TUART (*EUCALYPTUS GOMPHOCEPHALA*) WOODLANDS AND FORESTS OF THE SWAN COASTAL PLAIN

ECOLOGICAL COMMUNITY

DRAFT CONSERVATION ADVICE INCLUDING DRAFT LISTING ADVICE

OCTOBER 2017

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1. CONSERVATION OBJECTIVE

To mitigate the risk of extinction of the Tuart (*Eucalyptus gomphocephala*) woodlands and forests 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 through the recommended priority conservation and research actions set out in this advice.

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

- describing what the ecological community is, where it can be found and what vegetation classifications correspond to it
- to identify the ecological community
- identifying the key threats to the ecological community
- presenting evidence (listing advice) for why the ecological community merits listing as nationally threatened under the EPBC Act; and
- outlining the priority conservation and research actions that could appropriately be done to 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

2.1. Name of the 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 with the canopy dominated by the eucalypt *Eucalyptus gomphocephala* (tuart) (this name reflects some of the various *Nyoongar* names for this tree species). The ecological community includes the assemblage of plants and animals that occur in association with the tuart canopy. The ecological community has a discontinuous distribution in the west of the Swan Coastal Plain, of south west Western Australia. The ecological community was placed on the 2016 Finalised Priority Assessment List.

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 woodlands and forests are most prominent in the southern part of the range, with the distribution being most continuous from the Sabina River to Lancelin. The ecological community 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; Ruthrof et al, 2002).

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The distribution of the ecological community is inherently limited by the distribution of tuart, as its dominant species, although tuart trees do also occur as a non-dominant component of some other ecological communities, such as the nationally threatened Banksia woodlands of the Swan Coastal Plain (Department of the Environment and Energy, 2016). These other ecological communities are commonly found adjacent to the tuart forest and woodland and can overlap in distribution with tuart woodlands and forests (Tuart Response Group, 2004).

The main distribution of the ecological community occurs within the Swan Coastal Plain bioregion (SWA) IBRA region, 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 (Government of Western Australia, 2016). The ecological community occurs within the country of the *Nyoongar* nation (SWALSC, 2016).

Local government areas containing the ecological community as at August 2017 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 34km wide in the north to 23km 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 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. These 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). They have developed from wind-blown sands derived from the erosion of the underlying 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 Environment Protection and Biodiversity Conservation Act (EPBC) 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 (Bischoff, 2002).

From the Bassendean dunes the land rises to the Pinjarra Plain. This is a flat area of between 5 and 15km wide covered by alluvial sediments brought by rivers and streams flowing from the Darling and Dandaragan plateaux above (McPherson and Jones, 2005). The Bassendean dunes are generally separated from the Pinjarra Plain, but south of the Swan Coastal Plain, in the area occupied by the Tuart Forest National Park, the dunes overly the Pinjarra Plain (G. Keighery and B. Keighery, 2002). Further inland still is the Ridge Hill Shelf, which forms the foothills to the Darling Scarp plateau (Figure **1**).

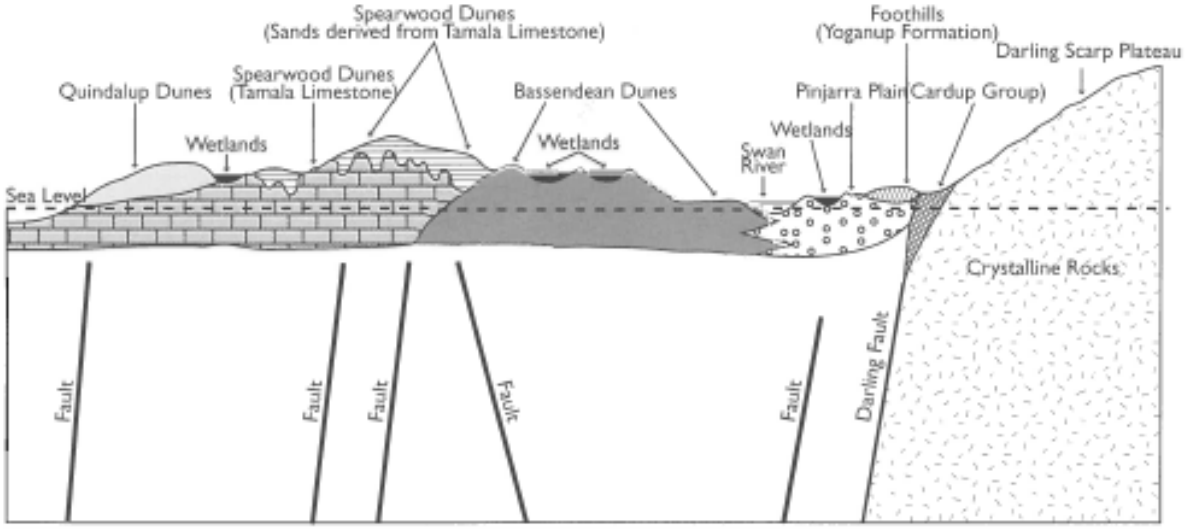

Figure 1 Landscape profile for the Swan Coastal Plain. The ecological community occurs mainly on the Spearwood and Quindalup dune systems, which are underlain by Tamala Limestone.

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

2.2.2. 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 550 mm in Jurien Bay to 810 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.

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	January max 30.9 July max 19.5	January 6.7 (annual low) July 114.2 (annual high) Annual 551.7
Perth Airport	January max 32 July max 17.9	January 9.6 (annual low) June 157.3 (annual high) Annual 767.4
Busselton	January max 28.5 July max 16.3	January 10.1 (annual low) June 167.1 (annual high) Annual 811.6

2.3. Vegetation

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 forest, open forest, woodland and open woodland, but can also include mallee structural formations (Department of the Environment and Heritage, 2003). The tuart trees range from multi-stemmed mallee 10-15m in height, particularly in the northern part of the range, to single trunked trees up to 40m in height, particularly in the southern part of the range (Florabank, undated). The primary defining feature is the dominance of *Eucalyptus gomphocephala* (tuart) in the uppermost canopy, although this may co-occur with various other tree species. There may also be a substantial midstorey, for example dominated by *Agonis flexuosa*. The understorey is often relatively open, including many non-woody species from the Asteraceae, Cyperaceae, Restionaceae and Orchidaceae families as well as lillies.

The south west 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, with these species also subject to substantial threats (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 heaths. Species richness varies with substrate, with tuart woodlands and forests on Spearwood dunes typically richer than sites on Quindalup dunes, although there may be more variation between Quindalup sites (Gibson et al. 1994).

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). G. 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. For example, *Veronica stolonifera* is likely to be restricted to tuart dominated areas.

The local expression of the ecological community is influenced by geology, soil composition and drainage, rainfall, site history and current and historical management. In many locations there has been substantial disturbance to the ecological community, which

is reflected in its current state: past clearance, with fire history and management involving grazing has had a strong influence on the current structural and floristic composition of the ecological community (Ruthrof et al, 2002). Strong differences between structure, species composition and richness of the ecological community that occur between Spearwood and Quindalup dunes as well as any occurrences on Bassendean dunes have also been associated with soil nutrient status; structural diversity is greatest on the Spearwood dunes while species richness is higher on Bassendean dunes (Government of Western Australia, 2000; Gibson et al, 2002).

Examples of the expression of Tuart woodlands and forests across its range: a) Guilderton b) Lake Clifton c) Myalup d) Ludlow

2.3.1. Tree canopy

Eucalyptus gomphocephala (tuart) is the dominant tree species within the 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. Where trees are exposed, 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, and sandy loam, sandy clay textures (Florabank, undated). Like many other eucalypts, it is likely that tuart hybridises with other species when nearby, so hybrid trees may form part of the ecological community (Coates et al, 2002). 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). 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 tuart range on the Swan Coastal Plain, considering various environmental characteristics suggested that soil pH and phosphorus content were the best predictors of its 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 these 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* (firewood banksia), *B.attenuata*, *C. calophylla* and *E. marginata* decreases (Gibson et al, 2002). This may explain the frequent occurrence of tuart on Spearwood dunes and dominance of other flora such as banksia species on the acidic and less nutrient rich Bassendean sands.

2.3.2. Understorey

There is substantial floristic 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) (G. Keighery, 2002). The structure of the understorey may vary from being open and grassy, particularly on Quindalup dunes to densely shrubby, or include a subcanopy of smaller trees. The extent to which the understorey is grassy or shrubby may depend in part on impacts of fire and grazing. In some areas on either Quindalup or Spearwood dunes there may also be substantial 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. Thus it is difficult to define a list of species that will be characteristic at all locations across the range.

Some native plants can be identified as commonly associated with the ecological community in various parts of its distribution. For example, some species characteristic of the northern part of the range are: *Chamelaucium uncinatum* (Geraldton wax), *Labichea cassioides* and *Lechenaultia linarioides* (yellow leschenaultia). 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) (G. Keighery 1999 cited in G. Keighery, 2002).

Other native plants 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, Muehlenbeckia adpressa, and Opercularia hispidula*

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

Herbs (monocot):

Perennial liliod herbs : *Acanthocarpus preissii, Dianella revoluta, Lomandra maritima, L. micrantha, 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*

Sedges

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

Annually renewed from seed : *Isolepis marginata, Triglochin calcitrapa and T. centrocarpum*

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 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).

Further information on plants likely to occur in the ecological community can be found at Appendix A – Species lists .

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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.

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 with 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. 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 (Abbot, 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 high grazing pressure on the understorey. The tuart woodlands with peppermint understorey in the southern part of the ecological community's range remain particularly important for both Western ringtail Possum (listed as 'vulnerable' in WA and nationally) and the *Trichosurus vulpecula* (Common 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 possums). Remaining populations of *Phascogale tapoatafa* (Southern Brush-tailed Phascogale) 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 nocturnal species take daytime refuge in tree hollows, and may now compete 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 Pistrelle) 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* (Quenda) and *Setonix brachyurus* (Quokka) (Hyder and Dell, 2009). *Bettongia pencillata* (Woylie) are likely to have formerly been part of some areas of the ecological community, performing an important role in turning over soil. Quenda continue to contribute to this task, and Numbats may also have played such a role in some areas (Dell et al, 2002). *Tachyglossus aculeatus* (echidna) is another soil engineer that 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 is pollination, particularly of the proteaceous species present (including banksias). *Tarsipes rostratus* (Honey Possum) is a small marsupial pollinators that is part of the ecological community, while *Cercartetus concinnus* (Pygmy Possum) would also have played a similar role but is now absent from the region. 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 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. In surveys across the landforms and vegetation types of the northern Swan Coastal Plain, Valentine et al (2009) found the highest abundance 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 have particular association with the ecological community are the skinks *Cryptoblepharus placiocephalus* (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. 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* (Shingleback) (Dell et al, 2002), as well as *Acritoscincus trilineatum* (South western cool skink) (Wentzel, 2010). Losses of reptile species in the region have been noted (Valentine et al 2009) and some species of particular conservation significance in the ecological community include *Lerista lineata* (Perth lined Lerista), and possibly *Morelia spilota imbricata* (How et al 2009). Several of the species identified by Valentine et al (2009) as commonly present in tuart forests tended be associated with long-unburnt sites.

2.4.3. Amphibians

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 there permanently, having a breeding burrow where the young hatch. The other amphibians present require access to free water, and sites near this have highest species richness (How et al, 2009).

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 boodang* (Scarlet robin), *Eopsaltria australis* (Western yellow Robin), *Acanthiza apicalis* (Inland thornbill) and *Smicornis 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), *Lichenostomus ornatus* (Yellow-plumed Honeyeater)

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Climacteris rufa (Rufous Treecreeper). The latter two species are now regionally extinct (Dell, et al. 2002).

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). Parrots are also amongst the many taxa likely to benefit from hollows in mature tuarts including *Platycercus spurius* (Red-capped Parrot) and *Platycercus zonarius* (Ring-necked Parrot). 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 *Calyptorynchus baudinii* (Baudin's cockatoo) and *Calyptorynchus banksii naso* (Forest red-tailed black cockatoo) (Department of Environment and Conservation, 2008). 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. 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 fuliginosa* (Grey Fantail).

Small gleaners such as *Acanthiza apicalis* (Broad-tailed Thornbill), *Smicrornis brevirostris* (Weebill), Western Gerygone (*Gerygone fusca*) and *Acanthiza chrysorrhoa* (Yellow-rumped Thornbill) and *Zosterops lateralis* (Grey-breasted White-eye) 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), although the ecological role they play is less well studied than for Banksia-dominated ecological communities (Dell et al 2002).

A range of migratory species identified in international treaties and listed under the EPBC Act 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,

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bees and wasps); Diptera (flies); Coleoptera (beetles);Lepidoptera (moths and butterflies); and Blattadea (cockroaches) (Ruthrof et al, 2002).

Some invertebrates noted particularly for their likely damage to tuart trees include *Haplonyx tibialis* (tuart bud weevils), as well as *Phoracantha impavida* and *P. semipunctata* (Tuart longicorns) (Tuart Response Group, 2004). The native earthworm species recorded on Quindalup and Spearwood dunes in the Perth region include *Austrohoplochaetella imparicystis* and *Woodwardiella liberti*, as well as a range of undescribed species and introduced species but their association with Tuart woodlands and forests is not clear (Abbot 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).

Further information on animals likely to occur in the ecological community can be found in Appendix A – Species lists

2.5. Key diagnostic characteristics

Key diagnostic characteristics assist in identifying a patch of native vegetation as being the threatened ecological community. In order to be considered a Matter of National Environmental Significance under the EPBC Act, areas of the ecological community must meet the key diagnostic characteristics and at least the minimum condition classes for national protection. The key diagnostic characteristics presented here summarise the main features of the ecological community. They are intended to aid its identification, noting that more details are provided in the other sections of this document.

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

- Occurs in the Swan Coastal Plain Bioregion (Department of the Environment, 2012) within the state of Western Australia

  and

- 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. It occurs below the Darling and Whicher escarpments where they define a plateau to the east of the Swan Coastal Plain.

  and

- Most often occurs as a woodland but can occur in a variety of structural forms, including closed forest, open forest, woodland, open woodland, closed mallee forest, open mallee forest, mallee woodland and open mallee woodland (Department of the Environment and Heritage, 2003)

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- The dominant canopy species is tuart (*Eucalyptus gomphocephala*), being the most abundant tree species in the canopy[1]. It may occur either as a single stemmed tree or occasionally as a mallee. While other tree species may be present in the canopy, they are less abundant than tuart.
- For a patch of vegetation to be identified as the ecological community, there must be established[2] tuart trees present, meeting the patch definition (see section 0 for more information on defining patches). [3]

2.5.1. Other diagnostic considerations

- Other tree species frequently present in the canopy or sub-canopy are: *Agonis flexuosa* (peppermint) and *Banksia grandis* (bull banksia) (both in the southern part of the range); *Banksia attenuata* (candlestick banksia), *Eucalyptus marginata* (jarrah); less commonly, *Corymbia calophylla* (marri).
- An understorey of native plants, which may include grasses, herbs and shrubs is typically present. The composition and structure of this understorey varies across the range of the ecological community. Some understorey plant species that are commonly present are listed in section 2.3.2.

2.5.2. Relationship with other ecological communities

- The range of the ecological community overlaps and interacts with other ecological communities of the Swan Coastal Plain, including some listed under the EPBC Act. At some locations more than one ecological community may be present. The following considerations apply to the identification of the ecological community where it is likely to overlap with some other listed ecological communities:
  - Banksia woodlands of the Swan Coastal Plain- where tuart occurs as an occasional emergent above a stratum dominated or co-dominated by Banksia species including *Banksia attenuata* (candlestick banksia, slender banksia), *B. menziesii* (firewood banksia) *B. prionotes* (acorn banksia) or *B.ilicifolia* (holly-leaved banksia) the patch is likely to be the Banksia woodlands of the Swan Coastal Plain, should other diagnostic characteristics and condition requirements for that ecological community be met. Where tuart forms the dominant species in the canopy or sub-canopy (the most abundant of trees species present), with no more than 40m between the canopies of the tuart trees, the tuart woodlands and forests ecological community is likely to be present. In some instances, particularly on Spearwood dune substrates both Banksia woodlands and Tuart woodlands and forests may be present.

[1] Tuart is considered 'dominant' in a patch where it is the most abundant (by number of stems) of the established trees present in the canopy.
[2] 'Established' refers to trees that are > 15cm diameter at breast height (DBH).
[3] Survey should occur at least two years following disturbance events such as fire, disease outbreaks, severe hydrological change or 'tuart decline' that is sufficiently severe to kill established trees, so that any tree regeneration is evident. Should this not be possible, the presence of the ecological community should be determined by information available on the likely pre-disturbance state.

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- 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) as well as sedges and grasses. Typically the ecological community has a more open structure than tuart woodlands and forests, but at mature sites an open tree canopy may develop, including tuart or *Banksia littoralis* (swamp banksia) trees. The nature of the ecological community may change with succession. Where tuart forms the dominant species in the canopy or sub-canopy (the most abundant of trees species present), with no more than 40m between the canopies of the tuart trees (meeting the patch definition), the tuart woodlands and forests ecological community is likely to be present. In some instances, in the areas between Quindalup dunes, both Sedgelands in Holocene Dune Swales and tuart woodlands and forests may be present.
- 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 the tuart woodlands and forests ecological community, with the tuart roots themselves likely to be part of both, should any other requirements such as minimum condition be met. 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.

2.6. Condition classes and thresholds

National listing focuses legal protection on patches of the ecological community that are the most functional, relatively natural and/or in comparatively good condition. Those patches of the highest condition are protected as a Matter of National Environmental Significance, as defined by the EPBC Act, and so the referral, environment assessment, approval and compliance provisions of the EPBC Act are likely to apply. Very degraded patches may not contribute so greatly to the conservation of the ecological community so will be largely excluded from national protection.

Although very degraded or modified patches are not protected as part of the ecological community listed under the EPBC Act, some of these patches may still retain important natural values, including habitat for flora and fauna and contributions to landscape function. These may be protected through state and local laws or schemes. These patches should not be excluded from recovery and other management actions. Suitable restoration and management actions may improve a patch's condition, such that it can be subsequently included as part of the ecological community fully protected under the EPBC Act. In some cases, the loss and degradation is irreversible or rehabilitation is impractical because many natural characteristics have been removed. For instance, areas permanently converted to improved pastures or built areas may not be effectively restored.

The Tuart woodlands and forests ecological community has been heavily cleared and degraded. Some remnants are small and isolated, particularly in the greater Perth area and

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to the north while others are large and yet heavily modified (particularly in the southern areas). Genetic studies suggest that the distribution of the central and southern extent was mainly continuous but that the northern outlying populations are likely to have been isolated for some time (Coates et al, 2002).

A small number of areas remain in good 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 and form a large patch are a high priority for protection and management. The condition classes in this Conservation Advice provide guidance on the qualities that characterise patches of different condition.

Benson and Howell (1990, cited in Casson et al, 2009) notes that perceived condition at any individual site can vary cyclically with factors such as fire or rain, leading transient expressions in above-ground vegetation due to cyclical emergence from seedbanks and tubers, growth and senescence. Condition assessments may return contrasting outcomes, depending when they are done relate to this cycle. . In contrast, disturbances such as clearing and grazing may be responsible for more permanent change, particularly to soil and water properties, and impair regeneration over the long term.

The species composition of this ecological community is influenced by, amongst other things, the disturbance history (including fire and grazing), patch size, proximity to other patches, proximity to highly disturbed areas, and recent rainfall and drought conditions. Plant surveys conducted during spring and early summer may more easily identify plants in the ecological community. However, the key diagnostic characteristics and condition classes are designed to allow identification of the ecological community irrespective of the season.

Several methods for measuring condition have been developed for the Swan Coastal Plain, in particular, one method for rapid assessment defined by B.Keighery (1994) has been widely used, including in the 'Bush Forever' initiative to identify bushland sites important for conservation in the Perth region (Government of Western Australia, 2000). A report on methods for condition survey in Western Australia by Casson et al (2009) cites an updated version of this 'Keighery scale' and a comparison with other methods. It also provides guidance on measuring a wide variety of condition attributes. The updated Keighery condition estimation method is the basis for the measures used here to identify the best quality patches of the ecological community that are part of the nationally protected ecological community.

A patch that meets the key diagnostic characteristics for tuart woodlands and forests should be considered part of the nationally protected ecological community if it meets the description of categories A (Pristine- Excellent), B (Very Good- Good) or C (Degraded but retaining important identified habitat, regeneration or landscape features). Categories A and B suggest a standard for restoration of patches of the ecological community to better condition, as well as helping to identify some of the most valuable areas for conservation.

Only patches meeting the description of category D (Degraded or Completely Degraded condition with no identified important habitat, regeneration or landscape features remaining) do not meet the requirements for national protection through the EPBC Act.

The vegetation of the region has been heavily cleared since the 19th century. Genetic studies suggest that the distribution of the central and southern extent was mainly continuous but that the northern outlying populations are likely to have been isolated for some time (Coates et al, 2002).

Table 2 Condition classes for patches of Tuart woodlands and forests

Category	Description	Non-native cover[a]	Min. size
A	**Patches that are in Pristine or Excellent condition – 'benchmarks' for restoration.** • Vegetation structure is intact. • Disturbance is not evident or only affect individual species. • Most understorey[b] plants are native, including at least 20 native species[c] in the patch.	<10%	0.5 ha
B	**Patches that are in Very good or Good condition** • Vegetation structure is largely intact or is altered. • There are obvious signs of disturbance, e.g. from repeated fires, tree dieback or decline, logging or grazing. • The understorey [b] includes at least 12 native species [c]	<50%	1 ha
C	**Patches that are degraded but retain important habitat, regeneration or landscape features** • Basic vegetation structure has been severely impacted by disturbance. There is scope for regeneration but requires intensive management. • There are obvious signs of disturbance such as very frequent fires, tree dieback of decline, logging, partial clearing or grazing • The understorey[b] includes at least 6 native species[c] **And** The patch retains evidence of regeneration **and/or** habitat features **and/or** landscape role as follows: **Regeneration:** • natural regeneration of canopy and/or understorey species typical of the ecological community; **or** **Habitat:** • tree hollows likely to support native fauna **or** very large trees (> 50cm DBH) **or** other features likely to provide valuable habit e.g. fallen wood in a range of sizes; • structures that are likely to provide valuable habitat for native fauna that are part of the ecological community; • populations of native fauna that are part of the ecological community; **or** **Landscape role:** An important landscape role, either because: • it has close proximity (<100m) to native vegetation[d], with any of these patches being at least 2ha in size; or • it is a significant example of the ecological community in a local area where it has otherwise been largely lost	>50%	2 ha
D	**Patches that are in a Degraded or Completely Degraded condition with NO identified important habitat, regeneration or features remaining** • Basic vegetation structure has been severely impacted by disturbance. There is scope for regeneration but this requires intensive management • There are obvious signs of disturbance such as very frequent fires, tree dieback of decline , logging, partial clearing or grazing • The understorey[b] contains few or no native[c] understorey species And/or DOES NOT retain any of the habitat, regeneration or landscape features identified in Category C.	>50%	NA

[a] Non native vegetation cover as % of perennial vegetation present in the ground layer or shrub layer
[b] Understorey vegetation cover includes vascular plant species of both the ground layer and the shrub layer up to 3m in height (where present). The ground layer includes herbs (graminoids and forbs) and low (≤0.5 m) shrubs.[c] 'Native' refers to species naturally occurring in south west Western Australia.[d]'Other native vegetation' refers to areas where ≥50% of the perennial vegetation cover across all layers is comprised of plant species naturally occurring in south west Western Australia.

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2.7. Further information to assist in determining the presence of the ecological community

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, such as the relative dominance of *Agonis flexuosa* (peppermint) in the canopy or sub-canopy. 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.

Defining a patch

A patch is a discrete and mostly continuous area of the ecological community. It contains a minimum of three established[4] tuart trees, with no greater than 40m between the outer edges of their canopies. At least two of these trees must be living[5]. The edge of any patch is defined as 20m beyond the outer edge of the canopy of individual tuart trees where the understorey consists of native vegetation, as defined in the condition classes at 2.6 (Figure 1). Following disturbance events that have caused the loss of established trees (for example, fire), the patch is part of the ecological community if there are at least five young tuarts with no more than 40m between the stems of each and tuart is the most abundant of trees species present at the site, regardless of maturity.

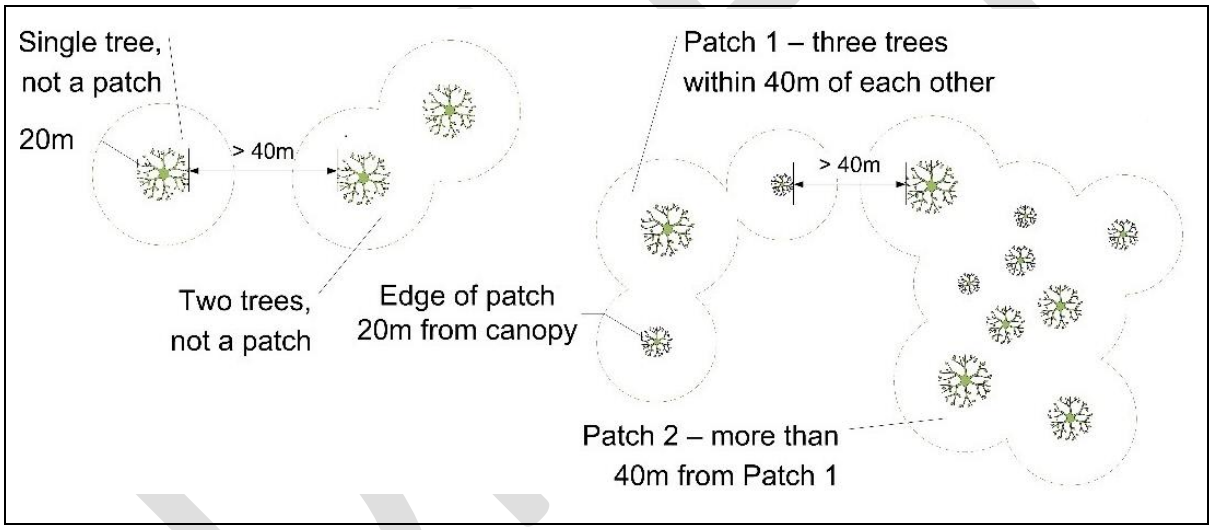

Figure 2 Patches contain at least three established tuart trees, with no more than 40m between their canopies. At least two of these tuart trees must be alive.

A patch may include small-scale (<40 m) variations, gaps and disturbances, such as roads, paths, breaks, watercourses, or other localised variations in vegetation that do not significantly alter the overall function of the ecological community (Figure 2). Such breaks

[4] Established' refers to trees that are > 15cm diameter at breast height (DBH).

[5] Where a dead or 'stag' tuart tree 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. As for living tuart trees, this canopy edge must be within 40m of another tuart canopy to be considered as part of the patch. Where no branches are present, the trunk of the tuart stag must be within 40m of another tuart canopy (of either a living or another dead tuart tree). If the species of a stag tree is unclear, where the canopy in a patch is otherwise dominated by tuart trees, the stag is presumed to be a tuart.

are still considered to be part of the patch and are generally included in patch size calculations. Where there is a break in native vegetation cover, from the edge of the tuart tree canopy of 40 m or more (e.g. due to permanent artificial structures, wide roads or other barriers; or due to water bodies more than 40m wide) then the gap typically indicates that separate patches are present. Large gaps (>40m across) are not included in patch size calculations.

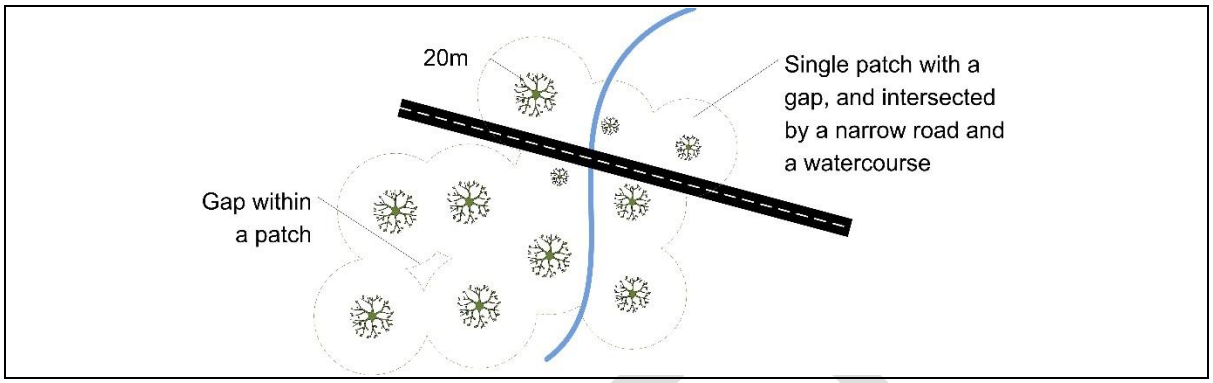

Figure 3 Small scale variations in cover (<40m across) can be included in a patch

Patches can contain areas in different states of condition. In assessing the patch note any areas that are either significantly higher or lower in quality, and the condition classes that would apply across these different parts of the site.

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 spray drift (fertiliser, pesticide or herbicide sprayed in adjacent land), weed invasion, water runoff and other damage.

Native vegetation that surrounds or adjoins the site forms an ideal buffer, so this vegetation should be retained. 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 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. For EPBC Act approval, changes in use of the land that falls within the buffer zone must not have a significant impact on the ecological community, but there are exemptions for continuing use (e.g. cropping, grazing or maintaining existing fire breaks). If the use of an area that directly adjoins a patch of the ecological community will be intensified, approval under the EPBC Act may also be required to avoid 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 20m past the canopy of established tuart trees, so the minimum buffer is 50m past the canopy) as this distance accounts for likely influences upon the root zone. A larger buffer zone (e.g. 50m) 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.

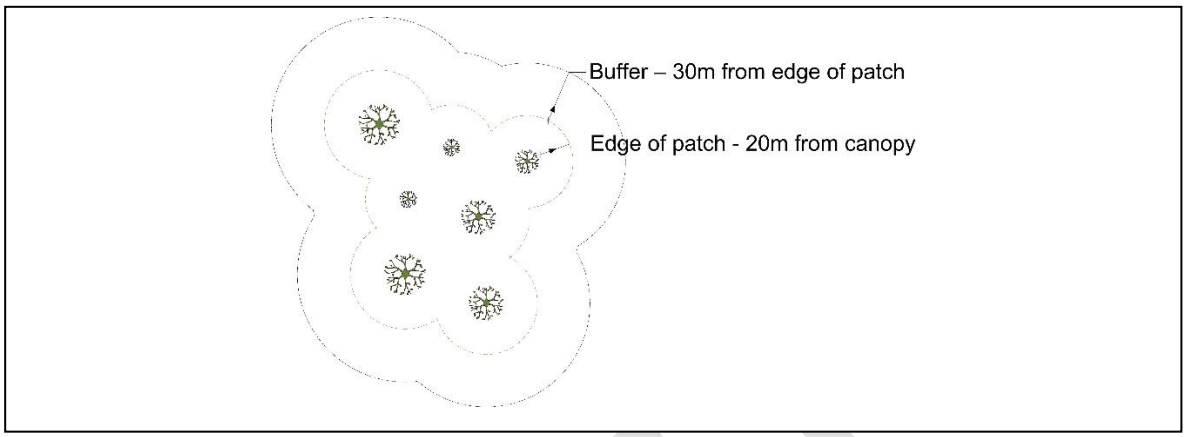

Figure 4 The buffer zone extents 30m beyond the edge of a patch

Revegetated areas and areas of regrowth

Revegetated or replanted sites (or areas of regrowth) may be part of the nationally protected ecological community, provided that the patch meets the key diagnostic characteristics and minimum condition class above. It is recognised that reconstruction/revegetation requires long term effort and commitment, and results or restoration efforts are uncertain.

Sampling protocol

Thorough and representative on-ground surveys are essential to accurately assess the extent and condition of the ecological community e.g. 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. Patches can vary markedly in their shape, size, condition and features. The size, number and spatial distribution of plots or transects must be adequate to represent variation across the patch. Sampling should address likely variation in species richness (any areas with apparently high native species richness should be included in the sample) and significant variation in the vegetation, landscape qualities and management history (where known) across the patch. For instance, localised weed cover, drainage lines, burned or grazed areas, saline zones. Plots of 0.01 ha (10m x 10m) are recommended by Keighery (1994), while 0.0625 ha (quadrats of 25 x 25 m) are the basis for methods described in Casson et al (2009). It is useful to record the search effort (identifying the number of person hours spent per plot and across the entire patch; along with the surveyor's level of expertise and limitations at the time of survey). Observing an approach to quadrat survey consistent with that for Bush Forever reference sites would have advantages of comparability of species counts.

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Timing of surveys and seasonal variation

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. Ideally, surveys should be held in more than one season to maximise the chance of detecting all species present. Many species are easiest to detect or identify in spring when many are flowering and reproducing (Casson et al 2009). However, for some species to be detected, surveys at other times will be required, so it is recommended that sites are visited multiple times. In particular, 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.

Tuart woodland recovering one year after 2016 fire in Yalgorup National Park

In addition to the effects of rainfall variation, presence and detectability of some species may also be affected by the time since disturbance such as fire so surveys should be planned to occur after an adequate time following adequate rainfall for some recovery, including any tree regeneration that is likely. An interval of at least 24 months post fire and other major disturbance events such as disease outbreaks, heavy grazing, severe hydrological change or 'tuart decline' that is sufficiently severe to kill established trees, so that likely regeneration of trees, as well as understorey species is evident. If it is not possible to wait this interval following the disturbance, the type and extent of the disturbance should be noted and other information used to infer the presence of the ecological community in its pre-disturbance state and its likely characteristics following recovery.

2.7.1. Guidance for impact assessment and mitigation

Actions that may have 'significant impacts' on any patches of the ecological community that meet the condition class requirements must be considered under the EPBC Act. 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. 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 may be possible for

some low quality patches, so these areas 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 the EPBC Act, 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.
- 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 EPBC or Western Australian listed threatened species.
- Presence of cryptogams, soil crust and leaf litter on the soil surface
- 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. This 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.

2.8. Area critical to the survival of the ecological community

The individual patches most critical to the survival of the ecological community would meet Categories A (pristine-excellent) and B (very good- good) condition in **Table 2**. However, given the high rates and loss of the ecological community across its range, all remnants are valuable. Large patches that are not yet reserved are likely to be of particular importance. Some of the other characteristics to be considered in identifying other areas of particular importance are identified in section 2.7. 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. Additional areas such as adjoining native vegetation and areas that meet the description of the ecological community but not the minimum condition class are also considered important for recovering the integrity of the ecological community. Populations or 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 survival of the ecological community.

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2.9. 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 forest and woodland ecological community described in this conservation advice may have occurred before 1750 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. Consideration of whether the nationally protected ecological community is present at any site should focus on whether the patch meets the description, particularly the key diagnostic characteristics and minimum condition class 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') which have been subsequently incorporated into the National Vegetation Information System (NVIS). Other approaches to vegetation classification in the region include Floristic Community Types, which are generally identified only as point locations and 'Vegetation Complexes', which incorporate landscape and vegetation characteristics. The most specific mapping of tuart trees across their extent occurred through the 'tuart atlas' maps published in 2003.

In estimating the likely pre 1750 extent of the ecological community we have included expert interpretation of existing Beard's Vegetation Association maps for the Swan Coastal Plain. 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-1750 extent of the ecological community. Areas identified as having a 'weak' level of tuart dominance were excluded (Department of Biodiversity, Conservation and Attractions, 2017a).

2.10. Existing protection

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 current extent of the ecological community, 5535 ha has been reserved by the Government of Western Australia in 20 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.

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).

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 and Keighery, 2002).

EPBC protection through Ramsar listing

The ecological community is not a core wetland community, but it can occur on the margins of wetland and riverine areas. It occurs in two sites protected under the Ramsar Convention. Approximately 223 ha of the ecological community occur in the Vasse-Wonnerup site and 2317 ha hectares are in the Peel-Yalgorup site. This is a total of 2 540 hectares, 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 (Hale and Butcher, 2007; Wetland Research and Management, 2007).

Protection through State/Territory legislation

In Western Australia, the *Biodiversity Conservation Act 2016* enables the identification and listing of threatened ecological communities. Tuart woodlands and forests have not been identified as a threatened ecological community. Some ecological communities are also identified as 'priority'. 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 Functional 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).

The use of the Western Australian priority ecological communities list is as follows:

"Possible threatened ecological communities that do not meet survey criteria or that are not adequately defined are added to the priority ecological community list under priorities 1, 2 and 3. These three categories are ranked in order of priority for survey and/or definition of the community, and evaluation of conservation status, so that consideration can be given to their declaration as threatened ecological communities." (Department of Environment and Conservation, 2013).

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 the *Environment Protection and Biodiversity Conservation Act* (Commonwealth, 1999) (**Table 3**).

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Table 3 Threatened and priority flora and fauna that may occur in the ecological community

Scientific names and listing status are current at August 2017.

Sources: Rottnest Island Authority (undated); Western Australian Herbarium (1998-_); G.Keighery (2002); G.Keighery and B.Keighery (2002)p. 144; Morris et al (2008); Abbot (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) Wetlands Research and Management (2007).

Scientific Name	Common Name	Nyoongar name(s) (may vary with location)	EPBC Act*	WA Declared Rare Flora, Fauna or priority taxa*	Notes (Keighery 2002)
Flora					
Acacia benthamii				Priority 2	
Caladenia huegelii	Grand spider orchid		E	Declared Rare Flora	
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 spsp. palustre	Blue devils			Priority 3	
Haloragis aculeolata				Priority 2	Poorly collected. Occasionally occurs in tuart woodland
Lasiopetalum membranaceum				Priority 3	Largely confined to tuart dominated communities
Rorippa sp. Yalgorup (GJK 14455)					Possibly lost from sites outside Tuart Woodlands and forests. Only found in two locations on Swan Coastal Plain.

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Scientific Name	Common Name	Nyoongar name(s) (may vary with location)	EPBC Act*	WA Declared Rare Flora, Fauna or priority taxa*	Notes (Keighery 2002)
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*	Vu	E (schedule 1)	
Calyptorhynchus latirostris	Carnaby's cockatoo	*Ngolyenok*	E	E (schedule 1)	
Calyptorynchus banksii naso	Forest red-tailed black cockatoo	*Karak*	Vu	Vu	
Mammals					
Bettongia penicillata	Brush-tailed bettong	Woylie	E	CE (regionally extinct)	
Dasyurus geoffroii	Western quoll	*Chuditch*	Vu	Vu	

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Scientific Name	Common Name	Nyoongar name(s) (may vary with location)	EPBC Act*	WA Declared Rare Flora, Fauna or priority taxa*	Notes (Keighery 2002)
Isoodon obesulus fusciventer	Southern brown bandicoot	*Quenda*	E	Priority 4	
Phascogale tapoatafa ssp.(WAM M434)	South western brush-tailed phascogale	*Wambenger*		CD	
Hydromys chrysogaster	Water rat	*Rakali*		Priority 4	
Falsistrellus mackenziei	Western false pipistrelle			Priority 4	
Pseudocheirus occidentalis	Western ringtail possum	*Ngwayir,womp, woder, ngoor, ngoolangit*	Vu	En	
Macropus eugenii derbianus	Tammar wallaby			P4 Formerly present?	
Macropus irma	Western brush wallaby			P4 Formerly present?	
Setonix brachyurus	Quokka	*Quak-a, Bungeup*	Vu	Vu Formerly present?	
Myrmecobius fasciatus	Numbat		Vu	E	

*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."

3. DESCRIPTION OF THREATS

The ecological community occurs within a landscape that has mixed uses, including agriculture, industrial use and housing. It has been identified as 'particularly susceptible to threatening processes such as land clearing, climate variability, changes in vegetation structure resulting from altered fire regimes and past grazing, hydrological factors and weed invasion' (Ecoscape, 2004). As the ecological community'national distribution is limited to the Swan Coastal Plain the entire range of the ecological community is vulnerable to disturbances such as disease outbreaks.

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In the past, clearing was primarily for agriculture and forestry. This also continues for industrial and urban development and resource extraction across the plain and particularly in the greater Perth area.

The nature of some areas of the ecological community may also have changed structurally and floristically in response to a combination of fire and heavy or prolonged grazing. This may have altered both the relative abundance of tree species as well as the nature and condition of the understorey.

3.1. 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 be in extremely poor condition and may not meet the minimum class for national protection. Keighery et al (2002) note that the area of tuart communities is often over-represented on maps as visible tuart tree canopy may occur without viable understorey. They also note that ecological communities containing tuart have experienced relatively high levels of disturbance, particularly due to the use of dune swales for grazing and stock shelter, particularly in coastal areas. Where there were larger remnants, condition was higher. At the most northerly extent of the range of tuart, remnants were restricted to low-lying areas and overall condition was very poor with few intact areas outside of reserves, due to a history of grazing and extensive clearing. They cite the work of G. 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': this was again attributed to the long history of grazing.

The Tuart Atlas 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. Only 36 per cent of the area (10 897 ha) had no visible disturbance, while approximately 60% (18207 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. Following this, the Tuart Response Group (2004) identified 10 864 ha of 'Indicative high conservation' tuart woodlands.

Damage to understorey vegetation has been so widespread that it is considered that no areas of the ecological community are considered to be unaffected, and habitat value has been substantially reduced in some places. Where the total grazing pressure, including by kangaroos, is high, this may be preventing regeneration of the understorey (Department of Parks and Wildlife, 2014b). Competition with weeds also compromises the understorey of native species (for example, in the Ludlow Forest area).

Many of the current and future threats to the ecological community are associated with the remaining impacts of the historical disturbance of grazing and clearing for agriculture. A more recent threat is posed by clearing and fragmentation for the rapid development of housing and associated infrastructure, which continues to cause substantial landscape change throughout the Swan Coastal Plain. The ecological community is also likely to be affected by the decline in rainfall that has occurred across the region in recent decades (Department of Environment and Conservation, 2011).

Across the Swan Coastal Plain, there has been a general loss of woodland and forest trees, including tuarts, related to these factors as well as additional stresses associated with soil

compaction and insect infestation, combined with low levels of recruitment. At Yalgorup in particular, there have been some rapid losses in condition of tuart trees. Many causes have been speculated and it is likely that a suite of factors have contributed to the decline. These may include air pollution, changes in fungi present, change in water quality and availability, damage by feral animals and reduced biological control of pests (Tuart Response Group, 2004; Barber and Hardy, 2006; Wentzel, 2010).

3.1.1. Patch size and distribution

Overall, the ecological community is highly fragmented, which reflects the pattern of much of the native vegetation across the Swan Coastal Plain. Patches in the northern part of the range of the ecological community are generally smaller and more isolated than those in the southern part (Keighery et al, 2002). This is likely to be a natural feature of the ecological community, but is also likely to have 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). Of 563 patches mapped in the 'current extent' the median patch size is 4.4 ha and the mean is 45 ha (analysis of Department of Biodiversity, Conservation and Attractions, 2017a and Tuart Response Group 2003)[6] (**Table 4 Remnant patch sizes**).Of these, very small patches constituted 18% patches, approximately half of the number of the patches were 'small', one quarter of patches were medium sized, 7% were 'large' 'and less than 1% were 'very large. Thus, the vast majority of remaining patches were medium sized or smaller (93% are less than 100ha). These patches are particularly vulnerable to a range of threats that act on small natural areas or populations. In spite of this, much of the area (>75%) is in a small number of 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 establishing formal conservation tenure. These large reserved patches remain vulnerable to certain types of threats such as disease, weeds and extensive fires.

Table 4 Remnant patch sizes

	Number of patches	Total area of patches in size category (ha)	% of patches	% of area
Very small patches ≤1ha	**99**	**47**	**18**	**0.2**
Small patches ≤10 ha[7]	**280**	**1107**	**50**	**4**
Medium Patches >10 ≤100 ha	**144**	**4854**	**26**	**19.**
Large Patches >100 ha ≤1000 ha	**37**	**10616**	**7**	**42**
Very large patches >1000 ha	**3**	**8790.3**	**0.5**	**34.6**

[6] For consistency with the patch definition in this Conservation Advice, where the gap between mapped canopies is less than 40m, the areas have been combined into a single patch.

Total	**563**	**25 414.2**		

Mean patch size ha	**45.1 ha**
Median patch size ha	**4.4 ha**
Smallest patch	**0.004 ha**
Largest patch	**5 561.7 ha**

Source: analysis of data from Department of Biodiversity, Conservation and Attractions, 2017a and Tuart Response Group 2003

The loss of the ecological community and surrounding vegetation since 1750 has led to fragmentation and increased edge effects, making it more susceptible to a range of threats associated with a changing landscape. When considering the size and distribution of patches of the ecological community it is also important to consider the adjacent vegetation and broader landscape. The Tuart woodlands and forests ecological community exists together with other types of native woody vegetation, supporting its function as part of the broader landscape, for example banksia woodlands and other woodlands and forests with canopies dominated by species such as jarrah, marri, and *Eucalyptus wandoo* (wandoo). Across the Swan Coastal Plain, much of this vegetation has been cleared, with only 27% of native vegetation remaining (Department of Food and Agriculture Western Australia, 2016). Of the 563 mapped patches of tuart forest, 65% adjoin native vegetation, 8% are within 40m of other native vegetation; 8% are within 100m of native vegetation and 19% are greater than 100m from native vegetation. 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).

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 identify that some bushland areas in outer Perth were only cleared and fragmented within the past 20 years (Ramalho et al 2014). 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 but not in larger patches, demonstrating one of the inherent vulnerabilities of small patches to threats associated with edge effects. The maintenance of small populations of tuart trees, particularly in disjunct populations at the northern edge of the range was also recognised as a management issue, with monitoring of recruitment levels recommended (Keighery et al, 2002).

3.2. Known threats

The range of threats faced by the ecological community is described here in categories, but in practice, these threats may interact, rather than act independently.

The primary known threats to the ecological community are:

3.2.1. Clearing and fragmentation of vegetation

The primary source of loss of the ecological community is clearing. This has occurred for various purposes. In the 19th and early 20th centuries it occurred for agriculture and large scale timber removal, while in recent times it is more likely to occur for residential and industrial development, related infrastructure, mining or quarrying. The expected large increase in the population of greater Perth is likely to result in greater fragmentation and clearing of remnants. Urban development is also occurring rapidly in other parts of the range of the ecological community, for example in the greater Bunbury region. All clearing and fragmentation of vegetation impacts directly on the regional populations of native fauna and indirectly, by reducing habitat and ecological connectivity. This is likely to impede ecological processes such as transfer of pollen and seeds as well as limiting faunal movement and occupation.

Expert interpretation of Beard's Vegetation mapping association polygons (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) identified those polygons most likely to have been dominated by tuart (strong and moderate association) before 1750. From this, the pre-1750 area extent of the ecological community is estimated to have been approximately 125 400 ha (Department of Biodiversity, Conservation and Attractions, 2017a).

The Tuart Atlas mapping from aerial photographs (Tuart Response Group, 2003) is likely to be the most direct representation of the modern area of occurrence of the tuart species, across its natural range. Of this Tuart Atlas mapped area, 25 410 ha fell within the areas identified as being dominated by tuart before 1750, and so likely to be part of the ecological community (analysis of Department of Biodiversity, Conservation and Attractions, 2017a and Tuart Response Group 2003).

This is likely to be a 'best case scenario' for the current extent of the ecological community, due to the acknowledged poor condition of some of the areas mapped in 2003, as well as likely clearing since this mapping occurred. To illustrate this likely trend, the intersection of this estimated extent of the ecological community (based on the 2003 mapping) with a more recent native vegetation map (2015 data) leaves approximately 17 000 ha (identified here as 'indicative immediate extent) (Department of Agriculture and Food Western Australia, 2016), which is 14% of the estimated pre-1750 extent. Given the strong pressures to clear native vegetation within the region this may indicate recent loss in extent though caution must be used in interpretation due to the different mapping methods used, so for analysis against the listing criteria in this draft Conservation Advice the 2003 extent figure is used (**Table 5 Estimated pre-1750 and recent spatial extent of the ecological community**Of this mapped area, some patches may have no native understorey, so a smaller area still is likely to meet the minimum condition class for national protection.

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Table 5 Estimated pre-1750 and recent spatial extent of the ecological community

Estimate of extent	Hectares	Portion of pre 1750 extent
Pre-1750 (Department of Biodiversity Conservation and Attractions 2017a).	125 400	___
2003 extent (analysis of Department of Biodiversity, Conservation and Attractions, 2017a and Tuart Response Group 2003)	25 410	20 %
Indicative 2015 extent (Analysis of Department of Biodiversity Conservation and Attractions 2017a, Tuart Response Group and Department of Agriculture and Food Western Australia (2016)	17 060	14 %

Agriculture and grazing

The Swan Coastal Plain has been subjected to European-style agriculture and grazing since 1829. 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. 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, including the Ludlow Forest in the south, kangaroo populations have increased substantially in recent times, with excessive grazing by rabbits kangaroos noted as a key threat in Tuart Forest National Park (Department of Parks and Wildlife, 2014a).

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 weed invasion. 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.

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).

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 but 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 risk

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of limbs dropping. The Regional Forest Agreement area does not include substantial areas of tuart trees.

Urban development and infrastructure

The Swan Coastal Plain is heavily impacted by urbanisation, with clearing also occurring for light industrial developments and associated infrastructure such as roads. 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, 2015). 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, Mandurah and Wanneroo (Tuart Response Group, 2003).

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. 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. While increased human populations near natural areas may lead to their appreciation there is often increased pressure on these areas, with problems including profusion of bike and four wheel drive trails, weed invasion, 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). Those native animals that are well adapted to urban environments may competitively exclude others that are less well adapted.

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 changes to hydrology. In the past, the requirement for timber to support mining and engineering operations led to further forest loss. More recently, tuart, or other native vegetation in its vicinity has been cleared to allow mining and quarrying to occur. The occurrence of Tuart woodlands and forests on limestone substrates is now the reason for clearance of the ecological community in various parts of its range. 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 committed by 2022 (Shire of Harvey Planning Department, 2017). Mining for mineral sands also occurred in the Ludlow Forest area between 2003 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). Mining projects are often also associated with either temporary or long term hydrological change.

3.2.2. Weeds

In many places weed invasion has substantially degraded the understorey of tuart woodlands and forests, increasing competition for light, space, water, and nutrients. 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. These areas have frequently been grazed, which has resulted in the introduction of weed seeds by stock and through 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 vulnerable to invasion by weeds of Mediterranean origin.

Remnants of the ecological community in the Perth region are particularly subject to weed invasion, often being dispersed by birds (G.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 (G. Keighery, 2002). Bridal creeper (*Asparagus asparagoides*) 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). Other weeds affecting the ecological community include arum lily (*Zantedeschia aethiopica*), blackberry nightshade (*Solanum nigrum*) and dune onion weed (*Trachyandra divaricata*). Annual grasses such as 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*) may promote fire (Keighery and Keighery, 2002; Ruthrof et al, 2013). 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.

One of the largest remnants of the ecological community is Ludlow Forest. 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 (193 recorded species). Even at sites where there has been weed control, the large area that is still invested means that re-establishment is a problem, with birds carrying seeds of weeds such as Arum lily (Onshore Environmental, 2017).

3.2.3. Invasive 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 (Abbot, 2008; Department of Parks and Wildife, 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*). Cats and foxes have also limited the success of translocation programs, for example, to re-establish populations of woylie

(Yeatman and Groom, 2012). Other species considered vulnerable to predation include western ringtail possum, brushtail possum, quenda, southern brush-tailed phascogale and water rat, as well as water birds that nest in the ecological community. In a peri-urban setting, there is a continous replenishment of feral cat populations (Department of Parks and Wildlife, 2014a). Stray cats 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 significant 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 (S*us scrofa)* also contribute to damage to vegetation and soils, particularly in wet areas (Casson et al, 2009), while rats (*Rattus rattus*) and 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 others that have increased their population sizes (for example, Eastern long-billed corella, Galah and Little Corella). Feral honeybees (*Apis mellifera*) also compete for hollows and food resources, including pollen and nectar, and can increase the seed set of some weeds (Department of Parks and Wildlife, 2014a, Conservation Commission of Western Australia, 2010).

3.2.4. Fire

Fire regimes have been changed throughout the region, in association with agriculture, urban development and the reduction of previous fire management by Indigenous people. Climate change is likely to be compounding changes to fire regimes. Likely effects of the changed fire regimes include changes to nutrient cycling, competition and plant regeneration. These changes are likely to have affected the composition and structure of the ecological community. The interactions between fire and grazing pressure are likely to be complex.

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 very intense fires (Zelinova (ed) 2002; Tuart Response Group, 2004). While much of the vegetation of the region is fire-adapted, and many species are fire dependent for recruitment, frequent hot 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 following fire as recruitment in between fire events is poor (Ruthrof et al, 2002). Tuarts do not form a lignotuber and 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 between 3-4 years has been suggested. 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, Bayeria*

cinerea, Ricenocarpus glaucus, Alyogyne huegelii, Myoporum insulare, Chamelauceum uncelatum.

In some places, increased dominance of *Agonis flexuosa* (peppermint) has been associated with changed fire regimes, but may also be associated with grazing. It is unclear how much competition these trees provide to adult tuart. If burning is very infrequent there may be no suitable seed bed for tuart seedlings to establish and their success limited by competition with peppermint (Tuart Response Group, 2004). In contrast, Archibald (2005) states that in Yalgorup National Park, fire frequency has reduced substantially and threatens the ecological community, in part, due to the increased dominance of peppermint, rather than tuart. The response of the various understorey species to fire regime change may be location- specific but frequent fire may have also allowed the encroachment of flammable annual weeds. Threatened fauna species in the ecological community considered vulnerable to fire include Baudin's and Carnaby's cockatoos, Western ringtail possum and southern brush-tailed phascogale. These species would be particularly vulnerable to the loss of hollows in 'veteran' trees, which may be susceptible to loss in even relatively cool burns (Department of Parks and Wildlife, 2014a). Fire regimes are important for determining understorey microhabitat including fallen wood and litter characteristics, which are very important for 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 morethis 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. 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).

3.2.5. Tree dieback and pathogens

Across the Swan Coastal Plain, there have been a series of events of tree dieback or decline affecting a variety of species, including key canopy species in the ecological community. 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, lack of beneficial mycorrhizal fungi, infection by *Phytopthora* 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 in the region due to *Phytophthora cinnamomi*. Tuart is not considered to be susceptible to *P. cinnamomi or Armillaria luteobalina* (Groves et al, undated;Tuart Response Group, 2004). Other plants in the ecological community are, however, susceptible, (for example, jarrah trees and a variety of understorey plants are affected by *P.cinnamomi* (Department of Parks and Wildlife,

2014a), while *A. luteobalina* commonly occurs on Quindalup dunes and can affect up to 40% of coastal plant species (Conservation Commission of Western Australia, 2010). The loss of these 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 animals such as woylie (Yeatman and Groom, 2012). Other *Phytopthora* species such as *P. multivora* may also be present, which could affect the health of tuart trees (Scott et al, 2009). 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 the engineering works may have increased the trees' susceptibility to biotic stressors such as pathogens, resulting in their loss in condition.

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. 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 has been associated at least in part to disease. These include Common brushtail possum, Western ringtail possum, Woylie and quokka (Abbot, 2006). This may also have contributed to some of the more recent failures of translocation for woylies (Abbot, 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).

3.2.6. Invertebrate pests

Various invertebrate species may impact on the growth and health of tuart trees. These include *Haplonyx tibialis* (tuart bud weevils), which reduce the canopy seed store. *Phoracantha impavida* and *P. semipunctata* (Tuart longicorns) can also damage or kill tuart trees by ringbarking (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 Brush-tailed phascogale (*Wambenger*) in the ecological community may have affected arthropod populations (Wentzel, 2010).

3.2.7. Climate change

Climate change is affecting south west 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, with the prediction that similar events are increasingly likely (Department of Environment and Conservation, 2011a). Between 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 (Ruthrof et al, 2016). Some fauna, such as quenda, being dependent on damp habitats may also be vulnerable to rainfall decline (Valentine et al, 2012).

Drought may also make the ecological community vulnerable to other disturbances, for example, ringbarking by Longicorn beetles (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 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 (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.

3.2.8. Water extraction and other hydrological change

With the reduction of rainfall throughout the region, recharge of surface acquifers as well as watercourses is expected to decline. For rivers in the south west, models of flow predict a decline of between 5% -40% between 2006 and 2030 (Environmental Protection Authority, 2006). Groundwater levels within the range of the ecological community have also reduced due to extraction to support urban development, agriculture, mining 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 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 seawater into groundwater may also have increased salinity and affected tuart trees there, but the relationship is not clear (Warden, 2009). The 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).

3.2.9. 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 soil engineers such as Woylie, 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.

3.3. Key Threatening Processes

The most relevant key threatening processes to tuart woodlands and forests, as defined at the national level under the EPBC Act are listed in Table 6 Potentially relevant key threatening processes identified in the EPBC Act..

Table 6 Potentially relevant key threatening processes identified in the EPBC Act. Source: 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

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4. SUMMARY OF ELIGIBILITY FOR LISTING AGAINST EPBC ACT CRITERIA

4.1. Criterion 1 – Decline in geographic distribution

Tuart woodlands and forests originally occupied much of the relatively fertile Spearwood dunes, as well as being present on other landforms of the Swan Coastal Plain. This area was attractive for primary industries such as logging, agriculture and grazing, and so was quickly cleared following non-Indigenous settlement in the 19th Century. 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.

Estimates of the decline vary somewhat with the mapping method. The pre-1750 extent has been estimated as 125 400 ha. This identifies areas that are likely to have been dominated by tuart (which is less than the area across which tuart trees occurred). The current extent has been determined by the area mapped in the Tuart Atlas (Tuart Response Group, 2003) (identifying all tuart tree occurrence) that fall within the area identified by experts as likely to have been dominated by tuart before 1750. This area is approximately 25 410 ha. Accordingly, the loss in spatial extent is estimated to be approximately 80%.

This is likely to over-estimate the remaining extent of the ecological community because:

- some of the remaining area is degraded to an extent that it is unlikely to meet the minimum condition class for inclusion in the ecological community.
- clearing has continued since the data was collected (particularly in the case of the Tuart Atlas which was based on 2002 data).

For these reasons it is likely that the ecological community has undergone a severe decline of at least 70%) in its geographic extent. It is thus eligible for listing as **endangered** under this criterion.

4.2. 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 current mapped area of the ecological community is estimated to be no more than 25 410 ha (as per criterion 1), which is also considered '**limited**' (<100 000 ha).

The area is fragmented, particularly in the central and northern portions. The mean patch size for the metropolitan area (between Rockingham and Burns Beach Road) is 13ha while that for northern areas (north of Burns Beach Road) is 31 ha. In southern areas (south of Rockingham) the mean patch size is 68 ha. Of the patches identified, very small (<1 ha) patches (constitute 17% per cent of the number of patches while 67% of patches are less than 10ha in size. The overall median patch size is 4.4 ha, and the mean patch size is 45 ha, which is considered overall to be '**restricted**' (<100ha).

The primary threat to the ecological community is associated with the location of its range – restricted to the Swan Coastal Plain, approximately centred in the same location as the city of Perth. The limitation of the ecological community to an area that is committed to ongoing urban growth is severely limiting to its recovery. The division of the once largely continous populations of at least some of the biota in the ecological community into

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separate populations, interrupted by large expanses of urban areas has imposed a significant change to the function of the ecological community.

Small patches are particularly vulnerable to a range of threats that can occur as 'edge effects', including weed invasion, which is noted as a particular problem for this ecological community. Fire is another threat that to small patches. Small populations of biota are also inherently vulnerable to extinction, with an 'extinction debt' often due in areas that have recently been fragmented.

The landscape context in which the ecological community occurs is also one of high disturbance and fragmentation: the median patch size for woody native vegetation across the Swan Coastal Plain is 1.44 ha. This limits the potential for recovery from disturbances such as fire.

Given the limited area and distribution of the ecological community and likelihood of ongoing fragmentation, threatening processes such as weed invasion, and loss through fire or disease 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)[8]. Therefore the ecological community is eligible for listing as **endangered** under this criterion.

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

Tuart (*Eucalyptus gomphocephala*) is the dominant tree canopy species across the range of the ecological community. It is the largest canopy tree species on the Swan Coastal Plain, which naturally lives for up to 350 years. It 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 important for the provision of hollows. This has critical importance for a range of species native to the Swan Coastal Plain, including some south west endemic species, such as Carnaby's, Baudin's and Forest red-tailed black cockatoos. Many of the trees in which these species nest are over 300 years old, with hollows only sufficient size 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. Throughout its range tuart trees also plays an important role in local climate, soil health and hydrology.
Based on the overall decline in area of the ecological community, estimated at approximately 80 per cent since 1750 (effectively beginning with non-Indigenous land use practices in the 1830s). Furthermore, the thinning of stands and loss of large old trees that were most likely to have held important habitat values means that it is likely that at least 50% of the population of the key canopy species, has been lost within the past 60 years (considering three generations of tuart, within the allowed time threshold), indicating a 'substantial' decline.

The transformation of many areas of tuart's former range of tuart 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

[8]The key canopy species in the ecological community is *Eucalyptus gomphocephala.* The generation time of this species is used here to define the 'immediate future' for 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 20 years (Jacobs, 1955; Florence, 1996). The maximum allowable time for five generations of this species (100 years), to define the 'near future' for this criterion is thus applied.

restored in the medium-term future. Additionally, other important parts of the ecological community, including fauna that play key functional roles have been lost from the region.

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.

4.4. 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. Much of the damage is intractable and many of the underlying threats continue. Available data on condition suggests that most sites are degraded or modified, with vegetation structure and composition substantially altered. A 2003 assessment indicated that at that time potentially only 10% of the original extent retained an intact understorey (Tuart Response Group 2003). The decline of the native understorey has been worsened by the invasion of this layer by a range of weeds including Arum lily and Bridal creeper. These limit the regeneration of native plants, particularly in combination with the impacts of changed fire regimes and grazing. Pathogens such as *Phytopthora* species and events of tree decline have also affected the ecological community in various locations.

The rapidly changing climate of South West Western Australia also compromises the health of woodlands and forests on the Swan Coastal Plain. Rapid losses of mature trees of various species in the Perth region have been associated with reduced water availability that may be associated with the long term changes to rainfall, as well as water extraction for agriculture and urban use. Water stress may also have contributed to the loss of trees through 'tuart decline' in the Yalgorup area' (Wentzel, 2010). Pressures associated with water availability are likely to intensify. The changes to fire regimes through management changes a drying climate, and weeds that promote frequent fires have also compromised condition.

Fauna play a critical role in ecosystem function. In response to clearing and fragmentation, as well as other disturbances such as grazing and change to fire regimes across the region many of the native fauna are regionally extinct. In the Perth region this includes almost all small mammals (Dell et al, 2002). Introduced predators, such as cats and foxes as well as disease are likely to have had substantial impacts on these mammals. The species lost include those of high functional importance, including soil engineers such as Quenda, that play an important role in establishing suitable conditions for regeneration. Cockatoos, and other birds and bats have also played an important role in control of herbivorous insects, but their loss from the landscape makes tuart trees more vulnerable to loss due to herbivory (Ruthrof et al, 2002; Casson et al 2009).

Changes in the landscape have also changed the competitive ability of native species, with some species such as Western grey kangaroos likely to have increased in some areas. This may also compromise the regeneration of native understorey plants.

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. 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.

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4.5. Criterion 5 – Rate of continuing detrimental change

The ecological community has experienced substantial clearing and fragmentation due to agriculture, forestry and grazing, although much of the primary clearing may have occurred more than a century ago. While the damage to the understorey and prevention of regeneration related to grazing continues, this is difficult to quantify. There is the possibility of a rapid expansion of tuart decline, but the likelihood of this is unknown.

Further, the ecological community continues to be cleared for development, and native flora and fauna preyed upon and displaced by weeds and feral animals. The 'Perth and Peel Green Growth Plan for 3.5 million' currently being developed is likely to predict further losses of remnants, but these have not yet been quantified (Government of Western Australia, 2015).

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.

4.6. 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.

More information on eligibility of the ecological community against the EPBC listing criteria can be found at Appendix E – Eligibility for listing against EPBC Act criteria

5. 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.

5.1. Principles and standards of protection and restoration

It is more effective to maintain existing high quality remnants of the 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 essential to maintain existing areas of the ecological community that are relatively intact and of high quality. It is usually more successful and cost-effective to retain these relatively intact remnants than to allow their degradation and destruction with the intention of restoration of these or other remnants from a more degraded state. 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 intact remnants on the basis of plans to set aside and/or restore other, potentially more disturbed, sites. The destruction of 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.

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. 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).

5.2. 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 NRM and community groups;
- determining conditions of approval for relevant controlled actions under the EPBC Act; 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 5.6. Avoid actions that are inconsistent with these recommendations and are likely to significantly affect the ecological community

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. High condition, 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.
    - Include high quality remnants or patches in important landscape positions in secure conservation reserves and allocate resources to their management for conservation purposes.
    - Apply recommended buffers of at least 30 m around patches of the ecological community. Wider buffers may be required where larger scale landscape change is occurring, for example hydrological modifications.
    - 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 even if they do not meet other requirements for identification as a patch of the nationally protected ecological community.
    - 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.
- 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 modifications to hydrology (including groundwater depth and salinity) as these have been associated with sudden 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 5.5 ‘Offsets’.

Other priorities

- Protect the native soil seed bank by minimising soil disturbance and removal.
- 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 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.
- Avoid slashing or mowing, but 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.

Preventing invasion by weeds, feral animals, ‘tuart decline’, dieback and other diseases

Highest priorities

- Prevent weed invasion and disease spread by minimising soil disturbance.
- Do not plant (or spread) known, or potential, environmental weeds within or near the ecological community:
    - prevent activities such as planting potentially invasive species in gardens or other landscaping near the ecological community; or dumping garden waste in or near patches of the ecological community.
    - control runoff, for example, during road construction, or urban runoff, 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.
- Prevent further introduction of feral animals and contain domestic animals within new residential areas (for example, cat containment areas).

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- Use plants from accredited nurseries (e.g. see the Nursery Industry Accreditation Scheme: Nursery and Garden Industry Australia, undated).
- 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 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).

Other priorities

- Ensure stock do not carry weeds into patches of the ecological community (for example, hold stock in other weed-free paddocks for an appropriate time prior to introduction).
- 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.
- Manage commercial and domestic apiaries to minimise feral bee colonisation of tree hollows.

Fire

- Great care is required when imposing fire in this ecosystem due to its vulnerability to weed incursion and sensitivity of fauna associated with the mature trees. Plan and 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. Rapid detection and fire suppression strategies to control fire are recommended.

- Fire planning: Use a landscape-scale approach and available knowledge on fire histories and age of stands, taking into account Indigenous knowledge and results from research to develop fire management strategies that promote conservation of the ecological community:
    - Identify the most suitable fire interval considering information such as the minimum time for maturity and seed production, as well as the fire intensity required by key plant species (in particular understorey species present at any particular site). Tuart may tolerate inter-fire intervals as short as 12 years from time to time but longer fire free intervals (>20 years) will also be necessary in each patch. Fire requirements will also be different for other species present in the ecological community. It is likely that at many sites, the appropriate fire regime for the ecological community will be at lower frequency than in the recent past.

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- Identify particular requirements of fauna, for example, habitat required for foraging (including seral stage), alternative habitat to use while patches recover from fire 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)

- Fire management: 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. Faunal populations in isolated patches may be vulnerable to permanent extinction following intense 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 and 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 and extinguishing fires from the bases of the relevant trees after the fire front has passed
  - avoid slashing or tree removal as part of fire management;
  - 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 ongoing); take monitoring results into account when managing future fire regimes. (For further information on monitoring priorities see section 5.3).

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).
- Manage populations of feral herbivores that damage native vegetation, including rabbits.
- Control access by herbivores (including kangaroos where present in high densities) by using temporary or permanent fencing of regrowth, revegetation areas, or sites with threatened, regionally important or diverse understorey species (fences may need to be specifically designed to exclude macropods). Ensure that stock do not introduce weed seeds to the patch (see weeds section). In some cases, increasing connectivity between suitable habitat may reduce the impacts on any one area.
- 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)

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- 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.

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 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.

Re-vegetation and regeneration

- Highest priorities
  - 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).
  - Where available, use locally collected seed to create an appropriate canopy and diverse understorey. Consider historical records and photographs to inform species selection. Consider particularly the needs of tuart and other species of conservation concern or known to be of functional importance for the ecological community. Consider the landscape context of the source of the seed, as this may influence the suitability of the offspring plants for the restoration site. 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.
  - 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. Some guidance for the southern Swan Coastal Plain is provided by Molloy et al (2009)

Other priorities

- Encourage appropriate use of local native species in developments and revegetation projects through local government and industry initiatives. It is important to use seeds and 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). Maintain the boxes, including controlling invasive species such as bees, and monitor outcomes.

Control invasive species and diseases

Highest priorities

- Map weed occurrence and prioritise management of weeds in high quality patches or where threatened or regionally significant 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, integrating this provision of alternative habitat provision and control of predators. Small infestations 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 disturgance 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 Phytopthora dieback and 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 *Phytopthora 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.

COMMUNICATION AND SUPPORT

Education, information and local regulation

- Develop information products and signage to help local communities, planners and managers recognise:
    - when the ecological community is present and why it is important to protect it;
    - how to appropriately manage patches of the ecological community; and

- responsibilities under state and local regulations and the EPBC Act.

- Promote knowledge about local weeds, means to control these and appropriate alternative species to plant.
- Liaise with Indigenous people with traditional knowledge of tuart woodlands and forests, to encourage conservation of this knowledge and 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.
- Develop education programmes 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 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.
- Ensure land managers have the most useful information about managing fire and weeds for the benefit of threatened species and ecological communities.
- 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.
    - Ensure commitment to follow-up after planting, such as care of newly planted vegetation by watering, mulching, 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

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- 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

- 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 programmes and activities, especially those managed by regional Catchment Councils and other Natural Resource Management groups.

5.3. 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. Research and ongoing management activities can often be integrated to achieve the best results in the face of ongoing change. Where possible, 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 survey and interpretation of other data such as aerial photographs and satellite images to more accurately document current extent, condition, threats, function, presence and use 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.
    - model the pre-1750 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).

- monitor changes in the extent of the ecological community with high resolution remote sensing at annual intervals.

- Determine priority areas for restoration in each natural resource management region to enhance connectivity and landscape resilience. Existing models such as Molloy et al (2009) may form the basis for this.
- 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, native fauna and invasive species in patches and across the broader landscape:
  - Keep precise records of fire history.
  - Implement a variety of fire regimes across the range of the ecological community and monitor the response of the ecological community (both flora and fauna), 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 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.
- 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.
- 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)
- 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).

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, potentially buffering, connecting and protecting existing remnants.
    - predator control options such as trapping and baiting, urban containment, exclusion fencing;
    - re-introduction of key fauna such as soil 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.

5.4. Restoration of degraded areas

Some patches, which would have been part of the ecological community in the past, are now in modified states that do not meet the typical vegetation description above. These degraded areas are part of the broader ecosystem and may contribute to the genetic diversity of the ecological community or to landscape function. In particular, while the understorey of tuart woodlands and forest naturally vary substantially in structure and composition, in many locations they have been substantially degraded.

Where sites are currently not in sufficient condition for national protection 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.

5.5. Offsets

Offsets are defined as measures that 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 than generally considered in establishing offsets, for example, large hollows may take centuries to form.

The use of offsets, therefore, should only proposed as a last resort to compensate for damage to the ecological community that cannot be avoided. There should be no further extensive clearance and damage to this ecological community because it has 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.
- The location of offset sites should be as close as possible to impact sites.
- 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)
- South of Rockingham, where larger remnants occur, offset activities should generally be planned to improve the quality of remnants through actions such as weed management.
- North of Rockingham, where remnants are smaller, offset activities should generally 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.
- Where possible, offset sites should be established to improve or retain landscape connectivity, considering other patches of the ecological community and other native vegetation
- Long term management arrangements should be established for all offset sites.

5.6. Existing plans/management prescriptions

National threat abatement plans and recovery plans relevant to the ecological community 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 Recovery Plan (Department of Parks and Wildlife 2014b)
- 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 (*Calytorhynchus latirostris*) recovery plan Department of Environment and Conservation (2012)
- 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)
- Draft Threat Abatement plan for disease in natural ecosystems caused by *Phytopthora cinnamomi* (Commonwealth of Australia, 2017)

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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
- Yanchep National Park
- Beekeepers Nature Reserve
- Bold Park Management Plan (2016-2021) (Botanic Gardens and Parks Authority, 2016b)

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).

6. 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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APPENDIX A – SPECIES LISTS

Flora

Plants likely to occur in the ecological community and notes on traditional uses (Bindon and Walley, 1998; Keighery, 2002; Hansen and Horsfall 2017).

^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.

Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
Adiantaceae	*Adiantum aethiopicum*	Common Maidenhair	Karbarra	Low fern, found in damp areas. Used to make medicines to relieve respiratory tract problems.
	Cheilanthes austrotenuifolia	Rock Fern		
	Carpobrotus modestus	Inland Pigface		
	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.
	Tetragonia tetragonoides	New Zealand Spinach		
Amaranthaceae	*Ptilotus drummondii*	Narrowleaf Mulla Mulla		
	Ptilotus manglesii	Pom Poms		
	Ptilotus polystachyus	Prince of Wales Feather		
	Ptilotus sericostachyus			
	Ptilotus stirlingii	Stirling's Mulla Mulla		
Anthericaceae	*Caesia micrantha*	Pale Grass-Lily		
	Chamaescilla corymbosa var. corymbosa	Blue Squill		
	Corynotheca micrantha var. micrantha	Sand Lily		
	Dichopogon capillipes			
	Sowerbaea laxiflora	Purple Tassels		
	Thysanotus arenarius			
	Thysanotus dichotomus	Branched Fringe Lily		
	Thysanotus manglesianus	Fringe Lily		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Thysanotus manglesianus/patersonii complex			
	Thysanotus multiflorus	Many-flowered Fringe Lily		
	Thysanotus patersonii	Twining Fringe Lily		
	Thysanotus sparteus			
	Thysanotus thyrsoideus			
	Tricoryne elatior	Yellow Autumn Lily		
	Tricoryne tenella			
Apiaceae	*Apium prostratum*	Sea Celery		
	Centella asiatica			
	Daucus glochidiatus	Australian Carrot		
	Eryngium pinnatifidum subsp. pinnatifidum	Blue Devils		
	Homalosciadium homalocarpum			
	Hydrocotyle alata			
	Hydrocotyle callicarpa	Small Pennywort		Leaves burnt and inhaled to treat pain. Vapour from crushed leaves used to treat headaches and cold symptoms.
	Hydrocotyle capillaris	Thread Pennywort		
	Hydrocotyle diantha			
	Hydrocotyle hispidula			
	Hydrocotyle pilifera var. glabrata			
	Hydrocotyle tetragonocarpa			
	Trachymene coerulea	Blue Lace Flower		Thrives in limestone areas. Bulbs and leaves used externally for aches and pains. Leaves crushed to help with headaches.
	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		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
Asteraceae	*Asteridea pulverulenta*	Common Bristle Daisy		
	Bracteanthum macranthum			
	Brachyscome iberidifolia	Swan River Daisy		
	Cotula australis	Common Cotula		
	Craspedia arenicola ms			
	Euchiton gymnocephalus			
	Gnaphalium indutus			
	Euchiton sphaericus	Star Cudweed		
	Ixiolaena viscosa	Sticky Ixiolaena		
	Lagenophora huegelii	Coarse Lagenophora		
	Millotia myosotidifolia			
	Millotia tenuifolia	Soft Millotia		
	Olearia axillaris	Coastal Daisybush		
	Olearia rudis	Rough Daisybush		
	Ozothamnus cordatus	Tangle Bush		
	Picris squarrosa			
	Pithocarpa pulchella	Beautiful Pithocarpa		
	Podolepis canescens			
	Podolepis gracilis	Slender Podolepis		
	Podolepis lessonii			
	Podotheca angustifolia	Sticky Longheads		
	Podotheca chrysantha	Yellow Podotheca		
	Podotheca gnaphalioides	Golden Longheads		
	Pterochaeta paniculata	Woolly Waitzia		
	Quinetia urvillei			
	Rhodanthe citrina			
	Rhodanthe corymbosa			
	Senecio hispidulus	Hispid Fireweed		
	Senecio lautus subsp. dissectifolius	Variable Groundsel		
	Senecio lautus subsp. maritimus	Variable Groundsel		
	Senecio quadridentatus	Cotton Fireweed		
	Senecio ramosissimus	Auricled Groundsel		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Siloxerus humifusus	Procumbent Siloxerus		
	Sonchus hydrophilus	Native Sowthistle		
	Waitzia aurea	Golden Waitzia		
	Waitzia suaveolens var. suaveolens	Fragrant Waitzia		
Brassicaceae	*Lepidium pseudohyssopifolium*			
	Lepidium rotundum	Veined Peppercress		
	Rorippa sp (Yalgorup) GK 14455			
	Stenopetalum gracile			
	Stenopetalum robustum			
Caesalpiniaceae	*Labichea cassioides*			
Campanulaceae	*Wahlenbergia multicaulis*			
	Wahlenbergia preissii			
Casuarinaceae	*Allocasuarina humilis*	Scrub She-oak		
Centrolepidaceae	*Centrolepis aristata*	Pointed Centrolepis		
	Centrolepis drummondiana			
Chenopodiaceae	*Enchylaena tomentosa var. tomentosa*	Barrier Saltbush		
	Rhagodia baccata subsp. baccata	Berry Saltbush		
	Rhagodia baccata subsp. dioica	Berry Saltbush		
	Threlkeldia diffusa	Coast Bonefruit		
Colchicaceae	*Burchardia congesta*	Milkmaids		
	Wurmbea monantha			
	Wurmbea tenella			
Commelinaceae	*Cartonema philydroides*			
Convolvulaceae	*Dichondra repens*	Kidney Weed		
Crassulaceae	*Crassula colorata var. colorata*	Dense Stonecrop		
	Crassula exserta			
	Crassula peduncularis	Purple Stonecrop		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
Cupressaceae	*Callitris preissii*	Rottnest Island Pine, Maro	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		
	Baumea juncea	Baumea Twigrush		
	Baumea vaginalis	Sheath Twigrush		
	Carex appressa	Tall Sedge		
	Carex preissii			
	Cyperus polystachyos	Bunchy Sedge		
	Gahnia trifida	Coast Saw-sedge		
	Isolepis cernua	Nodding Club-rush		
	Isolepis cyperoides			
	Isolepis nodosa	Knotted Club-rush		
	Isolepis stellata	Star Club-rush		
	Lepidosperma gladiatum	Coast Sword-sedge, Kerbin		
	Lepidosperma leptostachyum			
	Lepidosperma longitudinale	Pithy Sword-sedge		
	Lepidosperma sp. (Coastal terete BJK & NG 231)			
	Lepidosperma squamatum			
	Mesomelaena preissii			
	Mesomelaena stygia			
	Schoenoplectus validus			
	Schoenus clandestinus			
	Schoenus curvifolius			
	Schoenus grandiflorus	Large Flowered Bogrush		
	Schoenus humilis			
	Schoenus nitens	Shiny Bog-rush		
	Schoenus subflavus	Yellow Bog-rush		
	Tetraria octandra			

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
Dasypogonaceae	*Acanthocarpus preissii*			
	Dasypogon bromeliifolius	Pineapple Bush		
	Lomandra caespitosa	Tufted Mat Rush		
	Lomandra hermaphrodita			
	Lomandra maritima	Coastal Mat-rush		
	Lomandra micrantha subsp. micrantha	Small-flower Mat-rush		
	Lomandra preissii			
	Lomandra purpurea	Purple Mat Rush		
	Lomandra sericea	Silky Mat Rush		
	Lomandra suaveolens			
Dennstaedtiaceae	*Pteridium esculentum*	Bracken	Munda	Leaf tips and roots prepared as food. Crushed leaves used as wash for sores and relieve arthritis, also used to make medicine to treat intestinal worms.
Dilleniaceae	*Hibbertia cuneiformis*	Cutleaf Hibbertia		
	Hibbertia hypericoides	Yellow Buttercups		
	Hibbertia racemosa	Stalked Guinea Flower		
	Hibbertia subvaginata			
Droseraceae	*Drosera erythrorhiza*	Red Ink Sundew		
	Drosera glanduligera	Pimpernel Sundew		
	Drosera menziesii subsp. penicillaris	Pink Rainbow		
	Drosera pallida	Pale Rainbow		
	Drosera stolonifera	Leafy Sundew		
Epacridaceae	*Astroloma ciliatum*	Candle Cranberry	cadgeegurrup	Berries eaten
	Astroloma pallidum	Kick Bush	cadgeegurrup	Berries eaten
	Conostephium pendulum	Pink-tipped Pearl		
	Conostephium preissii			
	Leucopogon capitellatus			
	Leucopogon oxycedrus			
	Leucopogon parviflorus	Coast Beard-heath		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Leucopogon propinquus			
	Leucopogon racemulosus			
Euphorbiaceae	*Adriana quadripartita*	Bitter Bush		
	Beyeria cinerea			
	Euphorbia australis	Namana		
	Monotaxis grandiflora	Diamond of the Desert		
	Phyllanthus calycinus	False Boronia		
	Poranthera microphylla	Small Poranthera		
	Ricinocarpus glaucus	Wedding Bush		
Fumariaceae	** Fumaria capreolata*	Whiteflower Fumitory		
Geraniaceae	*Erodium cygnorum*	Blue Heronsbill		
	Geranium retrorsum			
	Geranium solanderi	Native Geranium		Low herb. Roots used to treat diarrhoea.
	Pelargonium littorale			
Goodeniaceae	*Dampiera linearis*	Common Dampiera		
	Lechenaultia floribunda	Free-flowering Leschenaultia		
	Lechenaultia linarioides	Yellow Leschenaultia		
	Scaevola crassifolia	Thick-leaved Fanflower		
	Scaevola nitida	Shining Fanflower		
	Scaevola thesioides			
Gyrostemonaceae	*Tersonia cyathiflora*	Button Creeper		
Haemodoraceae	*Anigozanthos humilis*	Cat's Paw		
	Anigozanthos manglesii	Mangles Kangaroo Paw		
	Conostylis aculeata	Prickly Conostylis		
	Conostylis candicans	Grey Cottonhead		
	Conostylis pauciflora subsp. pauciflora	Dawesville Conostylis		
	Conostylis setigera	Bristly Cottonhead		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	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.
	Phlebocarya ciliata			
Haloragaceae	*Haloragis aculeolata*			
Hypoxidaceae	*Hypoxis glabella*	Tiny Star		
Iridaceae	*Orthrosanthus laxus*	Morning Iris		
	Patersonia occidentalis	Purple Flag, Koma		
	Patersonia juncea	Rush Leaved Patersonia		
Juncaceae	*Luzula meridionalis*	Field Woodrush		
Juncaginaceae	*Triglochin calcitrapum subsp. incurvum*			
	Triglochin calcitrapum subsp. recurvum ms			
	Triglochin centrocarpum	Dwarf Arrowgrass		
	Triglochin trichophorum			
Lamiaceae	*Hemiandra pungens*	Snakebush		
Lauraceae	*Cassytha flava*	Dodder Laurel		Parasitic climber with no leaves. Climb over other plants with wiry stems. Fruits used as a laxative and applied to cuts and sores.
	Cassytha glabella	Tangled Dodder Laurel		Parasitic climber with no leaves. Climb over other plants with wiry stems. Fruits used as a laxative and applied to cuts and sores.
	Cassytha pubescens	Downy Dodder-laurel		
	Cassytha racemosa	Dodder Laurel		Parasitic climber with no leaves. Climb 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		
Lobeliaceae	*Isotoma hypocrateriformis*	Woodbridge Poison		
	Lobelia alata	Angled Lobelia		
	Lobelia gibbosa	Tall Lobelia		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Lobelia heterophylla	Wing-seeded Lobelia		
	Lobelia tenuior	Slender Lobelia		
Loganiaceae	*Logania serpyllifolia*			
	Logania vaginalis	White Spray		
	Mitrasacme paradoxa	Wiry Mitrewort		
Loranthaceae	*Amyema miquelii*	Stalked Mistletoe		
	Nuytsia floribunda	Christmas Tree,	Mudja, modya	
Malvaceae	*Alyogyne huegelii var. glabrata ms*			
	Alyogyne huegelii var. huegelii			
Mimosaceae	*Acacia alata var. tetrantha*		Kunart – wattle tree gum	
	Acacia cochlearis	Rigid wattle		
	Acacia cyclops	Coastal Wattle, red-eyed wattle	Munyuret	Dense shrub to tree. Yellow flowers Djilba-Birak (Spring-Summer or Birak-Djeran (Summer – Autumn). Seed pods are twisted . Juice of leaves used to treat eczema, seeds ground to make flour and baked. Juice used as insect repellant and sunscreen.
	Acacia huegelii			
	Acacia lasiocarpha	Panjang		
	Acacia pulchella var. glaberrima	Prickly Moses		
	Acacia rostellifera	Summer-scented Wattle		
	Acacia saligna	Orange Wattle		
	Acacia stenoptera	Narrow Winged Wattle		
	Acacia truncata			
	Acacia willdenowiana	Grass Wattle		
	Paraserianthes lophantha	Albizia		
Myoporaceae	*Eremophila glabra*	Tar Bush		
	Myoporum caprarioides	Slender Myoporum		
	Myoporum insulare	Native Juniper		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
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.
	Calothamnus quadrifidus	One-sided Bottlebrush		
	Calytrix angulata	Yellow Starflower		
	Chamelaucium uncinatum	Geraldton Wax		
	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.
	Eremaea pauciflora			
	Eucalyptus cornuta	Yate		
	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.

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Eucalyptus gomphocephala	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.
	Eucalyptus marginata subsp. marginata	Jarrah, Djara		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 used as disinfectant and as part of medicine for dysentry. Gum sometimes used to fill cavities in teeth. Leaves used for bedding, bark for roofing shelters.
	Eucalyptus mundijongensis			
	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.
	Hypocalymma robustum	Swan River Myrtle		
	Leptospermum spinescens			
	Melaleuca huegelii	Chenille Honey-myrtle		Melaleucas commonly used for antibacterial properties of oil.

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	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.
	Melaleuca rhaphiophylla	Swamp Paperbark		
	Melaleuca systena	Coastal Honeymyrtle		
	Melaleuca thymoides			
	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.
Olacaceae	*Olax benthamiana*			
Orchidaceae	*Acianthus reniformis*	Mosquito Orchids		
	Caladenia arenicola	Carousel Spider Orchid		
	Caladenia chapmanii			
	Caladenia crebra	Arrowsmith Spider Orchid		
	Caladenia flava subsp. flava	Cowslip Orchid		
	Caladenia georgei	Tuart Spider Orchid		
	Caladenia hirta	Sugar Candy Orchid		
	Caladenia latifolia	Pink Fairy Orchid		
	Caladenia longicauda	Common White Spider Orchid		
	Caladenia marginata	White Fairy Orchid		
	Caladenia speciosa	Sandplain White Spider Orchid		
	Caladenia vulgata	Spider Orchid		
	Corybas recurvus	Helmet Orchid		
	Cyanicula gemmata	Blue China Orchid		
	Cyanicula sericea	Silky Blue Orchid		
	Cryptostylis ovata	Slipper Orchid		
	Cyrtostylis huegelii	Mosquito Orchid		
	Diuris amplissima			
	Diuris corymbosa	Common Donkey Orchid		
	Elythranthera brunonis	Purple Enamel Orchid		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Elythranthera emarginata	Pink Enamel Orchid		
	Eriochilus dilatatus	White Bunny Orchid		
	Leporella fimbriata	Hare Orchid		
	Leptoceras menziesii	Rabbit Orchid		
	Lyperanthus nigricans	Red Beak Orchid		
	Microtis media	Tall Mignonette Orchid		
	Prasophyllum calcicola			
	Prasophyllum elatum	Tall Leek Orchid		
	Pterostylis aff. nana	Dwarf Snail Orchid		
	Pterostylis aff. vittata	Grey Banded Greenhood		
	Pterostylis aspera	Brown-veined Shell Orchid		
	Pterostylis brevisepala ms			
	Pterostylis recurva	Jug Orchid		
	Pterostylis rogersii			
	Pterostylis sanguinea	Dark Banded Greenhood		
	Pterostylis vittata	Banded Greenhood		
	Thelymitra benthamiana	Cinnamon Sun Orchid		
	Thelymitra crinita	Blue Lady Orchid		
Oxalidaceae	*Oxalis perennans*			
Papilionaceae	*Bossiaea eriocarpa*	Common Brown Pea		
	Brachysema praemorsum			
	Chorizema diversifolium	Yellow-eyed Flame Pea		
	Daviesia divaricata	Marno		
	Daviesia preissii			
	Gompholobium confertum			
	Gompholobium tomentosum	Hairy Yellow Pea		
	Hardenbergia comptoniana	Native Wisteria		
	Hovea chorizemifolia	Prickly Hovea		
	Hovea stricta	Hovea		
	Hovea trisperma var. trisperma	Common Hovea		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Isotropis cuneifolia subsp. cuneifolia	Granny Bonnets		
	Jacksonia calcicola			
	Jacksonia furcellata	Grey Stinkwood		
	Jacksonia sparsa ms			
	Jacksonia sternbergiana	Stinkwood, Kapur		
	Kennedia coccinea	Coral Vine		
	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.
	Nemcia reticulata			
	Sphaerolobium medium			
	Templetonia retusa	Cockies Tongues		
Phormiaceae	*Dianella brevicaulis*			
	Dianella revoluta	Blueberry Lily	Mangard	Flowering Kambarang-Birak (late Spring-Summer). Fruits eaten, roats roasted and eaten. Leaves used for sptring. Medicine for headaches used from leaves and from roots for colds.
	Stypandra glauca	Blind Grass		
Pittosporaceae	*Billardiera variifolia*			
	Billardiera heterophylla	Australian Bluebell		
	Pittosporum phylliraeoides-Pittosporum angustifolium?	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*			
	Austrodanthonia occidentalis			

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Austrodanthonia pilosa	Smoothflower Wallaby Grass		
	Austrostipa compressa			
	Austrostipa elegantissima	Feather Speargrass		
	Austrostipa flavescens			
	Austrostipa pycnostachya			
	Austrostipa semibarbata	Bearded Speargrass		
	Bromus arenarius	Sand Brome		
	Dichelachne crinita	Long Hair Plume Grass		
	Hemarthria uncinata	Matgrass		
	Microlaena stipoides	Weeping Grass		
	Poa drummondiana	Knotted Poa		
	Poa poiformis	Coastal Poa		
	Poa porphyroclados			
	Polypogon tenellus			
Polygalaceae	*Comesperma confertum*	Milkwort		
	Comesperma integerrimum	Milkwort		
Polygonaceae	*Muehlenbeckia adpressa*	Climbing Lignum		
	Muehlenbeckia polybotrya			
Portulacaceae	*Calandrinia brevipedata*	Short-stalked Purslane		
	Calandrinia calyptrata	Pink Purslane		
	Calandrinia corrigioloides	Strap Purslane		
	Calandrinia granulifera	Pygmy Purslane		
	Calandrinia liniflora	Parakeelia		
Primulaceae	*Samolus repens*	Creeping Brookweed		
Proteaceae	*Banksia attenuata*	Candlestick Banksia, Slender Banksia	Piara 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.

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	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.
	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.
	Banksia leptophylla var. leptophylla			
	Banksia littoralis	Swamp Banksia	Pungura	Large shrub or tree. Bright orange or yellow flowers Bunuru-Djilba (Autumn-Winter).
	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.
	Banksia prionotes	Acorn Banksia	Manyret	Flowering Bunuru-Djilba (Autumn and Winter). Fire sensitive. Infusions of flowers for sore throats and coughs, as well as refreshing drink.
	Banksia sessilis (formerly Dryandra sessilis)	Parrot Bush,	Pulgart , Pudjak	Shrub or small tree with spiky leaves. Small flowers Djeran-Kambarang (Autumn-Spring).
	Conospermum stoechadis x triplinervium	Common Smokebush		
	Conospermum triplinervium	Tree Smokebush		
	Grevillea crithmifolia			
	Grevillea preissii	Spider Net Grevillea		
	Grevillea vestita			
	Hakea lissocarpha	Honey Bush		
	Hakea prostrata	Harsh Hakea		
	Hakea trifurcata			

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Persoonia longifolia	Snottygobble, wild pear	Cadgeegurrup, kadgeegurr	Shrub or tree with green-yellow fruits, which can be eaten and keep the mouth moist. Mark used to make medication for skin and eye problems. Leaves used to make medication for colds and sore throats.
	Persoonia saccata	Snottygobble, wild pear	cadgegurrup	Fruits eaten
	Petrophile linearis	Pixie Mops		
	Petrophile serruriae			
	Petrophile striata			
	Stirlingia latifolia	Blueboy		
	Synaphea floribunda			
	Synaphea polymorpha	Albany Synaphea, Pinda		
	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.
Ranunculaceae	*Clematis linearifolia*	Slender Clematis	Taaruk	Climbing plant with white star-shaped flowers Makuru-Kambarang (Winter-Spring). Leaves used cautiously to treat skin irritation.
	Clematis pubescens	Common Clematis		
	Ranunculus colonorum	Common Buttercup		
	Ranunculus pumilio	Smallflower Buttercup		
Restionaceae	*Hypolaena exsulca*			
	Desmocladus aspera			
	Loxocarya pubescens			
Rhamnaceae	*Cryptandra arbutiflora*	Waxy Cryptandra		
	Cryptandra mutila			
	Spyridium globulosum	Basket Bush		
	Spyridium tridentatum			
	Trymalium ledifolium subsp. ledifolium			

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
Rubiaceae	*Opercularia hispidula*	Hispid Stinkweed		
	Opercularia vaginata	Dog Weed		
Rutaceae	*Boronia alata*	Winged Boronia		
	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.
	Leptomeria cunninghamii			
	Leptomeria preissiana			
	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*			
	Dodonaea aptera	Coast Hop-bush		
Scrophulariaceae	*Veronica stolonifera*			
Solanaceae	*Anthocercis ilicifolia*			
	Anthocercis littorea	Yellow Tailflower		
	Solanum symonii			
Stackhousiaceae	*Stackhousia monogyna*			
	Tripterococcus brunonis	Winged Stackhousia		
Sterculiaceae	*Guichenotia ledifolia*			
	Lasiopetalum membranaceum			
	Rulingia luteiflora			
	Thomasia cognata			
	Thomasia purpurea			
	Thomasia triphylla			
Stylidiaceae	*Stylidium bulbiferum*			
	Stylidium calcaratum	Book Triggerplant		

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Family	Plant taxa	Common names	Nygoongar name(s)	Notes, including some traditional uses^
	Stylidium glaucum	Dotted Triggerplant		
	Stylidium junceum	Reed Triggerplant		
	Stylidium repens	Matted Triggerplant		
Thymelaeaceae	*Pimelea argentea*	Silvery Leaved Pimelea		
	Pimelea calcicola			
	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*	Fogfruit		
Violaceae	*Hybanthus calycinus*	Wild Violet		
Xanthorrhoeaceae	*Xanthorrhoea brunonis*			
	Xanthorrhoea preissii	Balga, grasstree, blackboy	Balga, balka 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 as well as in medicine, flowers soaked to use drink. The pattern of flower opening used to determine direction.
Zamiaceae	*Macrozamia riedlei*	Zamia, Djiridji	Baio (fruit)	Fruits were buried and soaked to remove toxins before roasting and eating
Zygophyllaceae	*Zygophyllum apiculatum*			
	Zygophyllum fruticulosum	Shrubby Twinleaf		

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Fauna

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

*Species likely to have been formerly present.

Common name	Common name	Indigenous name(s)	Likely to use hollows or crevices
MAMMALS			
TACHYGLOSSIDAE			
Tachyglossus aculeatus	Echidna		
DASYURIDAE			
Phascogale tapoatafa	Southern Brush-tailed phascogale		y
Sminthopsis spp	Dunnart		?
*Antechinus flavipes**	Mardo	Mardo	y
Dasyurus geoffroii *	Chuditch, Western quoll	chuditch	y
PERAMELIDAE			
Isoodon obesulus	Southern Brown Bandicoot	quenda	
TARSIPEDIDAE			
Tarsipes rostratus	Honey Possum		y
PHALANGERIDAE			
Trichosurus vulpecula	Common Brushtail Possum		y
PSEUDOCHEIRIDAE			
Pseudocheirus occidentalis	Western Ringtail Possum		y
MACROPODIDAE			
Macropus fuliginosus	Western Grey Kangaroo	Yonger	
*Macropus irma**	Western Brush Wallaby, Black-gloved wallaby	Guhran	
*Macropus eugenii**	Tammar wallaby		
Macropus robustus	Wallaroo		
POTOROIDIDAE			
Setonix brachyurus	Quokka	Quokka	
*Bettongia penicillata**	Woylie; Brush-tailed bettong.	Woylie	
BURRAMYIDAE			
*Cercartetus concinnus**	Pygmy Possum		y
MYRMECOBIIDAE			
*Myrmecobius fasciatus**	Numbat		y
MURIDAE			
Rattus fuscipes	Western Bush Rat		y
Hydromys chrysogaster	Water Rat	Rakali	
*Pseudomys albocinereus**	Ash-grey Mouse		
VESPERTILIONIDAE			
Chalinolobus gouldii	Gould's Wattled Bat		y
Falsistrellus mackenziei	Western False Pipistrelle		y
Nyctophilus geoffroyi	Lesser Long-eared Bat		y
Nyctophilus timoriensis	Greater Long-eared Bat		y
Nyctophilus gouldi	Gould's Long-eared Bat		y
Vespadelus regulus	Southern Forest Bat		y
MOLOSSIDAE			
Mormopterus planiceps	Southern Freetail-bat		y
Tadarida (Nyctinomus)australis	White-striped Freetail-bat		y

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Common name	Common name	Indigenous name(s)	Likely to use hollows or crevices
CANIIDAE			
*Canus lupus dingo**	dingo		
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		
Delma concinna concinna			
Delma fraseri	Fraser's delma		
Delma grayii	Side-barred delma		
Lerista distinguenda	South-western orange-tailed slider		
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 fallens	Bar-shouldered Ctenotus, Plain Ctenotus		
Ctenotus australis	Western Limestone Ctenotus		
Ctenotus impar	Odd-striped Ctenotus		
Ctenotus labillardieri	Common South-west Ctenotus, Red-legged Ctenotus		
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		
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
BOIDAE			
Morelia spilota	Carpet snake	Wakal	y

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Common name	Common name	Indigenous name(s)	Likely to use hollows or crevices
TYPHLOPIDAE			
Ramphotyphlops 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 oblonga	Oblong turtle	Yargun buyi	
AMPHIBIANS			
Crinia insignifera	Sign-bearing Froglet		
Limnodynastes dorsalis	Bullfrog, Western Banjo Frog		
Heleioporus eyrei	Moaning Frog		
Myobatrachus gouldii	Turtle Frog		
Pseudophryne guentheri	Gunther's Toadlet		
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 haliaetus	Osprey	Doorn-doorn	
Elanus caeruleus	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		

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Common name	Common name	Indigenous name(s)	Likely to use hollows or crevices
TURNICIDAE			
Turnix varia	Painted Button-quail	Mooroolang	
COLUMBIDAE			
Phaps chalcoptera	Common Bronzewing	Koomara, wooda, nembing	
Ocyphaps lophotes	Crested Pigeon		
PSITTACIDAE			
Calyptorynchus 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
Cacatua roseicapilla	Galah	Djakal-ngakal	y
Cacatua pastinator butleri	Butler's Corella		y
Cacatua spp	*Corella	Manatj	y
Glossopsitta porphyrocephala	Purple-crowned Lorikeet	Kowara, kawoor	y
Trichoglossus haematodus	*Rainbow Lorikeet		y
Platycercus (Parpureicephalus) spurius	Red-capped Parrot	delyip	y
Platycercus icterotis	Western Rosella	Mayadang, bardinar	y
Platycercus zonarius	Ring-necked Parrot	Wakangkoor, doornart	y
Polytelis anthopeplus	+Regent Parrot	koora	y
Neophema elegans	Elegant Parrot	koolyidarang	y
CUCULIDAE			
Cuculus pallidus	Pallid Cuckoo	djoolaran	
Cuculus flabelliformis	Fan-tailed Cuckoo	Koordomal, djoolar	
Chrysococcyx basalis	Horsfield's Bronze Cuckoo		
Chrysococcyx lucidus	Shining Bronze Cuckoo		
STRIGIDAE			
Ninox novaeseelandiae	Boobook Owl	Nyawoo-nyawoo	y
TYTONIDAE			
Tyto alba	Barn Owl	Yoowintj, ngoorlam	y
PODARGIDAE			
Podargus strigoides	Tawny Frogmouth	Kambikoora, djoowi	
AEGOTHELIDAE			
Aegotheles cristatus	Australian Owlet-nightjar	yaartj	y
APODIDAE			
Apus pacificus	Fork-tailed Swift		
HALCYONIDAE			
Dacelo novaeguinea	*Laughing Kookaburra	Kaakaw	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	

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Common name	Common name	Indigenous name(s)	Likely to use hollows or crevices
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	
Lichenostomus ornatus	Yellow-plumed Honeyeater	miyamit	
Lichenostomus virescens	Singing Honeyeater	Kool-boort	
Melithreptus chloropsis	Western White-naped Honeyeater	djingki	
Phylidonyris nigra	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			
Petroica multicolor	Scarlet Robin	Kooba djiyat, dermo kalitj	y
Eopsaltria georgiana	White-breasted Robin	boyidjil	
Eopsaltria australis	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	
DICRURIDAE			
Myiagra inquieta	Restless Flycatcher	Djiring-djiring	
Rhipidura fuliginosa	Grey Fantail	kadjinak	
Rhipidura leucophrys	Willie Wagtail	Djidi-djidi	
Grallina cyanoleuca	Magpie Lark	Djilabit, diliboort	
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	
Hirundo nigricans	Tree Martin		
ZOSTEROPIDAE			
Zosterops lateralis	Grey-breasted White-eye (Silvereye)	diikir	
DICAEIDAE			
Dicaeum hirundinaceum	Mistletoebird	moonidjedang	
MOTACILLIDAE			
Anthus australis	Australian Pipit		

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APPENDIX B- NYOONGAR INDIGENOUS CULTURE AND TRADITIONAL LIFE IN THE TUART WOODLANDS AND FORESTS OF THE SWAN COASTAL PLAIN

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).

Nyoongar people, ecological knowledge and language

The Nyoongar (Noongar) people are the traditional owners of south west 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). The groups most strongly associated with the main area where Tuart woodlands and forests occur are Yuat (Yued), Whadjuk, and Bindjarep (Rooney, 2011), but the ecological community may also occur on the margins of other language areas. For this reason there are often alternative names or transcriptions of names for the plants and animals of the ecological community. Additionally, Nyoongar 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 Nyoongar names for plants and animals that are part of the ecological community, as well as some examples of their traditional uses are noted in the tables in Appendix A. 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 primarly summarised from Hansen and Horsfall (2017). Any medicinal use or consumption of these plants should only be made with expert guidance.

The importance of seasons

Traditional Nyoongar 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 Nyoongar calendar, summarised here from Bindon and Walley (1998), Wallace and Huston (eds) (1998) and Hansen and Horsfall (2017).

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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 hawks 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 funneling 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 scooop 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 reparied 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.

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 Nyoongar 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). Nyoongar elder Uncle 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. 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 Nyoongar 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 have 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).

Nyoongar 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

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).

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 going walkabout, old people camped at the top end of Lake Preston to take the mineral water there and gain strength (Harry Nannup pers.comm).

Wanil (peppermint) is a medium sized tree that is a common in the sub-canopy beneath tuart trees south of Perth. It traditionally has various medicinal and ceremonial uses, including the use of crushed leaves to relieve nasal congestion, to make a mouth wash or antiseptic (Hansen and Horsfall, 2017)

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 Nyoongar 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. 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 Nyoongar fire management. 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. Then 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).

APPENDIX C- ADDITIONAL INFORMATION ON LANDSCAPE, CORRESPONDING VEGETATION UNITS, ECOLOGY AND BIOLOGY AND MANAGEMENT

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).

Relationship with other vegetation classification systems

'Beard maps'

Perhaps the most widely available and used the broad scale vegetation association maps on the Swan Coastal Plain are those 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.

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, 2014). 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 7 Vegetation units dominated by tuart described by Beard cited in Hopkins et al (1996) and the National Vegetation Information System (NVIS). These have been used in this Conservation Advice for analysis of extent and level of reservation of the ecological community

Table 7 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 Heritage, 2003)
*__Key to Beard Codes__ (cited from Keighery et al 2002 after Beard 1979a, b and c, 1981)

Species e eucalypt 4 Tuart (*Eucalyptus gomphocephala*) 2 Jarrah (*Eucalyptus marginata*) 3 Marri (*Eucalyptus calophylla*)	**Physiognomy of dominant stratum** T Tall trees > 25 m tall M Medium trees 10 - 25 m tall L Low trees < 10 m tall	**Density of Canopy cover** 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 (**for NVIS codes see Department of the Environment and Heritage, 2003
2.0	2	Tall woodland; tuart (Eucalyptus gomphocephala)	e4Ti	Ti -01a	U^Eucalyptus gomphocephala, Eucalyptus marginata, Corymbia calophylla\tree\8\i;M Acacia cyclops, Comesperma integerrimum, Dryandra sessilis\shrub,liana\4\i;G Acanthocarpus preissii, Acianthus reniformis, Austrostipa elegantissima\forb,tussock grass,sedge
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,liana\2\c
6.0					U^Eucalyptus gomphocephala,^Eucalyptus marginata\tree\7\i

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Systems association code	Vegetation Association code (after Hopkins et al 2001)	Source description	Beard code*	Hopkins code*	NVIS level 5 description (for NVIS codes see Department of the Environment and Heritage, 2003
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,liana\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,liana\2\c
1011.0					U^Eucalyptus gomphocephala\tree\7\r
	1012	Mosaic: Medium open woodland; tuart / Low woodland; banksia		Li 09a/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,liana\2\c

Sources: Hopkins et al. (1996), Hopkins et al 2001 cited in Keighery et al (2002); Department of the Environment (2014) (NVIS),

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-1750 cover. Across the Swan Coastal Plain 29 complexes were originally identified. The mapping of these has since been extended and refined by

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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 8 Vegetation complexes (Heddle et al. 1980) containing tuart on part of the Swan Coastal Plain
Source: Keighery et al (2002) p.26

Structural formations listed for the vegetation complex.* if presence of formation is critical	**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%**

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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 9 Floristic Community Types that include tuart

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 acerosa* shrublands

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

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. 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 (Tuart Response Group, 2003). 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 extent of occurrence 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.

Relationship with other threatened ecological communities

A range of threatened ecological communities of the Swan Coastal Plain have been listed under the EPBC Act. Most of these are clearly distinct from tuart woodlands and forests, but several have similar characteristics or overlapping distributions and can co-occur (as described in 'Other diagnostic considerations').

- Banksia woodlands of the Swan Coastal Plain- where tuart occurs as an occasional emergent above a stratum dominated or co-dominated by Banksia species including *Banksia attenuata* (candlestick banksia, slender banksia), *B. menziesii* (firewood banksia) *B. prionotes* (acorn banksia) or *B.ilicifolia* (holly-leaved banksia) the patch is likely to be the Banksia woodlands of the Swan Coastal Plain, should other diagnostic characteristics and condition requirements for that ecological community be met. Where tuart forms the dominant species in the highest canopy layer (the most abundant of trees species present), and at least three tuart trees are present with no more than 40m between each canopy, the tuart woodlands and forests ecological community is likely to be present. In some instances, particularly on Spearwood dune substrates both Banksia woodlands and Tuart woodlands and forests may be present (Department of the Environment and Energy 2016).
- Sedgelands in Holocene Dune Swales: 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) as well as sedges and grasses. Typically the ecological community has a more open structure than tuart woodlands and forests, but at mature sites an open tree canopy may develop, including tuart or *Banksia littoralis* (swamp banksia) trees. The nature of the ecological community may change with succession. Where tuart forms the dominant species in the highest canopy layer (the most abundant of trees species present), and at least three tuart trees are present with no more than 40m between each canopy, the Tuart woodlands and forests ecological community is likely to be present. In these cases the Tuart woodlands and forests ecological community is likely to be present. In some instances, in the areas between Quindalup dunes, both Sedgelands in Holocene Dune Swales and Tuart woodlands and forests may be present (Department of the Environment, 2016a).
- 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 the tuart woodlands and forests ecological community, with the tuart roots themselves likely to be part of both, should any other requirements

such as condition requirements be met. 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 (Department of the Environment 2016b).

Other threatened ecological communities occurring on the Swan Coastal Plain may also share some characteristics with tuart woodlands and forests but are generally distinguished by their different structure or absence of tuart trees as a dominant canopy species.

Threatened ecological communities that do not exist as tuart forest, woodland or open woodland

- 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).

Threatened ecological communities not containing tuart as a dominant canopy species

- 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).

Further information on existing protection and management within 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 (6.8% of current extent) 2,049 ha. 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, Ludlow Forest and the Leschenault Peninsula, Yanchep and Yalgorup National Parks (Tuart Response Group 2004).

APPENDIX D– ADDITIONAL INFORMATION ON THREATS

Tuart woodlands and forests has been identified as particularly vulnerable to weed invasion. The soils of the Spearwood dunes that support tuart are relatively fertile, so have been used for grazing, which is in itself a source of weed seeds. Additionally, the use of fire to encourage grass growth has allowed further invasion. More recently, urban development of the Swan Coastal Plain has created a large reservoir of weed species from sources such as gardens. In some areas non-local species have been directly planted in tuart woodlands and forests. Dumping of garden refuse in bushland is another source of weeds. Birds are vectors for a number of weed species. The high perches provided by many tuart trees are attractive for birds such as ravens, which may deposit weed seeds in their faeces. Nutrient enhancement through domestic stock and runoff in agricultural areas also encourages weed growth (Keighery, 2002).

Surveys in 1984 identified that across the range of tuart, 28% of the flora was weed species. In the more heavily degraded sites of the Perth Metropolitan Region, the weed component was up to 37% (Keighery, 1984 cited in Keighery, 2002). More recently, 161 species of naturalised plants have been identified in tuart woodlands. Of these, 23 species, all of which are non-woody, occurred in more than 70% of sites (Keighery, 2002), as follows:

Scientific name	**Common name**
Monocotyledons	
Grasses	
Briza maxima	Large quaking grass
Briza minor	Lesser quaking grass, shivery grass
Cynodon dactylon	Couch grass
Ehrharta *longiflora*	Annual veldtgrass
Lagurus ovatus	Bouquet grass, Hares-tail grass
Vulpia myuros	Rat's –tail fescue
Annually renewed (geophytes):	
Romulea rosea	Onion grass, Guildford grass

Dicotyledons	
Annuals	
Anagallis arvensis	Pimpernel
Brassica tournefortii	Mediterranean turnip
Bellardia 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 indica	
Orobanche minor	Lesser broomrape
Petrorhagia prolifera	
Solanum nigrum	Black nightshade
Sonchus oleraceus	Sow thistle

Additional weeds within the range of the ecological community

Sources: Keighery 2002; Western Australian Herbarium (1998–); Australian Plant Name Index (undated).

*denotes seeds are likely to be distributed by birds.

Additional weed species likely to be found in tuart woodlands and forests include the following:

Scientific name	**Common name**
Trees	
Acacia pycnantha	Golden wattle
Agonis flexuosa (outside of its natural range	Peppermint
*Brachychiton populneus**	Kurrajong
Eucalyptus maculata	Spotted gum
*Olea europea**	Olive
Shrubs	
Leptospermum laevigatum	Victorian teatree
*Lycium ferocissimum**	African boxthorn
*Rhamnus alaternus**	Buckthorn
*Solanum linnaeanum**	Apple of Sodom
*Solanum nigrum**	Black Berry Nightshade
Grasses (annual)	
Bromus diandrus	Great Brome
Cynosurus echinatus	Rough dog's-tail
Lolium multiflorum	Italian Ryegrass
Lolium rigidum	Wimmera Ryegrass
Grasses (Perennial):	
Ehrharta calycina	Perennial Veldtgrass
Eragrostis curvula	African Lovegrass
Hyparrhenia hirta	Coolatai grass
Pennisetum purpureum	Napier grass, Elephant grass
Herbs (Monocotyledons)	
Annually renewed (geophytes):,	
*Asparagus asparagoides **	Bridal creeper
*Asparagus crispus**	Asparagus fern
Albuca major	
Chasmanthe aethiopica	African cornflag
Ferraria crispa	Black Flag
Freesia hybrid	Freesia
Gladiolus caryophyllaceus	Wild Gladiolus
Homeria 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
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

Other weeds that may be found in the ecological community (life forms not specified). Source, Keighery, 2002.

Plant taxa	**Common names**
* *Carpobrotus edulis*	Hottentot Fig
* *Tetragonia decumbens*	Sea Spinach
* *Amaryllis belladonna*	Easter Lily
* *Narcissus tazetta*	Jonquil
* *Schinus terebinthifolius*	Brazilian Pepper
* *Gomphocarpus fruticosus*	Swan Plant
* *Asphodelus fistulosus*	Onion Weed
* *Trachyandra divaricata*	Strap Lily, dune onion weed
* *Aster subulatus*	Bushy Starwort
* *Cirsium vulgare*	
* *Conyza albida*	Tall Fleabane
* *Conyza bonariensis*	Flaxleaf Fleabane
* *Cotula bipinnata*	Ferny Cotula
* *Cotula turbinata*	Funnel Weed
* *Dittrichia graveolens*	Stinkwort
* *Gamochaeta falcata*	
* *Hypochaeris glabra*	Flat Weed
* *Lactuca serriola*	Prickly Lettuce
* *Osteospermum ecklonis*	
* *Osteospermum clandestinum*	Stinking Roger
* *Pseudognaphalium luteoalbum*	Jersey Cudweed
* *Senecio diaschides*	
* *Sonchus asper*	Rough Sowthistle
* *Vellereophyton dealbatum*	White Cudweed
* *Cakile maritima*	Sea Rocket
* *Cardamine hirsuta*	Common Bittercress
* *Cardamine paucijuga*	
* *Heliophila pusilla*	
* *Raphanus raphanistrum*	Wild Radish
* *Wahlenbergia capensis*	Cape Bluebell
* *Arenaria serpyllifolia*	
* *Cerastium glomeratum*	Mouse Ear Chickweed
* *Corrigiola litoralis*	Strapwort
* *Minuartia hybrida*	
* *Petrorhagia velutina*	Velvet Pink
* *Polycarpon tetraphyllum*	Velvet Pink
* *Sagina maritima*	
* *Silene gallica*	French Catchfly
* *Silene nocturna*	Mediterranean Catchfly
* *Spergula arvensis*	Corn Spurry
* *Stellaria media*	Chickweed
* *Convolvulus arvensis*	
* *Crassula decumbens*	Rufous Stonecrop
* *Crassula glomerata*	
* *Crassula natans*	
* *Cuscuta epithymum*	Lesser Dodder
* *Cyperus tenellus*	Tiny Flat-sedge

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Isolepis marginata	
* *Euphorbia peplus*	Petty Spurge
* *Euphorbia terracina*	Geraldton Carnation Weed
* *Fumaria muralis*	Wall Fumitory
* *Centaurium erythraea*	Common Centaury
* *Erodium botrys*	Long Storksbill
* *Erodium cicutarium*	Common Storksbill
* *Geranium molle*	Dove's Foot Cranesbill
* *Chasmanthe floribunda*	African Corn Flag
* *Gladiolus undulatus*	Wild Gladiolus
* *Homeria flaccida*	One-leaf Cape Tulip
* *Juncus bufonius*	Toad Rush
* *Juncus capitatus*	Capitate rush
* *Stachys arvensis*	Stagger Weed
* *Acacia longifolia*	
* *Acacia paradoxa*	Kangaroo Thorn
* *Ficus carica*	Fig
* *Monadenia bracteata*	South African Orchid
* *Oxalis glabra*	
* *Oxalis pes-caprae*	Soursob
* *Lotus angustissimus*	Narrowleaf Trefoil
* *Lupinus angustifolius*	Narrowleaf Lupin
* *Lupinus cosentinii*	
* *Melilotus indicus*	King Island Melilot
* *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
* *Vicia sativa subsp. sativa*	Common Vetch
* *Phytolacca octandra*	Red Ink plant
* *Pinus pinaster*	Maritime Pine
* *Pinus radiata*	Radiata Pine
* *Plantago lanceolata*	Ribwort Plantain
* *Aira caryophyllea*	Silvery Hairgrass
* *Avena barbata*	Bearded Oat
* *Avena fatua*	Wild Oat
* *Briza maxima*	Blowfly Grass
* *Briza minor*	Shivery Grass
* *Bromus hordeaceus*	Soft Brome
* *Cynodon dactylon*	Couch
* *Cynosurus echinatus*	Rough Dog's Tail
* *Desmarzeria rigida*	
* *Ehrharta longiflora*	Annual Veldtgrass
* *Holcus lanatus*	Yorkshire Fog
* *Hordeum leporinum*	Barley Grass
* *Lolium perenne*	Perennial Ryegrass
* *Paspalum dilatatum*	Paspalum
* *Pentaschistis airoides*	False Hairgrass
* *Poa annua*	Winter Grass
* *Polypogon monspeliensis*	Annual Beardgrass
* *Stenotaphrum secundatum*	Buffalo Grass
* *Vulpia bromoides*	Squirrel Tail Fescue
* *Emex australis*	Double Gee
* *Rumex acetosella*	Sorrel
* *Anagallis arvensis var. arvensis*	Pimpernel
* *Anagallis arvensis var. foemina*	Pimpernel
* *Ranunculus muricatus*	Sharp Buttercup
* *Acaena echinata*	Sheep's Burr
* *Galium aparine*	Goosegrass
* *Galium murale*	Small Goosegrass
* *Sherardia arvensis*	Field Madder
* *Bartsia trixago*	Bellardia
* *Dischisma arenarium*	

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* *Dischisma capitatum*	Woolly-headed Dischisma
* *Kickxia spuria*	
* *Parentucellia latifolia*	Common Bartsia
* *Parentucellia viscosa*	Sticky Bartsia
* *Verbascum virgatum*	
* *Veronica arvensis*	Wall Speedwell
* *Verbascum thapsus*	
* *Physalis peruviana*	Cape gooseberry
* *Solanum americanum*	Glossy Nightshade
* *Tropaeolum majus*	Garden Nasturtium
* *Typha orientalis*	Bulrush
* *Urtica urens*	Stinging Nettle
* *Centranthus macrosiphon*	

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APPENDIX E – ELIGIBILITY FOR LISTING AGAINST EPBC ACT CRITERIA

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. 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 also led to severe losses in the extent of the ecological community. The likely pre 1750 extent of the ecological community (including areas identified as having 'strong' or 'medium' tuart dominance) is estimated as 125 407 ha (Department of Biodiversity, Conservation and Attractions, 2017).

To determine the modern distribution of the ecological community we have selected the areas mapped in the Tuart Atlas (Tuart Response Group, 2003) as having tuart present, that were part of the mapped pre-1750 extent. This is less than the total area mapped in the Tuart Atlas as some areas may have had tuart present but if not dominant in the canopy, would not match the description of the ecological community. Thus, the estimated current area of the ecological community is 25 410 ha. This indicates that the extent of the ecological community declined by approximately 80% between 1750 and the publication of the Tuart Atlas in 2003.

This estimate of loss is probably a conservative one, due to the likely poor condition of many of the mapped areas. Keighery et al (2002) noted that tuart communities are often over-mapped as a tuart canopy may be present without understorey. These areas in poor condition may not meet the minimum condition class in section 2.6 to be eligible for national protection. Secondly, clearing has continued at a considerable rate since the publication of the Tuart Atlas in 2003. While more recent maps of native vegetation extent on the Swan Coastal Plain are available, the differences in mapping methods require caution to be exercised in their interpretation. However, a broad indication of possible loss since 2003 is found in the further exclusion of areas not identified as native vegetation by Department of Food and Agriculture Western Australia (2016), (from the estimate of current extent derived from the intersection of the pre-1750 extent and the Tuart Atlas areas). This results in an approximate current extent of 17 070 ha, which is approximately 14% of the estimated pre-1750 extent (a loss of 86% of the pre-1750 area of the ecological community).

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Conclusion

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

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	-
AND 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

Extent of occurrence

The area over which the ecological community occurs is approximately 389 748 ha[9] which is considered to be a '**limited'** distribution (<1 000 000 ha).

Area of occupancy

The mapped area of the ecological community is estimated to be up to 25 410 ha Department of Biodiversity, Conservation and Attractions, 2017) and Tuart Response Group 2003), which is indicative of a '**limited'** distribution.

Patch size distribution

The patches of the ecological community are unevenly distributed across its range. In the southern part of the range, for example, south of Mandurah, the ecological community occurs mostly as a small number of large patches, primarily 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 mean patch size

[9] Calculation for the area of occupancy followed methods described in IUCN (2012). IUCN.

south of Rockingham is 68 ha, that in the metropolitan area (between Rockingham and Burns Beach Road) is 13 ha while that for patches north of Burns Beach Road is 31 ha (Figure 5 Patch sizes across the ecological community).

It is likely that the very northern extent has always been patchy, 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 rest of the distribution suggests that this population has historically been highly connected, and that most fragmentation and isolation in the central part of the range is a factor of relatively recent disturbance. 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).

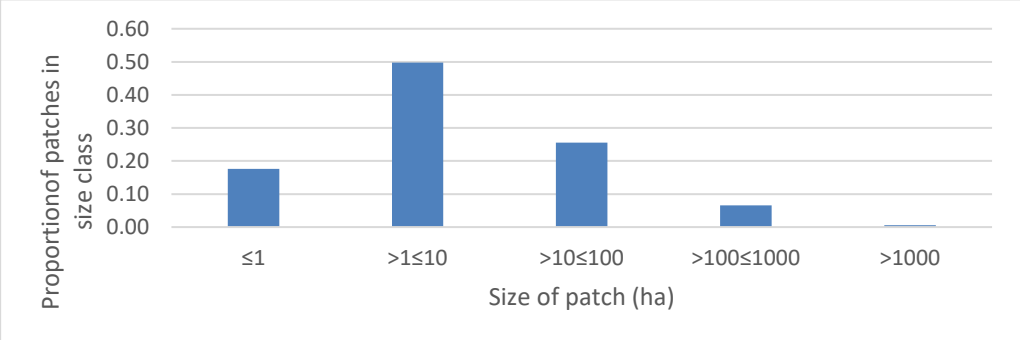
Very small patches of less than 1 ha each constitute 17% of the number of patches and 67% of patches are less than 10ha in size. The median patch size is 4.4 ha, which could be considered 'very restricted' (<10ha) (Figure 5b). However, this is not reflective of the distribution across the full range of the ecological community. While the greatest number of patches is small, a high proportion of the total area is concentrated in a few larger patches, particularly in the southern part of the range, (Figure 5c). The overall mean patch size is 45 ha. By this measure, the distribution of patches of the ecological community is considered to be **'restricted'**.

Figure 5 Patch sizes across the ecological community

a) Mean and median patch size variation across the range of the ecological community.

Portion of the range of the ecological community.	**Mean patch size (ha)**	**Median patch size (ha)**
North (north of Burns Beach Road)	31	4.7
Metro (Rockingham – Burns Beach Road)	13	2.6
South (south of Rockingham)	68	5.8

b) Proportion of patches of the ecological community in various size classes



c) Amount of the ecological community in patch size classes

Patch size (ha)	**Very small <1ha**	**Small >1<10ha**	**Medium >10<100ha**	**Large >100<1000ha**	**Very large >1000ha**	**Total**
Area (ha)	**47**	**11075**	**4854**	**10616**	**8790**	**25414**
% of total area	**0.2%**	**4%**	**19%**	**42%**	**35%**	**100%**

Threats related to the geographic distribution of the ecological community
The primary threat to the ecological community is associated with the location of its range – restricted to the Swan Coastal Plain, approximately centred in the same location as the city of Perth. The limitation of the ecological community to an area that is committed to ongoing urban growth is severely limiting to its recovery. The division of the once largely continuous populations of at least some of the 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, with an 'extinction debt' often due in areas that have recently been fragmented (Tilman et al, 1994). Small patches are particularly susceptible to a range of threats, including weed invasion, which is noted as a particular problem for this ecological community. In the central areas of the ecological community, the small patch size and ongoing fragmentation is occurring in urban environments. 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. These problems are all likely to strongly affect patches with high accessibility due to their high edge to area ratio, in spite of the substantial efforts made by many groups to manage these threats and protect their local reserves. Recovery from disturbances such as fire also reduced where there is little adjacent habitat (although spread of fire may also be reduced). This lack of potential to recover is likely to be problematic particularly in the central and northern areas. Ongoing development is likely to further fragment the remaining areas of the ecological community, as well as the surrounding native vegetation. Currently 65% of the remaining patches of the ecological community have some neighbouring native vegetation, but the likelihood is that more patches will become isolated in the future as urban infill occurs to accommodate the rapidly increasing population of greater Perth.

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, where the historic land use of forests in the Ludlow area, including Tuart Forest National Park, has led to significant weed problems, the efficacy of weed management is impaired by re-invasion from the surrounding area. The few large southern patches are also potentially susceptible to rapid loss through single large fire events, by spread of pathogens or occurrences such as 'tuart decline'.

Given the limited area and restricted distribution of the ecological community and likelihood of ongoing fragmentation, threatening processes such as weed invasion, and loss through fire or disease 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)[10]. Therefore the ecological community is eligible for listing as **endangered** under this criterion.

[10]The key canopy species in the ecological community is *Eucalyptus gomphocephala.* The generation time of this species is used here to define the 'medium term future' for 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 20 years (Jacobs, 1955; Florence, 1996). The maximum allowable time for five generations of this species (to threshold of 100 years), to define the 'near future' for this criterion is thus applied.

Criterion 3 – Loss or decline of functionally important species

Criterion 3 categories			
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	severe decline	substantial decline
Estimated decline over the last 10 years or three generations, whichever is longer of:	at least 80%	at least 50%	at least 20%
to the extent that restoration of the community is not likely to be possible in:	the immediate future	the near future	the medium-term future
restoration of the ecological community as a whole is *unlikely* in	10 years, or 3 generations of any long-lived or key species, whichever is the longer, up to a maximum of 60 years.	20 years, or 5 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years.	50 years, or 10 generations of any long-lived or key species, whichever is the longer, up to a maximum of 100 years.

Role of *Eucalpytus gomphocephala* as a functionally important species

Tuart (*Eucalyptus gomphocephala*) is the dominant tree canopy species across the range of the ecological community. It provides the basic structure of the woodlands and forests and is necessary for the retention of the ecological community.

Tuart is the largest tree occurring on the Swan Coastal Plain and thus has a unique structural role. The potentially large size of the canopy provides substantial habitat for a range of fauna, including a wide range of bird species (see appendix A), with canopy habitats including flowers, fruit, epiphytes, lichens and perched litter, in addition to foliage and bark (Wentzel, 2010). 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 such as possums and cockatoos as well as smaller animals such as brush-tailed phascogale. The availability of suitable tree hollows for nesting, roosting and raising young has been identified as a limiting factor for conservation of these species. While other trees in the ecological community may produce hollows, tuarts have been recognised particularly for their role in supporting threatened fauna that require large hollows (Dell et al, 2002; Department of Environment and Conservation, 2012). See appendix A for some examples of species in the ecological community likely to use hollows. Tuart trees also play a substantial role in creating conditions for understorey species to thrive, providing shade and shelter. Tuart trees flower and fruit intermittently, and at this time provide nectar for birds including *Lichenostomus 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).

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* 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 10m. *Falsistrellus mackenzei* (Western false pipistrelle) is a bat species with limited distribution that was 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).

Estimated decline of *Eucalyptus gomphocephala*

The overall decline in area of the ecological community, is estimated at approximately 80 per cent since 1750 (see criterion 1). One of the key defining characteristics of the ecological community is the dominance of tuart, so the decline in this species is almost synonymous with the loss in area of the ecological community. The actual losses may be greater in some cases, for example where tuart decline has occurred and tuart trees have been disproportionately lost within the area that is still mapped as tuart woodlands and forests. In some cases other factors such as change in fire regimes may have detrimental to the regeneration of tuart, for example, in competition with peppermint. There is little specific information available on the specific time of tuart tree losses since 1750. Declines are likely to have begun from the 1830s with the commencement of non-Indigenous land use practices. Some substantial losses of the largest trees may have occurred before 1900 through forestry (Harper et al, 1904). The preferential loss of these trees and overall thinning of stands suggests that the loss of the trees providing important habitat may be greater than the overall loss in range of the ecological community. With broad losses through the 20th century and into the 21st century suggest that at least 50% of the population of tuart trees across the pre-1750 range of the ecological community has been lost within the past 60 years (considering three generations of tuart, which is of greater length than the allowed time threshold), indicating a '**severe**' decline.

Likelihood of restoration

Across the pre-1750 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)[11]. In addition to loss in vegetation, this history of

[11] 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

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. The loss of fauna has also transformed the ecological community, with many of the species either threatened or extinct. This impacts on biodiversity and also the function of the ecological community (for example, through the loss of pollination and soil engineering processes). 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, critical habitat features such as large tree hollows are limiting for many 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). Given the high levels of threat facing some fauna such as Carnaby's Cockatoo, which has lost feeding habitat in other ecological communities, as well as breeding habitat this species may be lost from the ecological community before these critical habitat features are likely to be replaced. 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, 2015). While there have been efforts to restore elements of the remaining patches of the ecological community, its restoration as a whole is unlikely within 100 years[12].

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.

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

The integrity of the ecological community has been severely compromised through various types of local damage 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. Much of this damage 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.

[12] The key canopy species in the ecological community is *Eucalyptus gomphocephala.* The generation time of this species is used here to define the 'medium term future' for 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 20 years (Jacobs, 1955; Florence, 1996). The maximum allowable time for five generations of this species (to maximum threshold of 100 years), to define the 'near future' for this criterion is thus applied.

Vegetation structure and composition

The trees that form the canopy of the ecological community: primarily tuart, as well as other species such as jarrah, marri, karri and candlestick banksia, have been lost primarily through clearing. More recently there have been other causes of loss identified, such as hydrological change and diseases including *Phytopthora 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). In Tuart Forest National Park 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).

While data on understorey condition is limited, that available suggests that the vegetation at most sites is degraded or modified. A 2003 assessment indicated that at that time potentially only 10% of the original extent of tuart retained an intact 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.

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 (G. Keighery, 2002).

Some of these weeds (e.g. grasses) have the potential to affect the fire regimes in the ecological community. The ecological community has also been damaged by unsustainable grazing by stock. Changes to the landscape may also have resulted in the local increase of some native species such as Western grey kangaroos, which may be limiting the regeneration of the understorey.

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). While many of the remnants of the ecological community are adjacent to other native vegetation, 19% are more than 100m 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. Furthermore, the width of many of these connections 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, agriculture 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.

Habitat features

The canopy of the ecological community is dominated by tuart trees, which are the largest tree species on the Swan Coastal Plain. Individual trees naturally live for up to 350 years and old tuarts 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, including some south west endemic species, such as Carnaby's, Baudin's and Forest red-tailed black cockatoos. Many of the trees used by these species for nesting are between 300-500 years old, with trees only reaching sufficient size to produce these large hollows after more than 200 years (Western Australian Museum, undated). Of the vertebrate fauna species known to be part of the ecological community, many are understood to use hollows (see appendix A). The large size of mature tuart trees in the ecological community also supports other uses, for example, providing perches for raptors. The loss of mature tuart trees has reduced the availability of these habitat resources, compromising the integrity of the ecological community.

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 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 and Woylies 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). 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. With the degradation of the faunal assemblage of the ecological community and the region more generally, many of these functions have been compromised.

However, 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 south west, while now quenda and echidna are the only two of these species that still commonly occur. Even amongst these, the entire range of the

Southern Brown Bandicoot has reduced to approximately 40% of its former size (Valentine et al, 2016). The decline in populations of the woylie happened in stages across its distribution in the south west, possibly initially in response to disease, for example, the rapid loss of populations between Harvey and the coast between the 1870s and 1899 (Abbot, 2008). Another phase of decline has been attributed to poisoning, and later losses by predation as foxes spread through the region from the 1930s and 1940s, although some species may also have been subject to predation by cats (Burbidge and Woinarski). Efforts to translocate populations have met difficulties, possibly related to recurrence of disease (Abbot, 2008). In contrast, 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).
Woylies have also been noted for their likely role dispersing seeds and fungal spores throughout their home ranges (Abbot, 2008; Yeatman and Groom, 2012). The decline of this species and other seed dispersers and pollinators such as Yellow-plumed Honeyeater, Honey possum and Pygmy possum may 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).

Climate and hydrology
The rapidly changing climate of South West 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 south west. Water stress may also have contributed to the loss of trees through 'tuart decline' in the Yalgorup area' (Tuart Response Group, 2004). 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.

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. 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. 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.

Criterion 5 – Rate of continuing detrimental change

The ecological community has experienced substantial clearing and fragmentation due to agriculture, forestry and grazing, although much of the primary clearing may have occurred more than a century ago. While the damage to the understorey and prevention of regeneration related to grazing continues, this is difficult to quantify. There is 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 continues, but the rate at which this is occurring has not been assessed.

Further, the ecological community continues to be cleared for development, and the 'Perth and Peel Green Growth Plan for 3.5 million' currently being developed is likely to predict further losses of remnants, but these have not yet been quantified (Government of Western Australia, 2015).

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.

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.

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