take daytime refuge in tree hollows, and may now compete with each other and other fauna for these. As the largest tree species on the Swan Coastal Plain, mature Tuart trees have a particularly important role in providing habitat for these and other hollow-dependent animals including bat species, which use hollows for daytime roosting (Dell et al 2002). *Falsistrellus mackenziei* (Western False Pipistrelle) occurs in sites in or near old growth forest, including higher rainfall Tuart or mixed Tuart and Jarrah woodlands, especially where water is nearby (Environment Australia 1999). At least another seven insectivorous microbats have been recorded on the Swan Coastal Plain south of Perth, in habitats that include Tuart woodlands and forests (Bullen 2009).

Other mammal species that have broadly declined but may still be found in Tuart woodlands and forests include *Dasyurus geoffroii* (Chuditch), *Isoodon obesulus fusciventer* (Quenda) and *Setonix brachyurus* (Quokka) (Hyder and Dell 2009). *Bettongia pencillata ogilbyi* (Woylie) may have formerly been part of some areas of the ecological community. Where soil engineers, such as Quenda are present they perform an important role in turning over large quantities of soil. This has been shown to contribute to significant changes in physical and chemical soil characteristics, including soil moisture, hydrophobicity, the size distribution of litter and seedling recruitment processes (Valentine et al 2013; 2017). Quenda continue to contribute to this soil turnover, although as populations have declined, this may not be as effective as previously. Formerly, *Myrmecobious fasciatus* (Numbat) may also have played such a role in some areas (Dell et al 2002), though the ecological community is not likely to have been a major part of their former distribution. *Tachyglossus aculeatus* (Echidna) is another ecosystem engineer, and it has not suffered such severe declines, possibly due to its greater natural defences to predation by cats and foxes. Another important ecological role played by some mammals in Tuart woodlands and forests is pollination, particularly of the proteaceous species present (including Banksias). *Tarsipes rostratus* (Honey Possum) is a small marsupial pollinator that is part of the ecological community, while *Cercartetus concinnus* (pygmy possum) would also have played a similar role but its range has declined so that it may only persist in larger areas of native vegetation. Other small mammals identified in the ecological community include *Rattus fuscipes* (Western Bush Rat) and *Pseudomys albocinereus* (Ash-grey Mouse), although the latter may no longer be present (Dell et al 2002).

2.4.2 Reptiles

The reptile assemblage of Tuart woodlands and forests is quite diverse, including at least 43 species: this is more than half of the species occurring on the Swan Coastal Plain (Dell et al 2002). Although none of these are endemic to the ecological community, many reach their maximum numbers there, and remaining Tuart woodlands and forests provide important refugia in a largely cleared and fragmented landscape. In surveys across the landforms and vegetation types of the northern Swan Coastal Plain, Valentine et al (2009) found the highest abundance of reptiles in Tuart forest, although species richness was lower than in other vegetation types, and a small number of species were dominant. Amongst the species that are associated with the ecological community are the skinks *Cryptoblepharus buchanii* (Peron's Snake-eyed Skink) and *Menetia greyii* (Common Dwarf Skink); *Christinus marmoratus* (Marbled Gecko) and the legless lizard *Aprasia repens* (Sand plain Worm Lizard), which is a litter specialist (Dell et al 2002). Other species that are found in the ecological community across much of its range include *Hemiergis quadrilineata* (Two-toed Earless Skink), *Lerista elegans* (Elegant Slider) and *Tiliqua rugosa* (Bobtail, Shingleback) (Dell et al 2002), as well as *Acritoscincus trilineatus* (Western Three-lined Skink) (Wentzel 2010). Some reptile species have been lost from the region (Valentine et al 2009) and some species of particular conservation significance in the ecological community include *Lerista lineata* (Perth Slider), and *Morelia spilo*ta *imbricata* (Western Carpet Python) (How et al 2009). Several of the species identified by Valentine et al (2009) as commonly present in Tuart forests tend to be associated with long-unburnt sites.

2.4.3 Amphibians

At least seven amphibian species have been recorded in Tuart woodlands and forests, of which *Heleioporus eyrei* (Moaning Frog), *Limnodynastes dorsalis* (Banjo Frog), and *Myobatrachus gouldii* (Turtle Frog) are the most commonly recorded. Only the latter is able to live out of water permanently, having a breeding burrow where the young develop to metamorphosis. The other amphibians present require access to free water, and sites near this have highest species richness (How et al 2009). The association of the ecological community with riparian and wetland areas, including three Ramsar listed sites indicates their likely importance habitat for amphibians (and other aquatic fauna).

2.4.4 Birds

Dell et al (2002) consolidated data of bird assemblages of Tuart woodlands and forests from a variety of sources, including historical surveys, allowing them to identify a range of species that have declined or disappeared from the Swan Coastal Plain. They identified 92 species as having been recorded in the ecological community. This is slightly less than half of the bird species of the Swan Coastal Plain. Some other species may be found in the ecological community with further survey. Marked declines of a range of woodland species were noted in even larger reserves with little visible disturbance (Storr and Johnstone cited in Dell et al 2002). Some species that have been observed recently in Tuart forests and woodlands of the southern Swan Coastal Plain but have declined across the region include *Petroica multicolor boodang* (Scarlet Robin), *Eopsaltria griseogularis* (Western Yellow Robin), *Acanthiza apicalis* (Broad-tailed Inland Thornbill) and *Smicrornis brevirostris* (Weebill) (Dell and Hyder 2009).

Some additional declining species that have been identified as previously associated with Tuart woodlands and forests are *Falcunculus frontatus* (Crested Shrike-tit), *Strepera versicolor* (Grey Currawong), *Ptilotula ornata* (Yellow-plumed Honeyeater) and *Climacteris rufa* (Rufous Treecreeper). The latter two species are now regionally extinct (Dell et al 2002). Small insectivorous birds have been identified as a group of species declining across the Perth region. Repeated surveys in Underwood Avenue Bushland, which is the third largest bushland remnant in Perth, and contains Tuart woodland found substantial numbers of some of these declining species, including *Merops ornatus* (Rainbow Bee-eater), *Pardalotus striatus* (Striated Pardalote), *Gerygone fusca* (Western Gerygone), *Acanthiza chrysorrhoa* (Yellow-rumped Thornbill) and *Pachycephala rufiventris* (Rufous Whistler) (Abbott and Owen 2017).

Notwithstanding the broad declines in woodland species across the Swan Coastal Plain, the ecological community continues to provide a wide variety of habitat niches for birds. The association of the ecological community with some rivers and wetlands means that several duck species are represented, for example *Tadorna tadornoides* (Australian Shelduck) and *Chenonetta jubata* (Australian Wood Duck). The latter has been observed using mature Tuart trees for roosting and nesting sites at the Vasse-Wonnerup Wetlands Ramsar site (Wetlands Research and Management 2007). Many other bird species associated with wetlands, including a range of migratory species are present at these sites. Parrots are also amongst the many taxa likely to benefit from hollows in mature Tuarts including *Purpureicephalus spurius* (Red-capped Parrot) and *Barnardius zonarius* (Australian Ringneck). At some locations Tuart trees may provide the only suitable nest sites for the threatened *Calyptorhynchus latirostris* (Carnaby's cockatoo) (Dell et al 2002; Department of Parks and Wildlife 2016), while availability of suitable hollows is also a limitation for the other threatened black cockatoo species *Calyptorhynchus baudinii* (Baudin's Cockatoo) and *Calyptorhynchus banksii naso* (Forest Red-tailed Black Cockatoo) (Department of Environment and Conservation 2008). Use of hollows by other bird species, including by those new to the region, such as *Trichoglossus moluccanus* (rainbow lorikeet) and *Cacatua roseicapilla* (galah) contributes to the limitation of this resource. Populations of black cockatoo species have dramatically declined (Johnstone and Kirkby 2016). Observations of Carnaby's Cockatoo and Forest Red-tailed Black Cockatoo suggest that these species have substantially shifted their foraging and nesting range in the past two decades, but this can change from year to year. Amongst the changes observed is an increase in importance of areas including Tuart woodlands and forests on the southern part of the Swan Coastal Plain for breeding, making these areas critical for these species (Johnstone et al 2006; 2010; Johnstone and Kirkby 2016). The *Polytelis anthopeplus* (Regent Parrot) is exceptional in that it has increased on the Swan Coastal Plain, including in Tuart woodlands and forests south of Mandurah (Dell et al 2002). Overall, sixteen of the 92 bird species observed in Tuart woodlands and forests are identified by Dell et al (2002) as requiring tree hollows for breeding. These authors comment on the high importance of Tuart woodlands and forests, particularly in coastal locations for this group of species and also for some raptors, which may benefit from the high vantage points provided by tall Tuarts, even when dead.

The raptors recorded at a range of surveyed locations in Tuart woodlands and forests include *Hieraaetus morphnoides* (Little Eagle), *Falco cenchroides* (Nankeen Kestrel) and *Falco longipennis* (Australian Hobby), while scavengers include *Cracticus torquatus* (Grey Butcherbird) and *Corvus coronoides* (Australian Raven). Widespread aerial insectivores include *Pachycephala rufiventris* (Rufous Whistler) and *Rhipidura albiscapa* (Grey Fantail).

Small gleaners such as *Acanthiza apicalis* (Broad-tailed Thornbill), Weebill, *Gerygone fusca* (Western Gerygone), Yellow-rumped Thornbill and *Zosterops lateralis* (Grey-breasted White-eye, Silvereye) gather food from a variety of substrates within the ecological community. Nectarivores include *Lichmera indistincta* (Brown Honeyeater), *Anthochaera carunculata* (Red Wattlebird) and *Acanthorhynchus superciliosus* (Western Spinebill) (Dell et al 2002) and *Gavicalis virescens* (Singing Honeyeater) (Ruthrof et al 2002).
A range of migratory species identified in international treaties and listed under national environment law also occur in the ecological community. Many of these birds are most closely associated with adjoining wetland habitats but may use Tuart woodlands and forests for nesting. (Wetland Research and Management 2007; Department of Parks and Wildlife 2014a).

2.4.5 Invertebrates

As noted by the Tuart Response Group (2004), invertebrates in terrestrial ecosystems are highly diverse and have very high functional importance, as food, in nutrient cycling, pollination and management of predators. Nonetheless, specific information on the invertebrates in the ecological community is very limited. A study of mixed Jarrah and Tuart woodland found 84 insect species from five orders including: Hymenoptera (ants, bees and wasps); Diptera (flies); Coleoptera (beetles); Lepidoptera (moths and butterflies); and Blattodea (cockroaches) (Fox and Curry 1979 cited in Ruthrof et al 2002).

Some invertebrates noted particularly for their likely damage to Tuart trees include *Cryptoplus tibialis* (Tuart bud Weevils), as well as *Phoracantha impavida* and *P. semipunctata* (Common Eucaylpt Longhorn) (Tuart Response Group 2004). The native earthworm species recorded on Quindalup and Spearwood dunes in the Perth region include *Austrohoplochaetella imparicystis* and *Woodwardiella libferti,* as well as a range of undescribed species and introduced species but their association with Tuart woodlands and forests is not clear (Abbott and Wills 2002). Other taxonomic groups such as termites are also critical in breaking down woody material, as well as contributing to diversity and providing food to other species such as Echidna (Abensperg-Traun and Perry 1995).

Pollination is another important function provided by invertebrates in the ecological community, with some very specific relationships between plants and pollinators (for example, orchids and wasp species). Some native pollinators may be in competition with introduced honey bees (Department of Parks and Wildlife 2014a).

Amongst the other invertebrate taxa that are unique to the region include subterranean fauna. Five groups of as yet undescribed fauna have been identified in the Tuart Forest National Park (Department of Parks and Wildlife 2014a).

For further information on the species that are part of the ecological community see APPENDIX E – SPECIES LISTS.

3. IDENTIFYING AREAS OF TUART WOODLANDS AND FORESTS THAT ARE PROTECTED UNDER NATIONAL ENVIRONMENT LAW

3.1 Introduction

National listings complement State vegetation and other biodiversity protection laws by enhancing the protection of those components of Australia's biodiversity most at risk of extinction. For ecological communities, national listings focus legal protection on areas that remain in relatively good condition, and retain their natural composition and ecological function to a certain degree.

The Tuart woodlands and forests ecological community encompasses considerable natural variation across its range, including different forms and states. The ecological community is also subject to varying degrees of disturbance and degradation that have influenced the condition of patches. The ecological community has been either heavily cleared and/or degraded across much of its range. The state and condition of individual areas of this ecological community is influenced by, amongst other things, history of degradation (including clearing and regrowth, species invasions, eutrophication, sedimentation and erosion), patch size, proximity to other patches and proximity to highly disturbed areas. Contextual factors including disturbance histories (including fire, flooding and grazing), recent rainfall and drought conditions should all be taken into account when identifying areas that are part of the nationally protected ecological community, taking into account that these factors may sometimes temporarily mask good condition states. Both the natural variation and influence of degradation have been taken into account in developing the key diagnostic characteristics and condition thresholds for the Tuart woodlands and forests.

In order to be considered a Matter of National Environmental Significance (MNES) under national environment law, areas of the ecological community must meet the diagnostic characteristics and at least the minimum condition thresholds for national protection, if applicable. If a proposed action will or may have a significant negative impact on a MNES, it must be referred to the Australian Government for approval prior to undertaking that action.

Diagnostic characteristics (Section 3.2) assist in identifying a patch of native vegetation as being part of the Tuart woodlands and forests ecological community. These diagnostic characteristics summarise the main features of the ecological community, with more information provided in the other sections of this document.

Condition categories and thresholds (Section 3.3.1) are specified for many nationally-listed ecological communities, including Tuart woodlands and forests. Taking into account the definition of an ecological community and that it may occur in various natural states, these further recognise that patches of an ecological community can differ in their quality, with some patches having undergone substantial degradation.

Condition and size thresholds represent points at which an ecological community changes from one reference condition class or category, to another. The minimum thresholds help identify which areas of an ecological community, at a particular location and time, may be subject to significant impact considerations under national environment law. Areas that fall below specified minimum condition and/or size thresholds, and are in lower condition classes or categories, are of less significant conservation value and therefore are not considered a 'Matter of National Environmental Significance' (MNES) under national environment law. For example, very small and/or degraded patches that do not meet the minimum thresholds for size, native vegetation cover or species diversity, such as isolated paddock trees or remnants where native species have been largely replaced by perennial weeds, could be explicitly excluded from further consideration. This means that any actions that may significantly impact areas below the minimum condition and/or size thresholds do not need to be considered under national environment law and the referral, environment assessment, approval and compliance provisions are instead focussed on the most valuable remnants (or well restored areas) of the ecological community. Hence, minimum size and condition thresholds provide more certainty for landholders (and others) about when the nationally listed ecological community is present and guidance on which patches of the ecological community retain sufficient conservation values to be considered a MNES.

Once it is determined that the definition and minimum condition and/or size thresholds have been met, this confirms a nationally listed ecological community is present at a particular location, and other decisions (e.g. continuing-use or significant impact decisions) can then be made to determine if national environment law applies to an action that is likely to have a significant impact on a patch of the ecological community. Such decisions are based on full consideration of the impacts and context. Not all impacts to patches of a nationally listed ecological community will be determined to be significant.

Although patches of an ecological community below the minimum size and condition thresholds, or single isolated trees, are not protected under national environmental law, it is recognised that some of these patches and trees may still retain important natural values, including habitat for flora and fauna and contributions to landscape function. Such sites may be protected through State and local laws or schemes. In addition, these patches should be considered as possible sites for recovery and other management actions. Suitable recovery and management actions may improve some of these patches to the point that they may be regarded as part of a nationally protected ecological community. In addition, condition thresholds, classes and/or categories may assist a land manager (or others) with management decisions (e.g. thresholds may be used as indicative targets to restore the condition of a particular area from a lower condition class or category to a higher condition class or category).

Relative to the pre-European area of the ecological community, a small proportion of areas remain in moderate, high or very high ecological condition. Any remnants that retain a largely native understorey, include mature trees and other important habitat features, or are connected to other native vegetation are a high priority for protection and management.

This box outlines the key steps to identify patches of the nationally protected ecological community and to guide other decision making (e.g. environment impact assessment).

Step 1:

● Decide if the area meets the key diagnostic characteristics and define the boundary of the patch – Section 3.2.2.

Step 2:

● Determine the size of the patch as one of three categories: smaller than 0.5 ha; 0.5 ha to 5 ha; or 5 ha or greater.

● Consider the condition of the patch in context of the size category – Section 3.3.1.

a) If the patch that meets key diagnostic characteristics is **5 ha or greater** – and is of any condition – **it is part of the nationally protected ecological community**.

b) If the patch that meets key diagnostic characteristics is **smaller than 0.5 ha** – and is of any condition – **it is not part of the nationally protected ecological community**.

c) If the patch that meets key diagnostic characteristics is **0.5 ha up to 5 ha** in size – **conduct an on ground survey to determine its condition and whether it is part of the nationally protected ecological community** (refer to Section 3.3.1 for condition categories).

● Refer to advice on sampling protocol and other considerations during surveys (e.g. seasonality) – Section 3.4.

Step 3:

● The surrounding context of a patch must also be taken into account when considering factors that add to the importance of a patch that meets the size and condition thresholds – Section 3.4.5.

3.2 – Step 1 – Diagnostic characteristics, defining a patch

3.2.1 Key diagnostic characteristics

The ecological community is limited to patches of vegetation (with their associated biota) that meet all of the following key diagnostic characteristics:

- Occurs in the Swan Coastal Plain Bioregion, Western Australia (IBRA v7. Department of the Environment 2012).
- Primarily occurs on the Spearwood and Quindalup dune systems, but can also occur on the Bassendean dunes and Pinjarra Plain. It can occur on the banks of rivers and wetlands.
- The primary defining feature is the presence of at least two living established *Eucalyptus gomphocephala* (Tuart) trees in the uppermost canopy layer, although they may co-occur with trees of other species. There is a gap of no more than 60 m between the outer edges of the canopies of adjacent Tuart trees (refer to Section 3.2.2,

and Figures 3 and 4). These trees may occur either as single stemmed trees or as a mallee growth form.

- Most often occurs as a woodland but can occur in other structural forms, For example, forest, open forest, woodland, open woodland, and various mallee forms (NVIS Technical Working Group 2017).
- Other tree species may be present in the canopy or sub-canopy. They commonly include: *Agonis flexuosa* (Peppermint) and *Banksia grandis* (Bull Banksia) (both in the southern part of the range), *Banksia attenuata* (Candlestick Banksia), *Eucalyptus marginata* (Jarrah); and less commonly, *Corymbia calophylla* (Marri), *Banksia menziesii* (Firewood Banksia) and *Banksia prionotes* (Acorn Banksia).
- An understorey of native plants is typically present, which may include grasses, herbs and shrubs, although this is often modified by disturbance. Some understorey plant species that are most commonly present are listed in Section 2.3.3.
- Native fauna species that are most commonly present are noted in Section 2.4.

3.2.2 Defining a patch of the ecological community

- A patch of the ecological community is a discrete and mostly continuous area of vegetation that meets the key diagnostic characteristics.
- Boundaries for a patch can extend beyond a site or property boundary, or potential area of impact for a proposed action.
- The patch boundary is 30 m beyond the outer canopy of the established Tuart trees (≥15 cm diameter at breast height (DBH)), including dead Tuart trees (stags). See **Figure 3**.
- Where a dead Tuart tree (stag) is being considered for inclusion in a patch of the ecological community, the vertical projection of its outermost remaining branches is used to define the edge of its canopy. If the species of a stag tree is unclear, if the edge of its canopy is within 60 m of an identified Tuart tree the stag is presumed to be a Tuart.
- Patches of Tuart woodlands and forests may contain areas that vary in structural or biological complexity. One part of a patch may have a larger number of mature trees and more ecological diversity, whereas another part of the same patch may demonstrate fewer mature trees and less groundcover. Areas with soil exposed and/or plant litter can also be expected within this ecological community.

  Variation in quality or condition of vegetation across a patch should not necessarily be considered to be evidence of multiple patches. Patches of the ecological community can be spatially variable and are often characterised by one or more areas within a patch that meet higher condition thresholds amongst areas of lower condition.

  If an area meets the key diagnostic characteristics but the average condition across that area falls below the minimum condition thresholds, the largest area or areas of at least 0.5 ha that meet minimum condition thresholds on average, should be specified as the patch or patches of the nationally listed ecological community. This may result in multiple patches of the ecological community being identified within the overall area first identified as meeting the key diagnostics.
- A patch may include small areas without understorey vegetation, such as bare ground, as well as waterbodies or hardscape (e.g. roads, paths, car parks, or buildings) that do not significantly alter the overall function of the ecological community. These small areas do not break up a patch, or divide a patch into multiple patches, as long as there

are some parts of the canopy within 60 m of the outer edges of the canopies of adjacent Tuart trees (as per Section 3.2.1, and **Figure 3**). However, existing buildings and other human-made structures and gardens are not part of the nationally protected ecological community and should be excluded from the calculation of patch size and condition. See **Figure 4**.

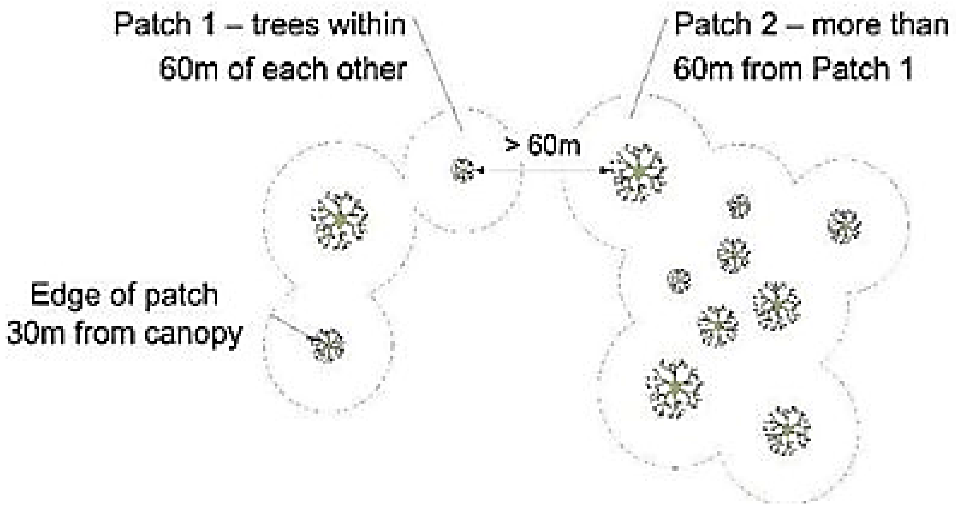

Figure 3. Patch boundaries

Patches of the ecological community extend to 30 m beyond the outermost canopy of the Tuart trees.

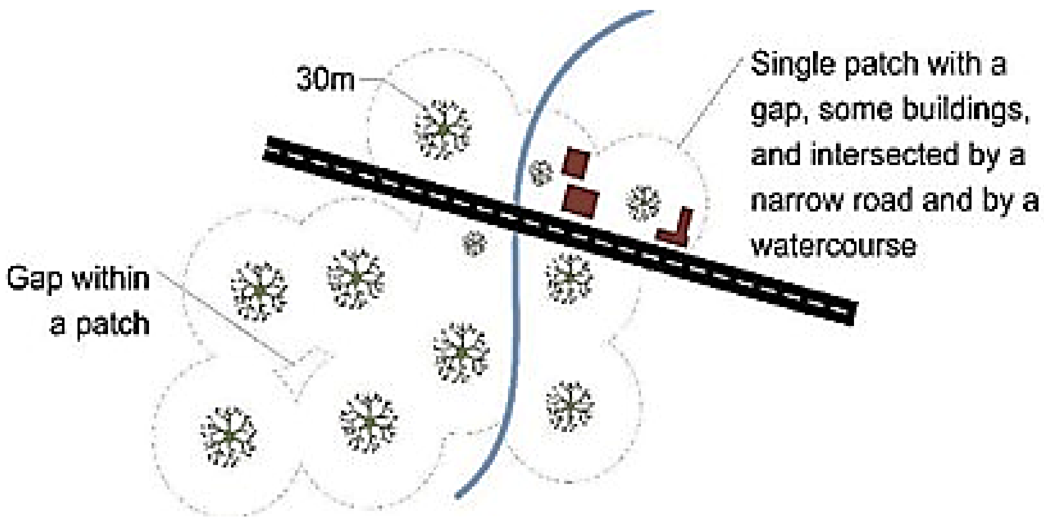

Figure 4. Variation within a patch, including small areas without understorey vegetation, and a small gap within a patch due to part of the Tuart canopy being >60 m apart.

3.2.3 Relationship with other ecological communities

The ecological community intergrades and/or interacts with other ecological communities of the Swan Coastal Plain, including some listed under national environment law:

- Banksia woodlands of the Swan Coastal Plain (Department of the Environment and Energy 2016) – where Tuart occurs as an occasional emergent above a stratum dominated or co-dominated by Banksia species including *Banksia attenuata*, *B. menziesii* (Firewood Banksia), *B. prionotes* (Acorn Banksia) or *B. ilicifolia* (holly-leaved Banksia) the patch is likely to meet the diagnostic characteristics for the Banksia woodlands of the Swan Coastal Plain. This is not common and most likely on Spearwood formation dunes.
- Sedgelands in Holocene Dune Swales (Department of the Environment 2016a) – this ecological community occurs in linear damplands, typically waterlogged in winter. Characteristic species include shrubs such as *Acacia rostellifera* (Summer-scented Wattle), *Acacia saligna* (Orange Wattle), *Xanthorrhoea preissii* (Grass Tree, Balga) as well as sedges and grasses. Typically the ecological community has a more open structure than Tuart woodlands and forests, but at mature sites a closer tree canopy may develop, including Tuart or *Banksia littoralis* (swamp Banksia) trees, which may meet the diagnostic characteristics for the Tuart woodlands and forests ecological community. This is not common and most likely in the areas between dunes on the Quindalup formation.
- Aquatic root mat community of caves of the Swan Coastal Plain (Department of the Environment 2016b) – at sites including Yanchep National Park, some groundwater fed streams and pools occurring in caves support dense root mats of Tuart trees. These root mats support a highly diverse and distinctive assemblage of cave fauna. It is likely that this ecological community occurs directly below some occurrences of the Tuart woodlands and forests ecological community. There are strong interactions between the two ecological communities and it is likely also that disturbance to either surface vegetation or groundwater may affect both ecological communities.

Appendix F.3 Relationship with other threatened ecological communities, also lists other ecological communities that occur on the Swan Coastal Plain (as at July 2018).

3.3 – Step 2 – Condition thresholds and categories

For confirmed patches of the ecological community, following the key diagnostic characteristics and patch definition above (Step 1), determine the following requirements for information on condition to indicate if they are part of the **nationally protected ecological community**:

- If the **patch is smaller than 0.5 ha** it is **not part of the nationally protected ecological community.**
- If the **patch is at least 0.5 ha and up to 5 ha** in size, conduct on ground surveys (see Section 3.4.3) to determine which condition category applies, referring to Section 3.3.1. Patches in this size range are presumed to be part of the nationally protected ecological community unless surveys indicate they do not meet the minimum condition required for national protection. For patches in this size range inclusion in the nationally protected ecological community is determined by surveyed characteristics such as native plant species richness and contribution to cover, habitat values, evidence of regeneration and landscape characteristics.
- **All patches of 5 ha or greater** that meet the key diagnostic characteristics **are part of the nationally protected ecological community**. It is not necessary to conduct additional surveys to confirm that they meet biotic condition thresholds (Table 2) and that they are protected. However more detailed survey may assist in environment impact assessment, planning and monitoring management, or in determining relative biodiversity value between and within different large patches (e.g. to be used in prioritising conservation works etc.). Patches of this size that meet the key diagnostic characteristics provide important contributions to local biodiversity, habitat features and contribute to ecological connectivity of the ecological community and other surrounding ecological communities. Larger patches are likely to be more resilient to some kinds of disturbance and native species loss associated with fragmentation. These characteristics are all important for the long term resilience of the ecological community across its range.

The measurement of condition using the approach of Keighery (1994) is commonly used in Western Australia. This approach emphasises the effects of disturbance on characteristics such as structure. The approach used in this Conservation Advice considers some similar characteristics but applies thresholds for characteristics such as plant species richness and landscape features to determine if an area is part of the nationally protected ecological community. Surveys conducted using the Keighery condition scale are likely to provide much of the information required to determine whether a patch meets the threshold condition for inclusion in the nationally protected ecological community. Plant surveys conducted during spring are recommended as they may more easily identify plants in the ecological community (see Section 3.4.3).

3.3.1 Condition categories and thresholds for patches of Tuart woodlands and forests

Table 2. Condition categories and thresholds

All patches ≥5 ha are part of the nationally protected ecological community, regardless of their understorey condition. That is, thresholds in this table do not apply to patches ≥5 ha, but the key diagnostic characteristics and patch definition must be met.

Patch size → **Biotic thresholds ↓**	**≥2 ha <5 ha**	**≥0.5 ha <2 ha**
Very high condition ≥80 % of all understorey^ vegetation cover is native# Or At least 12 native understorey^ species per 0.01 ha (10 m x 10 m plot or equivalent sample unit)	Medium sized patches with very high condition understorey. PART OF THE PROTECTED ECOLOGICAL COMMUNITY	Smaller patches with very high condition understorey. PART OF THE PROTECTED ECOLOGICAL COMMUNITY
High condition ≥60 % of all understorey^ vegetation cover is native# Or At least 8 native understorey^ species per 0.01 ha (10 m x 10 m plot or equivalent sample unit)	Medium sized patches with high condition understorey. PART OF THE PROTECTED ECOLOGICAL COMMUNITY	Smaller patches with high condition understorey. **AND** That either: have an important landscape role (≤100 m to native vegetation)* OR have a habitat role (≥2 very large trees per 0.5 ha)* OR show regeneration (≥15 seedlings and/or saplings per 0.5 ha)* PART OF THE PROTECTED ECOLOGICAL COMMUNITY
Moderate condition ≥50 % of all understorey^ vegetation cover is native# Or At least 4 native understorey^ species per 0.01 ha (10 m x 10 m plot or equivalent sample unit)	Medium sized patches with moderate condition understorey. **AND** That either: have an important landscape role (≤100 m to native vegetation)* OR have a habitat role (≥2 very large trees per 0.5 ha)* OR show regeneration (≥15 seedlings and/or saplings per 0.5 ha)* PART OF THE PROTECTED ECOLOGICAL COMMUNITY	<u>NOT</u> PART OF THE PROTECTED ECOLOGICAL COMMUNITY (but may be a focus for local protection or restoration)
Poor Has minimal or no native cover and species richness. That is: <50 % of all understorey^ vegetation cover is native# And Less than 4 native understorey^ species per 0.01 ha (10 m x 10 m plot or equivalent sample unit)	<u>NOT</u> PART OF THE PROTECTED ECOLOGICAL COMMUNITY (but may be a focus for local protection or restoration)	<u>NOT</u> PART OF THE PROTECTED ECOLOGICAL COMMUNITY (but may be a focus for local protection or restoration)

^ * – Table notes follow on the next page.

#'Native' refers to species naturally occurring in southwest Western Australia.

^ Understorey vegetation cover includes annual and perennial vascular plant species of both the ground layer and the shrub layer up to 3 m in height.

* Indicators of important landscape, habitat or regeneration features:

> Landscape – the patch occurs in close proximity (≤100 m) to another patch of native vegetation of at least 1 ha in size. Other patches of native vegetation can be other patches of the ecological community and/or other vegetation where ≥50 % of the vegetation cover across all layers is comprised of plant species naturally occurring in southwest Western Australia.
>
> OR
>
> Habitat – the patch contains a mean of ≥2 very large trees (≥50 cm DBH) per half hectare of any species native to southwest Western Australia.
>
> OR
>
> Regeneration – the patch displays evidence of natural regeneration of eucalypts (*Corymbia* or *Eucalyptus*) naturally occurring in southwest Western Australia, represented by seedlings, saplings or other sub-mature stages (<15 cm DBH) with at least a mean of 15 individuals per half hectare.

3.4 – Step 3 – Further information to assist in identifying patches of the protected ecological community and avoiding significant adverse impacts

Land use history and disturbance influences the state of vegetation, while the structural form and substrate of the ecological community also affects its species richness and diversity. For example, the frequency and intensity of fire may influence the level of cover or floristic assemblage. The landscape position of the patch, including its position relative to surrounding vegetation also influences how important it is in the broader landscape, for example, if it enables movement of native fauna or plant material or supports other ecological processes.

3.4.1 Buffer Zone

A buffer zone is a contiguous area adjacent to a patch that is important for protecting the integrity of the ecological community. As the risk of damage to an ecological community is usually greater where actions occur close to a patch, the purpose of the buffer zone is to minimise this risk by guiding land managers to be aware that the ecological community is nearby and take extra care. For instance, the buffer zone will help protect the root zone of edge trees and other components of the ecological community from physical damage from earthworks, spray drift (fertiliser, pesticide or herbicide sprayed in adjacent land), weed invasion, water runoff and other damage.

Native vegetation that surrounds or adjoins the patch forms an ideal buffer, so its retention would assist the viability of the ecological community. In such cases, the whole vegetation remnant can effectively act as a buffer around discrete, smaller patches of the ecological community.

The buffer zone is not itself part of the ecological community, so while having a buffer zone is strongly recommended, it is not formally protected as a Matter of National Environmental Significance. However, for national environment law approval, changes in use of the land that falls within the buffer zone must not have a significant impact on the ecological community. As for a patch of the ecological community, there are exemptions under national environment law for continuing use within the buffer zone (e.g. long-term ongoing cropping, grazing or maintaining existing fire breaks may be exempt). If the use of an area that directly adjoins a patch of the ecological community will be intensified, approval under national environmental law may also be required to avoid significant adverse impacts. The buffer zone may also be a suitable focus for revegetation or other restoration initiatives.

The recommended minimum buffer zone is 30 m from the outer edge of the patch (the patch boundary being defined as 30 m past the canopy of established Tuart trees, so the minimum buffer is 60 m past the canopy). This distance accounts for likely influences upon the root zone. A larger buffer zone should be applied, where practical, to protect patches that are of very high conservation value or if patches are located below drainage lines or a source of nutrient enrichment or groundwater drawdown, as Tuart trees are considered likely to be vulnerable to rapid change in groundwater conditions.

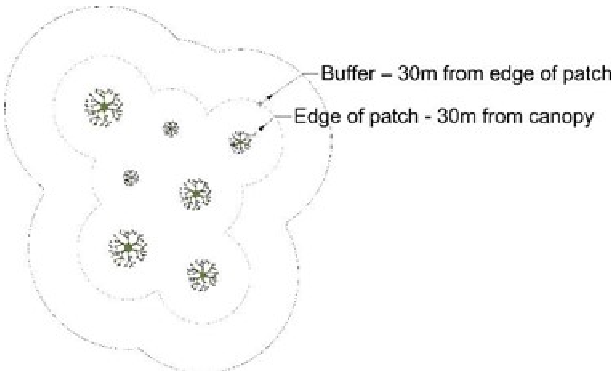

Figure 5. Buffer around patches

The minimum recommended buffer zone extends to 30 m beyond the patch.

3.4.2 Revegetated areas and areas of regrowth

Restoration of ecological communities requires long term effort and commitment, and results are uncertain (Standards Reference Group SERA 2016). If revegetated sites meet the key diagnostics and minimum condition thresholds for the Tuart woodlands and forests they are part of the nationally protected ecological community. Consistent with the key diagnostics, sites outside of the described natural range of Tuart woodlands and forests are not part of the nationally protected ecological community.

3.4.3 Sampling protocol

Whilst defining the patch boundary and determining if any of the patch meets the minimum condition thresholds can be relatively simple, more detailed assessment of the patch may be desirable for monitoring or management purposes, or be required for environmental approval processes. In these cases, thorough and representative on-ground surveys help to assess the extent and condition of the ecological community. Publications related to field survey such as Keighery (1994), Casson et al (2009) and the Australian Soil and Land Survey Field Handbook (National Committee on Soil and Terrain 2009) may provide guidance in some aspects.

Begin by reviewing maps and aerial imagery of the site and surrounding landscape context, as well as available information on management history and features such as flora and fauna species likely to be present. Where possible, walk around the site to help determine the patch boundary and native vegetation (including but not limited to Tuart woodlands and forests) in proximity of the patch (≤100 m), as this may provide important landscape connections. Walk through the site observing the vegetation structure and floristics (including understory cover and diversity), landscape qualities, proximity or connectivity to water (for fauna), areas of vegetation recruitment and likely habitat features such as tree hollows.

Determine the sampling plan to thoroughly represent the range of variation in vegetation structure and species present across the patch. In patches that have highly variable condition, divide the patch into areas that have more even condition. In locating sample plots, include areas with the maximum apparent native plant species understorey cover and diversity, areas with large trees or vegetation recruitment (seedlings or saplings). Sample adequately to cover each of these areas.

Sampling of species richness should be based on plot sizes of at least 100 m² (= 0.01 ha, 10 m x 10 m or an appropriate shape of equivalent size). Cover could be sampled throughout these plots, along transects, or by other methods that adequately represent the patch. Where areas are large or variable, more samples will be needed to accurately represent the patch. Record the search effort (identifying the number of person hours per plot and across the entire patch; along with the surveyor's level of expertise), with any rationale for the selection of plots and allocation of survey effort.

To assess attributes from the condition thresholds (Table 1), record all native species present in the understorey, any very large trees (≥50 cm DBH), and, any evidence of recruitment of eucalypts (seedlings, saplings or other juvenile trees in the genera *Eucalyptus* or *Corymbia*).

In measuring condition thresholds, areas that meet the key diagnostics are assumed to be the nationally protected ecological community unless survey effort is sufficient to show that the condition is poor enough to drop below the relevant threshold.

3.4.4 Timing of surveys, seasonal variation and post-disturbance surveys

Timing of surveys is an important consideration because the ecological community can vary in its appearance through the year and between years, depending on climatic conditions and other variables such as disturbance. Surveys should be timed to maximise detection of native species and ideally, surveys should be held in more than one season. Many species are easiest to detect or identify in spring when many are flowering and reproducing (Casson et al 2009). At least one hour per plot in early to mid-spring and a second survey in late spring may be required to detect the majority of species. Some annual weeds may be at maximum cover at other times, so additional surveys may detect these.

When conditions are adverse, for example, during drought, some plants may not flower, or leaves may not emerge. In years of low rainfall, assessors should recognise that many species may not be detected. In these situations it is preferable that surveys are carried out over more than one year.

In addition to the effects of variable rainfall, presence and detectability of some species may also be affected by the time since more severe disturbances such as fire.

After a disturbance event, for example fire, storm damage, disease outbreaks, severe hydrological change or 'Tuart decline', the presence of the ecological community is indicated by any information available on the pre-disturbance state, as well as evidence present at the site, for example, tree stumps, fallen logs and stags. Evidence of the pre-disturbance state may also include, for example, earlier surveys or vegetation mapping, photographs or literature and/or proximity (≤ 100 m) to native vegetation that meets the key diagnostic characteristics of the ecological community. Where a recently disturbed site is likely to be the

Tuart woodlands and forests ecological community, surveys should be delayed until there has been opportunity for regeneration (ideally this would be at least 2 years after the disturbance event, and at least 2 months after adequate rainfall to initiate some recovery). During this period of recovery from disturbance, all patches of 0.5 ha or larger that were previously identified or likely to have been identified as the ecological community are considered to be part of the nationally protected ecological community.

3.4.5 Other guidance for impact assessment and mitigation

Actions that may have a ‘significant impact’ on any patches of the ecological community that meet the key diagnostic characteristics and meet the minimum condition and size threshold requirements must be considered under national environment law. Therefore an action that may have a ‘significant impact’ on the ecological community should be referred to the Australian Government for assessment. The ecological importance of a patch is influenced by its surrounding landscape, for example, if it is connected to, or near other native vegetation, the patch may contribute substantially to landscape connectivity and function.

Land use history influences the state of vegetation, while the structural form of the ecological community also affects its species richness and diversity. For example, the frequency and intensity of fire may influence the level of cover or floristic assemblage.

Similarly, actions beyond the boundary of any patch may have a significant impact on the patch (for example, through changes in hydrology). For this reason, when considering actions likely to have impacts on this ecological community, it is important to also consider the environment surrounding any patches of the ecological community that meet the condition requirements.

Other patches that meet the condition requirements may occur in isolation and in addition to requiring protection, may also require management of the surrounding area to improve their ecological function.

In some cases patches do not currently meet condition requirements, and so are not recognised as part of the nationally protected ecological community (i.e. they are not a Matter of National Environmental Significance). However, recovery of these patches may be possible and therefore should be considered as a priority for management and funding or for inclusion in buffer zones.

The following indicators should be considered both when assessing the impacts of actions or proposed actions under national environment law, and when considering priorities for recovery, management and funding.

- Large size and/or a large area to boundary ratio. Patches with larger area to boundary ratios are less exposed to edge effects (such as disturbances such as weed invasion) and may be more resilient. However, patches that occur in areas where the ecological community has been most heavily cleared and degraded, or that are at the natural edge of its range, may also be important due to their rarity, genetic significance, or because of the absence of some threats.
- Evidence of recruitment of key native plant species or the presence of a range of age cohorts (including through successful assisted regeneration). For example, tree canopy species are present in a range of sizes from saplings to large hollow-bearing trees.
- Good faunal habitat as indicated by, for example, diversity of landscape including a variety of substrate types and/or access to water.
- Patches that contain a unique combination of species and/or rare or important species in the context of the particular ecological community or local region (for example, a patch with

unique fauna and/or understorey flora composition; or a patch that contains flora or fauna that has largely declined in the broader ecological community or region).

- High native species richness, possibly including many understorey plant species or native fauna species.
- Presence of threatened species listed under Western Australian or national environment law.
- Presence of cryptogams, soil crust and leaf litter or intact proteaceous root mats on or close to the soil surface where this is indicative of low disturbance.

Connections to other native vegetation remnants or restoration works (e.g. native plantings), in particular, if a patch is in an important position between (or linking) other key patches in the landscape or in providing access for fauna to water. Connectivity can contribute to movement of fauna and transfer of pollen and seeds. In locations where the landscape is generally cleared, roadside remnants may play a role in connecting remnant patches, although these areas can be subject to high disturbance along their edges.

3.5 Area critical to the survival of the ecological community

The Tuart woodlands and forests ecological community has been either heavily cleared and/or degraded across much of its range. Some remnants are small and isolated, while others are larger and yet have been heavily modified and subject to ongoing threats such as weed invasion and frequent burning. Given the high rates and loss of the ecological community across its range, all remnants contribute, but not all are protected as Matters of National Environmental Significance. Areas that are included within secure conservation reserves are very important to the survival of the ecological community. Improving the formal conservation reserve system is thus a priority, and large patches that are not yet reserved are likely to be of particular importance. Across some parts of the range, for example, in the Perth metropolitan area, clearing and fragmentation has been particularly severe. Retaining connectivity here is important, as genetic studies and early observations suggest that the distribution of the central and southern extent was once mainly continuous (Gardner 1979; Coates et al 2002). Particularly in this central area, even small patches may play an important role in retaining ecological connections (e.g. as 'stepping stones' between native vegetation and/or water). Some of the other characteristics to be considered in identifying other areas of particular importance are identified in Section 3.4.5. Some patches of the ecological community have particular local importance, provide critical habitat for species that are part of the ecological community or play other important landscape roles. Areas that meet the key diagnostic characteristics but not the minimum size and condition thresholds can also contribute to recovering the integrity of the ecological community, but are not themselves Matters of National Environmental Significance. Populations of many species are likely to be present across boundaries or ecotones between the ecological community and other native vegetation types, thus, retaining other nearby native vegetation is also important to the integrity of the ecological community.

3.6 Relationship with other vegetation classification systems

Across Australia and within Western Australia, several systems are used to classify ecological communities and vegetation types. This can create challenges of comparison as systems may emphasise different characteristics and vary in precision and accuracy, particularly if the distributions are modelled or mapped at coarse scales. The vegetation types defined and mapped provide an indication of where the Tuart forests and woodlands ecological community described in this conservation advice may have occurred before European occupation and currently, as well as characteristics such as likely condition. However, these mapped vegetation types may not be exactly equivalent to the ecological community so reference to these vegetation and mapping units should be taken as indicative rather than definitive of the ecological community. When considering whether the nationally protected ecological community is present at any site, focus on whether the patch meets the description, particularly the key diagnostic characteristics and minimum condition categories for the ecological community.

There are various iterations of the broad scale mapping of land systems and vegetation on the Swan Coastal Plain (in particular, the 'Beard maps': Beard et al 1979; 1981 widely cited including Hopkins et al 1996; Keighery et al 2002), which have been subsequently incorporated into the National Vegetation Information System (NVIS) (Department of the Environment and Energy 2018). Other approaches to vegetation classification in the region include Floristic Community Types (Gibson et al 1994), which are generally identified only as point locations and 'Vegetation Complexes'(Heddle et al 1980; Mattiske and Havel 1998), which incorporate landscape and vegetation characteristics. The most specific mapping of Tuart trees across their extent occurred through the 'Tuart atlas' maps (Tuart Response Group 2003).

In estimating the likely pre-European extent of the ecological community expert interpretation of existing Beard Vegetation Association maps for the Swan Coastal Plain has been utilised. The likely level of Tuart vegetation has been attributed to the mapped areas based on knowledge of the landscape and current vegetation. Areas identified as having 'strong' or 'moderate' Tuart dominance have been included in the estimate of the pre-European extent of the ecological community. Areas identified as having a 'weak' level of Tuart dominance were excluded (Department of Biodiversity, Conservation and Attractions 2017a).

For further information on vegetation classification in the vicinity of the ecological community see APPENDIX F – ADDITIONAL INFORMATION ON LANDSCAPE, CORRESPONDING VEGETATION UNITS, ECOLOGY AND BIOLOGY AND MANAGEMENT.

3.7 Existing protection

3.7.1 Formal reservation and conservation management

The estimates of protected areas of Tuart woodlands and forests vary somewhat dependent on the methods for quantifying extent, as well as the classes of land included, which may include a variety of levels of protection as well as various priorities for their management.

Of the indicative current extent of the ecological community, approximately 5700 ha has been reserved by the Government of Western Australia in 22 reserves (IUCN management categories I-IV) (analysis of Department of Biodiversity, Conservation and Attractions, 2017a, Tuart Response Group 2003 and Department of the Environment and Energy 2017a). This is 22% of the remaining extent of the ecological community and 5% of the estimated pre-European extent of the ecological community.

State owned or managed reserves in which the ecological community is likely to be found include Lake Joondalup Nature Reserve, Neerabup National Park, Tuart Forest National Park, Woodvale Reserve, Yalgorup National Park and Yanchep National Park (Department of the Environment and Energy 2017a).

The Tuart Response Group (2004) identified that the Tuart woodlands and forests on private land typically have poorer condition than those in conservation reserves noting that private land provides the 'lowest security of conservation purpose'. Of the areas identified as having the best condition understorey, 65% were found in parks, forests and reserves managed for conservation.

While a substantial proportion of the remnants of the ecological community with the best condition are in conservation reserves, these areas are not immune to threats such as weed invasion, fire and 'Tuart decline'. This is demonstrated by the rapid loss of condition of the Tuart woodlands and forests in Yalgorup National Park through 'Tuart decline' during the 1990s (Longman & Keighery 2002; Tuart Response Group 2002; 2004)).

3.7.2 National environment law protection through Ramsar listing

The ecological community can occur on the margins of wetland and riverine areas. It is known to occur in at least three sites protected under the Ramsar Convention. Approximately 223 ha of the ecological community occurs within the Vasse-Wonnerup System Ramsar site and 2317 ha in the Peel-Yalgorup System Ramsar site and 40 ha at the Thompsons Lake Nature Reserve which is part of the Forrestdale and Thomsons Lakes Ramsar site. This is a total of 2 580 ha, which is approximately 10% of the current extent of the ecological community (Commonwealth of Australia 2015a). Some wetland birds present at the sites, such as Australian Wood Duck and Australian Shelduck are known to use hollows of nearby trees, including Tuarts, for nesting. At the Vasse-Wonnerup site families of ducks have been observed moving from the Tuart forest to the wetlands (Conservation Commission of Western Australia 2005; Hale and Butcher, 2007; Wetland Research and Management, 2007).

3.7.3 Protection through State/Territory legislation

The State owned and managed conservation reserves mentioned above are protected and managed under the *Conservation and Land Management Act 1984* which provides for the conservation, protection and management of lands and of biodiversity. In Western Australia, the *Biodiversity Conservation Act 2016* enables the identification and listing of threatened ecological communities. As at July 2018, Tuart woodlands and forests have not been listed as a threatened ecological community. Some ecological communities are also identified as 'priority'. Following its inclusion in the Commonwealth Finalised Priority Assessment List, in November 2016 the ecological community was recognised by the Western Australian Government as Tuart (*Eucalyptus gomphocephala*) woodlands of the Swan Coastal Plain and listed as a Priority 3(iii) ecological community (Department of Biodiversity Conservation and Attractions, 2017b). Previously, some more specifically defined ecological communities containing Tuart were included on the priority list. Following the Floristic Community Types methods of Gibson et al (1994), these are: Quindalup *Eucalyptus gomphocephala* and / or *Agonis flexuosa* woodlands ('community type 30b') and Southern Swan Coastal Plain *Eucalyptus gomphocephala – Agonis flexuosa* woodlands (type 25). There is also a smaller association with "Northern Spearwood shrublands and woodlands ('community type 24') (priority 3) (Department of Biodiversity, Conservation and Attractions 2017b).

3.7.4 Listed threatened flora and fauna species

The ecological community provides habitat for a range of flora and fauna species listed under the *Wildlife Conservation Act* (Western Australia, 1950) and/or national environment law (see Table 3. Threatened and priority flora and fauna).

Table 3. Threatened and priority flora and fauna

Threatened and priority flora and fauna that may occur (or have formerly occurred) in the ecological community.

Scientific names and listing status are current at May 2018.

Sources: Rottnest Island Authority (undated); Western Australian Herbarium (1998-_); Abbott (2001);Keighery (2002); Keighery and Keighery (2002) p. 144; Wetlands Research and Management (2007); Morris et al (2008); Abbott (2009); Department of Parks and Wildlife (2014a); Department of Parks and Wildlife (2016); Department of Parks and Wildlife (2017a), Department of Environment and Energy (2016); Keighery and Keighery pers comm (2018).

Scientific Name	Common Name	Noongar name(s) (may vary with location)	EPBC Act* listing category	WA Declared Rare Flora, Fauna or priority taxa*	Notes
Flora					
Acacia benthamii				Priority 2	
Caladenia huegelii	Grand Spider Orchid		E	Declared Rare Flora (CE)	
Cardamine paucijuga				Priority 2	
Conostylis pauciflora subsp. *pauciflora*	Dawesville Conostylis			Priority 4	Occasionally occurs in Tuart woodland
Dodonaea hackettiana	Hackett's Hop Bush			Priority 4	
Eryngium pinnatifidum subsp. *Palustre*	Blue Devils			Priority 3	
Haloragis aculeolata				Priority 2	Poorly collected. Occasionally occurs in Tuart woodland
Jacksonia sericea	Waldjumi			Priority 4	
Lasiopetalum membranaceum				Priority 3	Largely confined to Tuart dominated communities
Pimelea calicola				Priority 3	

Scientific Name	Common Name	Noongar name(s) (may vary with location)	EPBC Act* listing category	WA Declared Rare Flora, Fauna or priority taxa*	Notes
Sarcozona bicarinata				Priority 3	Uncommon until after fire then locally abundant. On Swan Coastal Plain largely confined to Tuart woodlands (Keighery 2002)
Stenopetalum robustum					Only record on Swan Coastal Plain is from Tuart Forest Reserve.
Veronica stolonifera					Only known from a few records on the Quindalup and Spearwood Dunes between the Tuart Forest Reserve and Yanchep. Appears rare.
Fauna					
Birds					
Calyptorhynchus baudinii	Baudin's Cockatoo	*ngolak*	E	E	
Calyptorhynchus latirostris	Carnaby's Cockatoo	*ngolyenok*	E	E	
Calyptorhynchus banksii naso	Forest Red-tailed Black Cockatoo	*karak*	V	Vu	

Scientific Name	Common Name	Noongar name(s) (may vary with location)	EPBC Act* listing category	WA Declared Rare Flora, Fauna or priority taxa*	Notes
Tyto novaehollandiae novahollandiae	Masked Owl (southwest)			Priority 3	
Mammals					
Bettongia penicillata ogilbyi	Brush-tailed Bettong/ Woylie	*woylie, woli,wol*	E	CE (regionally extinct)	
Dasyurus geoffroii	Western Quoll	*chuditch, djooditj*	V	Vu	
Isoodon obesulus fusciventer	Southern Brown Bandicoot (southwest), Quenda	*quenda*		Priority 4	
Phascogale tapoatafa wambenger	Southwestern Brush-tailed Phascogale	*wambenger, balat, balawa, koming*		CD	
Hydromys chrysogaster	Water Rat, Rakali	*ngoodjo, modit, ngwiridjin, wamp, ngangaritj*		Priority 4	
Falsistrellus mackenziei	Western False Pipistrelle			Priority 4	
Pseudocheirus occidentalis	Western Ringtail Possum	*ngwayir,womp, woder, ngoor, ngoolangit*	CE	CE	
Notamacropus eugenii derbianus	Tammar Wallaby	*dama, bonin*		Priority 4 (Formerly present?)	
Notomacropus irma	Western Brush Wallaby	*kwara, koora, guhran*		Priority 4 (Formerly present?)	
Setonix brachyurus	Quokka	*kwoka, quak-a, bungeup, bamgop*	V	V (Formerly present?)	
Myrmecobius fasciatus	Numbat	*noombat, walpurti, wioo*	V	E (Formerly present?)	

Table continued on next page

Scientific Name	Common Name	Noongar name(s) (may vary with location)	EPBC Act* listing category	WA Declared Rare Flora, Fauna or priority taxa*	Notes
Reptiles					
Ctenotus ora	Coastal Plains Skink			Priority 3	
Lerista lineata	Perth Slider		Under assessment	Priority 3	
Neelaps calonotos	Western Black striped Snake			Priority 3	

*Threat categories: CE **=** Critically Endangered; E = Endangered; V = Vulnerable; CD = conservation dependent

**Priority flora and fauna definition for Western Australia. Reproduced from Department of Parks and Wildlife (2017b)

"Possibly threatened species that do not meet survey criteria, or are otherwise data deficient, are added to the Priority Fauna or Priority Flora Lists under Priorities 1, 2 or 3. These three categories are ranked in order of priority for survey and evaluation of conservation status so that consideration can be given to their declaration as threatened flora or fauna.

Species that are adequately known, are rare but not threatened, or meet criteria for near threatened, or that have been recently removed from the threatened species or other specially protected fauna lists for other than taxonomic reasons, are placed in Priority 4. These species require regular monitoring.

Assessment of Priority codes is based on the Western Australian distribution of the species, unless the distribution in WA is part of a contiguous population extending into adjacent States, as defined by the known spread of locations."

Note that a range of other species that may be part of the ecological community listed under the EPBC Act as marine or migratory species. This particularly applies to bird species, including many wetland species.

4. SUMMARY OF THREATS

4.1 Overview

The ecological community occurs within a landscape that has mixed uses, including agriculture, industrial use and housing. Many of the current and future threats to the ecological community are associated with the decreased condition and remaining impacts of the historical disturbance of prolonged grazing and clearing for agriculture (Keighery et al 2002), with urban development and associated infrastructure increasing in its effect on the ecological community in recent decades. With changes in landscape and its management, fire regimes have also changed, while additional biological threats include invasive species, disease and 'Tuart decline' as well as a general lack of recruitment of both canopy and understorey plants.

The primary known threats to the ecological community are listed here in categories, but these threats often interact, rather than act independently.

4.2 Primary threats to the ecological community

For a detailed description of threats, *see Appendix C*

- Clearing and fragmentation of vegetation associated with:
    - Agriculture and grazing
    - Logging and timber removal
    - Urban development and infrastructure
    - Mining and Quarrying
- Invasive flora and fauna:
    - Weeds
    - Invasive vertebrate animals
    - Invasive invertebrate animals
- Tree dieback and pathogens
- Altered fire regimes
- Climate change
- Water extraction and other hydrological change
- Loss of fauna supporting key ecological processes

4.3 Key Threatening Processes

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) provides for the formal identification and listing of 'key threatening processes' (Part 13 Section 183). A threatening process is defined as a key threatening process if it threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community.

The most relevant key threatening processes to Tuart woodlands and forests, as defined at the national level under the EPBC Act as at July 2018 are listed below (Department of the Environment and Energy (2017b):

- Land clearance
- Novel biota and their impact on biodiversity

- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants
- Predation, habitat degradation, competition and disease transmission by feral pigs
- Predation by feral cats
- Predation by European red fox
- Competition and land degradation by rabbits
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*)
- Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases

5. SUMMARY OF ELIGIBILITY FOR LISTING AGAINST EPBC ACT CRITERIA

For the detailed assessment of eligibility against the listing criteria, *see Appendix C*

5.1 Criterion 1 – Decline in geographic distribution

Tuart woodlands and forests originally occupied areas that have been attractive for agriculture, grazing, logging, mining, and urban development. The losses in the area occupied by the ecological community are likely to be ongoing, particularly with urban expansion. Further losses have occurred due to other factors such as Tuart decline.
The estimate of the pre-European area occupied by the ecological community is in the order of 125 400 ha (Appendix B). The current extent is estimated to be in the range of between 17 070 ha and 25 420 ha. Accordingly, the loss in area of the ecological community is estimated to be 80–86%. Due to the very poor condition of some areas and ongoing clearing this is likely to be conservative estimate of loss.

Based on these estimates, the ecological community is considered to have undergone a **severe** decline (defined as at least 70% loss) in its geographic distribution and is therefore eligible for listing as **endangered** under this criterion.

5.2 Criterion 2 – Limited geographic distribution coupled with demonstrable threat

The current extent of occurrence of the ecological community is approximately 389 748 ha (analysis of Department of Biodiversity, Conservation and Attractions 2017a and Tuart Response Group 2003). This reflects a **limited** distribution (<1 000 000 ha).

The area of occupancy of the ecological community, estimated from the current mapped area, is no more than 25 420 ha (as per criterion 1), which is also considered **limited** (<100 000 ha).

The ecological community is fragmented, particularly in the central and northern portions. Within the central part of the range occupied by the Perth metropolitan area, patches are smaller still. Additionally, patches in this central part of the range are located at greater distance from each other than in the other parts of the range. Of the patches identified in the 2003 area of occupancy 64% are less than 10 ha in size. The overall median patch size is 5.2 ha, which is considered overall to be **very restricted** (<10ha).

The primary threats to the ecological community are associated with the location of its range – restricted to the Swan Coastal Plain, which has been heavily cleared and fragmented. Small patches are particularly susceptible to a range of threats that can occur as ‘edge effects’, including weed invasion. Small populations of biota are also inherently vulnerable to extinction. Small patch sizes and large gaps between patches limits the potential for recovery from disturbances such as fire.This is particularly the case in the central part of the range. The commitment to ongoing urban growth across much of this area is severely limiting to the recovery of the ecological community.

Some large sized patches remain in the ecological community and there are additional factors that are not entirely a result of its spatial distribution that may cause loss of integrity of the ecological community within the immediate future (See Criterion 4 in Section 5.4). Given the nature of the distribution of the ecological community and likelihood of ongoing area loss and fragmentation, threats such as invasive species, inappropriate fire and Tuart decline will plausibly lead to its loss within the near future (considered to be 5 generations of *Eucalyptus* *gomphocephala*, up to the threshold of 100 years for this ecological community)[1]. Therefore the ecological community is eligible for listing as **endangered** under this criterion.

5.3 Criterion 3 – Loss or decline of functionally important species

Tuart (*Eucalyptus gomphocephala*) is an important tree canopy species across the range of the ecological community. It is the largest canopy tree species on the Swan Coastal Plain, and naturally lives for up to 350 years (Tuart Response Group 2004). It is likely that most production of viable seed occurs in trees of more than 40 years of age, which is used to define the generation time in assessing this criterion (see Appendix D.3, Criterion 3). Tuart provides the basic structure of the woodlands and forests and is necessary for the retention of the ecological community. The great stature of the tree is also important for the provision of hollows. This has critical importance for a range of species native to the Swan Coastal Plain that also play a functional role in the ecological community.

The overall decline in area of the ecological community is estimated at approximately 80-86% since 1750 (effectively beginning with non-Indigenous land use practices in the 1830s). At the beginning of the 20th Century, Tuart was an important forestry timber. The loss in the estimated area of the Tuart forestry resource in the area between Busselton and Fremantle between 1904 and 2003 was approximately 49 % indicating a substantial decline during that century (Harper et al 1904, Tuart Response Group 2003 and DPAW 2017). In the same area the loss between 1904 and 2015 is estimated as 65 % (DAFWA 2016). Further, comparison of the whole range of the ecological community in 2003 (Tuart Response Group 2003) and in 2015 (Department of Food and Agriculture Western Australia 2016) broadly indicates a loss of up to 32% of area over that 12 year period. Together this indicates that over approximately 110 years (less than three generations of Tuart) there has been a substantial loss in total area occupied by Tuart trees, within the former distribution of the ecological community.

Importantly for this criterion is the loss of mature Tuart trees within the remaining patches. This has occurred through a wide range of events, including thinning and selective logging of large trees; reducing habitat availability; Tuart decline; changed hydrology and extreme weather; impacts of borers and other invertebrates as well as impacts of disease and changed fire regimes. Together with limited successful recruitment to replace these trees this indicates a **severe** decline.

The transformation of many areas of Tuart's former range is permanent, with replacement by urban and industrial environments. This process of transformation is likely to continue with ongoing urban expansion, so there is no possibility that these areas will be restored in the medium-term future.

The loss of Tuart trees has been severe across the ecological community's range, and the ecological community is unlikely to be restored as a whole across its range within the near future so it is eligible for listing as **endangered** under this criterion.

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[1]The key canopy species in the ecological community is *Eucalyptus gomphocephala.* The generation time of this species is used here to define the time frames for potential loss of the ecological community. Individuals of the species are long-lived – up to 350 years (Tuart Response Group 2004) the average age of the trees producing viable seed germinating as seedlings is likely to be greater than 40 years (Jacobs 1955; Florence 1996). The maximum allowable time for five generations of this species (100 years), to define the 'near future' for likelihood of recovery discussed in this criterion is thus applied.

5.4 Criterion 4 – Reduction in community integrity

The integrity of the ecological community has been severely compromised through various types of local damage and broad scale landscape change, including loss of total area, thinning of trees, grazing of understorey, invasion by weeds and feral animals and 'Tuart decline'. Much of the damage is intractable and many of the underlying threats continue. Some types of damage are most pronounced in the central area of the ecological community's range, where Perth is located. The more southerly areas retain greater areas of the ecological community, with some large patches retained in formally protected areas, but these areas have also been susceptible to a range of major landscape threats including widespread invasion by weeds, severe fire events and major damage through 'Tuart decline'. Available data on condition across the range of the ecological community suggests that most sites are degraded or modified.

The damage to the ecological community includes important changes to the structure and floristics, permanent change to the landscape characteristics such as landscape connectivity, reduction in key habitat features such as hollows, and the loss of fauna supporting critical ecosystem functions. Some damage is concentrated in the central part of the ecological community, while other losses of integrity are evident throughout, including in large and important protected areas. The changing climate is an ongoing threat to integrity throughout the region.

Many of the changes to the ecological functions underpinning the ecological community are **very severe** throughout its range and of a long-term nature, with many of the underlying threats continuing. These losses severely compromise restoration of the ecological community as a whole, which is unlikely to occur in the immediate future. Therefore the ecological community is eligible for listing as **critically endangered** under this criterion.

5.5 Criterion 5 – Rate of continuing detrimental change

The ecological community has experienced substantial clearing and fragmentation due to a long history of agriculture, forestry and urban development. While the damage to the understorey and prevention of regeneration related to grazing continues, the current rate of change is difficult to quantify. There is also the possibility of a rapid expansion of Tuart decline, but the likelihood of this is unknown.

The ecological community continues to be cleared for development, and native flora and fauna preyed upon and displaced by weeds and feral animals.

While detrimental change is likely to continue, there is **insufficient information** available specifically on the rates of loss in the recent past, or for the immediate future to determine eligibility for this criterion.

5.6 Criterion 6 – Quantitative analysis showing probability of extinction

No quantitative analysis has been undertaken showing likelihood of extinction for this ecological community. Therefore there is **insufficient information** available to determine eligibility against any category for this criterion.

6. PRIORITY RESEARCH AND CONSERVATION ACTIONS

The conservation objective is to mitigate the risk of extinction of the Tuart woodlands and forests ecological community, and help recover its biodiversity and function by regulating significant impacts and by guiding management and recovery through the recommended priority conservation and research actions identified in the sections below.

6.1 Principles and standards of protection and restoration

It is always more effective to maintain existing remnants of the nationally protected ecological community than to allow their destruction or degradation with the intention of attempting rehabilitation of these or other areas. To meet the conservation objective, it is important to maintain existing areas of the ecological community that are relatively intact and of large and /or at least moderate quality. More intact remnants are likely to retain a fuller suite of native plant and animal species, and ecological functions, and thus likely to maintain their integrity for a longer time. The success in this maintenance is also influenced by other characteristics such as landscape context. It is likely that once some elements of the ecological community have been lost they are not recoverable, for example, through the regional or total extinction of fauna. While the loss of some components or processes underpinning the ecological community may not be immediately visible, their absence may impair the long term function of the Tuart woodlands and forests, for example, by reducing the ecological community's resilience or regenerative capacity.

This principle is highlighted in the National Standards for the Practice of Ecological Restoration in Australia (Standards Reference Group SERA (2016)):

> "**Ecological restoration is not a substitute for sustainably managing and protecting ecosystems in the first instance.**
>
> The promise of restoration cannot be invoked as a justification for destroying or damaging existing ecosystems because functional natural ecosystems are not transportable or easily rebuilt once damaged and the success of ecological restoration cannot be assured. Many projects that aspire to restoration fall short of reinstating reference ecosystem attributes for a range of reasons including scale and degree of damage and technical, ecological and resource limitations."

Standards Reference Group SERA (2016) – Appendix 2.

The principle serves to dissuade 'trade-offs' of higher quality remnants on the basis of plans to set aside and/or restore other, potentially more disturbed, sites. The destruction of relatively intact sites always results in a net loss of the functional ecological community because there is no guarantee of recovery.

Where restoration is to be undertaken, it should be planned and implemented with reference to guidance documents such as the *National Standards for the Practice of Ecological Restoration in Australia* (Standards Reference Group SERA 2016)). These standards outline the principles that convey the main ecological, biological, technical, social and ethical underpinnings of ecological restoration practice. More specific guidance regarding restoration of Tuart woodlands and forests, or information that is regionally specific may also become available. As restoration ecology is continually developing, it is also important to reflect on the experience of others who have worked on restoring the ecological community, as well as adapting restoration projects as site- level experience accumulates.

Restoration of many parts of the ecological community would require substantial and ongoing investment, so it is important to consider the priority actions for funding. To achieve cost-effective investments in conservation management it is important to consider the likely interaction of the various management actions being taken at any one site, as these may be synergistic or antagonistic. There are also likely to be interactions between sites and across regional boundaries. Additionally, when allocating management resources it is important to consider what is the minimum investment required for success and the follow up required to secure long term recovery (for example, for how many years should weed management be repeated).

Involve Traditional Owners early in the process of planning research and conservation actions and where possible, invite members of the Noongar community to be involved in projects.

6.2 Priority conservation actions

This conservation advice identifies a range of priority actions to guide planning of activities to abate threats or assist recovery. The actions are grouped as follows:

PROTECT the ecological community to prevent further loss of extent and condition;

RESTORE the ecological community within its original range by active abatement of threats, re-vegetation and other conservation initiatives;

COMMUNICATE WITH AND SUPPORT researchers, land use planners, landholders, land managers, community members, including the Indigenous community, and others to increase understanding of the value and function of the ecological community and encourage their efforts in its protection and recovery.

RESEARCH to improve our understanding of the ecological community and the best methods to aid its recovery.

This list of actions has been included to provide guidance for

- planning, management and restoration of the ecological community by landholders or regional Natural Resource Management and community groups;
- determining conditions for any approved relevant controlled actions under national environment law; and
- prioritising activities in applications for Australian Government funding programs.

These approaches are overlapping in practice and form part of an iterative approach to management that should include research, planning, management, monitoring and review. More detailed advice on some actions may also be found in other documents, for example, technical advice on weed management. Some relevant documents are listed in Section 6.5. Avoid actions that are inconsistent with these priority conservation activities and are likely to significantly affect the ecological community.

6.2.1 PROTECT

Preventing vegetation clearance and direct habitat degradation

Highest priorities

- Prevent further clearance, fragmentation or detrimental modification of remnants of the ecological community and of surrounding native vegetation, for example, during residential development. The higher condition patches, and older growth areas are particularly important for retention and management.
    - Identify and protect high quality remnants and recognise remnants in important landscape positions (for example, connecting other important patches of native vegetation) in advance of zoning and development planning decisions. Do not commit these high priority areas to clearing and land development. Ensure that planning includes sufficient buffers to avoid impacts on the ecological community from activities in adjacent areas.
    - Include the higher quality remnants or patches in important landscape positions in secure conservation reserves and allocate resources to their management for conservation purposes.
    - Apply local protection methods to important individual trees or locally significant remnants that are not part of the nationally protected ecological community but may contribute to landscape function.
    - Avoid disturbances to soil if likely to affect the ecological community (including the soil seed bank).
    - Apply recommended buffers of at least 30 m around the edges of patches of the ecological community. Wider buffers may be required where larger scale landscape change is occurring, for example hydrological modifications (see Section 3.4.1). Native vegetation provides the most effective buffers.
    - Protect mature trees, particularly with hollows, even if they are dead. Large and old trees provide many kinds of habitat. The relatively large hollows that may form in Tuart trees are particularly important for some species, including threatened cockatoos and possums. Large and old trees can also act as ‘stepping stones’ for fauna moving between remnants in an otherwise cleared landscape or vantage points for raptors. These very large trees may maintain their habitat value for threatened species, even if they do not meet other requirements for identification as a patch of the nationally protected ecological community. They are also important landscape carbon stores.
    - Prevent full or partial loss of isolated patches, for example, those surrounded by built environments, where these are the last remnants of the ecological community within a local area.
- Ensure that planning supports increased resilience within the landscape, for example, by retaining appropriate connectivity between patches of native vegetation and mature paddock trees near patches of the ecological community. Include the areas that form important landscape connections in formal reserve tenure or other conservation related tenure for protection and management in perpetuity. To inform this, some connectivity

mapping for the southern Swan Coastal Plain has been conducted, for example, by Molloy et al (2009).

- Avoid sudden or substantial modifications to hydrology quality and quantity (including groundwater depth and salinity) as these have been associated with decline and death of mature Tuart trees. Should hydrological change occur, monitor the rate and extent of change, as well as ecological indicators such as tree health.

- All possible options for avoiding impacts should be exhausted before mitigation and offsets are considered. Further, it is not appropriate to offset losses to this ecological community with any other ecological community. Further information is in Section 6.4 Offsets.

Other priorities

- Close and rehabilitate unnecessary roads and tracks and otherwise control access for patches that are to be protected and maintained.

- Prevent wood collection (for example, for firewood and fencing) that leads to loss and damage of trees and logs. This includes dead ‘stag’ trees, as these may still play important ecological roles.

- Prevent impacts to native vegetation, native fauna, hydrology, or soil structure from any developments and activities adjacent to or near patches of the ecological community by planning for and appropriately mitigating off-site effects. For instance, apply buffer zones and avoid activities that could cause significant hydrological change or eutrophication.

- Plan new roads, trails, walking or bike tracks, playgrounds and other structures to avoid impacts on patches of the ecological community.

- Retain habitat features for fauna, noting species requirements (for example, large rocks, logs embedded in the soil, hollow logs or tree hollows), or particular vegetation structure (for example, a continuous canopy or sub canopy, particularly of Peppermint is important for Western Ringtail Possum) (Department of Parks and Wildlife 2014b).

- Prior to removal of any trees, or use of heavy machinery that may also damage the understorey, ensure comprehensive flora and fauna surveys have identified threatened species on site and their potential shelter and nesting sites, for example hollows, burrows, rocks and tree crevices, as well as visible nests. Damage to these should be avoided altogether, but if approved for removal, care should be taken to appropriately relocate fauna. Refer to specific guidelines for survey and relocation of fauna likely to be present (for example, Johnstone and Kirkby (2006) recommendations for Carnaby’s and Baudin’s Black Cockatoos).

- Slashing and mowing of community margins if done with care can provide fire protective capabilities. If being used to manage biodiversity, mow in mosaics, avoid Tuart saplings, avoid seeding times and avoid mowing close to the ground. Remove cut material if feasible.

- Monitor tree recruitment and protect areas where there is natural recruitment (for example, use fences or tree guards to manage grazing).

Preventing invasion by weeds, introduced animals, 'Tuart decline', dieback and other diseases

Highest priorities

- Prevent weed invasion and disease spread by minimising soil disturbance.
- Do not plant or enhance the spread or abundance of known, or potential, environmental weeds within or near the ecological community:
    - Prevent dumping of garden waste in or near patches of the ecological community.
    - Prevent activities such as planting potentially invasive species in gardens or other landscaping near the ecological community.
    - Control runoff, for example, during and after road construction, and urban development, to prevent movement of weed material into natural areas.
    - Review the planting schedule for new developments to ensure that potential weeds or other inappropriate plants (e.g. likely to contaminate the local gene pool) are not included.
- Where prescribed burning is planned in a remnant, ensure that a full weed risk assessment has been undertaken prior to the burn and that follow up weed management is budgeted for and implemented in the first and subsequent growing seasons with appropriate monitoring to guide when and where to eliminate weeds.
- Prevent further introduction of non-native and non-Western Australian native animals and contain domestic animals within residential areas (for example, plan, regulate and encourage cat containment areas), especially when new suburbs are approved.
- Use local plants from accredited nurseries (e.g. see the Nursery Industry Accreditation Scheme: Nursery and Garden Industry Australia undated) in rehabilitation areas.
- Use appropriate hygiene to minimise the introduction or spread of weeds and diseases at susceptible sites. For example, keep vehicles and machinery to dedicated roads and out of remnants wherever possible. If vehicles must be taken into remnants ensure vehicles are washed first to remove soil, potential fungal pathogens and weed seeds; ensure that soil and road works use materials such as soil, gravel and water that are free of weeds and disease (such as *Phytophthora*) contamination.
- Implement other preventative measures to avoid spread of disease such as *Phytophthora* dieback, following guidelines such as those from the Dieback Working Group (2013 and the Draft Threat Abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi*, Commonwealth of Australia 2017).

Other priorities

- Prevent stock from carrying weeds into patches of the ecological community. Provide advice and support to landholders to assist with this.
- Monitor patches for local signs of new outbreaks by pathogens such as *Phytophthora* species (for example *P. multivora*), *Armillaria luteobubalina*, rapid increases in populations of invertebrates that affect the health of species that are part of the ecological community

(for example, longicorn beetles), or incursions by new weeds or pest animals, to allow for early management.

- Assist commercial and domestic apiaries to minimise feral bee colonisation of tree hollows and remove existing feral bee colonies

Preventing detrimental fire impacts

- Great care is required when imposing fire in this ecological community e.g. controlled or prescribed burns, particularly due to its vulnerability to post-fire weed incursion and sensitivity of fauna associated with the mature trees. Manage fire appropriately to maintain the integrity of the ecological community. The fire regime may vary according to location, landscape position, fire history, surrounding vegetation and other priorities such as protection of property. Public education, rapid detection and fire suppression strategies to control fire are recommended.

- Fire planning (including for Prescribed Burning): Use a landscape-scale approach and available regionally specific knowledge on fire histories and age of stands, taking into account Indigenous knowledge and results from research to develop fire management strategies that protect, enhance and promote conservation of the ecological community:

    - Identify suitable fire regimes (interval, intensity, and season for fire) at each site considering information such as the maturity and seed production rates, as well as the seed germination requirements by key plant species (in particular understorey species present at any particular site), as well as sensitivities of key fauna). Ensure fire frequencies allow sufficient recovery time for adequate regeneration of both key tree and understorey species, particularly in a drying climate. Substantial fire free intervals (multiple decades) are necessary for the full and ecologically competent regeneration of the ecological community. It is likely that at many sites, to achieve an appropriate fire regime active fire suppression is necessary (Zelinova et al 2002).

    - Identify particular requirements of fauna, for example, habitat required for foraging (including seral stage), alternative habitat to use while patches recover from fire (e.g. mosaic burning) and access to refugia during fire events.

    - Consider fire regimes appropriate for nearby ecological communities when planning burning (for example, where wetlands or threatened Banksia Woodlands are adjacent).

    - Consider weed problems following fires and plan for their management. For example, fire regimes need to be tailored to ensure weed management (ie: ensuring that repeat fires do not occur when soil stored weed seed is most viable, and/or extensive post-fire weed management is required as part of all fire planning). For prescribed burning, ensure that a weed risk assessment and weed management program is planned and budgeted for well ahead of the proposed burning program.

    - Before prescribed burning in or near this ecological community consider other options to achieve the protection of assets. For example, consider alternatives such as biomass control adjacent to key assets; slashing around key assets; weed control to remove flammable components.

    - If the aim of a prescribed burn is to protect property and people a more nuanced, strategically localised approach to the use of fire is recommended where strategic hazard reduction burning is undertaken adjacent to assets to be protected. Specifically note that elevated weed infestation and subsequent increased fire risks will result if weed control is not undertaken.
    - Refer to State Planning Policy 3.7 (SPP 3.7) Planning in Bushfire Prone Areas. SPP 3.7 to assist in planning that will reduce the risk of impacts of unplanned fire to the ecological community, as well as reducing the risk to life and property.
- Fire management (including Prescribed Burning): Manage fires to avoid disruption of the life cycles of component species of the ecological community; to ensure that they support rather than degrade the habitat necessary to the ecological community, to avoid invasion by exotic species, and to avoid increased impacts of other disturbances such as grazing or predation by feral predators. Note that faunal populations in isolated patches may be vulnerable to permanent extinction following fires.
    - Before burning consider soil moisture and weather conditions.
    - Within large patches burn different parts in rotation, rather than the whole area in any one season. Unburnt areas may provide refuge for, as well as source populations for recovery.
    - Avoid physical damage to the habitat and individuals of any threatened species during and after fire operations.
    - Ensure that he season of burning does not have negative impacts on the integrity of the community and understorey, species diversity and natural life cycles of component species, for example do not burn during reproductive seasons of threatened or functionally important species
    - Protect tree hollows, for example by minimising high intensity fires, removing fuel from the base of trees, without damaging understorey plants, and extinguishing fires from the bases of the relevant trees after the fire front has passed. For key habitat tree assets of outstanding ecological value, consider individual tree protective actions such as hand removal of flammable materials from the immediate base of the tree where these materials may preferentially lead to tree loss.
    - Avoid native vegetation removal as part of fire management or creation of new tracks or use of machinery through bushland. Slashing to maintain low native understorey as a fire break is preferred over a mineral earth fire break.
    - Manage grazing levels following fires. In patches with elevated kangaroo numbers and/or stock grazing there is potential for significant impact to post-fire recruitment unless grazing is managed.
    - Monitor outcomes of fire and manage consequences at the appropriate time (for example, monitoring and management of feral predators must take place immediately and be followed up; weed management must also be early and ongoing as in many cases stored soil seed may be dominated by weeds (Fisher et al 2009).

    - Take monitoring results into account when managing future fire regimes. (For further information on monitoring priorities see Section 6.3).

Preventing grazing damage

- Avoid long term grazing at high stocking densities. Persistent grazing can negatively affect understorey species composition and impact on biodiversity (Hobbs 2001).
- Where feasible, fence the highest quality remnants to prevent access by herbivores including stock and native herbivores where present in high densities. In particular, protect regrowth, revegetation areas, or sites with threatened, regionally important or diverse understorey species (fences may need to be specifically designed to exclude macropods). In some cases, increasing connectivity between areas of suitable habitat may reduce the impacts of kangaroos on any one area.
- Ensure that stock do not introduce weed seeds to the patch (also see preventing weeds section above, page 46).
- Use alternative methods such as careful use of herbicides on flammable weeds to reduce fuel loads where this is required.
- Manage populations of feral herbivores that damage native vegetation, including rabbits.
- Ensure that numbers of stock and grazing timing allows regeneration of plants: wherever possible avoid grazing during peak native plant flowering and seeding times (from spring to summer for many species)
- Provide alternative shelter areas for stock, for example, by planting shade trees in nearby cleared areas and moving watering points from within the ecological community to these areas.

6.2.2 RESTORE

Refer to the National Standards for the Practice of Ecological Restoration in Australia to assist in setting goals, planning actions, engaging with interested parties and monitoring outcomes for optimal regeneration, revegetation and restoration strategies for the ecological community, across the landscape (Standards Reference Group SERA 2016). The degree of intervention required for restoration will depend on the condition of the site and the surrounding landscape. Where these are relatively good, natural regeneration may occur with the reintroduction of ecosystem processes (e.g. fire Ruthrof et al 2015) or the removal of the main sources of damage, for example, grazing. At other sites, or for other attributes, more active intervention may be required, for example, weeding or re-introduction of fauna. It is important to have clear goals and targets for restoration and monitor progress. Sites may respond differently dependent on landscape context or conditions such as hydrology or weather, so the approach is likely to require adaptation. Note that in many situations, the goal of complete restoration may not be realistic, and the aim should be to reinstate ecological processes, structure and floristics and native fauna to the extent feasible to allow the ecological community to function and regenerate.

Some patches, which would have been part of the ecological community in the past, are now in modified states that do not meet the key diagnostic characteristics and condition thresholds. These degraded areas are part of the broader ecosystem and may contribute to the genetic diversity of the ecological community or to landscape function.

Where sites are currently not in sufficient condition to be part of the nationally protected ecological community they may have potential for restoration, possibly to a condition that will make them eligible for later inclusion in the nationally protected ecological community. Evidence that an area formerly contained the ecological community can include tree stumps, fallen logs, historical records, photographs, surrounding vegetation remnants, or reliable modelling of vegetation present before 1750.

Re-vegetation and regeneration

Highest priorities

- Identify sites where there are good opportunities for active restoration or natural regeneration, for example, where plantations have been removed.
- Aim to increase the overall extent that meets the description and condition thresholds for the ecological community. Aim to increase condition and appropriate landscape scale connectivity (including with other native vegetation types) in line with the condition categories and thresholds in Section 3.3.1)
- Check sites being rehabilitated for presence of seeds of native species in the soil. Where there is a good range of native seeds present, natural regeneration may be possible if suitable conditions are present (for example, grazing is controlled).
- Consider the landscape context of the source of the seed, as this may influence the suitability of the offspring plants for the restoration site. Where available, use seed collected from nearby sites with similar conditions (e.g. soil and topography) to create an appropriate canopy and diverse understorey.
- Consider historical records and photographs to inform species selection.
- Consider the current physical structure and age classes of vegetation present.
- Consider particularly the needs of Tuart and other species of conservation concern or known to be of functional importance for the ecological community.
- Use of ash beds may increase germination success for some species, including Tuart (Ruthrof et al 2015).
- Following seeding or planting protect from seed predators and herbivores.
- In conjunction with mapping patches of the ecological community, consider the landscape context and other areas of native vegetation to determine priority areas for restoration in each natural resource management region. This should be designed to enhance connectivity and landscape resilience. Some guidance for identifying priority connections for the southern Swan Coastal Plain is provided by Molloy et al (2009), while other tools such as the Western Australian Local Government Association's Environmental Planning Tool service may also assist (http://walga.asn.au/Policy-Advice-and-Advocacy/Environment/Environmental-Planning-Tool.aspx).
- Restore wildlife corridors and linkages (where appropriate) between remnants of the ecological community and other areas of native vegetation or reconstructed habitat, to reduce fragmentation and isolation and assist likely resilience to impacts of climate change.

Other priorities

- Encourage appropriate use of local native species in developments and revegetation projects through local government and industry initiatives. Where information exists to support this, consider giving preference to use seeds and understorey plants that will be resilient to future changes in climate.

- Implement effective adaptive management regimes using information from relevant research.

Restore habitat features

If necessary, supplement, (but do not replace) habitat by placing hollow logs, large rocks or other habitat features in or near to, the ecological community. These may include artificial hollows (e.g. various sized nest boxes) where these are limited or subject to excessive competition (for example, between possum species). This may be particularly important after disturbance such as a severe fire event. Maintain the boxes,

Control invasive species and diseases

Highest priorities

- Map weed occurrence and prioritise management of weeds in high or very high quality patches or where threatened or regionally significant species (e.g. WA priority species) are known to occur. Many of the weeds affecting Tuart are only seasonally apparent (for example, arum lily), so survey should be timed accordingly.
- Implement effective control and management techniques for weeds currently affecting the ecological community. Where weeds may be providing habitat for native species ensure that alternative habitat is available and necessary control of non-native predators is implemented. Small infestations of highly invasive weeds should be a priority for removal.

Other priorities

- Where feasible, control introduced pest animals through consolidated landscape-scale programs, considering flow-on impacts to other animals (such as increased competition).
- Manage weeds after fire, soil disturbance and, during revegetation works.
- Control weeds at the sides of new roads and housing and industrial developments near to the ecological community by targeted herbicide spraying or manual removal for several years after the works are complete.
- Manage occurrences of *Phytophthora* dieback and other fungal diseases such as *Armillaria luteobalina* with reference to specific guidelines (for example see Dieback Working Group, 2013 and the Draft Threat Abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi*, Commonwealth of Australia 2017).
- Ensure actions to control invasive or other pest species avoid impacts on non-target species and do not have any long-term adverse impacts upon the ecological community:
    - ensure workers are appropriately trained in the use of relevant herbicides and pesticides, best methods (for example, spot spraying, wiping, stem injection) and what to target;
    - avoid chemical spray drift and off-target damage within or near to the ecological community, having regard to minimum buffer zones.

6.2.3 COMMUNICATION AND SUPPORT

Education, information and local regulation

- Develop information products and signage to help local communities, industry representatives, planners and managers recognise:
    - when the ecological community is present and why it is important to protect it;

    - how to protect and appropriately manage patches of the ecological community; and
    - responsibilities under state and local regulations and national environment law

- Promote knowledge about local weeds, means to control these and appropriate alternative species to plant.
- Involve Indigenous people early in the process of planning research and conservation actions. Liaise with Noongar people with traditional knowledge of Tuart woodlands and forests, to encourage, where appropriate, sharing and use of the knowledge in protection and management of the ecological community. Create signage recognising Indigenous cultural values in important patches of the ecological community. Refer to representative groups such as Land Council working parties and regional Prescribed Body Corporate organisations for advice on appropriate material to include and wording.
- Develop education programs to discourage damaging activities such as the removal of dead timber, the dumping of rubbish (particularly garden waste),sale and use of weeds (e.g. arum lily) in local nurseries, nearby gardens and landscaping creation of informal paths, and the use of off-road vehicles in patches of the ecological community.
- Refer to traditional owners with experience in fire management and ecological responses. Provide land managers with information about managing fire and weeds for the benefit of the ecological community.
- Liaise with local fire management authorities and agencies and engage their support in fire management of the ecological community. Request these agencies to use suitable maps and install field markers to avoid damage to the ecological community.
- Encourage local participation in recovery efforts, removing threats and actively restoring existing patches, as well as supplementing these. This may be achieved by setting up recovery teams with appropriate expert and local participants; adoption of patches by local conservation groups; or encouraging short term involvement through field days and planting projects, with appropriate follow-up.
    - Ensure planners and participants are aware of appropriate species to plant across the range of the ecological community, the best opportunities to restore landscape connectivity and encourage natural regeneration and the best known techniques for the site conditions and species being planted (Ruthrof et al 2015).
    - Ensure commitment to follow-up after planting, such as care of newly planted vegetation by watering, weeding and use and removal of tree guards.
- Promote awareness and protection of the ecological community with relevant agencies and industries. For example with:
    - state and local government planning authorities, to ensure that planning takes the protection of remnants into account, with due regard to principles for long-term conservation; to ensure activities such as road widening and maintenance (or other infrastructure or development activities) involving substrate or vegetation disturbance do not adversely impact the ecological community.
    - land developers and construction industries, to minimise threats associated with land development;
    - extractive industries such as limestone quarrying companies
    - In new residential developments include measures to limit additional impacts from domestic animals and invasive plants. These may include:
        - public education, including the use of signs to both identify good examples of the ecological community and explain beneficial and detrimental activities;

    - cat exclusion areas;
    - requirements for registering and sterilising cats;
    - requirements for dogs to remain on leash in natural areas;
    - lists of suitable species for gardens to provide habitat and complement natural areas;
    - lists of invasive plant species to avoid planting in gardens.

Incentives and support

- Acknowledge, celebrate and support the efforts of land managers who undertake stewardship to protect and restore the ecological community
- Support opportunities for traditional owners or other members of the Indigenous community to manage the ecological community.
- Implement formal conservation agreements (for example, covenants) for sites containing the highest condition examples of ecological community.
- Develop coordinated incentive projects to encourage conservation and stewardship on private land, and link with other programs and activities, especially those managed by regional Catchment Councils and other Natural Resource Management groups.

6.3 Research and monitoring priorities

Relevant and well-targeted research and other information gathering activities are important in informing the protection and management of the ecological community. It is important to coordinate with individuals and groups that have responsibilities for planning and on ground management to ensure good choices in research questions and methods, and that the information gathered can be applied to the benefit of the ecological community.

It is better to plan monitoring before beginning or changing active management, considering what data will be necessary for the effectiveness of management to be evaluated or to address research questions. It is important to secure resources and establish arrangements for monitoring for the duration of the management activities, especially where a novel approach is used.

High priority research and monitoring activities to inform protection, management and restoration of the Tuart woodlands and forests ecological community include the following (many of which are summarised from Longman and Keighery 2002):

- Improve and update maps of the ecological community across its range:
    - Support field surveys and interpretation of other data such as aerial photographs and satellite images to more accurately document current extent, condition, threats, function, age class representation, floristics and use of the ecological community by regionally significant or threatened species. This may include an update and verification of the 2003 Tuart Atlas (Tuart Response Group 2003). This may include more accurate information on understorey composition and condition across the range of the ecological community. Verifying floristics, status and condition of mapped Tuart patches should be very high priority to facilitate identifying the highest priorities for retention and further conservation actions.
    - Consult with agencies such as local governments to ground truth maps of the ecological community

- Model the pre-European extent across the entire range of the ecological community to inform restoration and reservation for conservation; identify the most intact, high conservation value remnants and gain a better understanding of variation across the ecological community (including the less well recognised mallee form areas).
- The floristic composition of the Tuart woodlands and forests, including in the shrub and ground layer, varies across its range. The floristic community types that are Tuart woodlands and forests have been described for much of the community's range and reflect similarities in geography and soil type (Gibson et al 1994). Some sub-types are likely to be much rarer either due to loss or because they are naturally rare. Identify these through mapping so they can be targeted for conservation efforts.
- Investigate any further occurrences of 'Tuart decline, including mapping and involving multidisciplinary teams to assist in interpretation of causes and development of responses (Longman and Keighery 2002)
- Monitor changes in the extent (and where observable, condition) of the ecological community with high resolution remote sensing at annual intervals.

- Conduct research leading to the development of effective landscape-scale restoration techniques for the ecological community. Investigate the interaction between disturbance types such as fire, grazing and invasion by weeds and feral animals to determine how an integrated approach to threat management can be implemented.

- Research the effects of fire on floristics and structure of vegetation, the persistence of native fauna and flora and invasive species in patches and across the broader landscape:

  - Keep precise records of fire history.
  - Investigate the response of the ecological community (both flora and fauna) to a variety of fire regimes across the range of the ecological community, using an appropriate measure (species composition, populations of key species, etc.) with a monitoring design that aims to improve understanding of the species' response to fire.
  - Identify and publish appropriate fire management regimes to conserve and enhance the species that occur in various parts of the ecological community's range

- Undertake or support ongoing research aimed at managing feral animals and major weeds, such as bridal creeper. Develop biological controls for major weeds.

- Survey for emerging pests such as *Maskiella globosa*

- Assess the vulnerability of the ecological community to climate change, in particular, the reduction in water availability and investigate ways to improve resilience through other threat abatement and management actions.

- Identify groundwater resources likely to be supporting remnants of the ecological community; monitor change to these (for example, depth, seasonality, salinity and nutrient status) and any observable responses in the ecological community (Longman and Keighery 2002)

- Identify characteristics of individual Tuart trees that appear resilient to stress (Longman and Keighery 2002))

- Investigate further the role of various fungi in the ecological community (Longman and Keighery 2002), and the relationship with tree health and other disturbances such as fire.

- Monitor populations of borers and other invertebrates that may affect tree health and investigate the relationship between their populations, tree health and other disturbances such as fire.

- Investigate key ecological interactions, such as the role of fauna in pollination, seed dispersal, control of herbivores and nutrient cycling (Longman and Keighery 2002). Investigate relationships between hydrology, soil, plants, fungi and fauna. In particular, investigate actions, such as the role of fauna in pollination, seed dispersal and nutrient cycling. Also investigate the mechanisms of mammal decline and understanding the ecological role of mycophagous mammals; and decline of other fauna e.g. pollinators.

- Investigate the most cost-effective options for restoring landscape function, including:
    - re-vegetation or assisted regeneration of priority areas, including buffering, connecting and protecting existing remnants.
    - use of fencing to exclude grazing.
    - predator control options such as trapping and baiting, urban containment, exclusion fencing;
    - re-introduction of key fauna such as ecosystem engineers.
- Monitor changes in condition, including response to all types of management actions and use this information to increase understanding of the ecological community and inform recommendations for future management.

6.4 Offsets

Offsets are defined as measures that are intended to compensate for the residual adverse impacts of an action on the environment. The ecological outcomes of offsetting activities are generally uncertain. For instance, when replanting areas there is no guarantee that reconstruction of all layers of the ecological community will be successful and that diversity of flora and fauna, and adequate ecological function can be restored according to the standards outlined by the Standards Reference Group SERA (2016). Further, some of the functions of a replanted woodland or forest site are unlikely to be restored quickly and require longer times to be considered in establishing offsets, for example, large hollows may take centuries to form.

The use of offsets, therefore, should only be proposed as a last resort to compensate for damage to the ecological community that cannot be avoided. All options for avoidance and mitigation should be explored fully before the use of an offset is considered. Ideally, to enable the recovery of the ecological community further extensive clearance and damage should be limited, as it has already been greatly reduced in its extent and condition. Any proposals to offset should refer to the priority actions outlined in this Conservation Advice and ensure that offsets are consistent with the wording and intent of the EPBC Act Environmental Offsets Policy (Commonwealth of Australia 2012).

More specifically:

- Prioritise retention of remaining areas with mature trees and other high quality patches rather than attempt to offset damage to these areas.

- Offset sites must meet the key diagnostic characteristics for the ecological community, but sites used as offsets would not necessarily be expected to meet the minimum condition thresholds for inclusion in the nationally protected ecological community. Management and restoration committed as part of an offsetting agreement may be planned to increase the condition of an offset site so that it meets these minimum thresholds and becomes part of the nationally protected ecological community.

- Offset sites should be as similar as possible to the impact sites, recognising that the ecological community is variable across its range:
    - Location – The location of any offset sites should be as close as possible to impact sites. For example, where the impact site is located in the Perth metropolitan region the offset site should also be within this region.
    - Vegetation – offset sites should have a similar vegetation composition and structure to impact sites, including a similar age structure. This is particularly important where the impact site is on an expression of the ecological community that is rare across its range.
    - Landform – Offset sites should be on similar soils and landforms as impact sites (for example, an impact site on Quindalup dunes should also be offset on Quindalup dunes).
- Offsets are most likely to deliver long term benefits to the ecological community where secure tenure arrangements (e.g. conservation reservation or covenants) and management arrangements are established, so that they are not considered for future clearing or development.
    - Long term management arrangements (including allocation of associated budget for management) should be established.
    - The progress of offset sites should be monitored and success audited. Any subsequent offset proposals should be considered in the context of success of similar projects.
- In the southern part of the ecological community, where larger remnants occur, offset activities should generally, but not necessarily exclusively, be planned to improve the quality of remnants through actions such as weed management.
- In the central and northern part of the ecological community, where remnants are typically smaller, offset activities should generally, but not necessarily exclusively, be planned to increase the security of tenure of remnants (for example, by creation of formal reserves and application of covenants), or restoring degraded patches that were formally the ecological community to meet condition classes for national protection. Management and restoration activities may also be planned to increase the condition of these patches.
- Where possible, any offset sites of the ecological community should be established to improve or retain landscape connectivity, considering their proximity to other patches of the ecological community and other native vegetation
- Where offset arrangements, including restoration activities are established before the impact on the ecological community this increases the certainty that impacts will be adequately compensated.

6.5 Existing plans/management prescriptions

National threat abatement plans and recovery plans relevant to the ecological community (as at July 2018) include:

Threat abatement plan for predation by feral cats Department of the Environment (2015a).

Threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis (Department of the Environment and Heritage 2006)

Threat abatement plan for predation by the European red fox, (Department of the Environment, Water, Heritage and the Arts 2008).

Western Ringtail Possum (*Pseudocheirus occidentalis*) Recovery Plan (Western Australia Department of Parks and Wildlife 2017).

Forest black cockatoo (Baudin's Cockatoo *Calyptorhynchus baudinii* and Forest red-tailed black cockatoo *Calyptorynchus banksii naso*) Recovery plan (Department of Environment and Conservation 2008)

Carnaby's Cockatoo (*Calyptorhynchus latirostris*) recovery plan (Western Australian Department of Parks and Wildlife 2013)

Sedgelands in Holocene Dune Swales. Interim Recovery Plan no 314. (Department of Environment and Conservation 2011b)

National Recovery Plan for the Woylie (*Bettongia pencillata*) (Yeatman and Groom 2012)

Approved Conservation Advice (incorporating listing advice) for the Banksia Woodlands of the Swan Coastal Plain ecological community (Department of the Environment and Energy 2016)

Threat Abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi* (Australian Government Department of the Environment 2014)

Regional resources for vegetation conservation and management:

Bush Forever (Vols 1+2) (Government of Western Australia 2000)

Local Government Biodiversity Planning Guidelines for the Perth Metropolitan Region (Del Marco et al 2004)

Tuart Conservation Strategy (Tuart Response Group 2004)

Tuart Atlas (Tuart Response Group 2003)

Swan Coastal Plain South management plan 2016. Department of Parks and Wildlife (2016).

Management plans for reserves:

Tuart Forest National Park Management Plan (Department of Parks and Wildlife 2014a)

Yalgorup National Park (Department of Conservation and Land Management (1995)

Rockingham Lakes Regional Park (Conservation Commission of Western Australia 2010)

Beeliar Regional Park

Woodman Pt Regional park

Thomson Lake Nature Reserve

Trigg Bushland Reserve

Yanchep National Park

Beekeepers Nature Reserve

Bold Park Management Plan (2016-2021) (Botanic Gardens and Parks Authority 2016b)

Kings Park and Botanic Garden Management Plan 2014 – 2019 (Botanic Gardens and Parks Authority, 2014)

Ecological Character descriptions for Ramsar sites:

Ecological character description Vasse-Wonnerup wetlands Ramsar Site South West Western Australia (Wetland Research and Management 2007)

Ecological Character Description of the Peel-Yalgorup Ramsar Site (Hale and Butcher 2007)

Other management plans for specific areas:

Tuart Forest - Revegetation Management Plan (Natural Area Consulting 2013).

7. RECOVERY PLAN RECOMMENDATION

A recovery plan is not recommended for this ecological community at this time. The main threats to the ecological community and priority actions required to address them are largely understood. The Conservation Advice sufficiently outlines the priority research and conservation actions needed for this ecological community. In addition, a number of existing strategies, plans and guides are relevant to the management and/or recovery of the ecological community, or its component species. Many of the threats affecting the ecological community are best managed at a landscape scale, coordinated with management of other ecological communities. National listing and implementation of the priority research and conservation actions identified in this Conservation Advice will assist recovery of the ecological community, if adequately resourced and implemented over the long term.

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9. APPENDICES

APPENDIX A – NOONGAR INDIGENOUS CULTURE AND TRADITIONAL LIFE IN THE TUART WOODLANDS AND FORESTS

A.1 Living in the landscape of the Swan Coastal Plain

There is a very long history of human occupation of the Swan Coastal Plain, with some archaeological evidence of tools and scrapers estimated to be 38 000 years old. The Swan Coastal Plain has a high density of artefacts (an estimated 50 000 per square kilometre for part of the plain compared with fewer than 200 per square kilometre on the scarp). The association of archaeological sites with drainage areas reflects the high importance of permanent water bodies, where many people gathered seasonally (O'Connor et al 1989).

A.2 Noongar people, ecological knowledge and language

The Noongar (Nyoongar, Nyungar) people are the traditional owners of southwest Western Australia. Over many generations people have responded to changes to climate, landscape, flora and fauna to live within the ecological communities of the Swan Coastal Plain. These people moved throughout their traditional lands to gather resources and secure their livelihoods throughout the year. They have developed a highly organised use of resources to meet their needs through changing seasons. In this way they have accumulated a wealth of traditional knowledge about the land, weather, plants and animals and interactions between these. This knowledge is strongly associated with culture and spirituality. There are differences in dialect across the region, although language groups are not necessary related to land ownership (O'Connor et al 1989). Trade, as well as movement in response to seasonal conditions was important, and brought groups in contact. Many of the traditional pathways connected wetlands, such as the linear lakes now found in Yellagonga Regional Park (City of Joondalup 2011).

The groups most strongly associated with the main area where Tuart woodlands and forests occur are Yuat (Yued), Whadjuk, and Bindjarep (Binjareb) (Rooney 2011), as well as Wardandi but the ecological community may also occur on the margins of other areas. For this reason there are often alternative names or transcriptions of names for the plants and animals of the ecological community. Additionally, Noongar names may relate more to the appearance or use of a plant or animal, for example, the shape of a tree rather than its taxonomic definition (Bindon and Walley, 1998). Some plants and animals have many uses and so may have a range of associated names. Some Noongar names for plants and animals that are part of the ecological community, as well as some examples of their traditional uses are noted in APPENDIX E – SPECIES LISTS. The information presented here is a small sample of the many names and uses for these parts of the ecological community. The medicinal uses noted in the table are primarily summarised from Hansen and Horsfall (2017). Any medicinal use or consumption of these plants should only be made with expert guidance.

A.2.1 The importance of seasons

Traditional Noongar life on the Swan Coastal Plain is strongly seasonal and structured in response to availability of water and food. In general, warmer months were spent on the Plain while the cooler months were spent further inland at a higher elevation.

Six main seasons have been defined as part of the Noongar calendar (Table 4)

Table 4. Noongar seasonal calendar

Sources: Bindon and Walley (1998), Wallace and Huston (eds) (1998), Hansen and Horsfall (2017).

Season name	Months of year	Weather	Activities
Bunuru	February,March	hot easterly and north winds, low rainfall	Fishing and hunting near coast and permanent fresh water. Plant foods gathered included fruits of Zamia palms, roots of bulrushes and bohn plants.
Djeran	April,May	Cooler, southwesterly winds	Fishing and collecting bulbs and seeds. Move from coast to higher ground
Makuru	June, July	cold and wet, westerly gales. Highest rainfall.	Hunting kangaroos and emus and gathering foods such as yams, mainly on higher ground. Living in smaller family groups
Djilba	August September	Clear cold days with some warmer rainy periods	Hunting emus, possums and kangaroos, and gathering mainly on higher ground. Living in smaller family groups
Kambarang	October, November	rain decreasing	Return to coast and gather in larger groups near coastal water sources
Birak	December, January	hot and dry. Easterly daytime winds, evening sea breeze	Controlled local fires to assist hunting and promote plant growth.

The warmer seasons of *Kambarang, Birak* and *Bunuru* were spent on the plain, making use of coastal resources and more abundant water in wetlands, lakes and rivers. Foods found in the wetlands included freshwater crayfish, frogs, tortoises, waterfowl and fish. Eggs and birds including parrots, pigeons, cockatoos and raptors were collected from the surrounding forests (Bindon and Walley 1998). Some of the fish and waterfowl that are hunted in these coastal waterways migrate to other locations in winter. The gatherings of people at this time of year were relatively large, in comparison with the smaller family groups of the colder seasons. These large gatherings of people met to talk, trade and also enjoy delicacies such as drinks from the nectar in Banksia flowers (O'Connor et al 1989).

This was also the season when controlled burning on the plains was used to assist in hunting and preparing the country to re-grow over winter (Bindon and Walley 1998).

People also traditionally made use of fish traps and weirs in shallow areas and pools to trap fish at the coast (Bindon and Walley, 1998). *Mungur* (fish traps) were also built at the beginning of winter in some locations on rivers that pass through Tuart woodlands and forests including the Murray River and the Serpentine River near Barragup (Dix and Meagher 1976; O'Connor et al, 1989). These fish traps were successful at this time as with increased rain, fish would return to the lowlands after spawning upstream. The traps had fences made from branches across the stream, with a narrow opening funnelling to a race. Along the race the depth of the stream was reduced by stakes and brush placed on the stream bed. Alongside the race, fishers stood on shallow platforms to scoop fish from the water (Dix and Meagher, 1976). This activity would have involved hundreds of people (O'Connor et al 1989) and people would camp there for several months to trade fish and tools (Harry Nannup pers.comm).

In the colder seasons of *Djeran* and *Makuru* some of the lowland areas flooded, making travel and camping difficult (O'Connor et al 1989). However, at this time water became more reliable in the higher parts of the country, where people moved in smaller groups and concentrated their efforts on hunting. Amongst the lowland animals that were hunted were *marli (*Black swans; *Cygnus atratus*), which became easier prey as they moulted (Wallace and Huston, 1998). Other targets for hunters included *yonger* (kangaroos), Emus, Quenda and possums (Bindon and Walley 1998). *Mia* shelters were built and repaired at this time and kangaroo skins prepared to make cloaks (Wallace and Huston 1998).

At the end of *Djilba*, the warmer weather in the region was heralded by the golden flowering of the *modya* (*Nuytsia floribunda*; Western Australian Christmas Tree) and people returned to their coastal lands to enjoy the abundance of resources there.

A.3 Traditional livelihoods in the Tuart woodlands and forests

A wide range of foods and other resources were gathered from the Tuart woodlands and forests. At the end of *Djeran*, seeds from the *baio* (Zamia Palm) were harvested then soaked and buried to remove toxins. They could then be roasted and eaten. Another staple included *yanjet* (Bulrush) rhizomes, which were pounded to remove the fibre then made into a flattened damper and roasted. Another food found underground is the bulb of the *bohn* or *mardje* (Blood Root), which was roasted then mixed together with other foods to add a spicy flavour (Bindon and Walley 1998). Like a range of other plants, this also had additional uses including as medicine for diarrhoea and also as a dye (Hansen and Horsfall, 2017). *Warrain* (Yams; *Dioscorea hastifolia*) were also collected by women using their *wanna* digging sticks. To ensure continued harvest the shoots and tips of yams were put back into the holes so that they could re-sprout for the next season (Bindon and Walley 1998). Planning for the ongoing availability of resources, through careful harvest and land management practices such as restrictive burning are characteristic of traditional Noongar life (Hansen and Horsfall, 2017; Harry Nannup pers.comm).

Snacks that can still be found in the woodlands and forests include a range of berries, particularly *cadgeegurrup* (Native Cranberry; *Astroloma* spp. and wild pear; *Persoonia spp.*) (Bindon and Walley, 1998). Noongar Elder Harry Nannup tells of how when hunting for lizards as a young person he always had a pocket full of berries to eat, but these are now harder to find (Harry Nannup pers.comm). Another popular food included the *bardi* (Witchety Grub; *Bardistus cibarius*), found in large numbers in the stems of *balga* and easily collected when they climbed up the stems following the first rains. These were highly prized and eaten either raw or cooked (Wallace and Huston 1998).

Permanent and seasonal water sources were a focus for life and resource gathering. People would often move through their lands following rivers and other freshwater resources. The association of Tuart trees with water courses and wetland margins suggests that some of these commonly used pathways may have followed the Tuart woodlands and forests ecological community. Retaining or regaining access to these pathways is important for Noongar people to continue with cultural practices and nurture connections to their country (Harry Nannup pers.comm). At Perry Lakes, near where the ecological community is still present, women would collect turtles by wading in the wetlands and feeling with their feet. The extent of these lakes has been reduced by drainage but this area continued to be a popular place of Aboriginal people to camp until the 1940s. Lake Joondalup is another location where the ecological community occurs that was a favoured camping area where waterfowl and *yargun buyi* (long-necked tortoise) were hunted (O'Connor et al 1989). Mr Harry Nannup also recalled as a child camping under the large Tuart trees on the Serpentine River (Harry Nannup pers.comm).

Noongar people also developed an extensive knowledge of the medicinal uses of plants of Tuart woodlands and forests and used this to maintain health and treat a range of conditions. The means by which treatments were administered included steam pits and beds, lined with leaves and kangaroo skins; leaves and branches crushed and heated to release vapours; ointments made with emu and goanna fat; through smoke, or direct application of parts of plants such as the sap, or infusions made from plant parts. While many treatments were administered externally, some treatments were made to be ingested, for example as infusions. Eucalypts in the ecological community including Tuart, Marri and Jarrah were all used in various ways for their antiseptic properties and to assist with respiratory conditions. Flowers from a range of Banksia species were infused to create a drink soothing for sore throats (Hansen and Horsfall, 2017). Other examples of traditional uses of some of the plants in the ecological community are presented in Appendix E, Table 9).

Other resources were used for a range of purposes with common tools produced including spears, spear throwers, clubs, digging sticks (*wanna*), wooden carrying dishes (*mirlkoorn*), grindstones and skin cloaks (*booka*) (O'Connor et al 1989; Whitehurst 1997). Bark was used for making shelters and to wrap food for cooking (Hansen and Horsfall 2017). Shields were also made from bark slabs cut from trees. Where the cuts were made in the tree trunks sap was later collected and eaten. Sap from *balga* was used as a strong glue for fixing stone blades to handles (such as *kwetj*: axes), while leaves from the same trees were used for thatch and bedding (Bindon and Walley 1989). Stone was traded for a variety of purposes, including for making grinding stones, and spears. Ochre and clay was also traded for use in medicine and ceremony. In cold weather people warmed themselves in kangaroo skin cloaks, which were softened with animal grease and sewn using sinew thread (Hansen and Horsfall 2017).

A.3.1 Physical and cultural landscape features

The ecological community is strongly associated with limestone substrates. As a result, in several locations across the range of the ecological community there are also caves in the limestone. Water sources are often of particular cultural importance, in addition to being centres for resource availability and important for health. These are often of cultural significance, with some containing paintings. They may also contain important archaeological records and support unique biological assemblages. Disruption of drainage, for example through digging sewers may damage these caves (Harry Nannup pers.comm.). In some locations the removal of Tuart woodlands and forests for urban and rural residential development may have had a detrimental effect, along with declining rainfall, on the freshwater springs that flow in some areas from the limestone such as at Warrangup Springs. These springs which once always flowed are now dry for most of the year (Wilson pers.comm). Water sources are often of particular cultural importance, in addition to being centres for resource availability and important for health. Before moving on with the change of seasons, old people camped at the top end of Lake Preston to take (soak in) the mineral water there and gain strength (Harry Nannup pers. comm.).

A.3.2 Fire

Fire was a very important part of life, used for cooking food, hunting, warmth, signalling and to assist in tool production. It was also important in creating a social focus as well as for land management. The fireside was the place where a lot of knowledge and culture was passed between generations. Fires were initially created using the long flowering stems from *balga* as drills. They were then carried around between camps using a smouldering branch from a *boolgalla* (Bull Banksia) tree, carried beneath a cloak made from kangaroo skin (Bindon and Walley 1998; Hansen and Horsfall 2017).

Fire was particularly important for hunting. It was used by men to drive out kangaroos into open areas, while women and children could use fire to herd animals such as bandicoots, race horse goannas and shingle back lizards. They would also find other animals such as snakes in the ashes. Smoke was also used to drive possums from trees to hunt (Wallace and Huston 1998).

From season to season, fire has also been a key land management tool. Burning was sometimes done when leaving a camp to prepare it for the coming season. This restricted burning promoted new plant growth in winter. This in turn provided food for animals in these areas (Bindon and Walley, 1998; Harry Nannup, pers.comm).

The specific regime of burning has been subject to substantial debate, but it is suggested that changes in fire regimes with the reduction of direct land management by Noongar people has led to substantial changes in the ecological community, including the reduced availability of bush foods (Harry Nannup pers.comm). It is likely that one of the changes has been the scale of burning undertaken at any one time as well as its frequency. It is thought that traditional burning lead to a complex mosaic of patches of different ages (Abbott 2003). From the mid 1800s it was known that stock needed to be grazed both on the coastal sands and the foot hills soils to avoid nutritional problems (Bradby 1997). It is understood that in some situations, the pastoralists imitated some characteristics of Noongar fire management (Abbott 2003). To provide future feed for stock, as they moved their stock from the coastal lands each year they burnt the bush behind them in preparation for the following season. These practices changed as fertilisers were introduced. With the establishment of some conservation parks (e.g Yalgorup National Park) there was a policy of fire exclusion introduced which significantly changed the historical fire regimes (Wilson pers.comm), while more broadly, legislation such as the Bushfires Acts of 1902 and 1937 limited the season of burning (Abbot 2003).

APPENDIX B – SPATIAL DISTRIBUTION AND CONDITION

B.1 Spatial distribution of the ecological community

Expert interpretation of Beard's Vegetation mapping association polygons identified those polygons most likely to have been dominated by Tuart (strong and moderate association) before 1750 (extracted from Beard's 1:250,000 Statewide Pre-European Vegetation mapping of Western Australia; NVIS compliant version, Department of Agriculture and Food, Western Australia 2013). From this, the pre-European area of occupancy of the ecological community is estimated to have been in the order of 125 400 ha (Department of Biodiversity, Conservation and Attractions, 2017a) (Table 5).

To estimate current area of occupancy, areas of Tuart Atlas mapping (Tuart Response Group 2003) within the boundary of pre-European extent were analysed. The Tuart Atlas mapping from aerial photographs is likely have some errors in interpretation, but remains the most direct representation of the modern area of occurrence of the Tuart species, across its natural range. It was found that 25 420 ha of the Tuart Atlas mapping is contained within the boundary of pre-European area of occupancy, and so likely to be part of the ecological community and the best estimate of current area of occupancy at 2003 (analysis of Department of Biodiversity, Conservation and Attractions, 2017a and Tuart Response Group 2003). This estimate is likely to be a 'best case scenario' for the 2003 area of occupancy of the ecological community, due to the acknowledged poor condition of some of the areas mapped at that time, as well as likely clearing since this mapping occurred.

To illustrate change since 2003, estimated area of occupancy of the ecological community (based on the 2003 Tuart Atlas mapping) was intersected with a more recent native vegetation map (2015 data, Department of Agriculture and Food Western Australia, 2016). This leaves approximately 17 000 ha (identified here as '2015 area of occupancy'), which is 14 % of the estimated pre-European area of occupancy. Given the strong pressures to clear native vegetation within the region this may indicate recent loss in area of occupancy. Some caution must be used in interpretation due to the different mapping methods used (for example, scale of data capture and thresholds for canopy cover). For analysis against the listing criteria in this Conservation Advice the range between the 2003 and 2015 area of occupancy figures is used (Table 5).

The current extent of occurrence of the ecological community is the area enclosing all of its known current occurrences. It is measured as approximately 389 748 ha.

Table 5. Estimated pre-European and recent area of occupancy

Sources: Tuart Response Group 2003, Department of Agriculture and Food Western Australia 2016, Department of Biodiversity Conservation and Attractions 2017a

Estimate of area of occupancy	Hectares	Portion of pre-European area of occupancy
Pre-European area of occupancy	125 400	___
2003 area of occupancy	25 420	20 %
2015 area of occupancy	17 070	14 %

B.2 Patch size and distribution

The loss of the ecological community and surrounding vegetation since European occupation has led to its fragmentation. The occurrence and effects of clearing and fragmentation are similar to many other types of native vegetation across the Swan Coastal Plain. For Tuart woodlands and forests, patches in the northern part of its range are generally smaller and more isolated from each other than those in the southern part (Keighery et al 2002). This is somewhat a natural feature of the ecological community, but it has also been emphasised by clearing.

Size is often an important factor for the condition and resilience of a patch, but in some cases, the history and landscape context of individual sites may mean that some small remnants may be in better condition and display greater resilience than other larger remnants (Ramalho et al 2014). The ecological community varies in its structure and composition across its range in response to biogeographic factors, local environmental factors and disturbance history. Thus remaining patches of the ecological community across its range all contribute to its diversity and function.

Of the remaining patches identified in the 2003 area of occupancy the median patch size is 5.2 ha and the mean is 53 ha, indicating that the distribution of patch sizes is somewhat skewed (analysis of Department of Biodiversity, Conservation and Attractions 2017a and Tuart Response Group 2003) (Table 6). Of these patches, 14 % were classified as 'very small', 50 % were 'small', 28 % were 'medium', 8 % were 'large' 'and less than 1 % were 'very large' (Table 7, Figure 6). Thus, the vast majority (92 %) of remaining patches were medium sized or smaller. In spite of a large proportion of smaller sized patches, much of the area (>75 %) is in relatively few large or very large patches. The three largest patches are found in the southern part of the range, and are all substantially in conservation tenure. Large patches that are not yet reserved are likely to be a priority for including in formal conservation tenure. Nonetheless, large reserved patches still remain susceptible to certain types of threats such as disease, weeds and extensive fire, and it should be noted that the severe losses through 'Tuart decline' occurred largely within Yalgorup National Park, which is a large reserved remnant (Tuart Response Group 2002).

The patch size distribution pattern varies substantially across the range of the ecological community, with the largest patch sizes generally occurring in the south, where the majority of the area of the ecological community remains (Table 6). The smallest patch sizes are found in the central area, where metropolitan Perth is located. This seems likely to be the result of clearing and replacement of the ecological community in this area. It suggests particularly high susceptibility of the ecological community in this area to some types of damage, for example, by weeds. An additional implication is that connectivity across the entire range may be compromised by the small size of remnants in the central connecting area.

Patches that contain reserved areas (IUCN categories I-IV) are larger (apart from in the northern area, where the median size is slightly smaller) than patches in general. Thus, patches not containing reserves that are likely to be part of the protected ecological community are generally smaller. The three largest identified patches are found in the southern part of the range and are all substantially in conservation tenure. Large patches that are not yet reserved are likely to be a priority for including in formal conservation tenure. Nonetheless, large reserved patches still remain susceptible to certain types of threats such as disease, weeds and extensive fire, and it should be noted that the severe losses through 'Tuart decline' occurred largely within Yalgorup National Park, which is a large reserved remnant (Tuart Response Group 2002).

Further to the reduction in patch sizes, another aspect of fragmentation is the increase in distance between remaining patches. This has implications for ecological processes such as the regular safe movement of fauna for feeding and breeding, and transfer of seeds and pollen as well as more intermittent movements to seek refuge during recovery from disturbance. Across the range of the ecological community, over 70 % of patches are separated by a distance of more than 100 m, with most patches being 100 m to 500 m apart (Table 8, Figure 7). Spacing of patches of the ecological community also varies across its range. Approximately 85% of patches in the central part of the range are separated by at least 100 m. Patches in this area about half as likely to be within 100 m of another patch as the average situation across the whole range.

When considering the size and distribution of patches of the ecological community it is also important to consider the adjacent vegetation and broader landscape context. The Tuart woodlands and forests ecological community exists together with other types of native woody vegetation, supporting its ecological function, for example Banksia woodlands and other woodlands and forests with canopies dominated by species such as Jarrah and Marri. Across the Swan Coastal Plain, much of this vegetation has been cleared, with only 38 % of native vegetation remaining (Government of Western Australia 2016b). Patches in the central area are less likely to be adjoining woody native vegetation than those in other parts of the range, and more likely to be greater than 100 m from woody native vegetation than those in other parts of the range. Planning for the conservation and management of these areas of native vegetation that adjoin or are nearby patches of Tuart forests and woodlands is important for their ongoing ecological function (Molloy et al 2009).

Table 6. Variation in patch sizes across the range of the ecological community

Sources: Tuart Response Group 2003, Department of Biodiversity Conservation and Attractions 2017a

Part of range of the ecological community^	Number of patches	Area (ha)	Mean patch size (ha)	Median patch size (ha)
North	118	4418	37	5.8
Central	119	1834	15	3.4
South	239	19 162	80	6.4
Whole range	476	25 413	53	5.2

Patches below 0.1 hectares were excluded from the analyses, due to their potential to be artefacts of data processing.

^North: north of Burns Beach Road, Joondalup; Central: between Burns Beach Road, Joondalup and Rockingham; South: South of Rockingham.

Table 7. Remnant patch sizes for the ecological community

Sources: Tuart Response Group 2003, Department of Biodiversity Conservation and Attractions 2017a

	Number of patches	Total area of patches in size category (ha)	% of patches	% of area
Very small patches ≤1 ha	68	40	14.3	0.2
Small patches >1 ha ≤10 ha	237	963	49.8	3.8
Medium Patches >10 ha ≤100 ha	132	4535	27.7	17.9
Large Patches >100 ha ≤1000 ha	36	10470	7.6	41.2
Very large patches >1000 ha	3	9405	0.6	37.0
Total	476	25 413		

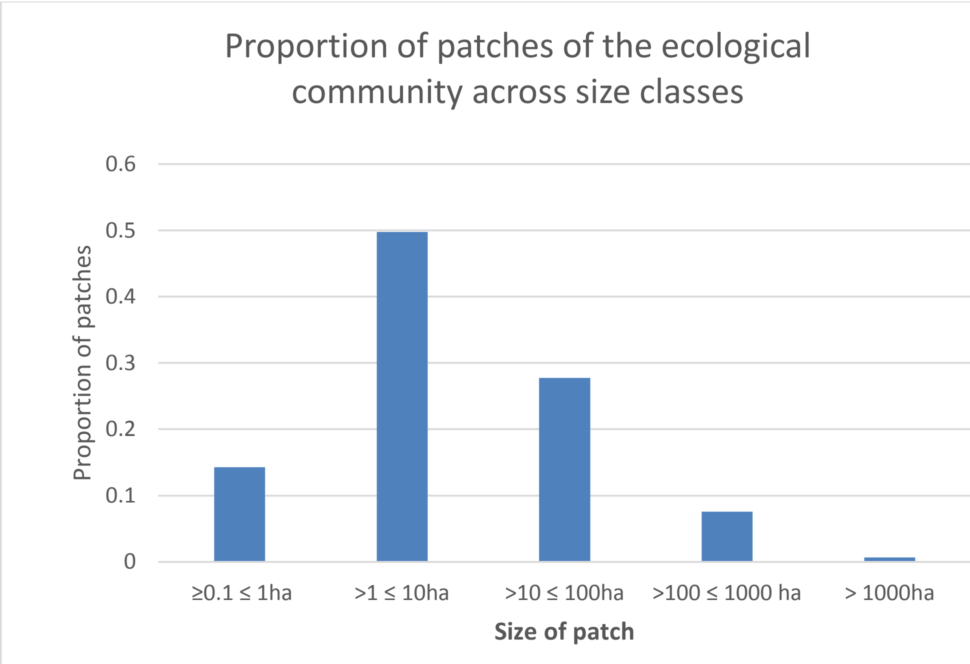

Figure 6. Proportion of patches of the ecological community in various size classes

Sources: Tuart Response Group 2003, Department of Biodiversity Conservation and Attractions 2017a

Table 8. Distance between patches of the ecological community

Percentage of patches of the ecological community separated by various distances across its range*

Sources: Tuart Response Group 2003, Department of Biodiversity Conservation and Attractions 2017a

Part of range of the ecological community^	≥60m<100m	≥100m<500m	≥500m<1000m	>1000m
North	24%	64%	6%	6%
Central	15%	65%	18%	3%
South	36%	58%	5%	1%
Whole range	28%	61%	8%	3%

*Distance between patches starts at 60 m to accommodate the patch definition for the ecological community described in this Conservation Advice.
^North: north of Burns Beach Road, Joondalup; Central: between Burns Beach Road, Joondalup and Rockingham; South: South of Rockingham.

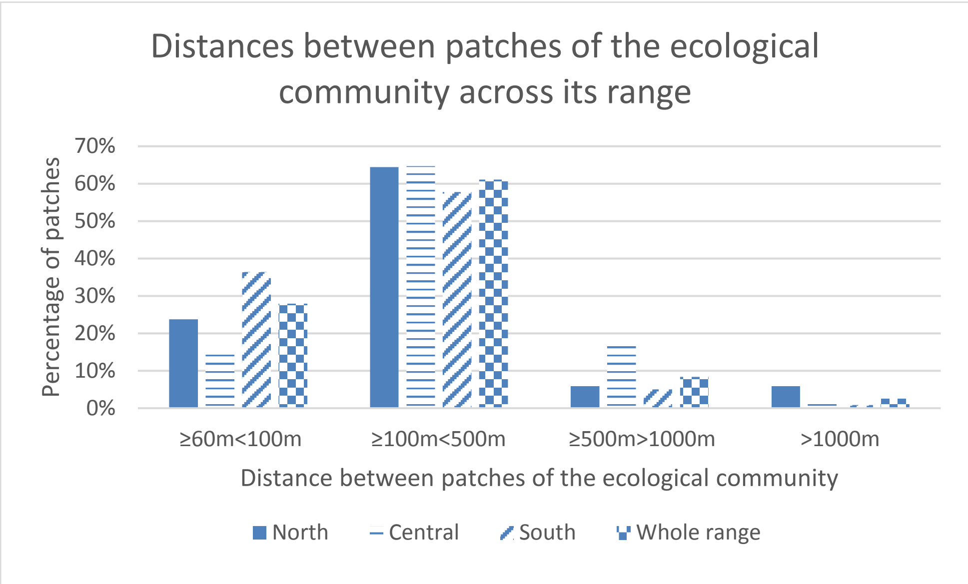

Figure 7. Distance between patches of the ecological community

B.3 Vegetation condition

Due to the land use history of the Swan Coastal Plain and the vulnerabilities associated with patchiness and fragmentation many areas of Tuart woodlands and forests are likely to have low condition. Across the region, there has been a general loss and decline in condition of woodland and forest trees, including Tuarts, combined with low levels of recruitment for this species. Declines in Tuart canopy were noted by a variety of authors throughout the 20th century (Edwards 2004), but declines since the 1990s have been particularly noteworthy. At Yalgorup National Park in particular, there have been some rapid losses in condition of Tuart trees (Edwards 2004; Tuart Response Group 2004; Barber and Hardy 2006; Wentzel 2010). Edwards (2004) further notes areas of similar loss of canopy at Neerabup, Yellagonga and

Tuart Forest National Park. Across the broader range of the ecological community, Edwards (2004) associated stand declines with soil nutrient enhancement and fragmentation.

Damage to understorey vegetation of the ecological community has been so widespread that it is considered that no areas are considered to be unaffected, and habitat value has been substantially reduced in some places (Keighery et al 2002). These authors also note that ecological communities containing Tuart have experienced relatively high levels of disturbance, in comparison with other ecological communities in the region. Where there were larger remnants, condition was found to be higher. At the most northerly extent of the range of Tuart, remnants were restricted to low-lying areas and overall condition was identified as very poor with few intact areas outside of reserves, due to a history of grazing and extensive clearing. They also cite the work of Keighery (1999), who assessed Tuart areas at 89 sites in 24 reserves of the southern Swan Coastal Plain. The site-specific estimates of vegetation condition did not identify any as being 'pristine' (Keighery et al 2002).

The Tuart Atlas (Tuart Response Group, 2003) identified canopy density (including all canopy species, not just Tuart), and also defined two understorey condition classes: 'no visible disturbance' and 'high visible disturbance', while a small portion was uninterpretable. Understorey disturbance increased as canopy cover decreased. Approximately 60 % (18 207 ha) were identified as having high disturbance (Tuart Response Group 2003). However, given the difficulty in interpreting understorey quality from aerial photographs, it is likely that some types of disturbance were not recognised.

APPENDIX C – DESCRIPTION OF THREATS

C.1 Overview

The ecological community occurs within a landscape that has mixed uses, including agriculture, industrial use and housing. Many of the current and future threats to the ecological community are associated with the decreased condition and remaining impacts of the historical disturbance of prolonged grazing and clearing for agriculture (Keighery et al 2002), with urban development and associated infrastructure increasing in its effect on the ecological community in recent decades.

The primary known threats to the ecological community are described here in categories, but these threats often interact, rather than act independently.

C.2 Clearing and fragmentation of vegetation

The primary source of loss of the ecological community is clearing with an estimated loss of at least 80% of total area of the ecological community since the commencement of European style land practices (see Section B.1 Spatial distribution of the ecological community). This clearing has occurred for various purposes, outlined below, that have changed in their relative importance over time. The impacts of the early clearing are ongoing, and often compounded by other factors including impacts associated with fragmentation.

The clearing of native vegetation directly reduces the amount of habitat available to dependant native species, while small patches inherently support smaller numbers of species (Macarthur and Wilson 1967). Fragmentation increases the vulnerability of patches to a range of threats due to increased perimeter to area ratio, increasing the influence of surrounding land uses and disturbances. The ability of patches to recover from disturbances such as disease or fire may be reduced where there is little adjacent habitat (although spread of fire threats may also be reduced).

Fragmentation also results in greater distance between patches. The central part of the range of the ecological community is particularly subject to barriers imposed by greater distance between patches. Increased distance between patches reduces the ability for fauna to successfully move throughout their range, and can limit genetic transfer in plants.

The effects of clearing and fragmentation can sometimes take decades to be fully realised, due to species loss as recruitment and recolonisation does not match deaths and patch level or regional extinctions. Ramalho et al (2014) found that for Swan Coastal Plain Banksia woodlands the species richness of small remnants halved within 50 years following isolation. They noted that some bushland areas in outer Perth were only cleared and fragmented within the past 20 years. Many areas of Tuart woodlands and forest are expected to respond in the same way given similarities in understorey components and threats. For these areas it is likely that the losses are already committed but yet to be realised, consistent with the concept of 'extinction debt', predicted to cause most severe species losses where there has already been substantial habitat destruction and fragmentation (Tilman et al 1994). Weediness was also found to increase over time in small patches, demonstrating one of the inherent vulnerabilities of small patches to threats associated with edge effects (Ramalho et al 2014).

C.2.1 Agriculture and grazing

The Swan Coastal Plain has been subjected to European-style agriculture and grazing since 1829. Much of the early clearing was associated with these activities. Grazing has continued since this time, with associated activities including tree removal and sowing of exotic pastures.

While in the Perth metropolitan area this is less likely to continue, more outlying areas of the ecological community may still be subject to this pressure in the future, including for dairy farming and horse pasture. The total grazing pressure is relatively high where the low-lying areas between dunes are used as shelter areas for stock and by Western Grey Kangaroos (Keighery et al 2002). The relatively fertile soils of the Spearwood dunes have been particularly affected by grazing (Keighery 2002). There is at least anecdotal evidence that in parts of the range, kangaroo populations have increased substantially in recent times, with excessive grazing by rabbits and kangaroos noted as a key threat in Tuart Forest National Park (Department of Parks and Wildlife 2014a; Brown et al 2016; Webb 2017). It is likely that changes to the landscape such as vegetation fragmentation may have resulted in changes in kangaroo populations, as well as their spatial distribution (Brown et al 2016).

Effects of ongoing grazing include changes to the nutrient status and structure of soils, affecting species composition and preventing regeneration of indigenous vegetation, as well as contributing to invasion by some weeds. Damage is often concentrated in the understorey, where the structure and floristics are substantially altered, with some weed species likely to be promoted. The competitive relationships between canopy or subcanopy species such as Tuart and Peppermint may also be altered by grazing, while the age structure of the trees is affected where recruitment is not successful.

Some of the impacts of heavy grazing have been demonstrated by the use of experimental exclusion plots, such as at Paganoni Reserve (Brown et al 2016) and in Tuart Forest National Park (Webb 2017). At Paganoni, excluding grazing after a fire did not change the native species richness, but the native species cover, particularly by shrubs , as well as some native grasses and geopyhytes was higher inside fenced areas (Brown et al 2016). In Tuart Forest National Park study areas that were fenced to exclude grazing had notable increases in diversity of native perennial species (but annuals and geophytes were unchanged). From this, 23 native species were identified as grazing sensitive. Some species were found to recuit in grazed areas but not persist. This may result in the exhaustion of soil seed banks and the ultimate loss of these species (Webb 2017). Excluding grazing also affected the growth of weeds. At Paganoni Reserve cover of weedy annual grasses and *Carpobrotis edulis* (Pig-face) increased in fenced plots, suggesting that grazing was limiting their growth. Similarly, in Tuart Forest National Park weed height and density, but not diversity increased in fenced plots. These results suggest that the management of grazing, weeds and fire should be carefully balanced, possibly with the use of temporary fencing to allow native plants to become established (Brown et al 2016).

In some areas the ecological community is cleared for cropping, including tree crops such as avocadoes, as well as vegetables. The extent of clearing is likely to be greater where pivot irrigation is installed.

C.2.2 Logging and timber removal

Tuart trees have long been valued as a timber source, with exports to England occurring in the early 1850s. The Western Australian Royal Commission on Forestry reporting in 1904 commented on the importance of the timber for its strength, as well as its limited range – then considered to be primarily between Fremantle and Busselton, with an area of approximately 40 000 ha. The trees in this southern area were considered best for timber due to their large, straight trunks. The value of the timber (with a price higher than Jarrah) and its proximity to transport facilities were deemed sufficient to “justify a vigorous conservation and early steps in replanting” (Harper et al 1904, p12). While there was ‘some cutting’ in the 1800s, Kay (1985) states that at the turn of the century a ‘high volume of standing timber remained’. After World War II there was a strong demand for wood and a new mill was established at Ludlow in 1955 (Kay 1985).

Impacts of logging and timber removal include the direct clearance of vegetation, construction of roads and regional changes to hydrology. Tuart forests are no longer logged commercially and the Regional Forest Agreement area does not include substantial areas of Tuart trees. However, small scale logging is still occurring (including large habitat trees in farm paddocks and urban areas) as well as removal of dead trees and timber for fencing and for firewood. In urban areas Tuart trees may be removed or heavily pruned to avoid the risk of limbs dropping. Following fires, trees may be removed to address safety concerns. For example, following a major fire in January 2016 there was an immediate response to remove trees considered to be dangerous, for example along the Forrest Highway, South West Highway and Lakelands Lake Clifton Road. In 2017 following further survey 374 trees were recommended for treatment such as pruning, crown reduction or complete removal. Of these 117 trees were removed. The tree species are not identified in each case, but where identified, many are Tuarts, with some Peppermint, Banksia and Jarrah also identified (Main Roads 2017).

C.2.3 Urban development and infrastructure

The Swan Coastal Plain is heavily impacted by urbanisation, with clearing also occurring for industrial developments and infrastructure such as roads and drainage. Perception of native vegetation creating a fire risk and associated construction of firebreaks can also lead to additional removal.

The rapid expansion of the Perth metropolitan area and other urbanisation of the Swan Coastal Plain in the Peel and greater Bunbury regions is demonstrated by the predictions that the population of the Perth and Peel regions is likely to increase to 3.5 million people sometime in the future (Government of Western Australia 2015a). The population of greater Perth was approximately 2 039 000 in 2015 (Australian Bureau of Statistics 2016). Clearing of native vegetation to accommodate housing and other development for this population growth is expected to lead to substantial loss of native vegetation. Within the area covered by this planned development, there are large unreserved areas of the ecological community in Local Government areas including Waroona, Rockingham, Cockburn, Mandurah and Wanneroo (Tuart Response Group 2003). Urban development is also occurring rapidly in other parts of the range of the ecological community, for example in the greater Bunbury region.

Beyond initial clearing, urbanisation comes with ongoing impacts such as the high density of exotic animals, including domestic pets (in particular, cats), which often displace or prey upon native fauna. In semi-urban areas other animals such as horses may also have impacts. Urban development also results in hydrological change and eutrophication through urban runoff, water diversion and groundwater extraction, as well as regional climate change, for example, due to urban heat islands.

Increased human populations near natural areas may lead to their appreciation but there is increased pressure on these areas, with problems including profusion of bike and four wheel drive trails, weed invasion, cubby construction, increased fire frequency and intensity (including through arson), rubbish dumping, mowing or ‘tidying up’ native areas and firewood collection, as well as impacts of busy roads adjacent to the natural areas (Del Marco et al 2004; Conservation Commission of Western Australia 2010). Threatened black cockatoos have been found killed by vehicle strike (Johnstone and Kirkby 2016), which is likely to affect all other native animals of the Tuart woodlands and forests that cross roads. In addition, native animals that are well adapted to urban environments may competitively exclude others that are less well adapted.

C.2.4 Mining and Quarrying

Mining and quarrying has occurred on the Swan Coastal Plain since the 19th century. This has led to damage of the ecological community through direct clearing of the areas to be mined, damage to soils, fragmentation of vegetation, as well as regional impacts such as temporary or long term changes to hydrology.

In the past, the requirement for timber to support mining and engineering operations led to further forest loss. The occurrence of Tuart woodlands and forests on limestone substrates is now a primary reason for clearance of the ecological community in various parts of its range, where basic raw materials such as sand, limestone, rock and clay are extracted. Between 1998 and 2017 an estimated 47.5 ha of the ecological community in the Shire of Harvey was cleared for limestone and sand extraction, with a further 12 ha of loss expected by 2022 (Shire of Harvey Planning Department 2017). The ecological community occurs on mineral sands which are rich in ilmenite, which is used for white pigment (Kay 1985). Mining for mineral sands occurred in the Ludlow Forest area between 2004 and 2007.In 2013 there were five active mining tenements and other pending tenements within the vicinity of Tuart Forest National Park (Department of Parks and Wildlife 2014a). The 109 ha disturbed at the Ludlow Mine for mining for mineral sands between 2003 and 2007 included substantial areas of Tuart forest, where rehabilitation activities are now occurring (Onshore Environmental Consultants 2017) . In the first few years of rehabilitation, monitoring shows a distinctive suite of fauna in the rehabilitated area, with greater affinity to areas of open ground with lower canopy cover (for example, a variety of skink species). In comparison, the mature woodland, which was not cleared, remains more suitable to arboreal species such as Brush-tailed Phascogale, Marbled Gecko and Striated Pardalote. Where areas are actively rehabilitated, they may provide more understorey cover than in degraded mature stands (Turpin et al 2015).

In association with the Perth and Peel Green Growth Plan for 3.5 million draft released in 2015, priority areas have been designated for future extraction of basic raw materials for a 30 year period. The draft plan for this states that basic raw materials Future Resource Extraction Areas would allow up to 2,500 ha of native vegetation clearing, 1,500 ha of pines removal that is not included within the Harvesting of Pines Action Plan and up to 60 ha of impacts to wetlands (Government of Western Australia 2015b p. 15). Regardless of whether this area includes Tuart woodlands and forests, it would reduce the connectivity and habitat availability across the Swan Coastal Plain, which is likely to have broader effects on the ecological community. As at April 2018 the Western Australian government has suspended work on the plan, subject to a review of risks and benefits.

C.3 Invasive flora and fauna

C.3.1 Weeds

In many places weed invasion has substantially degraded the understorey of Tuart woodlands and forests, increasing competition for light, space, water, and nutrients and preventing recruitment of native plants. There is a wide range of weed species recorded from Tuart woodlands and forests, from agricultural or garden sources, with their spread particularly aided by disturbance such as land clearing or grazing. Tuart woodlands and forests have been identified as being disproportionately affected due to the relatively fertile soils of the Spearwood dunes, compared with other nearby vegetation types occurring on less fertile soils (Keighery 2002). These areas have frequently been grazed, which has resulted in the introduction of non-native seeds by stock and through agricultural pasture improvement. They have also been burned, to encourage grass growth, allowing further weed invasion (Brown and Bettink 2009). The alkaline soils where the ecological community occurs may make the ecological community particularly susceptible to invasion by weeds of Mediterranean origin.

Weed seeds are often dispersed in remnants of the ecological community by birds. The high perches provided by many Tuart trees are attractive for birds such as ravens, which may deposit weed seeds in their faeces. Urban gardens act as a reservoir of seeds, while dumping of garden refuse in bushland is another source. In some areas non-local species have been directly planted in Tuart woodlands and forests (Keighery 2002). Surveys in 1984 found that in the Perth Metropolitan Region up to 37% of the flora in Tuart woodlands and forests were weeds. Over the whole range of Tuart woodlands and forests 28% were weed species. More recent surveys have identified 23 weed species that are present in over 70% of Tuart woodland and forest sites (Keighery 1989 cited in Keighery 2002). Up to 193 weed species have been recorded in Tuart Forest National Park, which contains substantial areas of the ecological community as well as other ecological communities.

Weeds affecting the ecological community (see APPENDIX E – SPECIES LISTS) include Bridal Creeper (*Asparagus asparagoides*), Arum Lily (*Zantedeschia aethiopica*), Geraldton Carnation Weed (*Euphorbia terracina*), Blackberry Nightshade (*Solanum nigrum*) and Dune Onion Weed (*Trachyandra divaricata*). Exotic annual grasses include Great Brome (*Bromus diandrus*), Rough Dog's Tail (*Cynosurus echinatus)*, Annual Veldtgrass (*Ehrharta longiflora*), Hares-tail Grass (*Lagurus ovatus*), Ryegrass (*Lolium* species) and Rat's-tail Fescue (*Vulpia myuros*), and these may all promote fire (Keighery and Keighery 2002).

Bridal creeper is a 'Weed of National Significance' affecting the ecological community, and can almost completely smother native vegetation (Wetland Research and Management 2007; Casson et al 2009). Some of the most prominent weeds are only seasonally observable, for example Arum Lily, which appears in winter and spring, covering large areas of ground, but has little or no vegetative cover in summer. Geraldton Carnation Weed is another major weed in the ecological community, having been recorded in reserves containing Tuart across the Swan Coastal Plain. It is unpalatable to grazers such as Western Kangaroo and is spread by ants and birds (Keighery and Keighery 2007). Some of the weeds result from deliberate planting, including of species native to the eastern states, such as the wattles *Acacia longifolia* (Sydney Golden Wattle) and *Acacia iteaphylla* (Willow-leaved Wattle), which have become invasive in southwest Western Australia (Florabase 1998-).

One of the largest remnants of the ecological community overlaps with Tuart Forest National Park. While this retains a high canopy cover, the understorey has been heavily degraded through activities such as forestry (including the introduction of pine trees), as well as grazing. This past disturbance has facilitated the introduction of a large suite of weeds (Department of Parks and Wildlife 2014a). Even at sites where there has been weed control, the large area that is still infested means that re-establishment is a problem, with birds and foxes carrying seeds of weeds such as Arum Lily (Herbiguide 1988-2014; Onshore Environmental 2017). The need for repeated control of weeds contributes to its substantial financial costs. There are also important relationships between weed invasion and other disturbances such as fire (see 'Inappropriate fire regimes' below).

C.3.2 Invasive vertebrate animals

Feral animal species present, and likely to affect the ecological community by predation on and competition with native fauna, include cats and foxes (Dell et al, 2002). Foxes (*Vulpes vulpes*) in particular are thought to have contributed to declines of native fauna since their spread in the 1920s (Abbott 2008; Department of Parks and Wildlife 2015). While there has been fox baiting since 1996 as part of the 'Western Shield' program, in some cases this has led to increased predation by cats (*Felis catus*). Predation by cats and foxes can also limit the success of translocation programs for native fauna (Yeatman and Groom 2012). Fauna considered susceptible to predation from cats and foxes include Western Ringtail Possum, Brushtail Possum, Quenda, South-western Brush-tailed Phascogale and Water Rat, as well as water birds that nest in the ecological community. In a peri-urban setting, where much of the ecological community occurs, there is a continuous replenishment of feral cat populations (Department of Parks and Wildlife 2014a). Stray cats and dogs, and those still in domestic ownership also have impacts on a wide range of native fauna (Conservation Commission of Western Australia 2010; Department of the Environment 2015a).

Rabbits are widespread throughout the region, and historically have been subject to substantial control efforts by physical, chemical and biological means. They continue to cause damage to vegetation through browsing, as well as through excavation of soil. Prevention of recruitment of new plants is a particular problem (Commonwealth of Australia 2016). Where Western Grey Kangaroos have become particularly abundant, such as in the south of the ecological community's range, they may also be limiting understorey growth and recruitment, but the role played by kangaroos requires further research (Department of Parks and Wildlife 2014a). Feral pigs (*Sus scrofa*) also contribute to damage to vegetation and soils, particularly in wet areas (Casson et al 2009), while Black Rats (*Rattus rattus*) and House Mice (*Mus musculus*) are also present, and compete with native fauna (Valentine et al 2009).

Tree hollows are an important and limited resource for a range of species in the ecological community. Competition for these hollows occurs between species, including some that are threatened, and other native species that have increased their population sizes (for example, Eastern Long-billed Corella, Galah and Little Corella).

C.3.3 Invasive invertebrate animals

Feral Honeybees (*Apis mellifera*) also compete for hollows and food resources, including pollen and nectar (Department of Parks and Wildlife 2014a, Conservation Commission of Western Australia 2010). The preparation of hollows for nests by black cockatoos is thought to make them more attractive to feral honeybees to establish hives. In studies of use of hollows by Carnaby's, Baudin's and Forest Red-tailed Black Cockatoos, as well as Western Long-billed Corella (*Cacatua pastinor pastinor*) approximately 20% of otherwise suitable hollows were occupied by feral bees (Johnstone and Kirkby 2007), indicating that this is a substantial problem. The same authors also identified feral bees attacking smaller native birds whilst feeding as a cause of mortality. They suggest a range of measures to reduce the impact of feral bees on native fauna. Feral bees are also a threat to commercial apiary.

Various invertebrate species may impact on the growth and health of Tuart trees. These include *Cryptoplus tibialis* (Tuart Bud Weevils), which reduce the canopy seed store. *Phoracantha impavida* (Tuart Longicorn) and *P. semipunctata* (Common Eucalypt Longhorn), as well as *Cryptophasa unipunctata* (Stem Girdler), can also damage or kill Tuart trees by ringbarking (Fox and Curry 1979, Tuart Response Group 2004). Pasture derived leaf feeders are also identified as a problem in the Tuart Forest National Park (Department of Parks and Wildlife 2014a). Populations of some insects may have increased with canopy opening and changed fire characteristics (Ruthrof et al 2002). Insect attack may also occur where increased levels of nitrogen in leaves make the leaves more attractive to herbivores. Where Tuart trees are suffering from other stresses, such as water stress, they may be more susceptible to insect attack such as by the bud weevils. Where black cockatoos such as Carnaby's Cockatoo, Baudin's Cockatoo and Forest Red-tailed Black Cockatoo, as well as Grey Currawong (*Strepera versicolor*) are present, they may help to control insects such as beetles that graze on Tuart leaves and under bark, larvae of *P. impavida* borers but this control may have been lost in some places with the decline of these species (Ruthrof et al 2002; Casson et al 2009). Similarly, decline of South-western Brush-tailed Phascogale (*Phascogale tapoatafa wambenger, wambenger*) in the ecological community may have reduced control of arthropod populations (Wentzel 2010).

C.4 Tree dieback and pathogens

Longman and Keighery (2002) note that there are several accounts of the decline and recovery of Tuarts over the last eighty years. Records show that Tuart decline was reported in the Perth area in from the 1920s, and widespread defoliation caused by insect damage was noted in the Ludlow Tuart forest in the late 1960s. Other reports from the 1960s and 1970s noted severe attack by borers, then recovery. Tuarts in Bold Park and other Perth suburbs declined due to insect attack in the 1980s, but have since recovered. In the 1990s in particular there was a rapid loss in condition of Tuart trees, sometimes leading to their death, particularly in Yalgorup National Park, near Preston Beach, but also in areas further north, towards Rockingham, and including the Perth metropolitan region. The impacts at Preston Beach were severe, with over 90% of trees affected (Barber and Hardy 2006), while it has been estimated that across Yalgorup National Park over 80% of mature trees died (Wentzel 2010). While there was some recovery through epicormic growth, repeated dieback of this growth eventually exhausted the reserves of the trees and was followed in some cases by their death. The causes are not well understood but there is a possible combination of factors including insect damage, hydrological change, including increased alkalinity and salinity, loss of beneficial mycorrhizal fungi and infection by *Phytophthora* spp. or other pathogens, including *Mycosphaerella cryptica* (Longman and Keighery 2002; Tuart Response Group 2003; Wentzel 2010).

It seems the occurrence of the severe decline has been restricted spatially. However the high rate of death and rapid spread of the problem have caused substantial concern, leading to comparisons with the extensive ecological losses of other native flora in the region due to *Phytophthora cinnamomi*. Tuart is not considered to be susceptible to root rot fungus *P. cinnamomi* (Groves et al, undated;Tuart Response Group, 2004), but is to other Phytophthora species such as *P. multivora* , which may be present at some sites (Scott et al 2009). In addition, other plants in the ecological community are, however, susceptible to *P. cinnamomi*. For example, Jarrah trees and a variety of understorey plants are affected by *P. cinnamomi* (Department of Parks and Wildlife 2014a). *Armillaria luteobubalina*, a root rot fungus, commonly occurs on Quindalup dunes and can affect up to 40% of coastal plant species (Conservation Commission of Western Australia 2010), including Tuart (Arbor Carbon 2011).

Losses in condition in Peppermint trees have also been observed in the southern part of the ecological community. This has been associated with the canker pathogen *Neofusicoccum australe*, which may be spreading its range in response to climate change (Dakin et al 2010).

This potentially has severe consequences for species such as the Western Ringtail Possum, which on the Swan Coastal Plain feeds primarily on Peppermint foliage (Department of Parks and Wildlife, 2014b).

Disease may also be responsible for some of the losses in faunal diversity. While likely to be related to several threats, the declines in populations of various mammal species in the late 19th and early 20th century have been associated at least in part to disease. These include common Brushtail Possum, Western Ringtail Possum and Quokka (Abbott 2006), which also occur in Tuart woodlands and forests. Diseases affecting mammals may also have contributed to some of the more recent failures of translocation more broadly (Abbott 2008; Yeatman and Groom 2012). As the climate changes, nutrition of some species, such as Western Ringtail Possum may be compromised, making them more susceptible to disease (Department of Parks and Wildlife 2014b).

Abiotic changes such as long term decline in rainfall, as well as more sudden changes to groundwater salinity and availability that may be associated with local events such as engineering works may increase the susceptibility of the Tuart woodlands and forests to biotic stressors such as pathogens, resulting in their loss in condition. The loss of native plants, in particular, proteaceous plants, may limit food availability for some fauna, for example nectar feeders. Similarly, fungi may also be impacted, which may limit the food available to digging fauna (Yeatman and Groom 2012).

C.5 Altered fire regimes

Fire regimes have been changed throughout the region, in association with agriculture, urban development and the reduction of previous fire management by Indigenous people that was characterised by its selectivity rather than ubiquity. There are often competing needs and priorities affecting fire regimes. It is likely that fire frequency has increased in some areas, while in others fire has been largely excluded, but may be subject to occasional intense fires. The season of fires may also have changed (Zelinova (ed) 2002; Tuart Response Group 2004). Archibald (2005) suggests that in Yalgorup National Park, fire frequency may have reduced substantially and threatens the ecological community though evidence indicate for many ecosystems a substantial increase in fire frequencies in post-European times (see Crosti et al 2007. Some of the changes to fire management have been in accordance with legislation, for example, preventing burning over summer months (Abbott 2003). Climate change is likely to compound changes to fire regimes (Hope et al 2015) as are changes to vegetation, such as the increase in annual, and highly flammable grass weeds.

Likely effects of the changed fire regimes include changes to nutrient cycling, competition, increase in flammability, weed increase and altered plant regeneration. These changes are likely to have affected the composition and structure of the ecological community, though effects may be location specific. The interactions between fire and grazing pressure are likely to be complex. Grassy weed invasion, for example, by perennial veldgrass (*Ehrharta calcina*) is a particular problem that is enhanced by fire, and may in turn also enhance fire risk (Fisher et al 2009), through increased flammability and ignition capability. Fire can create opportunities for fast invaders such as Coastal Pigface (*Carpobrotus edulis*), so management after a fire event is particularly important. In some cases, if a fire is sufficiently hot it may at least temporarily assist in weed management by killing adults and also destroying stored seed (Brown et al 2016).

While much of the vegetation of the region is fire-resistent, and many species are fire dependent for recruitment, fires may decimate some native fauna and prevent regeneration if they cause death of plants before reproductive maturity. While Tuart may rapidly recover from fire, without protection, seedlings may be lost through grazing, including by kangaroos (Department of Parks and Wildlife 2014a). The germination of many Tuart seedlings follows fire, as recruitment in between fire events is poor (Ruthrof et al 2002). This is applied in restoration through the use of ash beds to enhance germination (Ruthrof et al 2015), though the technique is not the only means by which Tuart regenerates from seed. Tuart seed capsules in the canopy also need to be heated sufficiently to open and release their seeds (Valentine and Ruthrof 2012). Establishment of Tuart seedlings may also be limited by competition with other species (Tuart Response Group 2004). Further research is required to fully understand ecological recovery following fire, including fire intervals required for individual species and ecological processes important in the ecological community, but in general, fire free intervals of multiple decades are likely to be necessary.

Having recruited, young trees may not survive fires until the bark is thick enough to be protective. It is not certain at what age this occurs, but at least 3-4 years has been suggested (Ruthrof et al 2002), although likelihood of survival of seedlings would be expected to increase with age. For many mature Tuarts there is a delay following fire before they recover sufficiently to produce viable seed. This is estimated to be a minimum of 4-9 years following fire for Tuart (Ruthrof et al 2002). While no single fire regime will be suitable for all desired outcomes, Burrows (2008) recommends that the interval between fires be at least twice the period for maturity of the slowest maturing of the fire sensitive species, for example *Hibbertia cuneiformis*, *Leucopogon racemulosus*, *Beyeria cinerea*, *Ricinocarpos glaucus*, *Alyogyne huegelii*, *Myoporum insulare*, *Chamelaucium uncinatum*. However with climate shifts and reduced growth capacity in native species the inter-fire intervals may need to be substantially longer to allow for adequate seeding to occur to fully replenish the soil seed bank. Burning during reproductive periods (e.g. flowering, seeding or nesting) or while annual plant and deciduous geophyte taxa are establishing prior to flowering may also have a negative effect on the persistence of species, especially in fragmented populations.

Threatened fauna species in the ecological community considered susceptible to fire include Baudin's and Carnaby's cockatoos, Western Ringtail Possum and Southern Brush-tailed Phascogale. These species would be particularly susceptible to the loss of hollows in 'veteran' trees, which may be lost in even relatively cool burns (Department of Parks and Wildlife 2014a) with hollow trees forming a chimney (Johnstone and Kirkby 2016). Fire scars can also be the site of new hollow development but this takes a long time to occur (Gibbons and Lindenmayer 2012), thus it is likely that there is an immediate loss in habitat for hollow dependent species. The 2016 Waroona-Yarloop fire had a "devastating impact on the flora and fauna of the area", including loss of foraging and breeding habitat for black cockatoos (Johnstone and Kirkby 2016). Some recovery is apparent but long-term consequences are not currently known. As discussed previously, removal of trees after fires creates an additional impact. These losses compound those of the earlier Tuart decline event in the region.

Fire regimes are important for determining understorey microhabitat including fallen wood and litter characteristics, which are very important for fauna, in particular, reptiles. On the northern Swan Coastal Plain, Valentine et al (2009) found highest reptile abundance in long-unburnt sites and in Tuart forest, particularly associated *Menetia greyii* (Common Dwarf Skink), *Morethia obscura* (Shrubland Morethia Skink) and *Lerista elegans* (Elegant Slider) with sites that had been long unburnt. Of these species, *Menetia greyii*, as well as *Hemiergis* *quadrilineata* (Two-toed Earless Skink), which was also common, are associated with deep leaf litter. In surveys of reptiles and frogs following and intense fire at in Tuart woodlands at Bold Park, frogs and reptiles showed different responses. In the year following the fire reptiles showed a slight decline in species richness but a sharp decline in abundance. Frogs retained their species richness and increased in number (How 2002). Fire regimes also influence the success of feral animals: in the same study house mice were most commonly found in recently burnt patches, while the effectiveness of hunting by foxes and cats has also been associated with recent fire (Commonwealth of Australia 2015).

Prescribed burning often results in aseasonal, high frequency, cool burning. The impacts of these burns are likely to result in loss of soil organics that are critical for understorey health; loss of fire sensitive understorey species that require longer fire free intervals (e.g. multiple decades) to regenerate; exacerbation of the weed cover both in extent, density and potentially diversity of weeds – leading to higher flammability and greater risk to the ecological community; including, greater risk to wildlife with aseasonal burning impacting on breeding cycles and periods of occupancy within the ecological community.

C.6 Climate change

Climate change is affecting southwest Western Australia at a rapid rate. Temperatures have been increasing since the early 20th century and are very confidently predicted to continue increasing, both as a mean as well as the maxima, with more very hot days likely. Rainfall has been declining in the region since the 1970s and this is also projected to continue, with early winter rain possibly declining by as much as 45% by 2090 (Hope et al 2015; CSIRO and Bureau of Meteorology). The long term reduction in rainfall is also strongly reflected in streamflow patterns, while groundwater levels have also declined (Petrone et al 2010) . Correspondingly, time spent in drought is expected to increase, while fire weather is also expected to increase (Hope et al 2015; CSIRO and Bureau of Meteorology).

The climate change occurring throughout the region is having direct ecological effects and is also likely to have indirect threats and interact with other factors such as fire regimes. In the long term, climate change is likely to change the character of the community by altering resource availability and the competitive relationships between species. Declines in rainfall directly affect plants and changes hydrology (Longman and Keighery 2002). Substantial losses of trees on the Swan Coastal Plain, including Tuarts, have been attributed to water stress (e.g. Matusick et al 2012), with the prediction that similar events are increasingly likely (Department of Environment and Conservation 2011a). During February and March 2011, 500 ha of Tuart woodland at Lake Coolongup suffered from canopy dieback, following hot conditions and lower than usual rainfall. The areas affected were generally water-shedding areas, where trees were subject to greatest water stress. In these areas almost all trees were affected (Matusick et al 2012). Some fauna, such as Quenda, being dependent on damp habitats are also likely to be vulnerable to rainfall decline (Valentine et al 2012).

More frequent drought may also make the ecological community susceptible to other disturbances, for example, ringbarking by Longicorn beetles, as their larvae have been found to have greater survival when feeding on water-stressed trees (Caldeira et al 2002; Department of Parks and Wildlife 2014a). Some areas of the ecological community are found adjacent to and in wetland communities, which are likely to be affected by reduction in rainfall and falling water tables. Greater fire frequency due to changed climatic conditions is likely to affect the ability of plants to recover and recruit, as well as impacting on faunal populations. Some species are particularly susceptible to extreme heat, for example Western Ringtail

Possums are known to suffer heat stress in temperatures of 35ºC or more (Department of Parks and Wildlife 2014b). An increase in the number and maximum temperature of very hot days is likely to be an additional threat to species near their physiological limits.

C.7 Water extraction and other hydrological change

The hydrology of the region is complex, with interactions between surface water and multiple aquifers. Horwitz et al (2008) describe some of the contributing elements, including climate variability, patterns of land use change, in particular to vegetation cover, patterns of water regulation, patterns of groundwater extraction and water infrastructure.

With the reduction of rainfall throughout the region, recharge of surface acquifers as well as watercourses is expected to decline (Petrone et al 2010). For rivers in the southwest, models of flow predict a decline of between 5% -40% between 2006 and 2030 (Environmental Protection Authority 2006). The increase in salinity of Lake Clifton has been observed over several decades, which has been attributed to reduced rainfall as well as influx of saline groundwater drawn from nearby hyper-saline lakes (Forbes and Vogwill 2016). Within the range of the ecological community, groundwater levels have reduced due to extraction to support urban development, agriculture, mining, quarrying or other industries. Extraction of groundwater is likely to decrease the availability of water to support large trees such as Tuart, as well as having broader effects on the ecological community, for example, by reducing regional groundwater levels and the base flow of streams. The effects of changed water availability and quality on flora and fauna may be far reaching, for example, Honey Possums are dependent on nectar from plants such as Banksias, many of which are groundwater-dependent.

The interaction between reduced rainfall and local water extraction may have contributed to the decline of Tuart trees at Yalgorup (Tuart Response Group 2004). It is possible that influx of saline water into groundwater may also have increased salinity and affected Tuart trees there, but the relationship is not clear (Warden 2009). Decline of other riverine trees in the area has been associated with changed salinity following the construction of the Dawesville Channel (Gibson 2001). The shallowness of the water table around wetlands, such as the Vasse-Wonnerup system increases the chance of contamination of groundwater, as well as surface water, by nutrients, heavy metals, pesticides or herbicides (Wetlands Research and Management 2007).

C.8 Loss of fauna supporting key ecological processes

In response to a range of the primary threats identified above, the ecological community has lost a substantial component of its fauna, including those that contribute substantially to ecological function. These include ecosystem engineers such as Quenda, pollinators such as Honey Possum, seed dispersers and trophic regulators (e.g. predators of damaging species) such as grey currawong. The loss of these fauna in the ecological community is likely to impair its ongoing function and likelihood of recovery (Fleming et al 2013;also see D.4 Criterion 4 – Reduction in community integrity).

APPENDIX D – ELIGIBILITY FOR LISTING AGAINST EPBC ACT CRITERIA

The EPBC listing criteria are interpreted here with reference to the relevant guidelines (Australian Government Department of the Environment and Energy 2017).

D.1 Criterion 1 – Decline in geographic distribution

Criterion 1 categories			
Category	**Critically Endangered**	**Endangered**	**Vulnerable**
Its decline in geographic distribution is **either**:	very severe	**severe**	substantial
a) Decline relative to the longer-term (beyond 50 years ago e.g. since 1750); **or**,	≥90%	**≥70%**	≥50%
b) Decline relative to the shorter-term (past 50 years).	≥80%	≥50%	≥30%

Tuart woodlands and forests originally existed on a range of soil types and landscape positions throughout the latitudinal extent of the Swan Coastal Plain. In particular it was found on the Spearwood dunes, also Quindalup dunes, limestone ridges and in some locations in swales, wetland margins and riparian areas. Much of this area was also highly attractive for primary industries such as logging, grazing and agriculture and was rapidly cleared following non-Indigenous settlement, beginning in the early 19th Century (Horwitz et al 2008). More recently, patches have also been cleared for housing and commercial development and associated infrastructure such as roads, with some areas also subject to mining and quarrying. The location of Perth, approximately in the middle of the extent of occurrence, as well as other towns throughout the length of the Swan Coastal Plain has led to particularly severe losses due to clearing in these areas. Losses are likely to continue with ongoing urban expansions to accommodate future population growth. Additional losses have occurred through decline of key species, most notable the 'Tuart decline' that occurred in locations such as Yalgorup National Park in the early 2000s. These losses are still not well understood, but have been linked to conditions that could re-occur.

Full information on the spatial distribution of the ecological community is outlined in Appendix B.

To provide the best estimate for indicative decline of the ecological community, firstly Beard's Vegetation mapping association polygons identified as having 'strong' or 'medium' Tuart dominance were used to provide the likely indicative pre-European area of the ecological community. This area occupied by the ecological community is estimated as 125 407 ha (Department of Biodiversity, Conservation and Attractions 2017).

Secondly, the indicative current area of the ecological community was determined using areas mapped in the Tuart Atlas (Tuart Response Group, 2003) as having Tuart present that were within the pre-European area occupied by the ecological community of 125 407 ha. This is less than the total area mapped in the Tuart Atlas as some areas may have had Tuart present at very low densities. Thus, the estimated area of the ecological community in 2003 is 25 420 ha. This estimate of loss is likely conservative, due to the likely poor condition of areas. Keighery et al (2002) noted that Tuart communities are often over-mapped as a Tuart canopy may be present without any understorey. The areas in poorest condition may not meet the minimum condition category in Section 3.3.1 to be eligible for national protection. Secondly, clearing has continued at a considerable rate since the publication of the Tuart Atlas in 2003.

This indicates that the area of the ecological community declined by approximately 80% between 1750 (effectively beginning with non-Indigenous land use practices in the 1830s) and the publication of the Tuart Atlas in 2003.

To broadly identify the trend since 2003, any areas not identified as native vegetation by Department of Food and Agriculture Western Australia (2016), were compared with the 'current' area occupied by the ecological community at 2003. This provides an approximate loss of 8350 ha since 2003, which is approximately 14% of the estimated pre-European area occupied by the ecological community (a loss of 86% of the pre-European area of the ecological community). There are some differences in mapping methods between the datasets (e.g. scale, thresholds for canopy cover), so the 'current area occupied by the ecological community' is estimated to be in the range of between 17 070 ha and 25 420 ha for the purpose of applying this criterion.

Based on the estimated range of loss of 80-86%, the ecological community is considered to have undergone a **severe** decline (at least 70%) in its geographic distribution and is therefore eligible for listing as **endangered** under this criterion.

D.2 Criterion 2 – Limited geographic distribution coupled with demonstrable threat

Criterion 2 categories			
Its geographic distribution is:	**Very restricted**	**Restricted**	**Limited**
2.1. Extent of occurrence (EOO)	< 100 km^2 (<10,000 ha)	<1,000 km^2 (<100,000 ha)	**<10,000 km^2 (<1,000,000 ha)**
2.2. Area of occupancy (AOO)	< 10 km^2 (<1,000 ha)	<100 km^2 (<10,000 ha)	**<1,000 km^2 (<100,000 ha)**
2.3. Patch size	**< 0.1 km^2 (<10 ha)**	< 1 km^2 (<100 ha)	-
<u>AND</u> the nature of its distribution makes it likely that the action of a threatening process could cause it to be lost in:			
the Immediate future [within 10 years, or 3 generations of any long-lived or key species, whichever is the longer, up to a maximum of 60 years.]	Critically endangered	Endangered	Vulnerable
the Near future [within 20 years, or 5 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years.]	**Endangered**	Endangered	Vulnerable
The Medium term future [within 50 years, or 10 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years.]	Vulnerable	Vulnerable	Vulnerable

Full information on the geographic distribution is outlined in Appendix B.

D.2.1 Extent of occurrence

The current extent of occurrence of the ecological community occurs is approximately 389 748 ha which is considered to be a **limited** distribution (<1 000 000 ha) (analysis of Department of Biodiversity, Conservation and Attractions 2017a and Tuart Response Group 2003). This reflects a **limited** distribution (<1 000 000 ha).

D.2.2 Area of occupancy

The current area of occupancy of the ecological community is estimated to be approximately 17 070 ha – 25 420 ha (as in criterion 1; Section B.2 Patch size and distribution which is indicative of a **limited** distribution (<100 000 ha).

D.2.3 Patch size distribution

The ecological community is fragmented and the patches are unevenly distributed across its range. In the southern part of the range, the ecological community occurs mostly as a small number of larger patches, many in formally protected areas. In the central and more northerly parts of the range the community is highly fragmented, with patches that are much smaller and more isolated. Indicative of this, the median patch size south of Rockingham is 6.4 ha, that in the central area (between Rockingham and Burns Beach Road) is 3.3 ha while that for patches north of Burns Beach Road is 5.8 ha (Section B.2 Patch size and distribution) (Tuart Response Group 2003, DPAW 2017). It is likely that the very northern extent patches of Tuart woodlands have always been naturally more isolated from each other, in amongst other vegetation types, and possibly disjunct from the main distribution, as indicated by the genetic distinctness of the Tuart population there (Coates et al 2002). In contrast, the genetic similarity of the Tuart across the central and southern areas suggests that this population has historically been highly connected, as is consistent with accounts such as that of Gardner (1979) and that most fragmentation and isolation in the central part of the range is a factor of relatively recent human disturbance.

The patches in the central area are more than twice as likely to be separated by a distance greater than 100 m than are those in the southern area ().The landscape context in which the ecological community occurs is also one of high disturbance with woody native vegetation highly fragmented across the Swan Coastal Plain (Department of Food and Agriculture Western Australia 2016).

While the greatest proportion of patches is small, a high proportion of the total remaining area is concentrated in a few larger patches, particularly in the southern part of the range. This in constrast to the pre-European distribution with more connected, larger patches, particularly in the southern and central parts of the distribution. Across the range of the ecological community 64% of patches are less than 10 ha in size. The median patch size is 5.2 ha, with a mean of 53 ha, indicating a skewed distribution of patch sizes. As loss and fragmentation of the ecological community has resulted in most patches being below 10 ha, the distribution of the ecological community is considered to be **very restricted**.

D.2.4 Threats related to the geographic distribution of the ecological community

As described in APPENDIX C – DESCRIPTION OF THREATS, the ecological community is subject to a number of past, current and future threats. The location of the ecological community, which is restricted to the Swan Coastal Plain and approximately centred in the same location as the city of Perth, is a primary cause of its loss. The division of the once largely continuous populations of biota in the ecological community into separate populations, interrupted by large expanses of urban areas has imposed a significant change to the function of the ecological community.

Small populations of biota are inherently vulnerable to extinction, while small patches of habitat are particularly susceptible to a range of threats, including weed invasion, noted as a particular problem for this ecological community. Degradation often worsens over time. In the central areas of the ecological community, which is highly urbanised, the smallest patch size and populations occur and fragmentation is ongoing. Types of localised damage to natural areas often associated with nearby urbanisation include arson, rubbish dumping, trampling and track construction, weed incursion, and invasion by feral animals.

Fragmentation also results in greater distance between patches. The central part of the ecological community is particularly likely to be subject to greater distance between patches, compromising ecological processes such as genetic transfer. Recovery from disturbances such as fire is also likely to be reduced in these more isolated patches with little adjacent habitat to provide refuge and allow re-colonisation.

Ongoing development is likely to further fragment the remaining areas of the ecological community, as well as the surrounding native vegetation, particularly in the central area as urban infill occurs to accommodate the rapidly increasing population of greater Perth. Ongoing urban growth and development of associated infrastructure is severely limiting to the ecological community's recovery.

In the southern areas, the concentration of the limited total distribution of the ecological community in a few large patches creates a different kind of vulnerability. For example, the historic land use of forests in the Ludlow area, including Tuart Forest National Park, has led to significant weed problems, and the efficacy of weed management is impaired by re-invasion from the surrounding area.

Over a large proportion of its range the highly fragmented geographic distribution of ecological community, coupled with demonstrable threats, means that it could be lost in the immediate future. However over its entire range, including less fragmented areas, impacts from threatening processes associated with the very restricted geographic distribution are likely to cause its loss within the **near future**. Other threats impact the integrity of the ecological community including its larger patches, and may not be entirely associated with the nature of its geographic distribution. For example, the few large southern patches are also potentially susceptible to rapid loss through single large fire events, by spread of pathogens and occurrences such as 'Tuart decline'. Effects on ecological community integrity are examined under Criterion 4 – Reduction in community integrity.

D.2.5 Conclusion

Given the limited area and **very restricted** patch distribution of the ecological community and likelihood of ongoing area loss and fragmentation, threats such as weed invasion, inappropriate fire regimes or Tuart decline will plausibly lead to its loss within the **near future** (considered to be 5 generations of *Eucalyptus gomphocephala*, up to the threshold of 100 years, for this ecological community)[2]. Therefore the ecological community is eligible for listing as **endangered** under this criterion.

[2] The key canopy species in the ecological community is *Eucalyptus gomphocephala.* Generation time of this species is used to define timeframes for this criterion and considers the mean age of the parents of the current cohort of seedlings. Individuals of the species are long-lived – up to 350 years (Tuart Response Group 2004) – so the average age of the trees producing viable seed germinating as seedlings is likely to be at least 40 years (Jacobs 1955; Florence 1996). For this reason, the likelihood that a threatening process could cause it to be lost in the 'near future' is measured over five generations, with the time-frame capped at 100 years (Australian Government Department of the Environment and Energy 2017).

D.3 Criterion 3 – Loss or decline of functionally important species

Category	Critically endangered	Endangered	Vulnerable
For a population of a native species likely to play a major role in the community, there is a:	very severe decline (at least 80% over the last 10 years or three generations, whichever is longer)	**severe decline** **(at least 50%** **over the last 10 years or three generations, whichever is longer)**	substantial decline (at least 20% over the last 10 years or three generations, whichever is longer)
to the extent that restoration of the community is not likely to be possible in:	the immediate future (10 years, or 3 generations of any long-lived or key species, whichever is the longer, up to a maximum of 60 years)	**the near future** **(20 years, or 5 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years)**	the medium-term future (50 years, or 10 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years)

D.3.1 Role of Eucalypytus gomphocephala *as a functionally important species*

Tuart (*Eucalyptus gomphocephala*) is an important tree canopy species across the range of the ecological community. It is the largest tree occurring on the Swan Coastal Plain and thus has a unique structural role. It is the largest canopy tree species on the Swan Coastal Plain and naturally lives for up to 350 years (Tuart Response Group 2004). It provides the basic structure of the woodlands and forests and is necessary for the retention of the ecological community. Throughout its range Tuart trees also play an important role in local climate, soil health and hydrology.

The potentially large size of the canopy provides substantial habitat for a range of fauna, including a wide range of bird species (see Sections 2.4.4 and E.3 Native Fauna), with canopy habitats including flowers, fruit, epiphytes, lichens and perched litter, in addition to foliage and bark (Wentzel 2010). Tuart trees flower and fruit intermittently, and at this time provide nectar for birds including *Gavicalis virescens* (Singing Honeyeater) and *Lichmera indistincta* (Brown Honeyeater) and a wide range of insects, while the seeds themselves are consumed readily by ants (Ruthrof et al 2002).

Given the great height of mature trees, some birds, such as raptors and woodswallows may continue to benefit even after a tree's death, as stags provide good vantage points as well as nest sites. However, this resource is only available temporarily if there is no replacement of these trees.

Tuarts are relatively fast-growing and long-lived, so develop very substantial trunks, although many of the largest trees have been removed through forestry. This size enables the development of relatively large hollows that can accommodate fauna including some south-west endemic species, such as Carnaby's, Baudin's and Forest Red-tailed Black Cockatoos. The availability of suitable tree hollows for nesting, roosting and raising young has been identified as a limiting factor for conservation of these species. Appendix E.3 further outlines some examples of species in the ecological community likely to use hollows. While other tree species present also produce hollows, Tuarts have been recognised particularly for their role providing large hollows (Dell et al 2002; Department of Environment and Conservation 2012). Many of the trees in which these species nest are over 300 years old, with hollows only sufficient size for large fauna such as black cockatoos after over 200 years (Gibbons and Lindenmayer 2002; Western Australian Museum undated). The loss of mature Tuart trees due to preferential clearing for agriculture and forestry has reduced the availability of these habitat resources.

Tuart trees also play a substantial role in creating conditions for understorey species to thrive, providing shade and shelter. In the absence of healthy Tuart trees, other parts of the ecological community may be transformed. In a study of the effects of Tuart decline on fauna in Yalgorup National Park, at sites with unhealthy Tuart there was substantially lower quantities of leaf litter, as well as shrub cover than at healthy sites. This changed habitat availability was reflected in the significantly different reptile assemblage, with *Acritoscincus trilineatum* (Western Three-lined Skink) one of the species that was significantly less abundant where there were not healthy Tuart trees present. The assemblage of bats was associated with the vegetation structure, with *Vespadelus regulus* (Southern Forest Bat) and *Nyctophilus spp*. (Vesper Bats) associated with canopy cover above 10 m. *Falsistrellus mackenzei* (Western False Pipistrelle) is a bat species with limited distribution that is also negatively affected by the dieback of the Tuart crown. Amongst the birds surveyed, nectarivores were identified as being particularly affected by the Tuart dieback. This has broader implications for pollination in the ecological community. The study also identified species that increased in the absence of healthy Tuart, showing that there is a complete transition in ecological community when this canopy species loses its dominance (Wentzel 2010).

D.3.2 Estimated decline of Eucalyptus gomphocephala

The key canopy species in the ecological community is *Eucalyptus gomphocephala*. Generation time of this species is used to define timeframes for this criterion and considers the mean age of the parents of the current cohort of seedlings (Australian Government Department of the Environment and Energy, 2017). However, where generation length varies under threat it is appropriate to consider the average age of reproducing Tuart trees in a more natural, pre-disturbance state (see definition of generation length in IUCN 2017). There is little specific information on this, although the age when trees begin maximum flower and seed production, may be taken as a very conservative minimum approximation of generation length and this can vary substantially between Eucalypts, but many species in the genus are not expected to produce “seed in quantity until the stands are 20-40 years old”. For most eucalypts the best time for seed production is when “height growth is nearly complete and the crown is extending vigorously in a lateral direction” (Florence 1996 p. 134). Further to this, stand spacing substantially affects the quantity of seed produced. Most seed is produced by larger dominant and co-dominant trees, with smaller suppressed trees contributing little to seed production (Florence 1996). This implies that more mature trees within a stand are likely to be parents of most seedlings, with younger trees suppressed until a canopy gap is opened. Individuals of the species are long-lived – up to 350 years (Tuart Response Group 2004). Thus, under natural conditions, with substantial seed production only likely to begin after 20-40 years, and given the likelihood of suppression by older dominant trees, most parent trees are likely to be at least 40 years in age. Hence, this age is used to define the generation time for the species in responding to this criterion, while for restoration, the maximum allowable time for five generations of this species (to threshold of 100 years), is used to define the ‘near future’.

Declines in the area occupied by Tuart trees are likely to have begun from the 1830s with the commencement of non-Indigenous land use practices. The overall decline in area of the ecological community, is estimated at between 80-86 per cent of its pre-European distribution (see criterion 1). One of the key defining characteristics of the ecological community is the presence of Tuart trees in the canopy, so the broad decline in spatial distribution of this species within the ecological community is almost synonymous with the loss in the area of these woodlands and forests. In the early 20th century Tuart was an important forestry timber, valued for its great strength. The estimated area of the Tuart forestry resource in 1904 was 100 000 acres (approximately 40 000 ha). The area of distribution was defined at this time as being mainly the southern area between Busselton and Fremantle, with the smaller trees of the central and northern areas not recognised for forestry purposes (Harper et al 1904). In 2003 the southern area of the ecological community from near Busselton to Fremantle was approximately 20 400 ha (a loss of 49% of the estimated 1904 distribution (Tuart Response Group 2003 and DPAW 2017). By 2015 the remaining area was 13 900 ha (a loss of 65% since 1904), indicating that the substantial loss in total extent over the 20th century has continued into the 20th century, beyond the cessation of commercial forestry of Tuarts in the late 1970s (DAFWA 2016). In the central area of the ecological community, where commercial forestry for Tuarts was less relevant, more losses have related to urban and suburban development. Across the entire range of the ecological community, comparison of the area of the ecological community in 2003 (Tuart Response Group 2003) and in 2015 (Department of Food and Agriculture Western Australia 2016) broadly indicates a loss of up to 32% of total area over this recent 12 year period, suggesting that outside of the southern range, 20th century losses have been even more pronounced.

More importantly in responding to this criterion, within the area still mapped as the ecological community, there have been losses of Tuart trees, indicating that the population decline is likely to be greater than that indicated by loss in total extent alone (see APPENDIX C – DESCRIPTION OF THREATS). For example, the commercial logging that occurred in the 20th Century within areas that are still occupied by the ecological community, such as Tuart Forest National Park. The usefulness of Tuarts for heavy engineering applications is likely to have led to the preferential loss of many large trees within these areas. Further, in the 1990s and early 2000s a substantial loss of Tuart trees (of 80-90%) occurred in locations such as Preston Beach and Yalgorup National Park, which were previous strongholds (Barber and Hardy 2006; Wentzel 2010). This was attributed to a complex set of threats described as ‘Tuart decline’ (Tuart Response Group 2002). Some of the same areas where then affected by a severe fire event in 2016, followed by tree removal to address public safety concerns, increasing the losses and compromising recovery. Pathogens such as *Phytophthora multivora* and *Armillaria luteobubalina*, as well as invertebrates such as *Phoracantha* spp have further impacted on populations within remaining patches. Changes to hydrology and extreme weather events are also suspected to have caused losses of Tuart trees. Lack of recruitment due to factors such as unsuitable fire regimes and grazing pressure on seedlings has also been identified as an ongoing problem for the trees (Valentine and Ruthrof 2012, Ruthrof et al 2015), which has led to a skewed distribution of age classes and suggests future population decline when currently mature trees are lost. Where mature trees have been lost, regeneration is limited by the lack of soil seed storage by Tuart, which generally holds seed in the canopy (Ruthrof et al 2002).

Thus, there have been broad losses of the range of Tuart trees since 1900 (approximately three generations of Tuart, as defined above). Further, within the remaining patches there has been thinning and loss of Tuart trees due to a range of causes. In combination with the lack of replacement of trees within remaining patches over recent decades, there has been at least a **severe** decline in Tuart trees.

D.3.3 Likelihood of restoration

Across the range of the ecological community on the Swan Coastal Plain native vegetation has been substantially changed and replaced by other land use types: in the northern part of the range some native vegetation remains 'modified or 'transformed'; in the southern portion much is 'replaced', while in the Perth metropolitan region it is 'removed' (Lesslie et al 2010)[3]. In addition to loss of vegetation, this history of transformation has included the removal, degradation or covering of soils with impermeable surfaces and transformation of hydrology, which are substantial barriers to the operation of ecological processes. Increased separation between patches also reduces the likelihood of recruitment, as seed drop may occur over shorter distances than occur between many patches. A study of post-fire germination found that most seedlings occurred within a short distance of adult Tuarts, with the average distance being 2 m (Valentine and Ruthrof 2012). This is consistent with the general observations of Eucalypts typically distributing seed only over short distances. Inadequate burn temperature and seed predation were suggested by Valentine and Ruthrof (2012) as factors limiting recruitment.

The loss of fauna has also transformed the ecological community, with many of the species either threatened or regionally extinct. This impacts on biodiversity and also the function of the ecological community (for example, through the loss of pollination and soil engineering processes) (Valentine et al 2012). Much of this transformation is permanent within societal timeframes, so restoration of all these underpinning elements of the ecological community is not possible. For example, lack of critical habitat features such as large tree hollows is limiting for some of the fauna of the ecological community, but it is estimated that development of these hollows takes over 200 years (Gibbons and Lindenmayer 2002; Western Australian Museum undated). With the reduction of effective ecological functions, it is likely that systemic problems such as Tuart decline will be more likely to occur.

The physical replacement of many natural areas with urban areas is a substantial impediment that is not likely to be removed in the foreseeable future, given the projected increase of the Perth and Peel regional population by approximately 75 % (to 3.5 million residents) within 30 years (Government of Western Australia 2015a). While there have been efforts to restore elements of the remaining patches of the ecological community, its restoration as a whole is unlikely within the near future.

D.3.4 Conclusion

The loss of Tuart trees has been at least **severe** across the ecological community's range, and the ecological community is unlikely to be restored as a whole across its range within the **near future** so it is eligible for listing as **endangered** under this criterion.

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[3] The Vegetation Assets States and Transitions (VAST) framework defines a range of classes applicable to land cover reproduced here from Lesslie et al 2010 (p.9)

Relevant vegetation cover classes

Class II: MODIFIED Native vegetation community structure, composition and regenerative capacity intact—perturbed by land use or land management practice

Class III: TRANSFORMED Native vegetation community structure, composition and regenerative capacity significantly altered by land use or land management practice

Class IV: REPLACED -ADVENTIVE Native vegetation replacement—species alien to the locality and spontaneous in occurrence and Class V: REPLACED -MANAGED Native vegetation replacement with cultivated vegetation

Class VI: REMOVED Vegetation removed

D.4 Criterion 4 – Reduction in community integrity

Criterion 4 categories			
Category	**Critically Endangered**	**Endangered**	**Vulnerable**
The reduction in its integrity across most of its geographic distribution is:	**very severe**	severe	substantial
as indicated by degradation of the community or its habitat, or disruption of important community processes, that is:	**very severe**	severe	substantial

D.4.1 Introduction

The integrity of the ecological community has been severely compromised through various types of local degradation and broad scale landscape change. Some of the damage is readily apparent, for example in the altered vegetation structure and plant species richness (Keighery et al 2002). There has also been damage to the ecological processes underlying the function and resilience of the ecological community. Some of the damage, such as clearing and fragmentation, has been concentrated in the central part of the range, where Perth occurs, but still occurs across the entire range. Other types of damage have substantially affected even large remnants and reserved areas in the southern part of the range, for example extensive weed invasion, severe fire events and major tree loss due to 'Tuart decline'.

Much of the damage to the ecological community is intractable and the underlying threats continue. The loss of key habitat features and of fauna species that play important roles in maintaining the ecological community are amongst the most difficult of the changes to overcome.

D.4.2 Vegetation structure and composition

Tuart trees are naturally long lived and are the largest tree species on the Swan Coastal Plain. Old Tuarts, as well as other canopy trees such as Jarrah and Marri are noted for their important ecological role in providing habitat, especially through the provision of hollows (Tuart Response Group 2004). This has critical importance for a range of species native to the Swan Coastal Plain (see Criterion 3 and Appendix A). Sub canopy trees such as Banksias and Peppermint also provide important habitat resources, including foods such as foliage and nectar. Many of the trees that form the ecological community have been cleared, compromising its integrity. More recently there have been other causes of loss identified, such as hydrological change and diseases including *Phytophthora cinnamomi* (affecting species such as Jarrah), and *P. multivora*, (which may affect Tuart), as well as long term changes in fire regimes (Scott et al. 2009). 'Tuart decline' occurring particularly in the Yalgorup area substantially reduced the tree canopy, particularly within the National Park (Tuart Response Group 2002). The 2016 Waroona Yarloop fires affected some of the area still in recovery. In Tuart Forest National Park, as well as more broadly, lack of recruitment of trees has also been identified as a problem, as mature trees are lost from the landscape, indicating that 'Tuart ecosystems are functionally degraded and are not self-sustaining' (Department of Parks and Wildlife 2014a, p.17; Ruthrof et al 2015).

In addition to the areas of the ecological community that have been lost (Criterion 1), available data suggests that the structure and composition of vegetation at most sites is degraded or modified. A 2003 assessment indicated that at that time at least 60 % of the areas mapped in the Tuart Atlas had a disturbed understorey (Tuart Response Group 2003). This indicates that any floral biodiversity associated with the understorey is likely to be compromised and habitat available to a range of fauna substantially reduced. The loss of understorey layers is also likely to have altered underlying biophysical qualities and processes, for example, soil characteristics, fire behaviour and hydrology.

Where native understorey has been lost or degraded, in many cases there has been invasion of non-native plants, with common weed species including arum lily, bridal creeper and non-native grasses. The iconic Tuart Forest National Park is amongst the areas greatly affected by weeds such as arum lily, while the remnants in the Perth Metropolitan Region have also shown a high incidence of weeds (see Threats: weeds). Some of these weeds (e.g. non-native grasses) affect the fire regimes in the ecological community (Fisher et al 2009). The ecological community has also been damaged by grazing by stock. Changes to the landscape may also have resulted in the local increase of some native species such as Western Grey Kangaroo, which may be limiting the regeneration of the understorey (Brown et al 2016).

D.4.3 Landscape connectivity

Across the range of the ecological community, the area of native vegetation loss has been substantial, with approximately 73 % of woody native vegetation already cleared (analysis of data from Department of Food and Agriculture Western Australia 2016). The reduction of physical linkages across the landscape reduces the ability of animals to forage and find breeding partners, with the smaller remnants likely to have lost many of their fauna. Some taxa, such as reptiles are particularly vulnerable to fragmentation and isolation (Wentzel 2010). Across its range, over 70 % of patches of the ecological community are at least 100 m from another patch of the ecological community. For the central part of the ecological community this figure is approximately 85 % of patches. While many of the remnants of the ecological community are adjacent to other native vegetation, 17% are more than 100 m from other native vegetation. This is likely to be beyond the reach of many taxa that are not able to traverse wide open spaces, for example, many small, insectivorous passerine birds, small lizards, terrestrial arthropods, and many other invertebrates. Movement of some fauna is further compromised if hard barriers exist, such as fences, roads, and buildings. Furthermore, where direct connections do exist their width may be not be sufficient to allow safe passage for vulnerable fauna (Molloy et al 2009). The gaps between remnants of the ecological community and distance from other native vegetation also compromises population processes for other biota, such as plants and fungi, by reducing the transfer of pollen, seeds and spores to other suitable areas.

These changes to landscape function are unlikely to be reversed, in the face of ongoing clearing to support urbanisation, infrastructure provision and extractive industries. The location of Perth in the centre of the range of the ecological community is a major barrier to the continuation of ecological processes across its range, as indicated by the smaller patch sizes and wider patch separation in this area.

D.4.4 Fauna

The assemblage of fauna species is a key part of the biodiversity and identity of the ecological community. They also make important contributions to ecological function, through processes such as soil engineering, pollination, seed dispersal and pest control.

In response to changes such as vegetation clearing and fragmentation, as well as other disturbances such as disease, grazing, introduction of new predators and change to fire regimes across the region many of these species have reduced populations or ranges. Some that may have been part of the ecological community are regionally lost (e.g. birds such as Grey Currawong and mammals such as Woylie) or completely extinct e.g. *Potorous platyops* (Broad-faced Potoroo) (Fleming et al, 2013; Burbidge and Woinarski, 2016). In the Perth region the losses include almost all small mammals (Dell et al, 2002). Many fauna play critical roles in ecosystem function, including maintenance of soil processes, pollination, seed dispersal and trophic regulation.

Soil engineers such as Quenda (also likely Woylies, at some locations in the past) turn over soil through their creation of foraging pits and other digging behaviour. This digging plays an important role in establishing suitable conditions for regeneration of plants by increasing soil permeability and water infiltration, reducing density, burying seeds and spreading beneficial mycorrhizae (Fleming et al 2013). For instance, while the foraging pits are not deep, the total soil turnover by individual Woylies has been estimated at 4.8 tonnes – 6 tonnes per year (Valentine et al 2012; Yeatman and Groom 2012), while that of Quenda has been estimated at 3.9 tonnes per year (Valentine et al 2012). Extrapolated across the former ranges and densities of these species in the region this turnover would have been substantial. In a study of diggings of Quenda in within an area of the ecological community in Yalgorup National Park, Valentine et al (2016) found that fresh diggings had higher moisture and were less hydrophobic than nearby undisturbed soil. Foraging pits also attracted fine litter, which potentially leads to higher nutrient levels. In combination, these characteristics may explain the higher rates of seedling recruitment for Tuart as well as *Acacia saligna* (Orange Wattle, Golden Wattle) and *Kennedia prostrata* running postman) found in sites with diggings mimicking those of Quenda. Digging fauna have also been noted for their likely roles in dispersing seeds and fungal spores throughout their home ranges.

The decline in populations of digging animals in the ecological community has been marked. At European colonisation at least nine digging animal species are believed to have been present in the southwest, while now Quenda and Echidna are the only two of these species that still commonly occur. Even amongst these, the entire range of the Quenda has reduced to approximately 40 % of its former size (Valentine et al 2016). Declines in mammals in the southwest has been related to disease, as well as poisoning, and predation by cats and foxes (Abbott 2008; Burbidge and Woinarski). Quenda have persisted on the urban-bush interface, but in reduced populations. Their preference for damp habitats is thought to make them vulnerable to the drying climate of the region (Valentine et al 2012).

The decline of seed dispersers and pollinators such as Yellow-plumed Honeyeater, Honey Possum and Pygmy Possum may also compromise the reproductive ability of plants in the ecological community (Dell et al 2002). The decline of insectivorous bird species such as Crested Shrike-tit, Grey Currawong, and Rufous Treecreeper, which were previously associated with Tuart woodlands and forests, as well as insectivorous mammals such as bats may also increase the susceptibility of plants to insect attack (Dell et al 2002; Casson et al 2009). Similarly, the decline in black cockatoos has been suggested as a possible cause of increased susceptibility of Tuart trees to damage by Tuart Longicorn larvae (Ruthrof et al 2002).

D.4.5 Climate and hydrology

The rapidly changing climate of southwest Western Australia is affecting the health of various woodlands and forests on the Swan Coastal Plain. Rapid losses of mature trees of various species in the Perth region, including Tuart, and other tree species associated with the ecological community have been linked to reduced water availability. This may be the result of water extraction for agriculture and urban use as well as the long term changes to rainfall recognised across the southwest. Water stress may also have contributed to the loss of trees through 'Tuart decline' in the Yalgorup area' (Tuart Response Group 2004). These factors have also been linked to broader biodiversity decline throughout the region (Horwitz et al 2008). These pressures associated with water availability are likely to intensify in the future. The changes to fire regimes through management changes as well as the drying climate, and increased presences of weeds that promote frequent fires have also compromised condition (Fisher et al 2009).

D.4.6 Conclusion

While active interventions make valuable contributions to conservation, many of the changes to the ecological functions underpinning the ecological community are **very severe** and of a long-term nature, with many of the underlying threats continuing and interacting. The damage includes important changes to the structure and floristics of the ecological community, permanent change to the landscape characteristics such as landscape connectivity, reduction in key habitat features such as hollows, and the loss of fauna supporting critical ecosystem functions. Some damage is concentrated in the central part of the ecological community, while other losses of integrity are evident throughout, including in large and important protected areas. These losses are likely to severely compromise restoration of the ecological community as a whole, which is unlikely to occur in the immediate future. Therefore the ecological community is eligible for listing as **critically endangered** under this criterion.

D.5 Criterion 5 – Rate of continuing detrimental change

Criterion 5 categories			
Category	**Critically Endangered**	**Endangered**	**Vulnerable**
Its rate of continuing detrimental change is:			
as indicated by a) degradation of the community or its habitat, or disruption of important community processes, that is:	very severe	severe	substantial
or b) intensification, across most of its geographic distribution, in degradation, or disruption of important community processes, that is:			
5.1 An observed, estimated, inferred or suspected *detrimental change* over the *immediate*[#] past or projected for the *immediate* future of at least:	80%	50%	30%

[#] The immediate timeframe refers to10 years, or 3 generations of any long-lived or key species believed to play a major role in sustaining the community, whichever is the longer, up to a maximum of 60 years.

The ecological community has experienced a long history of substantial clearing and fragmentation and continues to be cleared for development. While the damage to the understorey and prevention of regeneration related to grazing continues, data are insufficient to create a quantitative model of this. There is also the possibility of a rapid expansion of Tuart decline, but the likelihood of this is unknown. Similarly, other changes such as the invasion by weeds and feral animals continues, but the rate at which this is occurring has not been assessed throughout the ecological community's range.

The guidelines for listing against this criterion require a minimum detrimental change of at least 30 percent over the immediate past, or suspected for the immediate future. While detrimental change is likely to continue, there is **insufficient information** available on the rates of loss in the recent past, or planned for the immediate future to determine eligibility against any category for this criterion.

D.6 Criterion 6 – Quantitative analysis showing probability of extinction

Criterion 6 categories			
Category	**Critically Endangered**	**Endangered**	**Vulnerable**
A quantitative analysis shows that its probability of extinction, or extreme degradation over all of its geographic distribution, is:	at least 50% in the immediate future.	at least 20% in the near future.	at least 10% in the medium-term future.

No quantitative analysis has been undertaken showing likelihood of extinction for this ecological community. Therefore there is **insufficient information** available to determine eligibility against any category for this criterion.

APPENDIX E – SPECIES LISTS

E.1 Native Flora

Table 9. Native plants, Noongar names and traditional uses

Native plants likely to occur as part of the ecological community and notes on traditional uses.

Sources: Abbott 1983; Bindon and Walley 1998; Keighery 2002; City of Joondalup 2011; Hansen and Horsfall 2017. Scientific names current at May 2018.

^The majority of the information on traditional uses presented here is summarised from Hansen and Horsfall (2017). Use of these plants as food or medicine should only be made with expert knowledge. Some Noongar names for species are presented where these are known, but their use can vary with location.

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Aizoaceae	*Carpobrotus modestus*	Inland Pigface		
Aizoaceae	*Carpobrotus virescens*	Coastal Pigface	*bain, kolbolgo*	Succulent creeper. Flowers Makuru - Birak (Winter- Summer). Leaves used for medicine for various problems with digestive system and, as antiseptic and a variety of skin conditions. Fruit also edible.
Aizoaceae	*Tetragonia tetragonoides*	New Zealand Spinach		
Asparagaceae	*Acanthocarpus preissii*			
Asparagaceae	*Chamaescilla corymbosa var. corymbosa*	Blue Squill		
Asparagaceae	*Dichopogon capillipes*			
Asparagaceae	*Lomandra caespitosa*	Tufted Mat-rush		
Asparagaceae	*Lomandra hermaphrodita*			
Asparagaceae	*Lomandra maritima*	Coastal Mat-rush		
Asparagaceae	*Lomandra micrantha* subsp. *micrantha*	Small-flower Mat-rush		
Asparagaceae	*Lomandra preissii*			

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Asparagaceae	*Lomandra purpurea*	Purple Mat-rush		
Asparagaceae	*Lomandra sericea*	Silky Mat-rush		
Asparagaceae	*Lomandra suaveolens*			
Asparagaceae	*Sowerbaea laxiflora*	Purple Tassels		
Asparagaceae	*Thysanotus arenarius*			
Asparagaceae	*Thysanotus dichotomus*	Branched Fringe Lily		
Asparagaceae	*Thysanotus manglesianus*	Fringe Lily		
Asparagaceae	*Thysanotus manglesianus/ patersonii*			
Asparagaceae	*Thysanotus multiflorus*	Many-flowered Fringe Lily		
Asparagaceae	*Thysanotus patersonii*	Twining Fringe Lily		
Asparagaceae	*Thysanotus sparteus*			
Asparagaceae	*Thysanotus thyrsoideus*			
Asparagaceae	*Tricoryne elatior*	Yellow Autumn Lily		
Asparagaceae	*Tricoryne tenella*			
Amaranthaceae	*Ptilotus drummondii*	Narrowleaf Mulla Mulla		
Amaranthaceae	*Ptilotus manglesii*	Pom Poms		
Amaranthaceae	*Ptilotus polystachyus*	Prince of Wales Feather		
Amaranthaceae	*Ptilotus sericostachyus*			
Amaranthaceae	*Ptilotus stirlingii*	Stirling's Mulla Mulla		
Apiaceae	*Apium prostratum*	Sea Celery		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Apiaceae	*Centella asiatica*			
Apiaceae	*Daucus glochidiatus*	Australian Carrot		
Apiaceae	*Eryngium pinnatifidum*	Blue Devils		
Apiaceae	*Homalosciadium homalocarpum*			
Apiaceae	*Hydrocotyle alata*			
Apiaceae	*Hydrocotyle callicarpa*	Small Pennywort		Leaves burnt and inhaled to treat pain. Vapour from crushed leaves used to treat headaches and cold symptoms.
Apiaceae	*Hydrocotyle capillaris*	Thread Pennywort		
Apiaceae	*Hydrocotyle diantha*			
Apiaceae	*Hydrocotyle hispidula*			
Apiaceae	*Hydrocotyle pilifera* var. *glabrata*			
Apiaceae	*Hydrocotyle tetragonocarpa*			
Apiaceae	*Trachymene coerulea*	Blue Lace Flower		Thrives in limestone areas. Bulbs and leaves used externally for aches and pains. Leaves crushed to help with headaches.
Apiaceae	*Trachymene pilosa*	Native Parsnip		
Apocynaceae	*Alyxia buxifolia*	Dysentery Bush		Flowers Djeran - Birak (Autumn- Summer) Fruits Birak-Bunuru (Summer). Crushed bark used to make medicine for diarrhorea and dysentery.
Asphodelaceae	*Bulbine semibarbata*	Leek Lily		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Asteraceae	*Asteridea pulverulenta*	Common Bristle Daisy		
Asteraceae	*Brachyscome iberidifolia*	Swan River Daisy		
Asteraceae	*Bracteanthum macranthum*			
Asteraceae	*Cotula australis*	Common Cotula		
Asteraceae	*Craspedia* sp. Yalgorup National Park (G.J. Keighery 14449)			
Asteraceae	*Euchiton gymnocephalu s*			
Asteraceae	*Euchiton sphaericus*	Star Cudweed		
Asteraceae	*Gnaphalium indutum*			
Asteraceae	*Ixiolaena viscosa*	Sticky Ixiolaena		
Asteraceae	*Lagenophora huegelii*	Coarse Lagenophora		
Asteraceae	*Millotia myosotidifolia*			
Asteraceae	*Millotia tenuifolia*	Soft Millotia		
Asteraceae	*Olearia axillaris*	Coastal Daisybush		
Asteraceae	*Olearia rudis*	Rough Daisybush		
Asteraceae	*Picris squarrosa*			
Asteraceae	*Pithocarpa cordatua*	Tangle Bush		
Asteraceae	*Pithocarpa pulchella*	Beautiful Pithocarpa		
Asteraceae	*Podolepis canescens*			
Asteraceae	*Podolepis gracilis*	Slender Podolepis		
Asteraceae	*Podolepis lessonii*			

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Asteraceae	*Podotheca angustifolia*	Sticky Longheads		
Asteraceae	*Podotheca chrysantha*	Yellow Podotheca		
Asteraceae	*Podotheca gnaphalioides*	Golden Longheads		
Asteraceae	*Pterochaeta paniculata*	Woolly Waitzia		
Asteraceae	*Quinetia urvillei*			
Asteraceae	*Rhodanthe citrina*			
Asteraceae	*Rhodanthe corymbosa*			
Asteraceae	*Senecio hispidulus*	Hispid Fireweed		
Asteraceae	*Senecio pinnatifolius* subsp. *maritimus*	Variable Groundsel	*yoont djet*	
Asteraceae	*Senecio quadridentatus*	Cotton Fireweed		
Asteraceae	*Senecio ramosissimus*	Auricled Groundsel		
Asteraceae	*Siloxerus humifusus*	Procumbent Siloxerus		
Asteraceae	*Sonchus hydrophilus*	Native Sowthistle		
Asteraceae	*Waitzia nitida*	Golden Waitzia		
Asteraceae	*Waitzia suaveolens* var. *suaveolens*	Fragrant Waitzia		
Brassicaceae	*Lepidium pseudohyssopifolium*			
Brassicaceae	*Lepidium rotundum*	Veined Peppercress		
Brassicaceae	*Stenopetalum gracile*			
Brassicaceae	*Stenopetalum robustum*			

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Caesalpiniaceae	*Labichea cassioides*			
Campanulaceae	*Isotoma hypocrateriformis*	Woodbridge Poison		
Campanulaceae	*Lobelia anceps*	Angled Lobelia		
Campanulaceae	*Lobelia gibbosa*	Tall Lobelia		
Campanulaceae	*Lobelia heterophylla*	Wing-seeded Lobelia		
Campanulaceae	*Lobelia tenuior*	Slender lobelia		
Campanulaceae	*Wahlenbergia multicaulis*			
Campanulaceae	*Wahlenbergia preissii*			
Casuarinaceae	*Allocasuarina humilis*	Scrub She-oak		
Celastraceae	*Stackhousia huegelii*			
Celastraceae	*Tripterococcus brunonis*	Winged Stackhousia		
Centrolepidaceae	*Centrolepis aristata*	Pointed Centrolepis		
Centrolepidaceae	*Centrolepis drummondiana*			
Chenopodiaceae	*Enchylaena tomentosa var. tomentose*	Barrier Saltbush		
Chenopodiaceae	*Rhagodia baccata* subsp. *baccata*	Berry Saltbush		
Chenopodiaceae	*Rhagodia baccata* subsp. *dioica*	Berry Saltbush		
Chenopodiaceae	*Threlkeldia diffusa*	Coast Bonefruit		
Colchicaceae	*Burchardia congesta*	Milkmaids		Roots eaten
Colchicaceae	*Wurmbea monantha*			
Colchicaceae	*Wurmbea tenella*			

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Commelinaceae	*Cartonema philydroides*			
Convolvulaceae	*Dichondra repens*	Kidney Weed		
Crassulaceae	*Crassula colorata* var. *colorata*	Dense Stonecrop		
Crassulaceae	*Crassula exserta*			
Crassulaceae	*Crassula peduncularis*	Purple Stonecrop		
Cupressaceae	*Callitris preissii*	Rottnest Island Pine	*marro*	Medium sized tree with round woody cones. Leaves, bark and stems used to make smoke to treat respiratory problems. Infusions of leaves used for respiratory and sius conditions. Nuts pounded and used to treat skin problems.
Cyperaceae	*Baumea articulata*	Jointed Rush		
Cyperaceae	*Baumea juncea*	Baumea Twigrush		
Cyperaceae	*Baumea vaginalis*	Sheath Twigrush		
Cyperaceae	*Carex appressa*	Tall Sedge		
Cyperaceae	*Carex thecata*			
Cyperaceae	*Cyperus polystachyos*	Bunchy Sedge		
Cyperaceae	*Ficinia nodosa*	Knotted Club-rush		
Cyperaceae	*Gahnia trifida*	Coast Saw-sedge		
Cyperaceae	*Isolepis cernua*	Nodding Club-rush		
Cyperaceae	*Isolepis cyperoides*			
Cyperaceae	*Isolepis stellata*	Star Club-rush		
Cyperaceae	*Lepidosperma gladiatum*	Coast Sword-sedge, Kerbin		
Cyperaceae	*Lepidosperma leptostachyum*			

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Cyperaceae	*Lepidosperma longitudinale*	Pithy Sword-sedge		
Cyperaceae	*Lepidosperma sp.* (Coastal terete BJK & NG231)			
Cyperaceae	*Lepidosperma squamatum*			
Cyperaceae	*Mesomelaena preissii*			
Cyperaceae	*Mesomelaena stygia*			
Cyperaceae	*Schoenoplectus tabernaemontani*			
Cyperaceae	*Schoenus clandestinus*			
Cyperaceae	*Schoenus curvifolius*			
Cyperaceae	*Schoenus grandiflorus*	Large-flowered Bog-rush		
Cyperaceae	*Schoenus humilis*			
Cyperaceae	*Schoenus nitens*	Shiny Bog-rush		
Cyperaceae	*Schoenus subflavus*	Yellow Bog-rush		
Cyperaceae	*Tetraria octandra*			
Cyperaceae				
Dasypogonaceae	*Dasypogon bromeliifolius*	Pineapple Bush		
Dennstaedtiaceae	*Pteridium esculentum*	Bracken	*munda*	Leaf tips and roots prepared as food. Crushed leaves used as wash for sores and to relieve arthritis, also used to make medicine to treat intestinal worms.
Dilleniaceae	*Hibbertia cuneiformis*	Cutleaf Hibbertia		
Dilleniaceae	*Hibbertia hypericoides*	Yellow Buttercups		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Dilleniaceae	*Hibbertia racemosa*	Stalked Guinea Flower		
Dilleniaceae	*Hibbertia subvaginata*			
Droseraceae	*Drosera erythrorhiza*	Red-ink Sundew		
Droseraceae	*Drosera glanduligera*	Pimpernel Sundew		
Droseraceae	*Drosera menziesii* subsp. *penicillaris*	Pink Rainbow		
Droseraceae	*Drosera pallida*	Pale Rainbow		
Droseraceae	*Drosera stolonifera*	Leafy Sundew		
Ericaceae	*Astroloma ciliatum*	Candle Cranberry	*cadgeegurru p*	Berries eaten
Ericaceae	*Astroloma pallidum*	Kick Bush	*cadgeegurru p*	Berries eaten
Ericaceae	*Conostephium pendulum*	Pink-tipped Pearl		
Ericaceae	*Conostephium preissii*			
Ericaceae	*Leucopogon capitellatus*			
Ericaceae	*Leucopogon oxycedrus*			
Ericaceae	*Leucopogon parviflorus*	Coast Beard-heath		
Ericaceae	*Leucopogon propinquus*			
Ericaceae	*Leucopogon racemulosus*			
Euphorbiaceae	*Adriana quadripartita*	Bitter Bush		
Euphorbiaceae	*Beyeria cinerea*			
Euphorbiaceae	*Euphorbia australis*	Namana		
Euphorbiaceae	*Monotaxis grandiflora*	Diamond of the Desert		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Euphorbiaceae	*Ricinocarpus glaucus*	Wedding Bush		
Fabaceae	*Bossiaea eriocarpa*	Common Brown Pea		
Fabaceae	*Chorizema diversifolium*	Yellow-eyed Flame Pea		
Fabaceae	*Daviesia divaricata*	Marno		
Fabaceae	*Daviesia preissii*			
Fabaceae	*Gastrolobium praemorsum*			
Fabaceae	*Gompholobium confertum*			
Fabaceae	*Gompholobium tomentosum*	Hairy Yellow Pea		
Fabaceae	*Hardenbergia comptoniana*	Native Wisteria		
Fabaceae	*Hovea chorizemifolia*	Prickly Hovea		
Fabaceae	*Hovea stricta*	Hovea		
Fabaceae	*Hovea trisperma* var. *trisperma*	Common Hovea		
Fabaceae	*Isotropis cuneifolia subsp. cuneifolia*	Granny Bonnets		
Fabaceae	*Jacksonia calcicola*			
Fabaceae	*Jacksonia furcellata*	Grey Stinkwood		
Fabaceae	*Jacksonia horrida*			
Fabaceae	*Jacksonia sericea*	Waldjumi		
Fabaceae	*Jacksonia sternbergiana*	Stinkwood, Kapur		
Fabaceae	*Kennedia coccinea*	Coral Vine		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Fabaceae	*Kennedia prostrata*	Scarlet Runner, Running Postman	*Wollung*	Creeping groundcover with red pea flowers in Djeran-Kambarang (Autumn- Spring). Responds well to rain. Nectar used for sore throats, leaves infused to make a drink. Stems used to make twine.
Fabaceae	*Nemcia reticulata*			
Fabaceae	*Sphaerolobium medium*			
Fabaceae	*Templetonia retusa*	Cockies Tongues		
Geraniaceae	*Erodium cygnorum*	Blue Heronsbill		
Geraniaceae	*Geranium retrorsum*			
Geraniaceae	*Geranium solanderi*	Native Geranium		Low herb. Roots used to treat diarrhoea.
Geraniaceae	*Pelargonium littorale*			
Goodeniaceae	*Dampiera linearis*	Common Dampiera		
Goodeniaceae	*Lechenaultia floribunda*	Free-flowering Leschenaultia		
Goodeniaceae	*Lechenaultia linarioides*	Yellow Leschenaultia		
Goodeniaceae	*Scaevola crassifolia*	Thick-leaved Fanflower		
Goodeniaceae	*Scaevola nitida*	Shining Fanflower		
Goodeniaceae	*Scaevola thesioides*			
Gyrostemonaceae	*Tersonia cyathiflora*	Button Creeper		
Haemodoraceae	*Anigozanthos humilis*	Cat's Paw		Starchy roots eaten
Haemodoraceae	*Anigozanthos manglesii*	Mangles Kangaroo Paw	*kurulbrang,n ollamara, yonga marra).*	Starchy roots eaten
Haemodoraceae	*Conostylis aculeata*	Prickly Conostylis		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Haemodoraceae	*Conostylis candicans*	Grey Cottonhead		
Haemodoraceae	*Conostylis pauciflora* subsp. *pauciflora*	Dawesville conostylis		
Haemodoraceae	*Conostylis setigera*	Bristly Cottonhead		
Haemodoraceae	*Haemodorum spicatum*	Bloodroot	*mardja, bohn, mardje*	Root roasted and pounded as spice. Pounded with clay from termites' nests to reduce diarrhoea. Bulbs used as part of arthritis treatment. Colour used as a dye.
Haemodoraceae	*Phlebocarya ciliata*			
Haloragaceae	*Haloragis aculeolata*			
Hemerocallidaceae	*Caesia micrantha*	Pale Grass-lily		
Hemerocallidaceae	*Corynotheca micrantha var. micrantha*	Sand Lily		
Hemerocallidaceae	*Dianella brevicaulis*			
Hemerocallidaceae	*Dianella revoluta*	Blueberry Lily	*mangard*	Flowering Kambarang-Birak (late Spring-Summer). Fruits eaten, roots roasted and eaten. Leaves used for string. Medicine for headaches used from leaves and from roots for colds.
Hemerocallidaceae	*Stypandra glauca*	Blind Grass		
Hypoxidaceae	*Pauridia glabella*	Tiny Star		
Iridaceae	*Orthrosanthus laxus*	Morning Iris		
Iridaceae	*Patersonia juncea*	Rush-leaved Patersonia		
Iridaceae	*Patersonia occidentalis*	Purple Flag, Koma		
Juncaceae	*Luzula meridionalis*	Field Woodrush		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Juncaginaceae	*Triglochin centrocarpum*	Dwarf ArrowGrass		
Juncaginaceae	*Triglochin muelleri*			
Juncaginaceae	*Triglochin* sp. A Flora of Australia (G.J.Keighery 2477*)*			
Juncaginaceae	*Triglochin trichophorum*			
Lamiaceae	*Hemiandra pungens*	Snakebush		
Lauraceae	*Cassytha flava*	Dodder Laurel		Parasitic climber with no leaves. Climbs over other plants with wiry stems. Fruits used as a laxative and applied to cuts and sores.
Lauraceae	*Cassytha glabella*	Tangled Dodder Laurel		Parasitic climber with no leaves. Climbs over other plants with wiry stems. Fruits used as a laxative and applied to cuts and sores.
Lauraceae	*Cassytha pubescens*	Downy Dodder Laurel		
Lauraceae	*Cassytha racemosa*	Dodder Laurel		Parasitic climber with no leaves. Climbs over other plants with wiry stems. Fruits used as a laxative and applied to cuts and sores.
Linaceae	*Linum marginale*	Wild Flax		
Lindsaeaceae	*Lindsaea linearis*	Screw-fern		
Loganiaceae	*Logania serpyllifolia*			
Loganiaceae	*Logania vaginalis*	White Spray		
Loganiaceae	*Phyllangium paradoxum*	Wiry Mitrewort		
Loranthaceae	*Amyema miquelii*	Stalked Mistletoe		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Loranthaceae	*Nuytsia floribunda*	Christmas Tree	*mudja, modya*	
Malvaceae	*Alyogyne huegelii*			
Malvaceae	*Androcalva luteiflora*			
Malvaceae	*Guichenotia ledifolia*			
Malvaceae	*Lasiopetalum membranaceum*			
Malvaceae	*Thomasia cognata*			
Malvaceae	*Thomasia purpurea*			
Malvaceae	*Thomasia triphylla*			
Mimosaceae	*Acacia alata* var. *tetrantha*		*kunart - Wattle tree gum*	
Mimosaceae	*Acacia cochlearis*	Rigid Wattle		
Mimosaceae	*Acacia cyclops*	Coastal Wattle, Red-eyed Wattle	*munyuret, woolya wah, wilyawa*	Dense shrub to tree. Yellow flowers Djilba-Birak-Djeran (Spring-Autumn). Seed pods twisted. Seeds ground to make flour and baked. Juice of leaves used as soap, to treat eczema, insect repellant and sunscreen. Gum edible and used to create glue. Hosts edible grubs.
Mimosaceae	*Acacia huegelii*			
Mimosaceae	*Acacia lasiocarpa*	Panjang	*panjang*	
Mimosaceae	*Acacia pulchella* var. *glaberrima*	Prickly Moses		
Mimosaceae	*Acacia rostellifera*	Summer-scented Wattle		
Mimosaceae	*Acacia saligna*	Orange Wattle	*kudjong, cujong*	Edible seeds

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Mimosaceae	*Acacia stenoptera*	Narrow Winged Wattle		
Mimosaceae	*Acacia truncata*			
Mimosaceae	*Acacia willdenowiana*	Grass Wattle		
Mimosaceae	*Paraserianthes lophantha*	Albizia		
Myrtaceae	*Agonis flexuosa*	Peppermint, Willow Myrtle	*wonil*	Medium sized tree with weeping habit. White flowers in Djilba-Bunuru (Spring-Summer).Common sub-canopy beneath Tuart trees south of Perth. Crushed leaves used to relieve nasal congestion in babies. Leaves used to make mouthwash and antiseptic. Smoke used to treat respiratory problems. Ash mixed with fat for a poultice. Smoke used ceremonially.
Myrtaceae	*Calothamnus quadrifidus*	One-sided Bottlebrush	*kwowdjard,queitjat*	Nectar drunk directly, or flowers soaked to produce sweet drink, sometimes fermented.
Myrtaceae	*Calytrix angulata*	Yellow Starflower		
Myrtaceae	*Chamelaucium uncinatum*	Geraldton Wax		
Myrtaceae	*Corymbia calophylla*	Marri, Mari	*Marri,conrick, mnkar (red sap)*	Large tree, cream-pink flowers Biral-Djeran (Summer-Autumn), frequently grows with Jarrah. Large fruits. Leaves have antiseptic, decongestant and anti-inflammatory properties. Leaves used in steam pits, crushed or used to produce smoke. Sap or resin used as disinfectant and as part of medicine for dysentry. Flowers soaked for a sweet drink. Leaves used for bedding.

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Myrtaceae	*Eremaea pauciflora*			
Myrtaceae	*Eucalyptus cornuta*	Yate		
Myrtaceae	*Eucalyptus decipiens*	Redheart	*moit*	Mallee or small tree. Leaves have antiseptic, decongestant and anti-inflammatory properties. Leaves used in steam pits or crushed. Sap used as disinfectant and as part of medicine for dysentry. Leaves used for bedding.
Myrtaceae	*Eucalyptus gomphocephal a*	Tuart	*duart, morrol, mooarn, moorun, mouarn.*	Straight, tall tree with rough bark growing particularly on sand over limestone. Also appears as a smaller tree or mallee. White Birak-Djeran (Summer-Autumn). Leaves have antiseptic, decongestant and anti-inflammatory properties. Leaves used in steam pits or crushed. Sap used as disinfectant and as part of medicine for dysentry. Gum also sometimes used to fill dental cavities. Bark used for roofing shelters.
Myrtaceae	*Eucalyptus marginata* subsp. *marginata*	Jarrah	*djara, cherring*	Straight, tall tree growing on various soils in the South -west. White-pink flowers Makuru- Birak (Winter- Summer). Leaves have antiseptic, decongestant and anti-inflammatory properties. Leaves used in steam pits or crushed. Sap as disinfectant and to treat dysentry. Gum sometimes used to fill cavities in teeth. Leaves used for bedding, bark for waterproof roofing of shelters. Wood for spears, digging sticks, spear throwers.

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Myrtaceae	*Eucalyptus rudis* subsp. *rudis*	Flooded Gum, Kulurda	*moich*	Grows on sand in wet areas, white flowers from Makuru-Djilba (Winter-Spring). Leaves have antiseptic, decongestant and anti-inflammatory properties. Leaves used in steam pits or crushed. Sap used as disinfectant and as part of medicine for dysentry. Manna on leaves eaten. Leaves used for bedding.
Myrtaceae	*Eucalyptus xmundijongensis*			
Myrtaceae	*Hypocalymma robustum*	Swan River Myrtle		
Myrtaceae	*Leptospermum spinescens*			
Myrtaceae	*Melaleuca huegelii*	Chenille Honey-myrtle		Melaleucas commonly used for antibacterial properties of oil. Leaves used for smoking ceremony. Flowers used to create drink.
Myrtaceae	*Melaleuca preissiana*	Moonah	*moonah*	Shrub or tree with papery bark in swampy areas. Young leaves crushed and vapours inhaled to treat colds, sinusitis and headaches. Bark used for wrapping food, toilet paper and bandages.
Myrtaceae	*Melaleuca rhaphiophylla*	Swamp Paperbark	*yowarl, bibool boorn, yiembak*	Bark used for roofing, to carry water or wrap food to carry or for cooking. Bark also used as a torch.
Myrtaceae	*Melaleuca systena*	Coastal Honeymyrtle		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Myrtaceae	*Melaleuca teretifolia*	Banbar		Shrub or small tree with needle-like leaves. Grows in wet and swampy areas. Leaves and bark used to treat colds and headaches. Bark used as an anti-inflammatory bandage.
Myrtaceae	*Melaleuca thymoides*			
Olacaceae	*Olax benthamiana*			
Orchidaceae	*Acianthus reniformis*	Mosquito Orchids		
Orchidaceae	*Caladenia arenicola*	Carousel Spider Orchid	*karrar, kar*	
Orchidaceae	*Caladenia chapmanii*		*karrar, kar*	
Orchidaceae	*Caladenia crebra*	Arrowsmith Spider Orchid	*karrar, kar*	
Orchidaceae	*Caladenia flava* subsp. *flava*	Cowslip Orchid	*karrar, kar*	
Orchidaceae	*Caladenia georgei*	Tuart Spider Orchid	*karrar, kar*	
Orchidaceae	*Caladenia hirta*	Sugar Candy Orchid	*karrar, kar*	
Orchidaceae	*Caladenia latifolia*	Pink fairy Orchid	*karrar, kar*	
Orchidaceae	*Caladenia longicauda*	Common White Spider Orchid	*karrar, kar*	
Orchidaceae	*Caladenia marginata*	White Fairy Orchid	*karrar, kar*	
Orchidaceae	*Caladenia speciosa*	Sandplain White Spider Orchid	*karrar, kar*	
Orchidaceae	*Caladenia vulgata*	Spider Orchid	*karrar, kar*	
Orchidaceae	*Corybas recurvus*	Helmet Orchid		
Orchidaceae	*Cryptostylis ovata*	Slipper Orchid		
Orchidaceae	*Cyanicula gemmata*	Blue China Orchid		

Family	**Plant taxa**	**Common names**	**Noongar name(s)**	**Notes, including some traditional uses^**
Orchidaceae	*Cyanicula sericea*	Silky Blue Orchid		
Orchidaceae	*Cyrtostylis huegelii*	Mosquito Orchid		
Orchidaceae	*Diuris amplissima*			
Orchidaceae	*Diuris corymbosa*	Common Donkey Orchid		
Orchidaceae	*Elythranthera brunonis*	Purple Enamel Orchid		
Orchidaceae	*Elythranthera emarginata*	Pink Enamel Orchid		
Orchidaceae	*Eriochilus dilatatus*	White Bunny Orchid		
Orchidaceae	*Leporella fimbriata*	Hare Orchid		
Orchidaceae	*Leptoceras menziesii*	Rabbit Orchid		
Orchidaceae	*Lyperanthus nigricans*	Red Beak Orchid		
Orchidaceae	*Microtis media*	Tall Mignonette Orchid		
Orchidaceae	*Prasophyllum calcicola*			
Orchidaceae	*Prasophyllum elatum*	Tall Leek Orchid		
Orchidaceae	*Pterostylis* aff. *nana*	Dwarf Snail Orchid		
Orchidaceae	*Pterostylis* aff. *vittata*	Grey Banded Greenhood		
Orchidaceae	*Pterostylis aspera*	Brown-veined Shell Orchid		
Orchidaceae	*Pterostylis brevisepala ms*			
Orchidaceae	*Pterostylis recurva*	Jug Orchid		
Orchidaceae	*Pterostylis rogersii*			
Orchidaceae	*Pterostylis sanguinea*	Dark-banded Greenhood		
Orchidaceae	*Pterostylis vittata*	Banded Greenhood		Roots eaten

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Orchidaceae	*Thelymitra benthamiana*	Cinnamon Sun Orchid		
Orchidaceae	*Thelymitra crinita*	Blue Lady Orchid		
Oxalidaceae	*Oxalis perennans*			
Phyyllantheaceae	*Phyllanthus calycinus*	False Boronia		
Phyyllantheaceae	*Poranthera microphylla*	Small Poranthera		
Pittosporaceae	*Billardiera heterophylla*	Australian bluebell		
Pittosporaceae	*Billardiera variifolia*			
Pittosporaceae	*Pittosporum ligustrifolium*	Weeping Pittosporum	*wongin*	Weeping shrub or small tree that grows near watercourses.White flowers and yellow-orange fruits. Various parts of the plant used cautiously to relieve pain and cramps, also for treating skin conditions.
Plantaginaceae	*Plantago debilis*	Native Plantain		Low herb. Crushed leaves used to treat sprains, and skin problems.
Poaceae	*Amphipogon turbinatus*			
Poaceae	*Austrostipa compressa*			
Poaceae	*Austrostipa elegantissima*	Feather Speargrass		
Poaceae	*Austrostipa flavescens*			
Poaceae	*Austrostipa pycnostachya*			
Poaceae	*Austrostipa semibarbata*	Bearded Speargrass		
Poaceae	*Bromus arenarius*	Sand Brome		
Poaceae	*Dichelachne crinita*	Long Hair Plume Grass		

Family	**Plant taxa**	**Common names**	**Noongar name(s)**	**Notes, including some traditional uses^**
Poaceae	*Hemarthria uncinata*	Mat Grass		
Poaceae	*Microlaena stipoides*	Weeping Grass		
Poaceae	*Poa drummondiana*	Knotted Poa		
Poaceae	*Poa poiformis*	Coastal Poa		
Poaceae	*Poa porphyroclados*			
Poaceae	*Polypogon tenellus*			
Poaceae	*Rytidosperma occidentale*			
Poaceae	*Rytidosperma pilosa*	Smoothflower Wallaby Grass		
Polygalaceae	*Comesperma confertum*	Milkwort		
Polygalaceae	*Comesperma integerrimum*	Milkwort		
Polygonaceae	*Muehlenbeckia adpressa*	Climbing Lignum		
Polygonaceae	*Muehlenbeckia polybotrya*			
Portulacaceae	*Calandrinia brevipedata*	Short-stalked Purslane		
Portulacaceae	*Calandrinia calyptrate*	Pink Purslane		
Portulacaceae	*Calandrinia corrigioloides*	Strap Purslane		
Portulacaceae	*Calandrinia granulifera*	Pygmy Purslane		
Portulacaceae	*Calandrinia liniflora*	Parakeelia		
Primulaceae	*Samolus repens*	Creeping Brookweed		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Proteaceae	*Banksia attenuata*	Candlestick Banksia, Slender Banksia	*Piara, piara bealwara,ngong-yang-flower nectar*	Shrub or tree with bright yellow cylindrical flowers in Djilba- Bunuru (Spring-Summer). Nectar of Banksia flowers used to make a sweet drink and relieve sore throats and coughs. Regenerates after fire. Cones used as torch to carry fire.
Proteaceae	*Banksia dallaneyi* (formerly *Dryandra lindleyana*)	Couch Honeypot	*bullgalla*	Flowers Makuru - Kambarang (Winter-Spring). Regenerates after fire. Flowers soaked for sweet drink, also used to relieve sore throats and coughs.
Proteaceae	*Banksia grandis*	Bull Banksia	*boogalla, purgarla, mungite*	Flowers Djilba- Birak (Spring- early Summer). Flowers soaked for sweet drink, also used to relieve sore throats and coughs. Branch with cones wrapped in paperbark and used to carry fire.
Proteaceae	*Banksia leptophylla* var. *leptophylla*			
Proteaceae	*Banksia littoralis*	Swamp Banksia	*Pungura, hoongura, gwangia*	Large shrub or tree. Bright orange or yellow flowers Bunuru-Djilba (Autumn-Winter).
Proteaceae	*Banksia menziesii*	Firewood Banksia	*bulgalla*	Flowers Bunuru- Djilba (Autumn- Winter). Regrows from lignotuber after fire.Infusions of flowers for sore throats and coughs, as well as refreshing drink.
Proteaceae	*Banksia prionotes*	Acorn Banksia	*manyret*	Flowering Bununru-Djilba (Autumn and Winter). Fire sensitive. Infusions of flowers for sore throats and coughs, as well as refreshing drink.

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Proteaceae	*Banksia sessilis* (formerly *Dryandra sessilis)*	Parrot Bush,	*pulgart , pudjak*	Shrub or small tree with spiky leaves. Small flowers Djeran-Kambarang (Autumn-Spring). Branches used to drive fish into traps.
Proteaceae	*Conospermum stoechadis x triplinervium*	Common Smokebush		
Proteaceae	*Conospermum triplinervium*	Tree Smokebush		
Proteaceae	*Grevillea crithmifolia*		*berrung*	Nectar used to create sweet drink
Proteaceae	*Grevillea preissii*	Spider Net Grevillea	*berrung*	Nectar used to create sweet drink
Proteaceae	*Grevillea vestita*		*berrung*	Nectar used to create sweet drink
Proteaceae	*Hakea lissocarpha*	Honey Bush	*berrung*	Nectar used to create a sweet drink
Proteaceae	*Hakea prostrata*	Harsh Hakea	*pulgur*	Branches used to drive fish into traps
Proteaceae	*Hakea trifurcata*			
Proteaceae	*Persoonia longifolia*	Snottygobble, Wild Pear	*cadgeegurrup, kadgeegurr*	Shrub or tree with green-yellow fruits, which can be eaten and keep the mouth moist. Bark used to make medication for skin and eye problems. Leaves used to make medication for colds and sore throats.
Proteaceae	*Persoonia saccata*	Snottygobble, Wild Pear	*cadgegurrup*	Fruits eaten
Proteaceae	*Petrophile linearis*	Pixie Mops		
Proteaceae	*Petrophile serruriae*			
Proteaceae	*Petrophile striata*			
Proteaceae	*Stirlingia latifolia*	Blueboy		
Proteaceae	*Synaphea floribunda*			

Family	**Plant taxa**	**Common names**	**Noongar name(s)**	**Notes, including some traditional uses^**
Proteaceae	*Synaphea polymorpha*	Albany Synaphea, Pinda		
Proteaceae	*Xylomelum occidentale*	Woody Pear	*djandjin, danja*	Shrub to small tree with oak-like leaves. Grows on near coastal sands. Pear-shaped fruits with large woody seeds. Infusions of leaves and bark used to relieve pain. Seeds roasted and eaten.
Pteridaceae	*Adiantum aethiopicum*	Common Maidenhair	*karbarra*	Low fern, found in damp areas. Used to make medicines to relieve respiratory tract problems.
Pteridaceae	*Cheilanthes austrotenuifolia*	Rock Fern		
Ranunculaceae	*Clematis linearifolia*	Slender Clematis	*taaruk*	Climbing plant with white star-shaped flowers Makuru-Kambarang (Winter-Spring). Leaves used cautiously to treat skin irritation.
Ranunculaceae	*Clematis pubescens*	Common Clematis		
Ranunculaceae	*Ranunculus colonorum*	Common Buttercup		
Ranunculaceae	*Ranunculus pumilio*	Smallflower Buttercup		
Restionaceae	*Desmocladus aspera*			
Restionaceae	*Hypolaena exsulca*			
Restionaceae	*Hypolaena pubescens*			
Rhamnaceae	*Cryptandra arbutiflora*	Waxy Cryptandra		
Rhamnaceae	*Cryptandra mutila*			
Rhamnaceae	*Spyridium globulosum*	Basket Bush		
Rhamnaceae	*Stenanthemum tridentatum.*			

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Rhamnaceae	*Trymalium ledifolium* var. *ledifolium*			
Rubiaceae	*Opercularia hispidula*	Hispid Stinkweed		
Rubiaceae	*Opercularia vaginata*	Dog Weed		
Rutaceae	*Boronia alata*	Winged Boronia		
Rutaceae	*Diplolaena dampieri*	Southern Diplolaena		
Santalaceae	*Exocarpos sparteus*	Broom Ballart	*djuk*	Suited to calcareous sand over limestone. Fruits are edible. Leaves and twigs burnt to repel insects. Crushed leaves used to treat headaches.
Santalaceae	*Leptomeria cunninghamii*			
Santalaceae	*Leptomeria preissiana*			
Santalaceae	*Santalum acuminatum*	Quandong, Sandalwood, Native Peach	*dumbari, wonil, warnga*	Semi-parasitic small tree, small white flowers at several times of the year, followed by bright red fruits. Seeds mixed with animal fat used on sore muscles. Infusions of leaves used to treat diabetes. Fruits are high in vitamin C and eaten fresh or dried.
Sapindaceae	*Diplopeltis huegelii* subsp. *subintegra*			
Sapindaceae	*Dodonaea aptera*	Coast Hop Bush		
Sapindaceae	*Dodonaea hackettiana*	Hackett's Hop Bush		
Scrophulariaceae	*Eremophila glabra*	Tar Bush		
Scrophulariaceae	*Myoporum caprarioides*	Slender Myoporum		
Scrophulariaceae	*Myoporum insulare*	Native Juniper		

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Solanaceae	*Anthocercis ilicifolia*			
Solanaceae	*Anthocercis littorea*	Yellow Tailflower		
Solanaceae	*Solanum symonii*			
Stylidiaceae	*Stylidium bulbiferum*			
Stylidiaceae	*Stylidium calcaratum*	Book Triggerplant		
Stylidiaceae	*Stylidium glaucum*	Dotted Triggerplant		
Stylidiaceae	*Stylidium junceum*	Reed Triggerplant		
Stylidiaceae	*Stylidium repens*	Matted Triggerplant		
Thymelaeaceae	*Pimelea argentea*	Silvery Leaved Pimelea		
Thymelaeaceae	*Pimelea calcicola*			
Thymelaeaceae	*Pimelea rosea*	Rose Banjine		
Tremandraceae	*Tetratheca hirsuta* (glabrous)	Black-eyed Susan		
Typhaceae	*Typha domingensis*	Bulrush, Djandjid	*yanjet*	Found near water sources. Bulbs pounded and cooked as damper. Crushed flowers used as antiseptic. Leaves used to weave mats and baskets.
Urticaceae	*Parietaria debilis*	Pellitory		
Verbenaceae	*Phyla nodiflora*	Pogfruit		
Violaceae	*Hybanthus calycinus*	Wild Violet		
Xanthorrhoeaceae	*Xanthorrhoea brunonis*			

Family	Plant taxa	Common names	Noongar name(s)	Notes, including some traditional uses^
Xanthorrhoeaceae	*Xanthorrhoea preissii*	Balga, Grasstree, Blackboy	*balga, balka, baaluk, balka, barro, kooryoop, paaluc, palga, yarrlok; bigo (resin from stem)*	Widespread, particularly near watercourses. Tall flower spike Makuru to Birak (Winter-Summer). Many uses- flower stems used as spears, fire drills and torches, witchetty grubs (bardi) found in stems, fresh leaves eaten, resin used as glue and for tanning kangaroo and possum skins, for firelighters, as well as in medicine, flowers soaked to use drink. Leaves use to cover *mia mia* shelters and for bedding. Young leaf bases were also eaten. The pattern of flower opening used to determine direction.
Zamiaceae	*Macrozamia riedlei*	Zamia, Djiridji	*djiridji,dyergee, girijee, jeerajee; baio (fruit)*	Fruits were buried and soaked to remove toxins before roasting and eating the skin. Leaves used for shade or to make string.
Zygophyllaceae	*Zygophyllum apiculatum*			
Zygophyllaceae	*Zygophyllum fruticulosum*	Shrubby Twinleaf		

E.2 Invasive flora

Table 10. Weeds that are widespread in the ecological community

Source: Keighery (1999 cited in Keighery 2002) identified 23 non-woody species that occurred at more than 70% of surveyed Tuart woodland sites. Scientific names current at May 2018.

Plant taxon	Common name
Monocotyledons	
Grasses	
Briza maxima	Large Quaking Grass
Briza minor	Lesser Quaking Grass, Shivery Grass
Cynodon dactylon	Couch Grass
Ehrharta longiflora	Annual Veldt Grass

Plant taxon	Common name
Lagurus ovatus	Bouquet Grass, Hares-tail Grass
Vulpia myuros	Rat's–tail Fescue
Annually renewed (geophytes):	
Romulea rosea	Onion Grass, Guildford Grass
Dicotyledons	
Annuals	
Lysimachia arvensis	Pimpernel
Brassica tournefortii	Mediterranean Turnip
Bartsia trixago	Bellardia
Carduus pycnocephalus	Slender Thistle
Dischisma arenarium	
Euphorbia peplus	Petty Spurge
Hypochaeris species	Cat's Ear
Lupinus cosentinii	West Australian Blue Lupin, Sandplain Lupin
Medicago polymorpha	Burr Medic
Melilotus indicus	
Orobanche minor	Lesser Broomrape
Petrorhagia dubia	
Solanum nigrum	Black Nightshade
Sonchus oleraceus	Sow Thistle

Table 11. Additional weed species likely to be found in Tuart woodlands and forests

Sources: Western Australian Herbarium (1998–); Keighery 2002; Australian Plant Name Index (undated). Scientific names current at May 2018.

*denotes seeds are likely to be distributed by birds.

Plant taxon and life form	Common name
Trees	
Acacia longifolia	Sydney Golden Wattle
Acacia pycnantha	Golden Wattle
Acacia iteaphylla	Willow-leaved Wattle
Agonis flexuosa (outside of its natural range	Peppermint
*Brachychiton populneus**	Kurrajong
Corymbia maculata	Spotted Gum
*Olea europaea**	Olive

Plant taxon and life form	**Common name**
Shrubs	
Leptospermum laevigatum	Victorian Teatree
*Lycium ferocissimum**	African Boxthorn
*Rhamnus alaternus**	Buckthorn
*Solanum linnaeanum**	Apple of Sodom
*Solanum nigrum**	Blackberry Nightshade
Grasses (annual)	
Bromus diandrus	Great Brome
Cynosurus echinatus	Rough Dog's-tail
Lolium multiflorum	Italian Rye Grass
Lolium rigidum	Wimmera Rye Grass
Grasses (Perennial):	
Ehrharta calycina	Perennial Veldt Grass
Eragrostis curvula	African Love Grass
Hyparrhenia hirta	Coolatai Grass
Cenchrus purpureum	Napier Grass, Elephant Grass
Herbs (Monocotyledons)	
Annually renewed (geophytes)	
*Asparagus asparagoides **	Bridal Creeper
Myrsiphyllum declinatum	Asparagus Fern
Albuca flaccida	
Chasmanthe floribunda	African Cornflag
Ferraria crispa	Black Flag
Freesia hybrid	Freesia
Gladiolus caryophyllaceus	Wild Gladiolus
Moraea flaccida	One-leaf Cape Tulip
Lachenalia reflexa	Tiny Star
Watsonia meriana var. bulbillifera	Bugle Lily
*Zantedeschia aethiopica**	Arum Lily
Dicotyledons	
Annually renewed from seed	
Arctotheca calendula	Cape Weed
Carduus pycnocephalus	Slender Thistle
Centaurea melitensis	Maltese Cockspur

Plant taxon and life form	Common name
Cirsium vulgare	Spear Thistle
Centranthus macrosiphon	Spanish Valerian
Sherardia arvensis	Field Madder
Urospermum picroides	False Hawkbit
Ursinia anthemoides	Ursinia
Perennials:	
Euphorbia terracina	Geraldton Carnation Weed
Pelargonium capitatum	Rose Pelargonium

Table 12. Other weeds that may be found in the ecological community (life form unspecified)

Source: Keighery (2002). Scientific names current at May 2018.

Plant taxon	Common name
Aira caryophyllea	Silvery Hair Grass
Avena barbata	Bearded Oat
Avena fatua	Wild Oat
Centranthus macrosiphon	
Chasmanthe floribunda	African Corn Flag
Cynodon dactylon	Couch
Cynosurus echinatus	Rough Dog's Ttail
Dischisma arenarium	
Dischisma capitatum	Woolly-headed Dischisma
Emex australis	Double Gee
Galium aparine	Goose Grass
Galium murale	Small Goose Grass
Gladiolus undulatus	Wild Gladiolus
Hordeum leporinum	Barley Grass
Kickxia spuria	
Lolium perenne	Perennial Rye Grass
Lupinus angustifolius	Narrowleaf Lupin
Lupinus cosentinii	
Narcissus tazetta	Konquil
Parentucellia latifolia	Vommon Bartsia

Plant taxon	Common name
Parentucellia viscosa	Ticky Bartsia
Paspalum dilatatum	Paspalum
Physalis peruviana	Cape Gooseberry
Phytolacca octandra	Red Ink Plant
Pinus pinaster	Maritime Pine
Poa annua	Winter Grass
Polypogon monspeliensis	Annual Beard Grass
Pseudognaphalium luteoalbum	Jersey Cudweed
Ranunculus muricatus	Sharp Buttercup
Rumex acetosella	Sorrel
Sherardia arvensis	Field Madder
Solanum nodiflorum	Glossy Nightshade
Sonchus asper	Rough Sowthistle
Stenotaphrum secundatum	Buffalo Grass
Tetragonia decumbens	Sea Spinach
Tropaeolum majus	Garden Nasturtium
Typha orientalis	Bulrush
Urtica urens	Stinging Nettle
Verbascum thapsus	
Verbascum virgatum	
Veronica arvensis	Wall Speedwell
Vulpia bromoides	Squirrel-tail Fescue
Wahlenbergia capensis	Cape Bluebell
** Catapodium rigidum*	Rigid Fescue
Acacia longifolia	
Acacia paradoxa	Kangaroo Thorn
Acaena echinata	Sheep's Burr
Amaryllis belladonna	Easter Lily
Arenaria serpyllifolia	
Asphodelus fistulosus	Onion Weed
Bromus hordeaceus	Soft Brome
Cakile maritima	Sea Rocket
Cardamine hirsuta	Common Bittercress
Cardamine paucijuga	

Plant taxon	Common name
Carpobrotus edulis	Hottentot Fig
Centaurium erythraea	Common Centaury
Cerastium glomeratum	Mouse-ear Chickweed
Cirsium vulgare	
Convolvulus arvensis	
Conyza bonariensis	Flaxleaf Fleabane
Conyza sumatrensis	Tall Fleabane
Corrigiola litoralis	Strapwort
Cotula bipinnata	Ferny Cotula
Cotula turbinata	Funnel Weed
Crassula decumbens	Rufous Stonecrop
Crassula glomerata	
Crassula natans	
Cuscuta epithymum	Lesser Dodder
Cyperus tenellus	Tiny Flat-sedge
Disa bracteata	South African Orchid
Dittrichia graveolens	Stinkwort
Erodium botrys	Long Storksbill
Erodium cicutarium	Common Storksbill
Euphorbia peplus	Petty Spurge
Euphorbia terracina	Geraldton Carnation Weed
Ficus carica	Fig
Fumaria muralis	Wall Fumitory
Gamochaeta calviceps	
Geranium molle	Dove's foot Cranesbill
Gomphocarpus fruticosus	Swan Plant
Heliophila pusilla	
Holcus lanatus	Yorkshire Fog
Hypochaeris glabra	Flat Weed
Isolepis marginata	
Juncus bufonius	Toad Rush
Juncus capitatus	Capitate Rush
Lactuca serriola	Prickly Lettuce
Lotus angustissimus	Narrowleaf Trefoil

Plant taxon	Common name
Minuartia mediterranea	
Monoculus monstrosus	Stinking Roger
Osteospermum ecklonis	
Oxalis glabra	
Oxalis pes-caprae	Soursob
Pentameris airoides	False Hair Grass
Pinus radiata	Radiata Pine
Plantago lanceolata	Ribwort Plantain
Polycarpon tetraphyllum	Velvet Pink
Raphanus raphanistrum	Wild Radish
Sagina maritima	
Schinus terebinthifolius	Brazilian Pepper
Senecio diaschides	
Silene gallica	French Catchfly
Silene nocturna	Mediterranean Catchfly
Spergula arvensis	Corn Spurry
Stachys arvensis	Stagger Weed
Stellaria media	Chickweed
Symphyotrichum subulatum	Bushy Starwort
Trachyandra divaricata	Strap Lily, Dune Onion Weed
Trifolium angustifolium	Narrowleaf Clover
Trifolium arvense	Hare's-foot Clover
Trifolium campestre	Hop Clover
Trifolium cernuum	Drooping flower Clover
Trifolium dubium	Suckling Clover
Trifolium glomeratum	Cluster Clover
Trifolium repens	White Clover
Vellereophyton dealbatum	White Cudweed
Vicia sativa subsp. sativa	Common Vetch

E.3 Native Fauna

Table 13. Fauna that are likely to be present or may have formerly been present

Sources: Abbott (2001); Liddlelow et al (2002); Bindon and Walley (1989); Conservation Commission of Western Australia (2010); Dell et al (2002); Gibbons and Lindenmayer, (2002); Australian Biological Resources Study (2009); How, Maryan and Stevenson (2009); Hyder and Dell (2009), Valentine et al (2009), Rooney (2011), Valentine and Ruthrof (2012); Klesch (ed) 2014; Davis and Doherty (2015).

Scientific names current at May 2018.

*Species may have been formerly present. **Recent introductions

Species name	Common name	Indigenous name(s)	Likely to use hollows or crevices
MAMMALS			
TACHYGLOSSIDAE			
Tachyglossus aculeatus	Echidna	*nyingarn*	
DASYURIDAE			
Phascogale tapoatafa wambenger	Southern Brush-tailed Phascogale	*wambenga, balat, balawa, koming koming*	y
Sminthopsis spp	Dunnart	*donat?*	?
*Antechinus flavipes**	Mardo	*mardo, donat*	y
*Dasyurus geoffroii **	Chuditch, Western quoll	*Chuditch, djooditj*	y
PERAMELIDAE			
Isoodon obesulus fusciventer	Southern Brown Bandicoot	*Quenda, kwenda*	
TARSIPEDIDAE			
Tarsipes rostratus	Honey Possum	*ngoolboongoor, djebin, dat*	y
PHALANGERIDAE			
Trichosurus vulpecula	Common Brushtail Possum	*koomal*	y
PSEUDOCHEIRIDAE			
Pseudocheirus occidentalis	Western Ringtail Possum	*ngwayir, womp, woder, ngoor, ngoolangit*	y
MACROPODIDAE			
Macropus fuliginosus	Western Grey Kangaroo	*yonger, yongka*	
*Notamacropus irma**	Western Brush Wallaby, Black-gloved Wallaby	*guhran, kwara, koora*	
*Notamacropus eugenii**	Tammar wallaby	*dama, bonin*	
Osphranter robustus	Wallaroo	*bikada*	
Setonix brachyurus	Quokka	*kwoka, bangop*	
POTOROIDIDAE			

Species name	Common name	Indigenous name(s)	Likely to use hollows or crevices
*Bettongia penicillata**	Woylie; Brush-tailed Bettong.	*Woylie, woli, wol*	
BURRAMYIDAE			
*Cercartetus concinnus**	Western Pygmy Possum	*mandada, nyeranit*	y
MYRMECOBIIDAE			
*Myrmecobius fasciatus**	Numbat	*noombat, wioo*	y
MURIDAE			
Rattus fuscipes	Western Bush Rat	*modit*	y
Hydromys chrysogaster	Water Rat	*modit, ngoodjo, ngwiridjin, wamp wamp, ngangaritj*	
*Pseudomys albocinereus**	Ash-grey Mouse	*noodji*	
VESPERTILIONIDAE			
Chalinolobus gouldii	Gould's Wattled Bat		y
Falsistrellus mackenziei	Western False Pipistrelle		y
Nyctophilus geoffroyi	Lesser Long-eared Bat	*bam-be, barbalon*	y
Nyctophilus major	Greater Long-eared Bat	*bam-be, barbalon*	y
Nyctophilus gouldi	Gould's Long-eared Bat	*bam-be, barbalon*	y
Vespadelus regulus	Southern Forest Bat		y
MOLOSSIDAE			
Mormopterus planiceps	Southern Freetail-Bat		y
Austronomusaustralis	White-striped Freetail-Bat		y
CANIIDAE			
Canus familiaris	Dingo	*doot*	
REPTILES			
GEKKONIDAE			
Christinus marmoratus	Marbled Gecko		y
CARPHODACTYLIDAE			y
Underwoodisaurus milii	Barking Gecko		
DIPLODACTYLIDAE			
Crenadactylus ocellatus	South-western Clawless Gecko		y
Diplodactylus spinigerus	Western Spiny-tailed Gecko		
PYGOPODIDAE			
Aprasia repens	Sand-plain Worm Lizard		

Species name	Common name	Indigenous name(s)	Likely to use hollows or crevices
Delma concinna concinna			
Delma fraseri	Fraser’s Delma		
Delma grayii	Side-barred Delma		
Lialis burtonis	Burton’s Snake-Lizard		
Pygopus lepidopodus	Common Scaly-foot		
AGAMIDAE			
Pogona minor	Dwarf Bearded Dragon		
SCINCIDAE			
Acritoscincus trilineatum	Western Three-lined Skink		
Cryptoblepharus buchananii	Buchanan’s Snake-eyed Skink		
Cryptoblepharus plagiocephalus			y
Ctenotus inornatus	Bar-shouldered Ctenotus, Plain Ctenotus		
Ctenotus australis	Western Limestone Ctenotus		
Ctenotus impar	Odd-striped Ctenotus		
Ctenotus labillardieri	Common South-west Ctenotus, Red-legged Ctenotus		
Ctenotus ora			
Cyclodomorphus celatus	Western Slender Blue-tongue		
Egernia kingii	King's Skink		
Egernia napoleonis	South-western Crevice-skink		y
Hemiergis peronii	Lowlands Earless Skink		
Hemiergis quadrilineata	Two-toed Earless Skink		
Lerista distinguenda	South-western Orange-tailed Slider		
Lerista elegans	Elegant Slider		
Lerista lineata	Perth slider		
Lerista lineopunctulata	Dotted-line Robust Slider		
Lerista praepedita	Blunt-tailed West-coast Slider		
Menetia greyii	Common Dwarf Skink, Grey's Menetia		

Species name	Common name	Indigenous name(s)	Likely to use hollows or crevices
Morethia lineoocellata	West Coast Morethia Skink		
Morethia obscura	Shrubland Morethia Skink		
Tiliqua occipitalis	Western Blue-tongue		
Tiliqua rugosa	Bobtail, Shingle-back Lizard	*youern*	
VARANIDAE			
Varanus rosenbergi	Heath Monitor		
Varanus gouldii	Sand Goanna, Racehorse Goanna	*carta, kaadar*	
Varanus tristis	Black-headed Monitor		y
PYTHONIDAE			
Morelia spilota	Carpet Snake	*wakal*	y
TYPHLOPIDAE			
Anilios australis	Southern Blind Snake		
ELAPIDAE			
Brachyurophis fasciolatus	Narrow-banded Shovel-nosed Snake, Narrow-banded Snake		
Brachyurophis semifasciatus	Southern Shovel-nosed Snake		
Neelaps bimaculatus	Black-naped Snake		
Neelaps calonotos	Western Black-striped Snake		
Parasuta nigriceps	Mitchell's Short-tailed Snake		
Pseudonaja affinis	Dugite	*dookatj*	
Simoselaps bertholdi	Jan's Banded Snake		
CHELIDAE			
Chelodina colliei	Oblong Turtle	*yargun buyi*	
AMPHIBIANS			
LIMNODYNASTIDAE			
Limnodynastes dorsalis	Bullfrog, Western Banjo Frog		
Heleioporus eyrei	Moaning Frog		
MYOPATRACHIDAE			
Crinia insignifera	Sign-bearing Froglet		
Myobatrachus gouldii	Turtle Frog		
Pseudophryne guentheri	Gunther's Toadlet		

Species name	Common name	Indigenous name(s)	Likely to use hollows or crevices
HYLIDAE			
Litoria adelaidensis	Slender Tree Frog		
Litoria moorei	Moore's frog, Motorbike Frog, Western Green and Golden Bell Frog		
BIRDS		*djiyada*	
CASUARIIDAE			
Dromaius novaehollandiae	Emu	*wetj*	
ANATIDAE			
Tadorna tadornoides	Australian Shelduck		y
Anas gracilis	Grey Teal	*ngoonan*	y
Anas superciliosa	Pacific Black Duck	*yederap, yet*	y
Chenonetta jubata	Australian Wood Duck	*koorak*	y
ACCIPITRIDAE			
Pandion cristatus	Osprey	*doorn-doorn*	
Elanus axillaris	Black-shouldered Kite		
Haliastur sphenurus	Whistling Kite		
Accipiter cirrocephalus	Collared Sparrowhawk		
Accipiter fasciatus	Brown Goshawk	*djil-djil, karkany*	
Aquila audax	Wedge-tailed Eagle	*walitj*	
Hieraaetus morphnoides	Little Eagle		
Circus assimilis	Spotted Harrier		
FALCONIDAE			
Falco peregrinus	Peregrine Falcon	*kwedalbar*	y
Falco cenchroides	Nankeen Kestrel		
Falco berigora	Brown Falcon	*karkany*	
Falco longipennis	Australian Hobby		
TURNICIDAE			
Turnix varius	Painted Button-quail	*mooroolang*	
COLUMBIDAE			
Phaps chalcoptera	Common Bronzewing	*koomara, wooda, nembing*	
Ocyphaps lophotes	Crested Pigeon		
CACATUIIDAE			

Species name	Common name	Indigenous name(s)	Likely to use hollows or crevices
Calyptorhynchus banksii naso	Forest Red-tailed Black Cockatoo	*karak, didandi*	
Calyptorhynchus baudinii	Baudin's Cockatoo	*ngoorlak, ngoolyak*	y
Calyptorhynchus latirostris	Carnaby's cockatoo	*ngoorlak, ngoolyanak*	y
Eolophus roseicapilla	Galah	*djakal-ngakal*	y
Cacatua pastinator butleri	Butler's Corella		y
Cacatua spp**	Corella	*manatj*	y
PSITTACIDAE			
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	*kowara, kawoor*	y
*Trichoglossus haematodus***	Rainbow Lorikeet		y
Parpureicephalus spurius	Red-capped Parrot	*delyip*	y
Platycercus icterotis	Western Rosella	*mayadang, bardinar*	y
Barnardius zonarius	Australian Ringneck	*wakangkoor, doornart*	y
Polytelis anthopeplus	Regent Parrot	*koora*	y
Neophema elegans	Elegant Parrot	*koolyidarang*	y
CUCULIDAE			
Cacomantis pallidus	Pallid Cuckoo	*djoolaran*	
Cacomantis flabelliformis	Fan-tailed Cuckoo	*koordomal, djoolar*	
Chrysococcyx basalis	Horsfield's Bronze Cuckoo		
Chrysococcyx lucidus	Shining Bronze Cuckoo		
STRIGIDAE			
Ninox novaeseelandiae	Southern Boobook	*nyawoo-nyawoo*	y
TYTONIDAE			
Tyto javanica	Barn Owl	*yoowintj, ngoorlam*	y
Tyto novahollandiae novahollandiae	Masked Owl (southwest)		y
PODARGIDAE			
Podargus strigoides	Tawny Frogmouth	*kambikoora, djoowi*	
AEGOTHELIDAE			
Aegotheles cristatus	Australian Owlet-Nightjar	*yaartj*	y
APODIDAE			
Apus pacificus	Fork-tailed Swift		

Species name	Common name	Indigenous name(s)	Likely to use hollows or crevices
ALCEDINIDAE			
*Dacelo novaeguinea***	Laughing Kookaburra		y
Todiramphus sanctus	Sacred Kingfisher	*kanyinak*	y
MEROPIDAE			
Merops ornatus	Rainbow Bee-eater	*birin-birin*	
MALURIDAE			
Malurus lamberti	Variegated Fairy-wren		
Malurus pulcherrimus	Blue-breasted Fairy-wren		
Malurus splendens	Splendid Fairy-wren	*djidi-djal*	
PARDALOTIDAE			
Pardalotus punctatus	Spotted Pardalote	*widap-widap*	
Pardalotus striatus	Striated Pardalote	*wida-wida*	y
ACANTHIZIDAE			
Gerygone fusca	Western Gerygone	*waralyboordang*	
Smicrornis brevirostris	Weebill	*djiyaderbaat*	
Acanthiza apicalis	Broad-tailed Thornbill	*djoobi-djoolbang*	
Acanthiza chrysorrhoa	Yellow-rumped Thornbill	*djida*	
Acanthiza inornata	Western Thornbill	*djobool-djobool*	y
Sericornis frontalis	White-browed Scrubwren	*koorkal*	
MELIPHAGIDAE			
Lichmera indistincta	Brown Honeyeater	*djndjokoor*	
Ptilotula ornata	Yellow-plumed Honeyeater	*miyamit*	
Gavicallis virescens	Singing Honeyeater	*kool-boort*	
Melithreptus chloropsis	Western White-naped Honeyeater	*djingki*	
Phylidonyris niger	White-cheeked Honeyeater	*bandin*	
Phylidonyris novaehollandiae	New Holland Honeyeater	*bandiny*	
Acanthorhynchus superciliosus	Western Spinebill	*booldjit*	
Anthochaera carunculata	Red Wattlebird	*dangkarak, djankang*	
Anthochaera lunulata	Western Little Wattlebird	*dangkarak*	
PETROICIDAE			

Species name	Common name	Indigenous name(s)	Likely to use hollows or crevices
Petroica multicolor	Scarlet Robin	*kooba djiyat, dermo kalitj*	y
Eopsaltria georgiana	White-breasted Robin	*boyidjil*	
Eopsaltria griseogularis	Western Yellow Robin	*bamboon*	
NEOSITTIDAE			
Daphoenositta chrysoptera	Varied Sittella	*koomaldidayit*	
PACHYCEPHALIDAE			
Pachycephala pectoralis	Golden Whistler	*bidilmidang*	
Pachycephala rufiventris	Rufous Whistler		
Colluricincla harmonica	Grey Shrike-thrush	*koodilang*	
MONARCHIDAE			
Myiagra inquieta	Restless Flycatcher	*djiring-djiring*	
Grallina cyanoleuca	Magpie Lark	*djilabit, diliboort*	
DICRURIDAE			
Rhipidura fuliginosa	Grey Fantail	*kadjinak*	
Rhipidura leucophrys	Willie Wagtail	*djidi-djidi*	
CAMPEPHAGIDAE			
Coracina novaehollandiae	Black-faced Cuckoo- shrike	*djilak, noolarko*	
ARTAMIDAE			
Artamus cyanopterus	Dusky Woodswallow		y
Artamus cinereus	Black-faced Woodswallow	*biwoyen*	
CRACTICIDAE			
Cracticus tibicen	Australian Magpie	*koolbardi*	
Cracticus nigrogularis	Pied Butcherbird	*worl djaloo, yoort dijidi, kwadalang*	
Cracticus torquatus	Grey Butcherbird	*wardawort*	
Strepera versicolor	Grey Currawong	*djarbarn, djilak*	
CORVIDAE			
Corvus coronoides	Australian Raven	*waardong*	
HIRUNDINIDAE			
Hirundo neoxena	Welcome Swallow	*kanamit*	
Petrochelidon nigricans	Tree Martin		
TIMALIDAE			

Species name	**Common name**	**Indigenous name(s)**	**Likely to use hollows or crevices**
Zosterops lateralis	Grey-breasted White-eye (Silvereye)	*diikir*	
NECTARINIDAE			
Dicaeum hirundinaceum	Mistletoebird	*moonidjedang*	
MOTACILLIDAE			
Anthus australis	Australasian Pipit		

APPENDIX F – ADDITIONAL INFORMATION ON LANDSCAPE, CORRESPONDING VEGETATION UNITS, ECOLOGY AND BIOLOGY AND MANAGEMENT

F.1 Geology

The Perth Basin was formed when Australia separated from India, due to the breaking up of Gondwana Land, with a subsiding trough, allowing the accumulation of sediments. This separation was complete by the Jurassic, 140MA, and uplift and erosion occurred but marine sediments also intermittently accumulated in the trough, parallel to the coastline and bounded on east by the fault line that is now marked by the Darling Scarp. This has formed the general landscape pattern of the Swan Coastal Plain as a series of features parallel to the coast, which narrows from approximately 34km wide in the north to 23km wide in the south (McPherson and Jones 2005). During the past 2.5 million years, both wind blown and alluvial sediments have accumulated in these bands, resulting in the modern soils of the Swan Coastal Plain (Swan River Trust 1987 after Playford 1976).

F.2 Relationship with other vegetation classification systems

F.2.1 1:250 000 Statewide Pre-European Vegetation mapping of Western Australia

Perhaps the most widely available and used the broad scale vegetation association maps on the Swan Coastal Plain are the 1:250,000 Statewide Pre-European Vegetation mapping of Western Australia produced by Beard et al (1979, 1981 widely cited including Hopkins et al 1996; Keighery et al, 2002). These are consolidated in Hopkins et al (1996). Six of the units defined on these maps were identified by Keighery et al (2002) as dominated by Tuart, although they may have other important floristic components. These units may also not reflect the full extent of Tuart as various other units have Tuart as a smaller component.

F.2.2 National Vegetation Information System (NVIS)

The National Vegetation Information System is an amalgamation of information on the types of native vegetation present across Australia (Department of the Environment and Energy 2018). The information has been extrapolated to infer the vegetation likely to have been present before 1750. There are also maps available of the current extent of the vegetation types identified, but these may not recognise more recent losses or transformations. The system classifies vegetation at various levels of specificity, identifying dominant overstorey species, structural classes and understorey characteristics. For the Swan Coastal Plain, the categories used are based on the maps by Beard and others described above. While a broader group of systems associations are likely to contain some Tuart trees, those listed below were identified by Keighery et al (2002) as dominated by Tuart (Table 14). These have been used in this Conservation Advice for analysis of extent and level of reservation of the ecological community.

Table 14. Vegetation Associations and NVIS

Vegetation units dominated by Tuart described by Beard cited in Hopkins et al (1996) and the National Vegetation Information System (NVIS) Department of the Environment and Energy (2018)

Sources: Hopkins et al (1996), Hopkins et al 2001 cited in Keighery et al (2002); Department of the Environment and Energy 2018)

*__Key to Beard Codes__ (cited from Keighery et al 2002 after Beard 1979a, b and c, 1981)

Species	**Physiognomy of dominant stratum**	**Density of Canopy cover**
e eucalypt 4 Tuart (*Eucalyptus gomphocephala*) 2 Jarrah (*Eucalyptus marginata*) 3 Marri (*Eucalyptus calophylla*)	T Tall trees > 25 m tall M Medium trees 10 - 25 m tall L Low trees < 10 m tall	i Woodland Incomplete canopy – open not touching. Projective foliage cover 10 - 30%. r Open Woodland Rare but conspicuous. Projective foliage cover < 10%.

Systems association code	Vegetation Association code (after Hopkins et al 2001)	Source description	Beard code*	Hopkins code*	NVIS level 5 description: V5.0 (extracted 2018)
2.0	2	Tall woodland; Tuart	e4Ti	Ti -01a	U+ ^*Eucalyptus gomphocephala*,*Eucalyptus marginata*,*Corymbia calophylla*\^tree\8\i;M ^*Acacia cyclops*,*Comesperma integerrimum*,*Dryandra sessilis*\^shrub,vine,cycad\4\i;G ^*Acanthocarpus preissii,Acianthus reniformis,Austrostipa elegantissima*\^forb,tussock Grass,sedge\2\i
6.1	6	Medium woodland; Tuart & Jarrah	e2,4Mi	Mi-026	U+ ^*Eucalyptus gomphocephala,Eucalyptus marginata,Corymbia calophylla*\^tree\7\i;M ^*Acacia cyanophylla,Acacia cyclops,Dodonaea aptera*\^shrub\4\i;G *Acacia dilatata,Allocasuarina humilis,Calothamnus quadrifidus*\^shrub,vine\2\c
6.0					U+ ^*Eucalyptus gomphocephala,Eucalyptus marginata*\^tree\7\i

Systems association code	Vegetation Association code (after Hopkins et al 2001)	Source description	Beard code*	Hopkins code*	NVIS level 5 description: V5.0 (extracted 2018)
9 98.1	998	Medium woodland; Tuart	e4Mi	Mi-02a	U+ ^*Eucalyptus gomphocephala,Corymbia calophylla,Eucalyptus decipiens*\^tree\7\i;M ^*Acacia cyanophylla,Anthocercis littorea,Dodonaea aptera*\^shrub\4\i;G ^*Acacia dilatata,Allocasuarina humilis,Calothamnus quadrifidus*\^shrub,vine\2\c
998.0					U+ ^*Eucalyptus gomphocephala*\^tree\7\i
1010.1	1010	Medium open woodland; Marri & Tuart	e3,4Mr	Mr-02b	U+ ^*Eucalyptus gomphocephala,Corymbia calophylla,Banksia attenuata*\^tree\7\i
1011.1	1011	Medium open woodland; Tuart	e4Mr	Mr-02a	U+ ^*Eucalyptus gomphocephala,Corymbia calophylla,Eucalyptus decipiens*\^tree\7\r;M ^*Acacia cyanophylla,Anthocercis littorea,Dodonaea aptera*\^shrub\4\r;G ^*Acacia dilatata,Allocasuarina humilis,Calothamnus quadrifidus*\^shrub,vine\2\c
1011.0					U+ ^*Eucalyptus gomphocephala*\^tree\7\r
	1012	Mosaic: Medium open woodland; Tuart / Low woodland; Banksia		Li 09a/Mr-02a	

F.2.3 Vegetation complexes

Heddle et al (1980) used an alternative approach to mapping vegetation types, defining 'vegetation complexes' for the Darling System, which includes the Darling Plateau, Swan Coastal Plain, Dandaragan Plateau, Collie Basin and Blackwood Plateau. These complexes incorporate soil and landform types with floristic and structural characteristics of the vegetation, reconstructing the pre-European cover. Across the Swan Coastal Plain 29 complexes were originally identified. The mapping of these has since been extended and refined by Mattiske and Havel (1998). Heddle et al (1980) identify seven complexes that characteristically have structural formations comprising Tuart, and Keighery and Keighery (in Keighery et al 2002; p.26) evaluated these for their dominance by Tuart and comment that it is also present in the Quindalup complex.

Table 15. Vegetation complexes containing Tuart on part of the Swan Coastal Plain

Source: Heddle et al (1980); Keighery et al (2002) p.26

Structural formations listed for the vegetation complex.	**Vegetation complex** Units after Heddle *et al*. (1980)	**Percentage that is Tuart dominated** estimated by BJ and GJ Keighery in Keighery et al (2002)
Spearwood Dunes		
Open forest	KARRAKATTA COMPLEX - NORTH: Predominantly low open forest and low woodland of *Banksia* species. *Eucalyptus todtiana,* less consistently open forest of *E.gomphocephala - E. todtiana - Banksia* species	**approx. 30 %**
Open forest (with Jarrah and Marri)	KARRAKATTA COMPLEX - CENTRAL AND SOUTH: Predominantly open forest of *Eucalyptus gomphocephala - E. marginata - E. calophylla* and woodland of *E. marginata - Banksia* species	**approx. 50 %**
Open forest (with Jarrah and Marri) Woodland	COTTESLOE COMPLEX - CENTRAL AND SOUTH: Mosaic of woodland of *Eucalyptus gomphocephala* and open forest of *E. gomphocephala - E. marginata - E.calophylla;* closed heath on the limestone outcrops	**approx. 20 %**
Combinations of Bassendean Dunes/Pinjarra Plain/Spearwood Dunes		
Open forest (with Jarrah and Marri)	CALADENIA COMPLEX: Mosaic of vegetation from adjacent vegetation complexes of Karrakatta, Yanga and Bassendean	**approx. 5 %**
Open forest (with Jarrah and Marri)	CANNINGTON COMPLEX: Mosaic of vegetation from adjacent vegetation complexes of Bassendean, Karrakatta, Southern River and Vasse	**approx. 5 %**
Marine (lagoonal and estuarine) Deposits		
Tall woodland Open forest (with Jarrah and Marri)	YOONGARILLUP COMPLEX: Woodland to tall woodland of *Eucalyptus gomphocephala* with *Agonis flexuosa* in the second storey. Less consistently an open forest of *E. gomphocephala - E. marginata - E. calophylla*	**approx. 50 %**
Open forest (with Jarrah and Marri) Woodland	VASSE COMPLEX : Mixture of the closed scrub of *Melaleuca* species fringing woodland of *E. rudis - Melaleuca* species and open forest of *E. gomphocephala - E. marginata - E.calophylla*	**approx. 10 %**

F.2.4 Floristic Community Types (Gibson et al 1994)

Gibson et al (1994) analysed the similarity between the floristic assemblages recorded in plot-based surveys to define Floristic Community Types (FCTs) for the southern Swan Coastal Plain (from Dunsborough in the south to Seabird in the north). Of the 43 Floristic community types and subtypes defined, twelve had Tuart present, but for many of these it was only present at a small proportion of the sites classified as that floristic community type. Only FCT 25 'Southern *Eucalyptus gomphocephala – Agonis flexuosa* woodlands' found on the Spearwood dunes had Tuart present at more than half of the sites (82 %). This was present as a variety of structural units including low forest, woodland, open woodland, open tree, mallee (Gibson et al 1994). Tuart is also considered to be dominant in FCT 30b 'Quindalup *Eucalyptus gomphocephala* and/or *Agonis flexuosa* woodlands' (Keighery et al 2002).

Table 16. Floristic Community Types that include Tuart

Table reproduced in part from Keighery et al (2002) p.74, primary source: Gibson et al (1994)

FCT Code	**Floristic Community Type Name** (communities in which Tuart is a defining species are in **bold**)
Supergroup 2 - Seasonal Wetlands	
16	Highly saline seasonal wetlands
17	*Melaleuca rhaphiophylla - Gahnia trifida* seasonal wetlands
19b	Woodlands over sedgelands in Holocene dune swales
Supergroup 3 - Uplands centred on Bassendean Dunes	
21a	Central *Banksia attenuata - Eucalyptus marginata* woodlands
Supergroup 4 - Uplands centred on Spearwood and Quindalup Dunes	
24	Northern Spearwood shrublands and woodlands
25	**Southern *Eucalyptus gomphocephala – Agonis flexuosa* woodlands**
26b	Woodlands and mallees on Limestone
28	Spearwood *Banksia attenuata* or *Banksia attenuata - Eucalyptus* woodlands
29a	Coastal shrublands on shallow sands
30b	**Quindalup *Eucalyptus gomphocephala* and/or *Agonis flexuosa* woodlands**
30c2	Woodlands and shrublands on Holocene dunes (re-allocated from 30c and 30a Gibson *et al.* 1994)
S11	Northern *Acacia rostellifera - Melaleuca systena* shrublands

F.2.5 An Atlas of Tuart Woodlands on the Swan Coastal Plain in Western Australia (Tuart Atlas) (Tuart Response Group 2003)

In response to widespread concern regarding the decline of Tuart and associated ecological communities, a 'Tuart Response Group' was appointed by the Western Australian Government in 2001. This group commissioned a project to map the extent of Tuart across the Swan Coastal Plain (Tuart Response Group 2003). The maps were based on the definition of canopies in 2002 aerial photographs at a scale of 1:10 000. Canopy density and understory condition were also estimated. While the presence of Tuart is likely to have been relatively precisely defined, the maps have not been updated. Given the likelihood of loss since 2002 the current area remaining is likely to be less than this estimate. It may be important to also note that the Tuart atlas mapped areas (as Tuart) that included Tuart trees over grazed pasture or mown recreational areas. Many of these areas are not mapped as remnant vegetation, therefore impacting on the value of remnant vegetation mapping in analysis.

F.3 Relationship with other threatened ecological communities

A range of threatened ecological communities of the Swan Coastal Plain has been listed under national environment law. Most of these are clearly distinct from Tuart woodlands and forests, but several have similar characteristics in some occurrences.

The ecological community intergrades and/or interacts with:

- Banksia woodlands of the Swan Coastal Plain (Department of the Environment and Energy 2016) – where Tuart occurs as an occasional emergent above a stratum dominated or co-dominated by Banksia species including *Banksia attenuata*, *B. menziesii* (Firewood Banksia), *B. prionotes* (Acorn Banksia) or *B. ilicifolia* (holly-leaved Banksia) the patch is likely to meet the diagnostic characteristics for the Banksia woodlands of the Swan Coastal Plain. This is not common and most likely on Spearwood formation dunes.
- Sedgelands in Holocene Dune Swales (Department of the Environment 2016a) – this ecological community occurs in linear damplands, typically waterlogged in winter. Characteristic species include shrubs such as *Acacia rostellifera* (Summer-scented Wattle), *Acacia saligna* (Orange Wattle), *Xanthorrhoea preissii* (Grass Tree, Balga) as well as sedges and grasses. Typically the ecological community has a more open structure than Tuart woodlands and forests, but at mature sites a closer tree canopy may develop, including Tuart or *Banksia littoralis* (swamp Banksia) trees, which may meet the diagnostic characteristics for the Tuart woodlands and forests ecological community. This is not common and most likely in the areas between dunes on the Quindalup formation.
- Aquatic root mat community of caves of the Swan Coastal Plain (Department of the Environment 2016b) – at sites including Yanchep National Park, some groundwater fed streams and pools occurring in caves support dense root mats of Tuart trees. These root mats support a highly diverse and distinctive assemblage of cave fauna. It is likely that this ecological community occurs directly below some occurrences of the Tuart woodlands and forests ecological community. There are strong interactions between the two ecological communities and it is likely also that disturbance to either surface vegetation or groundwater may affect both ecological communities.

The following threatened ecological communities may share some characteristics with Tuart woodlands and forests but are generally distinguished by their different structure or absence of Tuart trees as a defining feature:

- Shrublands on southern Swan Coastal Plain ironstones: Shrublands and woodlands on Perth to Gingin ironstone (Perth to Gingin ironstone association) of the Swan Coastal Plain (EPBC critically endangered) (Department of the Environment and Water Resources undated a)

- Clay pans of the southern Swan Coastal Plain (EPBC Critically Endangered), (Department for Sustainability, Environment, Water, Population and Communities 2012).

- Thrombolite (microbial) community of coastal freshwater lakes of the Swan Coastal Plain (Lake Richmond) (EPBC Endangered) (Department of the Environment 2016c).

- Thrombolite (microbialite) Community of a Coastal Brackish Lake (Lake Clifton) (EPBC Critically Endangered (Department of the Environment 2016d).

- Shrublands and Woodlands on Muchea Limestone of the Swan Coastal Plain (EPBC Endangered) (Department of the Environment and Heritage 2000).

- Shrublands and woodlands of the eastern Swan Coastal Plain (EPBC Endangered) (Department of the Environment 2016e).

- *Corymbia calophylla – Xanthorrhoea preissii* woodlands and shrublands of the Swan Coastal Plain (EPBC Endangered) (Department of the Environment and Water Resources undated b)

- *Corymbia calophylla – Kingia australis* woodlands on heavy soils of the Swan Coastal Plain (EPBC Endangered) (Department of the Environment 2016f).

- Assemblages of plants and invertebrate animals of tumulus (organic mound) springs of the Swan Coastal Plain (EPBC Endangered) (Department of the Environment 2016g).

F.4 Further information on existing protection and reserve tenure

The level of protection afforded by conservation tenure depends on the type of reserve. In Western Australia, mining cannot be carried out in a National Park or Class A nature reserve, except with permission of both houses of the State Parliament. Mining can be approved in other reserve types by the State Minister responsible for mines in consultation with the Minister responsible for the reserve (Environmental Defender's Office of Western Australia 2011).

The largest area of the ecological community protected is in the Tuart Forest National Park 2 049 ha (6.8% of current extent). This is a large and valuable reserve on the southern Swan Coastal Plain, classified by the state government as 'Class A nature reserve' (Department of Parks and Wildlife 2014a). However, this reserve is not representative of the variation present across the ecological community and has also had substantial past disturbance including grazing and forestry (Keighery and Keighery 2002). More generally, across the range of the ecological community protected areas may not be representative. The area south of Perth to Mandurah has been noted to contain few reserves (Keighery et al 2002), also the northern and eastern extremes of the range have been identified as particularly poorly protected (Tuart Response Group 2003).

While formal reservation provides some protection to the ecological community, many threats require active management. The *Western Australian Conservation and Land Management Act 1984* requires the Department of Biodiversity, Conservation and Attractions to manage lands under their responsibility in accordance with management plans. Some of the relevant plans for Tuart woodlands and forests conservation include Yellagonga Regional Park, Tuart Forest National Park and the Leschenault Peninsula, Yanchep and Yalgorup National Parks (Tuart Response Group 2004).