Environment Protection and Biodiversity Conservation Act 1999 **(EPBC Act) (s 266B)**

Approved Conservation Advice (incorporating listing advice) for the Banksia Woodlands of the Swan Coastal Plain ecological community

1. The Threatened Species Scientific Committee (the Committee) was established under the EPBC Act and has obligations to present advice to the Minister for the Environment and Energy (the Minister) in relation to the listing and conservation of threatened ecological communities, including under sections 189, 194N and 266B of the EPBC Act.
2. The Committee provided its advice on the Banksia Woodlands of the Swan Coastal Plain ecological community to the Minister as a draft of this conservation advice. In 2016, the Minister accepted the Committee's advice, adopting this document as the approved conservation advice.
3. The Minister amended the list of threatened ecological communities under section 184 of the EPBC Act to include the Banksia Woodlands of the Swan Coastal Plain ecological community in the **endangered** category. Western Australia recognises components of this ecological community as threatened.
4. Draft sections of this conservation advice, and the proposed conservation category, were made available for expert and public comment for a minimum of 30 business days. The Committee and Minister had regard to all public and expert comment that was relevant to the consideration of the ecological community.
5. This approved conservation advice has been developed based on the best available information at the time it was approved; this includes scientific literature, advice from consultations, and existing plans, records or management prescriptions for this ecological community.

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Conservation objective:

To mitigate the risk of extinction of the Banksia Woodlands of the Swan Coastal Plain ecological community, and maintain its biodiversity and function, through the protections provided under the *Environment Protection and Biodiversity Conservation Act 1999* and through the implementation of priority conservation actions (see section 5, below).

1. DESCRIPTION OF THE ECOLOGICAL COMMUNITY

The ecological community is a woodland[1] associated with the Swan Coastal Plain of southwest Western Australia. A key diagnostic feature is a prominent tree layer of *Banksia*, with scattered eucalypts and other tree species often present among or emerging above the Banksia canopy. The understorey is a species rich mix of sclerophyllous shrubs, graminoids and forbs. The ecological community is characterised by a high endemism and considerable localised variation in species composition across its range.

1.1 Name of the ecological community

This advice follows the assessment of a public nomination to list the 'Banksia Dominated Woodlands of the Swan Coastal Plain IBRA Region' as a threatened ecological community under the EPBC Act.

It is recommended that the ecological community be named **Banksia Woodlands of the Swan Coastal Plain**. The name appropriately describes the typical dominant to codominant canopy trees, and the structure[1] and location that characterise the ecological community. The national ecological community includes ecological communities recognised as threatened in Western Australia (see *section 2.4*, below). Throughout this document the full name of the ecological community may be abbreviated to 'Banksia Woodlands' or 'the ecological community'.

1.2 Location and physical environment

The Banksia Woodlands ecological community is located in the southwest of Western Australia, which is recognised as a global biodiversity hotspot (Hopper and Gioia, 2004).

The Banksia Woodlands ecological community is largely restricted to the Perth (SWA02) and Dandaragan (SWA01) subregions of the Swan Coastal Plain IBRA bioregion[2], from around Jurien Bay in the north to Dunsborough in the south. The ecological community also extends into immediately adjacent areas on the Whicher and Darling escarpments (which lie within

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[1] The term 'woodland' has been chosen as the most typical structure, but the ecological community may also be considered to include examples of shrubland, open woodland or forest under some classification systems. The percentage canopy cover is more than 2% and typically less than 50%. The structure and appearance may also vary due to disturbance history. Similarly, component species of the dominant upper sclerophyllous layer may be variously considered 'tall or large shrubs' or 'small trees'.

[2] IBRA refers to the Interim Biogeographic Regionalisation of Australia v7 (2012). The Swan Coastal Plain Bioregion is comprised of the Dandaragan Plateau (SWA01) and Perth (SWA02) subregions. Adjacent areas on the Whicher and Darling escarpments are mostly within the Northern Jarrah Forest (JAF01) and Southern Jarrah Forest (JAF02) subregions.

JAF01 and JAF02 subregions of the Jarrah Forests IBRA bioregion), to the south and east, where pockets of Banksia Woodlands may also occur.

The Swan Coastal Plain, Perth subregion, consists of five main geomorphic entities that are roughly located parallel to the coastline (McArthur and Bettenay, 1974; McArthur, 2004). These geomorphic entities include the three coastal sand dune systems with ages increasing inland from the coast:

- the Quindalup System (Holocene; youngest and most westerly, fringing the current coastline);
- the Spearwood System (middle to late Pleistocene); and
- the Bassendean System (late Pliocene to early Pleistocene).

Juxtaposed with these aeolian-formed dune systems, the Pinjarra Plain stretches inland to the Ridge Hill Shelf and is composed of alluvial soils. The Ridge Hill Shelf lies furthest inland and is a narrow strip composed of laterite or sandy-covered spurs that forms the foothills of the Darling Scarp.

The Dandaragan Plateau consists of cretaceous marine sediments mantled by sands and laterites with Banksia woodlands on sands, (whilst heaths and shrublands occur on laterites and gravelly sands).

The Swan Coastal Plain dune systems are generally composed of well-drained and weathered white/cream (Quindalup), pale yellow (Spearwood) or grey (Bassendean) quartz sands, which form coarse-textured soils that are extremely poor in nutrients (McArthur and Bettenay, 1974; McArthur et al., 2004). The Quindalup and, to a lesser extent, Spearwood systems, have a primary carbonate-rich origin, and limestone occurs in the profile and at the base of both dune systems. In contrast, the Bassendean dune system is characterised by deep siliciclastic sands that are not associated with underlying carbonate lithologies (McArthur and Bettenay, 1974; McArthur et al., 2004). The high content of shell fragments and carbonate material in the Quindalup System means that these sands are alkaline, typically in the pH range of 8 to 9. In contrast, Bassendean and Pinjarra soils are acidic, typically in the pH range of 5 to 6 (McArthur et al., 2004). The soils surrounding lower interdunal swamps and lakes are poorly drained and rich in organic matter. On the Dandaragan Plateau sands are slightly acidic rather than basic and in the valleys and slopes where Banksia Woodlands occur.

The Banksia Woodlands ecological community mainly occurs on deep Bassendean and Spearwood sands or occasionally on Quindalup sands, typically at the eastern edge. The ecological community also occurs where there are shallow sands over more complex stratigraphic sequences of the foothills (Ridge Hill Shelf), Whicher Scarp and Gingin/Dandaragan Scarp. The ecological community may also occur in other limited scenarios. For example, localised transitions occur where alluvial, limestone, and other lithic substrates are juxtaposed with Bassendean and Spearwood sands. Unusual examples of Banksia Woodlands also occur on sandflats at some locations, where overbank flows of rivers periodically enrich soil moisture and nutrient status.

In summary, the Banksia Woodlands ecological community:

- typically occurs on well drained, low nutrient soils on sandplain landforms, particularly deep Bassendean and Spearwood sands and occasionally on Quindalup sands;
- is also common on sandy colluvium and aeolian sands of the Ridge Hill Shelf, Whicher Scarp and Dandaragan Plateau; and,
- in other less common scenarios, as described above.

The community occurs within an annual rainfall band of approximately 535 to 900 mm on deep sands and 650 to 750 mm on lateritic sands (Beard, 1990). There is a very strong seasonal variation in climate with a clear peak in rainfall during winter and long periods of summer drought (usually five to six months) coupled with high temperatures. Some areas, and some types of Banksia Woodlands are very sensitive to variations in groundwater (Groom et al., 2000; Froend and Drake, 2006). Due to summer drought and vegetation flammability, these are fire prone habitats that include species with a range of life history traits that allow them to persist in this fire prone environment (through resilience to survive fires as well as species that are killed by fire but then germinate after fire).

1.3 Vegetation

1.3.1 Flora

Banksia Woodlands were formerly the dominant vegetation type of the Swan Coastal Plain bioregion, particularly of the Perth subregion (DPaW, 2014b).

The principal structural features of the ecological community are:

- A distinctive upper sclerophyllous layer of low trees[1] (occasionally large shrubs more than 2 m tall), typically dominated or codominated[3] by one or more of the *Banksia* species identified below.
- An emergent tree layer of medium or tall (>10 m) height *Eucalyptus* or *Allocasuarina* species may sometimes be present above the *Banksia* canopy.
- An understory that is often highly species-rich consists of:
  - A layer of sclerophyllous shrubs of various heights; and,
  - A herbaceous ground layer of cord rushes, sedges and perennial and ephemeral forbs, that sometimes includes grasses. The development of a ground layer may vary depending on the density of the shrub layer and disturbance history.

The canopy of the Banksia Woodlands is most commonly dominated or co-dominated by *Banksia attenuata* (candlestick banksia, slender banksia) and/or *B. menziesii* (firewood banksia). Other *Banksia* species that dominate in some examples of the ecological community are *B. prionotes* (acorn banksia) or *B.ilicifolia* (holly-leaved banksia).

Banksia littoralis (swamp banksia) may also be codominant but where it becomes dominant, it typically is not the Banksia Woodlands ecological community as it indicates a different, dampland community. *B. burdettii* (Burdett's banksia) is more common on the Dandaragan

[3] Refers to relevant *Banksia* species typically being amongst the most common plant species in the upper sclerophyllous layer. There may be localised exceptions to this, either as natural variation or due to disturbance history (e.g. fire). To determine presence of the ecological community, refer to *section 2. Guidance for determining whether the Banksia Woodlands ecological community protected under the EPBC Act is present*.

Plateau where it is often a co-dominant, but being a large shrub where it becomes dominant, it typically forms a tall shrubland and not the Banksia Woodlands ecological community.

Other trees of a medium height that may be present, and may be codominant with the *Banksia* species across a patch, include *Eucalyptus todtiana* (blackbutt, pricklybark), *Nuytsia floribunda* (Western Australian Christmas tree), *Allocasuarina fraseriana* (western sheoak), *Callitris arenaria* (sandplain cypress), *Callitris pyramidalis* (swamp cypress) and *Xylomelum occidentale* (woody pear).

Emergent taller trees that can occur above the *Banksia* canopy may include *Corymbia calophylla* (marri), *Eucalyptus gomphocephala* (tuart) and *E. marginata* (jarrah).

Key species in the sclerophyllous shrub layer of the ecological community include members of the families Asteraceae, Dilleniaceae, Ericaceae, Fabaceae, Myrtaceae and Proteaceae. Widespread species include *Adenanthos cygnorum* (woolly bush), *Allocasuarina humilis* (dwarf sheoak), *Bossiaea eriocarpa* (common brown pea), *Conostephium pendulum* (pearl flower), *Daviesia* spp., *Eremaea pauciflora*, *Gompholobium tomentosum* (hairy yellow pea), *Hibbertia hypericoides* (yellow buttercups), *Jacksonia* spp., *Kunzea glabrescens*, *Petrophile linearis* (pixie mops), *Philotheca spicata* (pepper and salt), *Stirlingia latifolia* (blueboy), *Phlebocarya ciliata*, *Hypolaena exsulca* and *Xanthorrhoea preissii* (balga).

Key species in the herbaceous ground layer include members of the families Cyperaceae, Droseraceae, Haemodoraceae, Orchidaceae, Restionaceae and "lilies" from various families. Widespread species include *Amphipogon turbinatus* (tufted beard grass), *Burchardia congesta* (milkmaids), *Caladenia* spp. (spider orchids), *Dasypogon bromeliifolius* (pineapple bush), *Desmocladus flexuosus*, *Drosera erythrorhiza* (red ink sun dew), *Lepidosperma squamatum*[4] (a tufted sedge), *Lomandra hermaphrodita*, *Lyginia barbata* (southern rush), *Lyginia imberbis*, *Mesomelaena pseudostygia* (semaphore sedge), *Patersonia occidentalis* (purple flag), *Podolepis* spp., *Stylidium brunonianum* (pink fountain trigger plant), *Stylidium piliferum* (common butterfly trigger plant), *Trachymene pilosa* (dwarf parsnip), and *Xanthosia huegelii* (heath xanthosia).

Consistent with observations across most of the Southwest Australian Floristic Region (Hopper and Gioia, 2004; Hopper, 2009), Banksia Woodlands are characterized by a high species richness (α-diversity) and high species geographic turnover (ß-diversity) in the shrub and herbaceous layers. Despite the common structural features of the ecological community across the Swan Coastal Plain bioregion, which include a canopy dominated or codominated by *Banksia* species and a species-rich shrub and herbaceous understorey, only a small proportion of the understorey species are widespread (see above). Many understorey species are locally endemic and most do not occur across the full range of the ecological community.

The floristic diversity in Banksia Woodlands is primarily associated with the understorey. While around 15 native trees are associated with the overstorey, surveys have recorded more than 600 native plant taxa from 233 sampled points on the Swan Coastal Plain that contain

[4] *Lepidosperma angustatum* may be listed in previous studies as occurring in Banksia Woodlands, but recent taxonomic changes means that it is now considered to be largely restricted to the south coast of WA.

one or more of the four characteristic *Banksia* tree species – *B. menziesii*, *B. attenuata*, *B. prionotes* and/or *B. ilicifolia*. An average of 50 plant taxa have been recorded within 100 m^2 sample plots of Banksia Woodlands in the Perth area (Keighery and Keighery, 2016).

1.3.2 Variability

In addition to the high species geographic turnover (ß-diversity) noted above, the Banksia Woodlands ecological community shows north–south and east–west gradients in species distribution. The structure (height, cover, density) and composition of Banksia Woodlands varies in relation to three major environmental gradients.

- *Rainfall gradient.* The composition and vegetation structure of the community changes as rainfall increases from north to south, and to a lesser extent, west to east. At the northern end of the ecological community's distribution, where rainfall is lower, Banksia Woodlands may exhibit lower tree height and density, gradually intergrading with Kwongan heath, which occupies upper slopes and ridges (sometimes on laterite without a sand mantle), while Banksia Woodlands are increasingly confined to lower slopes and deeper sands (Beard, 1989). In the central and southern areas of the ecological community's distribution, where rainfall is higher, Banksia Woodlands include mixed assemblages of *Eucalyptus*, *Allocasuarina* and *Banksia* in the canopy or subcanopy. These mixed stands also occur on the eastern Swan Coastal Plain where rainfall is higher due to orographic effects of the Gingin Scarp and Darling Scarp.
- *Soil (or Edaphic) gradient*. As described above (see *1.2 – Location and physical environment*), the Banksia Woodlands mainly occur on the Bassendean and Spearwood coastal sand dune systems and, to a lesser extent, the Quindalup dune system. Species richness generally increases in an easterly direction with the lowest diversity on the youngest sands (Quindalup) and the highest on the oldest sands (Bassendean). There are some other floristic differences between the Bassendean and Spearwood dunes, for example, *Eucalyptus gomphocephala* (tuart) occurs only as an emergent tree on Spearwood sands. The ecological community does not typically occur on alluvial, granite, limestone, laterite and other lithic substrates. The sandy deposits of the Dandaragan Plateau are mainly of colluvial and alluvial origin, but also include minor marine deposits from ancient shorelines and re-worked sediments from further west on the Swan Coastal Plain. Localised transitions occur where these substrates are juxtaposed with Bassendean and Spearwood sands. Unusual examples of Banksia Woodlands occur on sandflats at some locations, where overbank flows of rivers periodically enrich soil moisture and nutrient status. These woodlands have an understorey dominated by ephemeral forbs and a relatively low diversity and density of shrubs, unlike most other forms of the community.
- *Topographic gradient*. Banksia Woodlands typically occur on the tops and slopes of sand dunes, but do not occur on clay flats.

Groundwater levels, groundwater quality, and seasonal fluctuations of groundwater flows interact with the above factors, to influence the structure and composition of the Banksia Woodlands. The dominant *Banksia* species in the woodlands are generally opportunistic phreatophytes (deep-rooted species) and in many areas obtain at least part of their water needs from groundwater at the water table (where the water table is close to the surface), but the depth at which groundwater can be exploited varies greatly between species. This leads to compositional changes in the dominant Banksia species in the dunal landscape depending on water table depth. Typically, *Banksia littoralis* and *B. ilicifolia* are confined to seasonal damplands in interdunal swales where the water table is less than five metres deep throughout the year, whereas other species occur at higher elevations on the dunes. The extent to which *Banksia attenuata* in particular is groundwater dependent decreases with increasing water table depth, and this species is generally unable to access groundwater in areas where the water table depth is more than about 30 metres (Zencich et al., 2002).

The composition of the Banksia Woodlands, particularly in the shrub and ground layers, can exhibit a high degree of variation across short distances (e.g < 500m). Encompassing this variation, floristic sub-communities described on the Swan Coastal Plain, reflecting similarities in geography and soil type, are assigned to Banksia Woodlands (Gibson et al., 1994). (Table 1, adapted from Government of Western Australia, 2000).

In addition to variation due to environmental gradients, the structure and composition of the ecological community may vary from that described above due to natural or human-induced disturbance, including fire. The *key diagnostic characteristics* (*section 2.2.1*) help determine if the ecological community is present at a site that has undergone recent disturbance.

A number of vegetation communities or floristic community types are encompassed within the Banksia Woodlands ecological community. Some of these sub-communities within the Banksia Woodlands are highly restricted and listed as Threatened or Priority ecological communities in Western Australia. These have higher significance than sub-types known to be more common and should be provided specific or additional protection, particularly where assigned a higher threat rank than the Banksia Woodlands listing.

Further detail on each of these floristic community types is provided in *Appendix B – Detailed information on sub-communities*, to provide information to assist with consideration of particular sites of the ecological community.

Table 1: Floristic Community Types with relationships to the Banksia Woodlands ecological community

Refer to *Appendix C – Detailed description of national context* for further information on each Floristic Community Type.

Note:

- a number of these Floristic Community Types are not mapped, and the studies only surveyed Banksia Woodlands south of the Moore River, hence other types of Banksia Woodlands outside the study areas are not included in the table. Floristics of the Banksia Woodlands in the northern portion of the Swan Coastal Plain have not been identified to the same level of detail and floristic community types are therefore not described below for that portion of the community's range. Griffin (1990, 1994) provide descriptions of some of the Banksia woodland assemblages in the northern portion of the Swan Coastal Plain; and,
- *FCT 20c Eastern shrublands and woodlands corresponds with a separate EPBC ecological community listing, Shrublands and Woodlands of the eastern Swan Coastal Plain. Occurrences of this FCT should be considered under that separate listing (Department of the Environment, 2016).

FCT	FCT name	Distribution	ASR	WA TEC
Supergroup 3 – Uplands centred on Bassendean Dunes and Dandaragan Plateau				
20a	*Banksia attenuata* woodlands over species rich dense shrublands	PMR+/S	64.5	EN (WA)
20b	Eastern *Banksia attenuata* and/or *Eucalyptus marginata* woodlands	PMR+/N	59.7	EN (WA)
*20c	Eastern shrublands and woodlands	PMR	60.4	CR (WA); EN (EPBC Act)
21a	Central *Banksia attenuata - Eucalyptus marginata* woodlands	≥PMR/N	52.0	
21b	Southern *Banksia attenuata* woodlands		57.5	P3
21c	Low lying *Banksia attenuata* woodlands or shrublands	PMR+	38.5	P3
22	*Banksia ilicifolia* woodlands	>PMR/C	30.0	P2
23a	Central *Banksia attenuata - Banksia menziesii* woodlands	PMR	59.0	
23b	Northern *Banksia attenuata - Banksia menziesii* woodlands	>PMR/S	47.0	P3
23c	North-eastern *Banksia attenuata - Banksia menziesii* woodlands	(PMR)	53.0	
S9	*Banksia attenuata* woodlands over dense low shrublands	(PMR)/S	*38.9*	
Supergroup 4 – Uplands centred on Spearwood and Quindalup Dunes				
24	Northern Spearwood shrublands and woodlands	PMR*	38.9	P3
25	Southern *Eucalyptus gomphocephala – Agonis flexuosa* woodlands	>PMR/S	48.1	P3
28	Spearwood *Banksia attenuata* or *Banksia attenuata - Eucalyptus* woodlands	>PMR/S	55.1	
Whicher Scarp FCTs (Keighery et al., 2008)				
A1	Central Whicher Scarp Mountain Marri Woodland WHSFCT_A1 (Keighery et al., 2008 indicates *B.attenuata* is a dominant)	Whicher Scarp	63.6	P1

FCT	FCT name	Distribution	ASR	WA TEC
A2	North Whicher Scarp Jarrah and Woody Pear woodland WHSFCT_A2 (Keighery et al., 2008 indicates *B.attenuata* is a dominant)	Whicher Scarp ±	79.6	
A3	North Whicher Scarp Banksia and Woody Pear woodland WHSFCT_A3 (Keighery et al., 2008 indicates *B.attenuata* is a dominant)	Whicher Scarp	62.5	
A4	Whicher Scarp *Banksia grandis*, Jarrah and Marri woodland WHSFCT_A4 (Keighery et al., 2008 indicates *B.attenuata* is a dominant)	Whicher Scarp	68.0	
B1	Swan Coastal Plain /North Whicher Scarp *Banksia attenuata* woodland WHSFCT_B1 (Keighery et al., 2008 indicates *B.attenuata* is a dominant)	Whicher Scarp ±	55.6	
B2	West Whicher Scarp *Banksia attenuata* woodland WHSFCT_B2 (Keighery et al., 2008 indicates *B.attenuata* is a dominant)	Whicher Scarp ±	34.0	P1
C2	Whicher Scarp Jarrah woodland on deep coloured sands WHSFCT_C2 (Keighery et al., 2008, indicates *B.attenuata* is generally present and often dominant)	Whicher Scarp	67.3	P1

Source: Gibson et al. (1994); Government of Western Australia, 2000; Keighery et al. (2008); Urban Bushland Council, 2011.

<u>Legend to table</u>

Column 1: FCT (Floristic Community Type) Codes

The numbers of the types additional to Gibson *et al.* (1994) are italicised if they are subsets of an existing group (in types 19, 20, 23 and 30) and italicised and preceded by an S if they are supplementary groups.

Column 2: FCT name and General Description

Descriptions are based on generalised information from all plots in the group. Structural units are categorised into forest, woodlands, shrublands, sedgelands and herblands after Gibson *et al.* (1994).

Column 3: Distribution in relation to the Perth Metropolitan Region

PMR	confined to PMR	N	Northernmost location in the PMR
PMR+	predominantly in PMR	S	Southernmost location in the PMR
(PMR)	rare in PMR	C	PMR central to distribution
blank	outside PMR		
>PMR	distribution goes well beyond the PMR		
	* except for isolated occurrence outside normal range		

Column 4: ASR (Average Species Richness) per Floristic Community Type

Average species richness per 10m x 10m plot, excluding those species only occurring in a single plot (single records). Some community types can have a high proportion of single records and these estimates of average species richness are underestimates in some cases (Gibson et al., 1994).

Column 5: WA TEC (Threatened and Priority Ecological Communities in WA)

CR = Critically Endangered; EN = Endangered; P1, P2, P3 = WA priority ecological community categories

1.4 Fauna

Banksia Woodlands support a rich and diverse array of fauna species on the Swan Coastal Plain.

Forty indigenous mammal species were considered to have occurred in the Swan Coastal Plain bioregion at the time of non-Indigenous settlement, including iconic species such as the bilby, numbat and woylie (Burbidge et al., 2009). Ten of these mammal species are now entirely extinct from the bioregion. With regard to the native ground mammal fauna known from the Swan Coastal Plain at the time of non-Indigenous settlement, over 70 % have become regionally extinct (Kitchener et al., 1978). Other species have declined in numbers or contracted their range, generally to the northern plain, which is relatively less disturbed. The larger patches of Banksia Woodlands can still support viable populations of *Tarsipes rostratus* (Noolbenger, honey possum), and *Pseudomys albocinereus* (Noodji, ash-grey mouse). Being nectar feeders, Noolbenger particularly rely on *Banksia* flowers as a food resource and have a key role in the ecological community as pollinators.

The extended flowering phenology of the dominant *Banksia* species plays a significant role in maintenance of nectar feeding bird populations that rely on all-year-round flowering for their food, successful breeding and persistence. The bird assemblages of the Swan Coastal Plain is numerically dominated by nectrivores (How and Dell, 2000). However, the most iconic bird species of the Swan Coastal Plain are the black cockatoos: *Calyptorhynchus latirostris* (Carnaby's black cockatoo), *Calyptorhynchus banksii naso* (forest red-tailed black cockatoo, karrak) and *Calyptorhynchus baudinii* (Baudin's black cockatoo). Carnaby's black cockatoo typically breeds in eucalypt forests and woodlands in the wheatbelt, east of the coastal plain, but migrates to the coast each year, where they feed upon the flower and fruiting cones of *Banksia* and related species within the ecological community. In so doing, they help to disperse any seeds not directly eaten, sometimes over several kilometres.

The Swan Coastal Plain is exceptional in its reptile species richness (How and Dell, 2000). Some reptile species are endemic to the Swan Coastal Plain, such as *Lerista lineata* (Perth slider, Perth lined lerista) and *Neelaps calonotus* (black-striped snake) while other species are near-endemics, such as *Ctenophorus adelaidensis* (western heath dragon, sandhill dragon), *Delma concinna* (javelin lizard), *Diplodactylus polyophthalmus* (spotted sandplain gecko), *Lerista christinae* (bold-striped slider) and *Pletholax gracilis* (keeled legless lizard). There is a marked change in the reptile assemblages across the Swan Coastal Plain that reflect the underlying sandy soil structure of the differing Quindalup, Spearwood and Bassendean landforms and the Banksia Woodlands that dominate them. The fossorial turtle frog (*Myobatrachus gouldii*) is a highly unusual amphibian species in this ecosystem, as it is associated with Banksia Woodlands due to its diet. The turtle frog eats termites that feed on *Banksia* wood (Callaby, 1956). However, the implications of the turtle frog's preying upon the termites to the Banksia trees is not yet fully understood.

Some characteristic vertebrate species currently known to occur in the ecological community include:

Mammals:
Tarsipes rostratus (Noolbenger, honey possum)
Pseudomys albocinereus (Noodji, ash-grey mouse)
Macropus irma (Kwoora, western brush wallaby)
Isoodon obesulus (quenda)

Birds:
Acanthorhynchus superciliosus (western spinebill)
Anthochaera carunculata (red wattlebird)
Anthochaera lunulata (western wattlebird)
Calyptorhynchus banksii naso (forest red-tailed black cockatoo)
Calyptorhynchus baudinii (Baudin's cockatoo)
Calyptorhynchus latirostris (Carnaby's cockatoo)
Lichmera indistincta (brown honeyeater)
Malurus splendens (splendid fairy-wren)
Pachycephala rufiventris (rufous whistler)
Petroica boodang (scarlet robin)
Phylidonyris niger (white-cheeked honeyeater)
Phylidonyris novaehollandiae (New Holland honeyeater)
Zosterops lateralis chloronotus (western silvereye)

Reptiles:
Ctenophorus adelaidensis (western heath dragon, sandhill dragon)
Ctenotus australis (western limestone ctenotus)
Ctenotus inornatus (syn. *Ctenotus fallens*) (west-coast laterite ctenotus)
Delma concinna (javelin lizard)
Diplodactylus polyophthalmus (spotted sandplain gecko)
Hemiergis quadrilineata (two-toed earless skink)
Lerista christinae (bold-striped slider)
Lerista elegans (elegant slider)
Lerista lineata (Perth slider, Perth lined lerista)
Morethia lineoocellata (west coast morethia)
Neelaps calonotus (black-striped snake)
Pletholax gracilis gracilis (keeled legless lizard)

Frogs:

Heleioporus eyrei (moaning frog) and *Limnodynastis dorsalis* (pobblebonk) are dependent on Banksia Woodlands for a significant portion of their lifecycle, as non-breeding aestivating habitat. On the Swan Coastal Plain *Myobatrachus gouldii* (turtle frog) only occur in Banksia Woodlands, so the ecological community provides breeding habitat and their entire lifecycle is completed there. Their direct-developing eggs hatch underground amongst the banksia roots (Mitchell, *pers. comm.*).

The invertebrate component of the ecological community is less well known than the vertebrates. Several endemic taxa are known from localised woodlands on the Swan Coastal Plain and there is a clear biogeographic association between some invertebrate groups and landform types that underpin the dominant Banksia Woodlands (Harvey et al., 1997). In southwestern Australia, pollinating and herbivorous insects exhibit relationships with plants species that are host-specific to varying degrees, and it is highly likely that biota of the Banksia Woodlands also exhibit host-specificity contributing to endemism at the community level. Most of these relationships remain to be documented and studied.

Some examples of patterns of invertebrate diversity associated with Banksia Woodlands include:

- *Synemon gratiosa* (graceful sun moth)
- Endemic *Antichiropus* millipedes
- Pollination of some rare orchids in the region is dependent on various species of thynnid wasps such that each wasp species targets a particular species of orchid (Swarts and Dixon, 2009).
- At least 38 native species of earthworms are estimated to occur in the Perth metropolitan region of the Swan Coastal Plain, with diversity increasing away from the coast (Abbott and Wills, 2002). Native earthworm species in the Perth metropolitan region are under-represented in disturbed areas (e.g. garden samples), where they are largely replaced by introduced species. Introduced species were not found in undisturbed remnants (Abbott, 1982). This suggests that urban development has been detrimental to the native earthworm fauna and that remnant vegetation fragments will continue to provide refuges in the future (Abbott and Wills, 2002).
- Abensperg-Traun and Perry (1995) detail 16 termite species found in Banksia Woodlands adjacent to the Gnangara Pine Planation. The genera recorded in Banksia Woodlands but not in adjacent pine plantations were *Kalotermes*, *Microcerotermes*, *Nasutitermes*, *Occasitermes* and *Paracapritermes*.
- Various genera and species of ants are specifically noted as occurring in Banksia Woodlands by Heterick (2009). *Dolichoderus* species are particularly abundant in Banksia Woodlands north and south of Perth. *Myrmecia clarki*, a small, dark ant with yellow mandibles also is quite common in Banksia Woodlands around Perth. Other ant species observed foraging on *Banksia* or in *Banksia* woodlands include: *Camponotus johnclarki*, *Camponotus chalceus*, various species of *Stigmacros* in the Perth area, *Amblyopone clarki* and *Austroponera rufonigra* (syn. *Pachycondyla rufonigra*).

1.5 Fungi

The Swan Coastal Plain is rich in fungi species. There have been no comprehensive surveys of fungi in Banksia woodlands across the Swan Coastal Plain, though survey data for fungi are available for some reserves and sites in the Perth region (Bougher, 2011; Perth Urban Bushland Fungi, 2011). Table 2 lists some fungi species of conservation significance.

Table 2: Some of the fungi species in the Banksia Woodlands and their conservation status in Western Australia.

Species	**Priority rating**
Amanita carneiphylla	P2
Amanita drummondii	P3
Amanita fibrillopes	P3
Amanita griseibrunnea	P2
Amanita quenda	P1
Amanita wadjukiorum	P3
Amanita walpolei	P2
Lecania sylvestris	P2

2. GUIDANCE FOR DETERMINING WHETHER THE BANKSIA WOODLANDS ECOLOGICAL COMMUNITY PROTECTED UNDER THE EPBC ACT IS PRESENT

2.1 Introduction

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

The Banksia Woodlands ecological community encompasses considerable natural variation across its range, as recognised by the identification of several intergrading floristic community types (regarded here as 'sub-communities' within the national ecological community). The ecological community is also subject to varying degrees of disturbance and degradation that have influenced the quality of a patch. Notably, the ecological community occurs in a highly cleared and modified landscape. Both the natural variation and influence of degradation have been taken into account in developing the key diagnostic characteristics and condition thresholds for the Banksia Woodlands.

The key diagnostic characteristics presented here summarise the main features that characterise the Banksia Woodlands ecological community. These are intended to aid the identification of the ecological community, noting that a broader description is given in earlier sections.

Condition categories recognise that patches of an ecological community can differ in their quality, and that some patches have undergone sufficient degradation. Condition thresholds provide guidance on when a patch of an ecological community retains sufficient conservation values to be considered a 'Matter of National Environmental Significance', as defined under the EPBC Act. Patches that do not meet the minimum condition thresholds, therefore, are excluded from full national protection, and this effectively means that the referral, assessment and compliance provisions of the EPBC Act are focussed on the most valuable elements of the ecological community.

Although very degraded or modified patches of an ecological community are not protected under the EPBC Act, it is recognised that some patches can still retain some important natural values that may be crucial for certain species or habitats. Such sites may also be protected through State and local laws or schemes. Therefore, these patches should not be excluded from recovery and other management actions. Suitable recovery and management actions may improve some of these patches to the point that they may be regarded as part of the ecological community fully protected under the EPBC Act. Management actions should, where feasible, also aim to restore patches to meet any high quality condition thresholds where these are outlined.

For EPBC Act referral, assessment and compliance purposes, the national ecological community is limited to patches that meet the following key diagnostic characteristics, condition thresholds, and minimum patch sizes:

Step 1: use the key diagnostic characteristics to determin if the ecological community is present – *section 2.2.1*;

Step 2: determine the condition of the patch using Table 2 – *section 2.2.2*;

Step 3: consider if the patch meets a minimum size threshold – *section 2.2.3*;

Step 4: the surrounding context of a patch must also be taken into account when considering factors that add to the importance of a patch that meets the condition thresholds – *section 2.2.4*).

Note: boundaries for a patch may extend beyond a site boundary or potential area of impact for a proposed action.

2.2 Key diagnostic characteristics and condition thresholds

2.2.1 Step 1: Key diagnostic characteristics

These key diagnostic characteristics are the first step in identifying the Banksia Woodlands ecological community, acknowledging that the ecological community encompasses a number of recognised sub-communities (e.g. Floristic Community Types). Some of these sub-communities have a higher threatened status, where listed individually on the WA lists of threatened and priority ecological communities (WA TECs, PECs) (see *Appendix B – Detailed information on sub-communities* for further details on each sub-community). Consequently, the condition thresholds (and thresholds for Significant Impact decisions) may differ for some sub-communities of the Banksia Woodlands ecological community.

Location and physical environment:

- The Banksia Woodlands ecological community primarily occurs in the Swan Coastal Plain IBRA bioregion.
  - This covers the coastal plain from around Jurien Bay south, through Perth, to around Dunsborough. It also includes the Dandaragan Plateau.
  - Pockets of the Banksia Woodlands ecological community also extend into the adjacent lower parts of the Darling and Whicher escarpments that lie within the Jarrah Forest IBRA bioregion to the immediate east and south of the Swan Coastal Plain.

AND

Continued on next page

Soils and landform:

- The Banksia Woodlands ecological community:
    - typically occurs on well drained, low nutrient soils on sandplain landforms, particularly deep Bassendean and Spearwood sands and occasionally on Quindalup sands;
    - is also common on sandy colluvium and aeolian sands of the Ridge Hill Shelf, Whicher Scarp and Dandaragan Plateau; and,
    - in other less common scenarios (e.g. tranisitional substrates, sandflats), as described under *Section 1.2*.

AND

Structure:

- The structure of the ecological community is a low woodland to forest (see footnote [1], page 5) with these features:
    - A distinctive upper sclerophyllous layer of low trees[1] (occasionally large shrubs more than 2 m tall), typically dominated or codominated[3] by one or more of the *Banksia* species identified below; AND
    - Emergent trees of medium or tall (>10 m) height *Eucalyptus* or *Allocasuarina* species may sometimes be present above the *Banksia* canopy; AND
    - A often highly species-rich understorey that consists of:
        - a layer of sclerophyllous shrubs of various heights; and,
        - a herbaceous ground layer of cord rushes, sedges and perennial and ephemeral forbs, that sometimes includes grasses. The development of a ground layer may vary depending on the density of the shrub layer and disturbance history.

AND

Composition:

- The canopy is most commonly dominated or co-dominated by *Banksia attenuata* (candlestick banksia, slender banksia) and/or *B. menziesii* (firewood banksia). Other *Banksia* species that dominate in some examples of the ecological community are *B. prionotes* (acorn banksia) or *B.ilicifolia* (holly-leaved banksia); AND
- The patch must include at least one of the following diagnostic species:
    - *Banksia attenuata* (candlestick banksia)
    - *Banksia menziesii* (firewood banksia)
    - *Banksia prionotes* (acorn banksia)
    - *Banksia ilicifolia* (holly-leaved banksia); AND
- If present, the emergent tree layer often includes *Corymbia calophylla* (marri), *E. marginata* (jarrah), or less commonly *Eucalyptus gomphocephala* (tuart); AND

- Other trees of a medium height that may be present, and may be codominant with the *Banksia* species across a patch, include *Eucalyptus todtiana* (blackbutt, pricklybark), *Nuytsia floribunda* (Western Australian Christmas tree), *Allocasuarina fraseriana* (western sheoak), *Callitris arenaria* (sandplain cypress), *Callitris pyramidalis* (swamp cypress) and *Xylomelum occidentale* (woody pear); AND
- The understorey typically contains a high to very high diversity of shrub and herb species that often vary from patch to patch. Some of the more widespread and potentially characteristic species present in the ecological community are outlined above in *Section 1 – Description*, and in descriptions of vegetation types that relate to the Banksia Woodlands (e.g. Gibson et al., 1994).

Contra-indicators:

- Patches clearly dominated by *Banksia littoralis* are not part of the Banksia Woodlands ecological community but indicates a different, dampland community is present.
- Patches clearly dominated by *Bankia burdettii* are not part of the Banksia Woodlands ecological community but indicates a tall shrubland and not the Banksia Woodlands ecological community.
- FCT 20c – Eastern shrublands and woodlands, corresponds with a separate EPBC ecological community listing, Shrublands and Woodlands of the eastern Swan Coastal Plain. Occurrences of this FCT should be considered under that separate listing.

2.2.2 Step 2: Condition thresholds

The condition threshold categories presented below describe different values and functional attributes of the ecological community and the thresholds for their inclusion in the ecological community protected under the EPBC Act. It is recognised that any single patch of a threatened ecological community may be degraded to some degree but contributes to the overall function of the ecological community (and other environmental components) across the often fragmented landscape.

Although very degraded/modified patches are not protected as the ecological community listed under the EPBC Act, it is recognised that patches that do not meet the condition thresholds may still retain important natural values and may be critical to protecting those patches that meet minimum thresholds. They may also be protected through State and local laws or schemes. Therefore, these patches should not be excluded from recovery and other management actions. Suitable recovery and management actions may improve these patches to the point that they may be regarded as part of the ecological community and become fully protected under the EPBC Act. Management actions should aim to restore patches to meet the highest quality condition thresholds outlined below, that is feasible, given circumstances and resources.

Note in particular, but also refer to *2.2.4 – Further information to assist in determining the presence of the ecological community and significant impacts*:

- Assessments of a patch should initially be centred on the area of highest native floristic diversity and/or cover, i.e. the best condition area of the patch.
- Consideration must be given to the timing of surveys and recent disturbanceIdeally surveys should be undertaken in spring with two sampling periods to capture early and late flowering species. Spring sampling is necessary as flowering is needed to accurately identify many species and active growth will indicate population sizes of ephemeral natives and weeds. Timing of surveys in recently disturbed areas should allow for a reasonable interval after the disturbance (natural or human-induced) to allow for regeneration of species to become evident, and be timed to enable component species to be identified. For example, immediately after a fire one or more vegetation layers, or groups of species (e.g. obligate seeders), may not be evident for a time.
- The surrounding context of a patch must also be taken into account when considering factors that add to the importance of a patch that meets the condition thresholds.
- Certain vegetation components of the Banksia Woodlands ecological community merit consideration as critical elements to protect. Three components are recognised as threatened in their own right in WA and, as such, are priorities for protection. They are detailed in Table 1 and in *Appendix B*.
- A relevant expert (e.g. ecological consultant, local NRM or environment agency) may be useful to help identify the ecological community and its condition.

Table 3: Condition categories and indicative measures/thresholds for assessment.
To be considered as part of the ecological community for EPBC Act referral, assessment and compliance purposes, a patch should meet at least the **Good Condition** category.

	Indicative condition measures/thresholds	
Keighery (1994) Vegetation Condition Scale (Government of WA, 2000)	**Typical native vegetation composition**	**Typical weed cover**
Pristine No obvious signs of disturbance.	Native plant species diversity fully retained or almost so[5]	Zero or almost so weed cover/abundance
Excellent Vegetation structure intact; Disturbance only affecting individual species; Weeds are non-aggressive species.	High native plant species diversity[5]	Less than 10%.
Very Good Vegetation structure altered; Obvious signs of disturbance eg: from repeated fires, dieback, logging, grazing. Aggressive weeds present	Moderate native plant species diversity[5]	5 – 20%
Good Vegetation structure altered but retains basic vegetation structure or ability to regenerate it. Obvious signs of disturbance, e.g. from partial clearing, dieback, logging, grazing. Presence of very aggressive weeds.	Low native plant species diversity[5]	5 – 50%
Degraded Basic vegetation structure severely impacted by disturbance. Requires intensive management. Disturbance evident such as partial clearing, dieback, logging and grazing Presence of very aggressive weeds at high density.	Very low native plant species diversity[5]	20 – 70%
Completely Degraded Vegetation structure is no longer intact and the area is completely or almost completely without native flora. Equivalent to 'Parkland Cleared'.	Very low to no native species diversity[5]	Greater than 70%

[5] Relative to expected natural range of diversity for that vegetation unit (e.g. Floristic Community Type), where comparative data exists.

2.2.3 Step 3: Minimum patch size

Minimum patch sizes apply for consideration of a patch as part of the listed ecological community for EPBC Act referral, assessment and compliance purposes.

Where patches meet different levels of condition, different minimum patch sizes apply:

'Pristine' – no minimum patch size applies

'Excellent' – 0.5 ha or 5,000 m^2 (e.g. 50 m x 100 m)

'Very Good' – 1 ha or 10,000 m^2 (e.g. 100 m x 100 m)

'Good' – 2 ha or 20,000 m^2 (e.g. 200 m x 100 m)

To be considered as part of the EPBC Act ecological community a patch should meet at least the **Good Condition** category – see Table 3.

Given the high proportion of smaller patches (e.g. less than 5 ha) remaining that make up the ecological community, small patches are protected in some circumstances (i.e. if they meet the minimum size thresholds specified above), particularly if they contribute to beta diversity[6] and connectivity. These smaller remnants can make significant contributions to conservation of plants and invertebrates of the ecological community, particularly in parts of the distribution where the community is very highly fragmented. This concept recognises that any single patch of a threatened ecological community may be degraded to some degree but contributes to the overall function of the ecological community (and other environmental components) across the landscape.

2.2.4 Step 4: Further information to assist in determining the presence of the ecological community and significant impacts

The following information should also be taken into consideration when applying the key diagnostic characteristics and condition thresholds (to assess a site to determine if the EPBC-protected ecological community is present and determine the potential impacts on the ecological community).

Land use history influences the state of any patch of the ecological community, while the structural form of the ecological community also affects its species richness and diversity. 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.

A **patch** is a discrete and mostly continuous area of the ecological community. A patch may include small-scale (<30 m) variations, gaps and disturbances, such as tracks, paths or breaks (including exposed soil, leaf litter, cryptogams and watercourses/drainage lines), or localised variations in vegetation that do not significantly alter the overall functionality of the

[6] **Beta diversity** here refers to the turnover of species between sites.

ecological community. Such breaks are generally included in patch size calculations. Where there is a break in native vegetation cover, from the edge of the tree canopy of 30 m or more (e.g. due to permanent artificial structures, wide roads or other barriers; or due to water bodies typically more than 30m wide) then the gap typically indicates that separate patches are present.

Variation in canopy cover, quality or condition of vegetation across a patch should not initially be considered to be evidence of multiple patches. Patches can be spatially variable and are often characterised by one or more areas within a patch that meet the key diagnostic characteristics and condition threshold criteria amongst areas of lower condition. Average canopy cover and quality across the broadest area that meets the general description of the ecological community should be used initially in determining overall canopy cover and vegetation condition. Also note any areas that are either significantly higher or lower in quality, gaps in canopy cover and the condition categories that would apply across different parts of the site respectively. Where the average canopy cover or quality falls below the minimum thresholds, the next largest area or areas that meet key diagnostics (including minimum canopy cover requirements) and minimum condition thresholds should be specified and protected. This may result in multiple patches being identified within the overall area first considered.

The Banksia Woodlands ecological community is highly diverse and variable. Composition often changes across a patch, but structure and presence of a significant Banksia component are unifying features.

A **buffer zone** is a contiguous area immediately adjacent to a patch of the ecological community that is important for protecting its integrity. The purpose of the buffer zone is to help protect and manage the national threatened ecological community. The edges of a patch are considered particularly susceptible to disturbance and the presence of a buffer zone is intended to act as a barrier to further direct disturbance.

As the area of the buffer lies to the outside, around a patch, it is not part of the ecological community and is not formally protected as a matter of national environmental significance. Where the buffer on a particular property is subject to existing land uses, such as cropping, ploughing, grazing, spraying, etc., they can continue due to ‘continuing use’ exemptions in the EPBC Act. However, practical application of a buffer zone is strongly recommended. For instance, it is recommended that care be exercised in the buffer zone to minimise the risk of any significant adverse impacts extending into those patches. Note: if the activity within the buffer zone is likely to have a significant impact on the ecological community then it would require EPBC Act approval.

The recommended minimum buffer zone for the ecological community is 20–50 metres from the outer edge of a patch, and the appropriate size depends on the nature of the buffer and local context (e.g. slope). A larger buffer zone should be applied, where practical, to protect patches that are of particularly high conservation value, or if patches are down slope of drainage lines or a source of nutrient enrichment, or groundwater drawdown.

Restored (revegetated or replanted) sites are not excluded from the listed ecological community so long as the patch meets the description, key diagnostic characteristics and condition thresholds above, and there is evidence of post-regeneration recruitment that could contribute to longer-term maintenance of the patch. It is recognised that revegetation or restoration requires appropriate techniques as well as long-term management and considerable time for a degraded patch to reach high quality condition (Stevens et al., 2016).

Sampling protocols. Thorough and representative on-ground surveys are essential to accurately assess the extent and condition of the ecological community. A minimal sampling protocol involves developing a quick/simple map of the vegetation, landscape qualities and management history (where possible) of the site. The site should then be thoroughly sampled to represent the range of variation in vegetation cover and species diversity, starting with the area of maximum apparent native plant species diversity. At least one hour per plot in early to mid spring and a second survey in late spring may be required to detect the majority of species. Sampling should be based upon plot sizes of at least 100 m^2 (= 0.01 ha, 10m x 10m, or an appropriate shape of equivalent size). However, larger and more variable areas of vegetation will need more samples or plots to assess a site accurately. Recording the search effort (identifying the number of person hours per plot and across the entire patch; along with the surveyor's level of expertise) can be useful for future reference.

Timing of surveys. Whilst identifying the ecological community and its general condition is possible at most times of the year, consideration must be given to the role that season and disturbance history may play in an assessment. For example, flowering may be necessary to identify some shrub species and active growth will indicate population sizes of annual weeds. Immediately after a fire one or more vegetation layers, or groups of species (e.g. obligate seeders), may not be evident for a time. The cover of native plants also varies between seasons and between years in response to variability in environmental conditions, and also with respect to cycles of recurring disturbance such as fire. Timing of surveys should therefore allow for a reasonable interval after a disturbance (natural or human-induced) to allow for regeneration, and be timed to enable component species to be detected and identified. For instance, surveys at least one year post fire may be required to assess a site against the key diagnostic characteristics and minimum condition thresholds.

Surrounding environment, landscape context and other significance considerations – The ecological community is dynamic and exists as a complex mosaic of species determined partly by water availability, substrate and landscape position. On top of this natural variation, a variety of anthropogenic disturbances have been imposed upon the ecological community since European settlement of the region.

Patches that are more species rich and less disturbed are likely to provide greater biodiversity value. Additionally, patches that provide corridors or linkages within a largely modified landscape are particularly important as wildlife habitat and to the viability of biota within those patches of the ecological community into the future, provided that threats are adequately managed.

Therefore, in the context of actions that may have ‘significant impacts’ and require approval under the EPBC Act, it is important to consider the environment surrounding patches that meet the condition thresholds. Some patches that meet the condition thresholds occur in isolation and require protection, as well as priority actions, to link them with other patches. Other patches that are interconnected with other ecological communities have additional conservation values, such as contributing to landscape complementarity, or providing movement opportunities for biota. In these instances, the following indicators should be considered when assessing the impacts of actions or proposed actions under the EPBC Act, or when considering recovery, management and funding priorities for a particular patch:

- Large size and/or a large area to boundary ratio – larger area/boundary ratios are less exposed and more resilient to edge effect disturbances such as weed invasion and human impacts;
- Evidence of recruitment of key native plant species following disturbance (including through successful assisted regeneration);
- Faunal habitat as indicated by patches that meet a diversity of habitat requirements, and that contribute to movement corridors;
- High species richness, most evident from the variety of native plant species but may also be shown by a high number of native fauna species;
- Presence of listed threatened species or key functional species such as key pollinator and dispersal animals;
- Scarcity of weeds and feral animals or opportunities to manage them efficiently;
- Absence or limited symptoms of dieback;
- Connectivity to other native vegetation remnants or restoration works (e.g. native plantings). In particular, a patch in an important position between (or linking) other patches in the landscape (taking into account that connectivity should aim to not exacerbate the incidence or spread of threats e.g. weeds);
- Linear road reserves often contain remnant native vegetation in varying levels of condition with a range of canopy and understorey species. These areas can also act as important links to larger patches of nearby vegetation. In many instances linear road reserves are the only remnant native vegetation; and,
- Occurrence of the patch is:
    - in an area where the ecological community has been most heavily cleared and degraded, so is locally or regionally at risk; or
    - of a ‘sub-community’/ floristic community type that is recognised as a threatened or priority ecological community by the Western Australian Government; or
    - at the edge of the range of the ecological community.

2.3 Area critical to the survival of the ecological community

The areas considered critical to the survival of the Banksia Woodlands covers all patches that meet the key diagnostic characteristics and condition thresholds for the ecological community, plus the buffer zones, particularly where this comprises surrounding native vegetation. This is because this ecological community occurs in a landscape that has often been very heavily cleared and modified, and now exists as mostly very small and highly fragmented patches.

Note that additional areas that do not meet the minimum condition threshold may also be critical to the survival of the ecological community depending on factors such as their size and shape, landscape linkages to other patches and landscape position, because they could retain some biodiversity or habitat values, e.g. as wildlife corridors. It is important to consider the *Surrounding environment, landscape context and other significance considerations*, in *section 2.2.4*, above.

Certain vegetation components (sub-communities) of the Banksia Woodlands ecological community merit consideration as critical elements to protect. Some components are recognised as threatened in their own right in WA and, as such, are priorities for protection. They are detailed in Table 1 and *Appendix B – Detailed information on sub-communities*.

2.4 National context and other existing protection

<u>Relationships to other EPBC-listed ecological communities</u>

There are currently eleven nationally-listed ecological communities that occur on the Swan Coastal Plain. Most of these are distinctive from the Banksia Woodlands as they represent non-vegetation communities (e.g. thrombolites), or different vegetation strucures and assemblages (e.g claypans or *Corymbia calophylla-Kingia australis* woodlands).

The 'Shrublands and woodlands of the eastern Swan Coastal Plain' listed as Endangered in July 2000, coincides with one of the component Floristic Community Types / sub-communities of the Banksia Woodlands ecological community (Table 1). However, 'Shrublands and woodlands of the eastern Swan Coastal Plain' remains a separate EPBC ecological community listing (Department of the Environment, 2016), and occurrences of this Floristic Community Type should be considered under that separate listing.

<u>Relationships to State-listed and priority ecological communities</u>

The Banksia woodlands ecological community includes three ecological communities on the state's list of Threatened Ecological Communities, which is endorsed by the Western Australian Minister for the Environment. These are (Table 1):

- '*Banksia attenuata* woodlands over species rich dense shrublands' – Endangered;
- '*Banksia attenuata* and/or *Eucalyptus marginata* woodlands of the eastern side of the Swan Coastal Plain' – Endangered; and
- 'Shrublands and woodland of the eastern side of the Swan Coastal Plain' – Critically Endangered.

The national ecological community also relates to eight Western Australian Priority Ecological Communities that are either provisionally identified as threatened or require further survey effort, as determined by the WA Threatened Ecological Communities Scientific Committee (Table 4).

Table 4. Priority ecological communities identified in Western Australia with relationships to the Banksia Woodlands ecological community.

Community Name	WA Category
Banksia ilicifolia woodlands, Southern Swan Coastal Plain (FCT 22)	P2
Swan Coastal Plain *Banksia attenuata – Banksia menziesii* woodlands (FCT 23a, 23b and/or 23c)	P3
Low lying *Banksia attenuata* woodlands or shrublands (FCT 21c)	P3
Southern *Banksia attenuata* woodlands (FCT 21b)	P3
Banksia woodland of the Gingin area restricted to soils dominated by yellow to orange sands	P2
Central Whicher Scarp Mountain Marri Woodland (WHSFCT_A1)	P1
West Whicher Scarp *Banksia attenuata* woodland (WHSFCT_B2)	P1
Whicher Scarp Jarrah woodland on deep coloured sands WHSFCT_C2)	P1

Listed threatened flora and fauna species associated with the ecological community

As at July 2016, 20 flora and 9 fauna species that are listed nationally, or listed in Western Australia, are likely to occur in the ecological community (*see Appendix A*). They include 16 nationally listed threatened plant species and 8 nationally listed threatened animal species.

Level of protection in reserves

About 81,800 hectares of the ecological community are estimated to occur within reserves across the range of the ecological community, most of which are within the Perth subregion of the Swan Coastal Plain bioregion. This represents about 24.3 percent of the estimated extent of the ecological community (Table 5).

Table 5. Extent of the Banksia Woodlands ecological community estimated to be protected in reserves.

Subregion	Current extent (ha)	Extent in reserves (ha)	% protected
Dandaragan (SWA01)	81.067.8	24,671.2	30.43
Perth (SWA02)	253,540.6	57,054.9	22.50
Jarrah Forests (JAF01/02)	1,881.4	105.9	5.63
TOTAL	**336,489.9**	**81,832.0**	**24.32**

Source: Government of Western Australia (2016).

Analysis was based upon the estimated extent of major and partially corresponding vegetation system-associations identified in Table C2 of Appendix C. Reservation was based on extent within IUCN I-IV reserves across the range of the ecological community (i.e. both subregions of the Swan Coastal Plain, plus adjacent areas of the Jarrah Forests bioregion.

3. SUMMARY OF THREATS

The main ongoing threats to the Banksia dominated woodlands ecological community are as follows:

- The greatest threat is clearing and fragmentation. This includes:
  - clearing for urban developments, especially in the Perth metropolitan region but also in the urban centres of Bunbury and Busselton;
  - associated urban degradation/disturbance such as rubbish dumping, uncontrolled vehicle access, wildflower and seed harvesting;
  - clearing for agriculture and horticulture (mainly in the past); and
  - mining for basic raw materials (e.g. road/building materials), mineral sands and silica sands, that involve vegetation clearing and hydrological impacts.
- Dieback diseases (especially those caused by *Phytophthora* species).
- Invasive species.
- Fire regime change (particularly increased fire frequency; prescribed burning during late autumn to late spring when plants are in active growth, flowering and seed development and animals are active).
- Hydrological degradation (groundwater abstraction, eutrophication, soil acidification).
- Climate change (increasing temperatures, declining rainfall, changing rainfall timing).
- Grazing (including overabundance of kangaroos particularly in peri-urban reserves).
- Decline in pollinating and seed dispersing fauna.
- Loss of keystone Banksia species and fragmenting of nectar/pollen nutritional networks e.g. loss of *Banksia ilicifolia* in water drawdown areas.

4. SUMMARY OF ELIGIBILITY FOR LISTING AGAINST EPBC ACT CRITERIA

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

The ecological community has transformed in nature from being almost continuous across much of its distribution, to now becoming very highly fragmented into numerous small and scattered patches.

There are ongoing threats to the ecological community, most notably from clearing for urban development, but also due to weed invasion, groundwater extraction, loss of fauna, dieback disease and potential impacts from climate change. These are reducing the integrity of the ecological community and its capacity for survival into the future.

Criterion 1 – Decline in geographic distribution

The Committee considers that there has been a substantial decline in geographic extent overall across the Swan Coastal Plain, in the order of 50 to 60 percent. The Committee also notes patterns of very severe regional declines, fragmentation into smaller patches, especially in the central distribution of the ecological community around the Perth metropolitan region, and recognition of separate components as threatened under State legislation. These contribute to the overall impacts of decline in extent and are consistent with a decline in geographic distribution that is **substantial**. Therefore, the ecological community has been demonstrated to have met the relevant elements of Criterion 1 to make it **eligible** for listing as **Vulnerable**.

Criterion 2 – Small geographic distribution coupled with demonstrable threat

Patch size distribution indicates the ecological community now has a highly fragmented geographic distribution with most patches (about 82%) under ten hectares in size and facing demonstrable threats. The median patch size has reduced from an estimated pre-European value of 146 ha to a current size of only 1.6 ha. The Committee considers that the heavily fragmented nature of its geographic distribution plus the nature of the threats to the ecological community over the near future indicates that the ecological community has met the relevant elements of Criterion 2 to make it **eligible** for listing as **Endangered**.

Criterion 3 – Loss or decline of functionally important species

There is insufficient information to determine the eligibility of the ecological community for listing in any category under this criterion.

Criterion 4 – Reduction in community integrity

The Banksia Woodlands exological community is subject to a number of threats across its range and the combined impacts of these threats have severely reduced the integrity of the ecological community. Furthermore the combined effects of threats have a compounding detrimental effect on the integrity of the ecological community and increase the complexity of appropriate management requirements at various scales. For example, types of the ecological community, such as those dominated by *Banksia ilicifolia* are declining at a higher rate due to the effects of clearing, lowered water tables and *Phytophthora* disease (Stevens et al., 2016). In particular, the patterns of fragmentation, degradation and invasive species plus what is likely to be a long-term shift in water availability (the impacts of which are yet to become fully evident) indicate that community has – and will continue to – experience a serious reduction in its integrity. Given the very high diversity and complexity of this ecological community, full restoration is unlikely to be possible over a short time-frame.

The Committee considers that the available information indicates the ecological community has met the relevant elements of Criterion 4 to make it **eligible** for listing as **Endangered**.

Criterion 5 – Rate of continuing detrimental change

The available information indicates that, in the recent past and projected into the immediate future, there is considerable ongoing and planned clearing of Banksia Woodlands in the Swan Coastal Plain, especially in the region around Perth.

The guidelines for listing against this criterion require a minimum detrimental change of at least 30 percent over the immediate past, or suspected for the immediate future. The available information indicates that, despite some recent known loss of the ecological community, the degree is below the minimum indicative value. The ecological community is therefore **not eligible** for listing under any category for this criterion.

Criterion 6 – Quantitative analysis showing probability of extinction

There are no quantitative data available to assess this ecological community under this criterion. Therefore, it is **not eligible** for listing under this criterion.

5. PRIORITY RESEARCH AND CONSERVATION ACTIONS

5.1 Conservation objective

The conservation objective provides the goal and rationale for the priority actions identified here.

The conservation objective is to mitigate the risk of extinction of the Banksia Woodlands of the Swan Coastal Plain ecological community, and help recover its biodiversity and function, through:

- protecting it using the *Environment Protection and Biodiversity Conservation Act 1999*; and
- implementing priority conservation actions (as outlined in Sections 5.2 – 5.4 below).

5.2 Priority protection and restoration actions

It is more practical and cost-effective to maintain existing high quality remnants than to allow their degradation and then attempt rehabilitation of these or other areas. The more disturbed and modified a patch of the ecological community, the greater is the recovery effort required. To gain the most cost-effective outcomes of investments in management it is important to consider the likely interaction of management actions at any one site, as these may be synergistic or antagonistic. There are also likely to be interactions between sites. Additionally, when allocating resources it is important to consider the minimum investment required for success and the follow up required to secure long term recovery.

The three key approaches to achieve the conservation objective are:

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.

These approaches are overlapping in practice and form part of an iterative approach to management that should include research, planning, management, monitoring and review.

Priority actions are recommended for the abatement of threats and to support recovery of the ecological community. Actions inconsistent with these recommendations that are likely to significantly affect the ecological community should not be undertaken.

In assessment of activities that may have a significant impact on the ecological community, incorporate the relevant actions listed below when determining recommendations including conditions of approval. Applications to Australian Government funding programs should also consider prioritising these restoration activities. Also take into consideration the information outlined in *section 2.2.4 – Further information to assist in determining the presence of the ecological community and significant impacts*.

5.2.1 PROTECT

Preventing vegetation clearance and direct habitat damage

Highest priorities

- Map the boundaries, condition, and risk level to major sub-types of the ecological community. This will identify the areas in most urgent need of protection and restoration.
  - Enter mapped information into a GIS-enable database to enable identification of occurrences during environmental impact assessment and to facilitate protection and management.
  - Notify land managers of the occurrences on land that they manage to encourage compliance with legislation and management of occurrences.
- Prevent further clearance, fragmentation or detrimental modification of remnants of the ecological community and of surrounding native vegetation, for example, during residential development, basic raw materials extraction, and associated infrastructure development. High conservation value, unmodified and older growth areas are particularly important for retention and management.
  - Overall, efforts should be made to increase the remaining extent, condition and landscape scale connectivity (including with other surrounding native vegetation types).
  - Identify high quality remnants in advance of zoning and development planning decisions and avoid clearing or damaging them.
  - Recognise the landscape position of remnants of the ecological community and ensure that planning supports increased resilience within the landscape (for example, by retaining appropriate connectivity between remnants of all naturally occurring ecological communities).
  - 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 avoiding or mitigating off-site effects. For instance, apply recommended buffers of at least 20–50 m around patches of the ecological community and avoid activities that could cause significant hydrological change or eutrophication. Wider buffers may be required where there is larger scale landscape change, for example hydrological modifications.
  - Protect mature trees, particularly with hollows, even if they are dead. Large and old trees may have numerous fissures that provide shelter; support diverse insects and their predators; and act as ‘stepping stones’ for fauna moving between remnants in an otherwise cleared landscape.
  - Retain other native vegetation remnants and mature isolated trees near patches of the ecological community where they are important for connectivity.

  - Prevent firewood collection that leads to loss and damage of trees and logs.
  - Manage access to remnants to prevent, for example, disturbance and spread of plant pathogens and weeds.
  - New walking or bike tracks should be near, rather than through patches of the ecological community.
- Ensure that areas that form important landscape connections, such as wildlife corridors or other patches of particularly high quality or regional importance are considered for inclusion in formal reserve tenure or other conservation related tenure for protection and management in perpetuity.
- Liaise with local councils and State authorities to ensure that cumulative impacts, from activities undertaken as part of broader or related projects (e.g. road works, developments), are reduced when planning individual activities.
- Avoid the requirement for offsetting, by avoiding and mitigating impacts to the ecological community first. Further to 'like-for-like' principles, match offsets to the same sub-community (usually Floristic Community Type), as it is not appropriate to offset losses of one component with other components of the ecological community, given the high local endemism and β-diversity. Further information is in *Section 5.4 – Offsets*.

Other priorities

- Protect the soil seed bank by minimising soil disturbance and removal.
- Retain habitat features for fauna, noting species requirements (e.g. fallen timber, particular structure of vegetation). For example, for many bird species the quality of native vegetation as habitat can be improved by leaving fallen logs and leaf litter in situ, controlling weed species, taking care of the canopy by controlling against dieback *Phytophthora cinnamomi*, and controlling wildfires by public awareness and vigilance (Davis et al., 2013).
- 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.

Preventing weeds, feral animals, dieback and other diseases

Highest priorities

- Prevent weed invasion by minimising any 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, e.g. urban runoff to prevent movement of weed material into natural areas, or elevating soil nutrients that encourage establishment of weeds over natives.

- Detect and control weeds early. Small infestations should be a priority for removal.
- Prevent further introduction of feral animals and contain domestic animals within new residential areas.
- Monitor for *Phytophthora cinnamomi* and other plant pathogens to minimise the risk of new infestations in areas that are not yet infested. Manage early for local eradication.
- 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 effectively washed first to remove potential fungal pathogens and weed seeds.

Groundwater

- Manage groundwater extraction by monitoring changes to levels of groundwater over the long-term. Use the results of monitoring to ensure adverse impacts to native vegetation are minimised.

Fire

- Use a landscape-scale approach and available knowledge on fire histories and age of stands, to identify appropriate fire regimes. Fires must be managed to ensure that where possible, prevailing fire regimes do not disrupt the life cycles of the component species of the ecological community, that they support rather than degrade the habitat necessary to the ecological community, that they do not promote invasion of exotic species, and that they do not increase impacts of other disturbances such as grazing or predation by feral predators.
- Given the cycle of fires promoting grassy weed establishment and higher fuel loads, manage the fire-weed cycle by controlling invasive weed species before and after any fire events.
- In some areas of Banksia Woodlands (e.g. Gnangara Groundwater System) 8–16 years is currently recommended as an appropriate fire interval for the ecological community: however, a mosaic pattern of burning and fire ages is recommended, with retention of some long-unburnt areas (10–30 years since last fire) that provides habitat for a variety of fauna and flora (Wilson et al., 2014). Physical damage to the habitat and individuals of the threatened species must be avoided during and after fire operations.
- Implement appropriate fire management regimes for the ecological community taking into account results from research. These may include some of the following actions:
    - do not burn during reproductive seasons of threatened or functionally important or characteristic flora, and fauna species;
    - do not burn if soil moisture is very low, or relatively dry conditions are predicted for the coming season;

- where controlled burns are deemed necessary, use small scale (<1 ha) mosaic burning patterns to reduce impacts of too frequent fires on the ecological community and associated flora and fauna;
- within large patches burn different parts in rotation, rather than the whole area in any one season;
- avoid slashing or tree removal as part of fire management;
- consider fire regimes appropriate for nearby ecological communities when planning burning (for example, where wetlands are adjacent);
- monitor outcomes of fire and manage consequences (e.g. weeds and feral predators); take results into account when managing future fire regimes. (For further information on monitoring priorities see *section 5.3*).

Preventing grazing damage

- Where feral herbivores (e.g. rabbits) are present or there is an overabundance of native herbivores (e.g. kangaroos) install temporary or permanent fencing to protect regrowth, revegetation areas, or sites with threatened, regionally important or diverse understorey species.
- Manage populations of feral grazing animals that damage native vegetation.

5.2.2 RESTORE

Re-vegetation

Highest priorities

- Implement optimal regeneration, revegetation and restoration strategies for the ecological community, across the landscape. In general, use locally collected seed where available to create an appropriate canopy and diverse understorey, however, choosing sources of seed closer to the margins of their range may increase resilience to climate change.
- Site specific restoration, including consideration of the appropriate Floristic Community Type, is important to the success of restoration efforts. Complex ecosystem processes support the floristically rich woodlands in a harsh environment of infertile, low water-holding soils and hot, dry summers. Disturbances, particularly since European settlement, amplify this complexity: major past disturbances (e.g. land clearing, logging, grazing) combine with ongoing threats associated with urbanisation (e.g. fragmentation, invasive species, arson, off-road vehicles) and contemporary stressors (e.g. climate change) (Stevens et al., 2016).
- 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.
- Consider particularly the needs of species of conservation concern or known to be of functional importance for the ecological community, for example feed trees for Carnaby’s cockatoo.

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. For example, refer to best-practice guides for restoring Banksia Woodlands (Stevens et al., 2016) and the National Standards for the Practice of Ecological Restoration in Australia to assist in setting goals, planning actions and monitoring outcomes (Society for Ecological Restoration Australasia, 2015).

Control invasive species and diseases

Highest priorities

- Map weed occurrence and prioritise management of weeds in very good to pristine quality patches or where threatened or regionally significant species are known to occur.
- Implement effective control and management techniques for weeds currently affecting the ecological community, such as *Ehrharta calycina*, integrating this with alternative habitat provision and predator control.

Other priorities

- Where feasible, control introduced pest animals through consolidated landscape-scale programs.
- Manage weeds before and after fire, and during revegetation works to maximise success of restoration.
- Manage weeds at the sides of new roads and housing and industrial developments near to the ecological community by regular monitoring, and control by targeted herbicide spraying or manual removal for several years after the works are complete.
- 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 methodologies (e.g. spot-spraying, 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.

5.2.3 COMMUNICATION AND SUPPORT

Education, information and local regulation

- Develop a communication strategy, education programs, 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 local native species to plant.
- Develop education programs to discourage damaging activities such as the removal of dead timber, the dumping of rubbish (particularly garden waste), creation of informal paths and the use of off-road vehicles in patches of the ecological community.
- Encourage local participation in recovery efforts, removing threats and actively restoring existing patches, as well as facilitating these. This may be achieved by setting up a recovery team(s) 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 (taking into account local sub-communities), 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 land managers (including pastoralists, indigenous communities, IPAs, etc) are given information about managing fire for the benefit of threatened species and ecological communities.
    - Ensure commitment to follow-up after planting, such as care of newly planted vegetation by watering, mulching, weeding 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;
    - land developers and construction industries, to minimise threats associated with land development;
    - local councils and state authorities, to ensure road widening and maintenance activities (or other infrastructure or development activities) involving substrate or vegetation disturbance do not adversely impact the ecological community. This includes avoiding the introduction or spread of weeds and avoiding planning new roads or paths through patches of the ecological community.
- 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.
- 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.

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 on private tenure that contain the ecological community.
- Develop coordinated incentive projects to encourage conservation and stewardship on private land, and link with other programs and activities, especially those managed by regional catchment councils.

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. Coordination with individuals and groups with responsibilities for planning and on ground management is important to ensure that research questions and methods are well chosen, 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. It is important that any monitoring is planned before management commences, considering data requirements to address research questions. Monitoring must also be resourced for at least the duration of the management activities, especially for those using a novel approach.

High priority research and monitoring activities to inform protection, management and restoration of the Banksia Woodlands of the Swan Coastal Plain ecological community include the following:

- Review data: consolidate information over entire extent of the ecological community and improve and update maps of the ecological community across its range (e.g. Swan Bioplan mapping for areas south of Perth):
    - 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.
    - support and enhance existing programs to model the pre-European extent across the entire range of the ecological community to inform restoration; identify the most intact, high conservation value remnants and gain a better understanding of variation across the ecological community.

- Identify major sub-types of the community, and map their boundaries and condition. Determine the level of risk to sub-types.
- Dieback mapping, risk assessment.
- Integrated weed management over large areas.
- Undertake or support ongoing research aimed at managing major weeds and feral animals.
- Research the effects of fire on floristics and structure of the sub-types of the community, and fauna in patches and across the broader landscape:
    - Keep precise records of fire history.
    - Monitor the response of the ecological community to fire, using an appropriate measure (species composition, populations of key species, etc) with a monitoring design that aims to improve understanding of the response to fire of the sub-types.
    - Identify and publish appropriate fire management regimes to conserve identified sub-types, key species and the broader ecological community.
- 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
- Long term monitoring of groundwater decline and its impacts.
- Conduct research leading to the development of effective landscape-scale rehabilitation and maintenance of vegetation condition for the ecological community. Investigate the interactions between threats (e.g. fire regimes, climate change, *Phytophthora* dieback, hydrological changes) to determine how an integrated approach to threat management can be implemented.
- Emerging weeds and relationship with disturbance (fire, physical).
- Determine priority areas for restoration to enhance connectivity and landscape resilience.
- 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.
- Weed, and predator control options such as trapping and baiting, urban containment, exclusion fencing; re-introduction of key fauna.
- Understanding plant-fungal-hydrological relationships.
- Investigate key ecological interactions, 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.

- Cryptic biota and turnover.

- Legacy effects of water table decline (especially on Bassendean systems – no pH buffer capacity, water table decline results in loss of calcium, restoring water table may not restore soil chemistry).
- Further assess the vulnerability of the ecological community to climate change and investigate ways to improve resilience through other threat abatement and management actions.

Future research to optimise restoration of Banksia Woodlands (identified in Stevens et al., 2016) includes:

- alleviation of deep intractable dormancy;
- optimising broadcase seeding tehnology;
- defining genetic provenance;
- optimising plant survival;
- understanding pollination services; and
- increasing seed resources of framework *Banksia* species through native seed farming.

5.4 Offsets

Offsets are defined as measures that compensate for the residual adverse impacts of an action on the environment. Further clearance and damage to this ecological community should not occur. Therefore, offsetting is a last resort. It should only be proposed as an attempt to compensate for damage to the ecological community that is deemed unavoidable. The ecological outcomes of offsetting activities are generally uncertain: offsetting with replanted areas is insufficient as there is no guarantee that Banksia Woodlands reconstruction will be successful and, given the long ecological lags in the potential recreation of a resilient and functioning patch of the ecological community, the loss of mature banksias and other trees, for example, severely compromises the viability of the ecological community. Areas that already meet the condition thresholds are protected by this listing, so are not be used as an offset unless there is a substantial net conservation benefit such as a perpetual change in land tenure for conservation purposes, with ongoing threat abatement measures and monitoring put in place. With regard to any proposals involving offsets for this ecological community, which has been greatly reduced in spatial extent and condition, the aims are to:

- enable options to avoid the need to offset;
- retain remaining high quality patches (in good or higher condition) rather than offset;
- ensure that offsets are consistent with the wording and intent of the EPBC Act Environmental Offsets Policy (Commonwealth of Australia, 2012), including:
    - ‘like-for-like’ principles based on meeting the overall definition of the ecological community and considering the particular species composition, maturity of trees, vegetation structure and other habitat and landscape features at a particular site (e.g. do not use offsets distant from the site of impact, as there is local variation of the ecological community);

  - how proposed offsets will address key priority actions outlined in this Conservation Advice and any other relevant recovery plans, threat abatement plans and any other Commonwealth management plans;

- match offsets to the same sub-community (usually Floristic Community Type), as it is not appropriate to offset with other components of the ecological community, given the high local endemism and β-diversity;
- maintain (or increase) the overall area, quality and ecological function of the remaining extent of the ecological community and improve the formal protection of high quality areas through a combination of the following measures:
  - protecting and managing offset sites in perpetuity in areas dedicated under legislation for conservation purposes; that is, do not allow reduction in their size, condition and ecological function in the future through ongoing threat abatement measures and adaptive management based on monitoring; and/or
  - increase the area and improve ecological function of the woodlands, for example by enhancing landscape connectivity (e.g. protecting and linking smaller remnants), habitat diversity and condition; and/or
  - restoring good condition patches to meet higher condition categories (see the condition categories in the condition thresholds in Table 3), particularly to ensure that any offset sites add additional value to the remaining extent.

Restoration activities may include patches that do not meet the key diagnostics and/or condition thresholds for national protection in Table 3 but which formerly were the ecological community, have valuable landscape attributes and the likelihood of restoration to a better, more intact condition is high (hence restoration will add area to the remaining extent of the ecological community that meets the definition for EPBC Act protection in this Conservation Advice). This particular measure should not be undertaken unless in combination with one or more of the other three measures in the dot point above.

5.5 Existing plans/management prescriptions relevant to the ecological community

There is no approved state recovery plan for the ecological community, as defined in this listing. However, management prescriptions exist in the form of threat abatement plans and recovery plans relevant to the sub-communities or species that occur in it. These include:

Centre for Phytophthora Science and Management (2006). Review and Evaluation of the 2001 National Threat Abatement Plan for Dieback Caused by the Root-Rot Fungus *Phytophthora cinnamomi*. Prepared by the Centre for Phytophthora Science and Management for the Australian Government Department of the Environment and Heritage. (*Also see latest national threat abatement plan, Department of the Environment (2014), below*).

Department of Conservation and Land Management (1995).Yalgorup National Park Management Plan 1995 – 2005 No. 29.

Available on the internet at:
http://www.dpaw.wa.gov.au/images/documents/parks/management-plans/decarchive/yalgorup.pdf

Department of the Environment (2014). Threat abatement plan for disease in natural ecosystems caused by *Phytophthora cinnamomi*. Department of the Environment, Canberra.

Available on the internet at:
http://www.environment.gov.au/biodiversity/threatened/publications/threat-abatement-plan-disease-natural-ecosystems-caused-phytophthora-cinnamomi

Department of Environment and Conservation (2012). Parks and reserves of Yanchep and Neerabup Management Plan 2012 No. 76, Department of Environment and Conservation, Perth.

Available on the internet at:
http://www.dpaw.wa.gov.au/images/documents/parks/management-plans/decarchive/20120235_yanchep_mgt_plan_2012.pdf

Department of Environment and Conservation (2010). Jandakot Regional Park Management Plan 2010.

Available on the internet at:
http://www.dpaw.wa.gov.au/images/documents/parks/management-plans/decarchive/jandakot_management_plan_2010.pdf

Department of Environment and Conservation (2008). Forest Black Cockatoo (Baudin’s Cockatoo *Calyptorhynchus baudinii* and Forest Red-Tailed Black Cockatoo *Calyptorhynchus banksii naso*) Recovery Plan.

Available on the internet at:
http://www.environment.gov.au/resource/forest-black-cockatoo-baudin%E2%80%99s-cockatoo-calyptorhynchus-baudinii-and-forest-red-tailed

Department of the Environment, Water, Heritage and the Arts (DEWHA) (2008). Threat abatement plan for competition and land degradation by rabbits.

Available on the internet at:

http://www.environment.gov.au/biodiversity/threatened/publications/tap/competition-and-land-degradation-rabbits

Department of Parks and Wildlife (2014). Swan Coastal Plain South draft management plan 2014, Department of Parks and Wildlife, Perth.

Available on the internet at:
http://www.dpaw.wa.gov.au/images/documents/parks/management-plans/Swan_Coastal_Plain_South_Draft_Management_Plan.pdf

English V and Blyth J (2000). Eastern Shrublands and Woodlands (Swan Coastal Plain Community 20c) Interim Recovery Plan 2000–2003, Department of Conservation and Land Management, Western Australia.

Available on the internet at:
http://www.environment.gov.au/resource/interim-recovery-plan-eastern-shrublands-and-woodlands-swan-coastal-community-20c-2000-2003

English V and Blyth J (2006). Shrublands and Woodlands on the Eastern side of the Swan Coastal Plain (Community type 20c) Interim Recovery Plan 2006–2011, Department of Environment and Conservation, Western Australia.
Available on the internet at:
https://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/recovery_plans/Approved_interim_recovery_plans_/communities/scp20c_irp230_update.pdf

Stevens JC, Rokich DP, Newton VG, Barrett RL and Dixon KW (Eds) (2016). Restoring Perth's Banksia woodlands. UWA Publishing. Crawley, Western Australia.

5.6 Recovery plan recommendation

A Recovery Plan is not recommended at this time because the Conservation Advice sufficiently outlines the Priority Research and Conservation Actions needed for this ecological community. There are also a number of existing documents for conservation and threat abatement (e.g. Bush Forever Plan (Government of Western Australia, 2000), Restoring Perth's Banksia woodlands (Stevens et al., 2016), the Threat Abatement Plan for disease in natural ecosystems caused by *Phytophthora cinnamomi*) that support these recovery actions. Taking into account the benefits of listing the ecological community and implementation of the recovery and threat abatement priorities and actions specified in the conservation advice, a recovery plan for the ecological community is not required at this time. It is recommended that the actions in the Conservation Advice and this decision be reviewed within five years, after evaluating the effectiveness and completeness of the actions.

APPENDICES

Appendix A – Species lists

Table A1: Listed threatened flora species that are likely to occur in the Banksia Woodlands of the Swan Coastal Plain ecological community.

CR = Critically endangered, EN = Endangered, VU = Vulnerable.

WA Status = status under the *Wildlife Conservation Act 1950*.

Scientific Name	**Common Name**	**EPBC Status**	**WA Status**
Anthocercis gracilis	slender tailflower	VU	VU
Banksia aurantia	orange dryandra	CR	VU
Banksia mimica	summer honeypot	EN	VU
Caladenia huegelii	king spider-orchid	EN	CR
Calytrix breviseta subsp. *breviseta*	swamp starflower	EN	CR
Chamelaucium sp. *Gingin* (N.G. Marchant 6)	Gingin wax	EN	VU
Conospermum undulatum	wavy-leaved smokebush	VU	VU
Diplolaena andrewsii		Not listed	VU
Drakaea elastica	glossy-leafed hammer orchid	EN	CR
Drakaea micrantha	dwarf hammer orchid	VU	EN
Eucalyptus x *balanites*	Cadda Road mallee	EN	CR
Grevillea althoferorum subsp. *fragilis*		Not listed	CR
Grevillea bracteosa subsp. *bracteosa*		Not listed	EN
Grevillea christineae	Christine's grevillea	EN	EN

Scientific Name	**Common Name**	**EPBC Status**	**WA Status**
Grevillea corrugata		EN	VU
Grevillea curviloba subsp. *incurva*	narrow curved-leaf grevillea	EN	EN
Leucopogon sp. Flynn (F.Hort, J.Hort & A.Lowrie 859)		Not listed	CR
Macarthuria keigheryi	Keighery's macarthuria	EN	EN
Ptychosema pusillum	dwarf pea	VU	VU
Verticordia densiflora var. *pedunculata*	long-stalked featherflower	EN	EN

Table A2: WA priority flora species that are likely to occur in the Banksia Woodlands of the Swan Coastal Plain ecological community.

Species are not listed under the WA *Wildlife Conservation Act 1950*, but are assigned a priority status:

P1 = Priority 1: Poorly-known species (on threatened lands); P2 = Priority 2: Poorly-known species (some on conservation lands); P3 = Priority 3: Poorly-known species (some on conservation lands); P4 = Priority 4: Rare, Near Threatened and other species in need of monitoring.

Scientific name	Common name	WA status
Acacia benthamii		P2
Acacia semitrullata		P4
Actinotus whicheranus		P2
Amperea micrantha		P2
Anigozanthos humilis subsp. Badgingarra (S.D.Hopper 7114)		P2
Anigozanthos humilis subsp. *chrysanthus*	golden catspaw	P4
Boronia capitata subsp. *gracilis*		P3
Caladenia speciosa	sandplain white spider orchid	P4
Calectasia elegans	elegant tinsel lily	P2
Caustis sp. Boyanup (G.S.McCutcheon 1706)		P3
Dillwynia sp. Capel (P.A.Jurjevich 1771)		P1
Franklandia triaristata	lanoline bush	P4
Grevillea evanescens		P1
Isopogon drummondii		P3
Johnsonia inconspicua		P3
Lasiopetalum membranaceum		P3
Laxmannia jamesii	James paper lily	P4
Persoonia rudis		P3
Schoenus griffinianus		P4
Thelymitra variegata	Queen of Sheba	P2
Verticordia lindleyi subsp. *lindleyi*		P4

Table A3: Listed threatened fauna species that are likely to occur in the Banksia Woodlands of the Swan Coastal Plain ecological community.

CR = Critically endangered, EN = Endangered, VU = Vulnerable.

WA Status = status under the *Wildlife Conservation Act 1950*.

Scientific name	Common name	EPBC Act status	WA status
Mammals			
Dasyurus geoffroii	chuditch, western quoll	VU	VU
Phascogale tapoatafa wambenger	Southwestern brush-tailed phascogale, wambenger, wambenga	Not listed	VU
Pseudocheirus occidentalis	western ringtail possum	VU	VU
Setonix brachyurus	quokka	VU	VU
Birds			
Calyptorhynchus baudinii	Baudin's cockatoo	VU	EN
Calyptorhynchus latirostris	Carnaby's cockatoo	EN	EN
Calyptorhynchus banksii naso	forest red-tailed black cockatoo	VU	VU
Insects			
Leioproctus douglasiellus	A short- tongued bee	CR	EN
Neopasiphae simplicior	A native bee	CR	EN

Table A4: WA priority fauna species that are likely to occur in the Banksia Woodlands of the Swan Coastal Plain ecological community.

Species are not listed under the WA *Wildlife Conservation Act 1950*, but are assigned a priority status:

P1 = Priority 1: Poorly-known species (on threatened lands); P2 = Priority 2: Poorly-known species (some on conservation lands); P3 = Priority 3: Poorly-known species (some on conservation lands); P4 = Priority 4: Rare, Near Threatened and other species in need of monitoring.

Scientific name	Common name	WA status
Mammals		
Falsistrellus mackenziei	western false pipistrelle	P4
Isoodon obesulus fusciventer	quenda	P4
Macropus irma	western brush wallaby	P4
Birds		
Ninox connivens connivens	barking owl (southwest pop.)	P2
Tyto novaehollandiae novaehollandiae	masked owl (southwest ssp.)	P3
Reptiles		
Ctenotus gemmula (SCP pop.)	jewelled southwest skink	P3
Ctenotus ora	coastal plains skink	P1
Lerista lineata	lined skink	P3
Neelaps calonotus	black-striped snake	P3
Invertebrates		
Austroconops mcmillani	a biting midge	P2
Austrosaga spinifer	cricket	P3
Hylaeus globuliferus	bee	P3
Glossurocolletes bilobatus (syn. *Leioproctus bilobatus*)	bee	P2
Leioproctus contrarius	bee	P3
Synemon gratiosa	graceful sunmoth	P4
Throscodectes xiphos	cricket	P1
Cataxia maculata (syn. *Arbanitis inornatus*)	trapdoor spider	P1

Appendix B – Biology and ecological processes

B1. Ecology of ten common dominant trees in Banksia Woodlands of the Swan Coastal Plain

The content of this section is reproduced from Powell (2016) with permission from the editors. It contains information on components of the ecological community, including three of the four key diagnostic Banksia species.

Candle Banksia – *Banksia attenuata*

Candle banksia has a wide range, from the Murchison River to Bremer Bay. It is one of the two most common banksias on the Swan Coastal Plain, the other being the firewood banksia, *B. menziesii*. Both are typical of Perth's well-drained, nutrient-poor sandy soils.

Candle banksia is a little taller than firewood banksia, growing up to 10 metres. It can be distinguished from firewood banksia by its narrow leaves and slender, bright yellow flower spikes, produced from mid-spring to early autumn.

Associated life

When candle banksia is in flower, honeyeaters are frequent nectar feeders, and they and other birds such as robins, willie wagtails and black-faced cuckoo-shrikes pluck insects off the spikes. Bee-eaters, summer migrants to Perth, will focus on a single candle banksia, catching honeybees in the air as they approach or leave the tree. The birds often return to a favourite perch, where they remove the stings by banging them on the branch. As many as 150 stings have been found on one perch. Another bird to benefit greatly from candle banksia is Carnaby's black cockatoo, which eats both seeds and the weevil larvae in the fruiting cones.

Moth larvae burrow into the axis of candle banksia's flower spike, and the larvae of both moths and weevils burrow into the cones to eat the seeds. Candle banksia's rough bark provides habitat for the fence skink.

Ecology

Candle banksia regenerates well, if the bushland is not too weedy. Its bark resists fire, and mature trees usually survive, resprouting strongly near the ends of the branches. Young saplings are often burnt to the ground but resprout from the fire-resistant rootstock.

Candle banksia uses its cluster roots, which form dense mats near the surface, to absorb nutrients from the poor sandy soils. Such roots are highly susceptible, however, to the introduced root-rot fungus *Phytophthora cinnamomi.*

As well as its surface roots, candle banksia has deep roots that extend to moist soil just above the water table, enabling it to withstand hot, dry conditions in summer. Its occurrence well to the north of Perth shows its ability to grow in dry environments. It cannot, however, extend its deep roots quickly enough to withstand sudden drops in the water table. Many candle banksias in Perth die as a result of extraction of groundwater or pronounced drought.

Cultivation

Candle banksia is of value as one of the most typical trees of the Swan Coastal Plain and is a prime food resource for native animals and an outstanding horticultural and restoration subject.

Firewood Banksia – *Banksia menziesii*

Firewood banksia is admired for its richly coloured flower spikes. As they develop they change from silver-grey to rich pink and then to orange, pink and even red.

This small tree of up to 8 metres is typical of banksias. It is crooked and gnarled with cones that have prominent seed-filled 'beaks', toothed leaves and rough bark. Though an attractive small tree, the common name refers to past uses of the timber as firewood.

Ecology

Like candle banksia, firewood banksia regenerates well in bushland that is relatively weed-free. Young plants to older trees are fire-hardy, resprouting from the stem base or along the stem.

On the Swan Coastal Plain north of Pinjarra, firewood banksia and candle banksia are the most abundant large banksias and nearly always grow together. They flower at different times of the year, firewood banksia in autumn to early spring, and candle banksia in late spring and summer; this timing has possibly evolved so that the two species do not compete for pollinators. Some animals depend on a supply of nectar the whole year round, and these two banksias almost ensure this. There are brief periods in autumn and spring (when one species is just starting to flower and the other is finishing) when only occasional flowers are produced – but at these times other plant species are providing flowers: saw-tooth banksia (*Banksia prionotes*) in autumn, and bull banksia, holly-leaf banksia and many shrub species in spring.

Like the other banksias, firewood banksia is highly susceptible to *Phytophthora cinnamomi* or by sudden drops in the water table as a result of water extraction.

Associated life

Firewood banksia's flowers are a valuable source of nectar to honey-foraging birds and insects. The cones are used by the burrowing larvae of two species of weevil, and the larva of a moth burrows in the flower spikes. Another moth larva eats the tissue between a leaf's surfaces, producing scribble-like marks.

Brown pouch-like blisters on the leaves are caused by a rust-fungus (similar blisters on saw-tooth banksia are caused by a scale insect).

In Bold Park, over four years, more than 20 species of macrofungi have been observed fruiting on a dead log of firewood banksia, illustrating the ecological value of dead wood in bushland. A succession of different fungi appear as the log ages.

Cultivation

As one of the two most typical banksias of Perth's coastal plain, firewood banksia is an important framework species in restoration providing forage and roosting sites for a number of birds and insect species.

Holly-leaf Banksia – *Banksia ilicifolia*

Holly-leaf banksia is quite distinctive among banksia trees in possessing flowers in compact heads, rather than spikes, with short and broad, rather than long, leaves. Growing to about 10 metres, it is of similar size to candle banksia, firewood banksia and bull banksia, but is more upright in habit. Like other banksias, it produces its new leaves chiefly in summer.

It is less abundant than candle banksia or firewood banksia, occurring as scattered individuals or in small groups, particularly in low-lying areas close to the water table.

Ecology

Holly-leaf banksia flowers change colour from yellow to pink then finally red. The pink and red flowers help to attract honey-eating birds from a distance, but only the yellow flowers contain substantial amounts of nectar and pollen. Both the insects and the birds feed almost exclusively on these flowers, which are also the flowers whose stigmas are receptive to pollination.

The seeds of holly-leaf banksia develop more rapidly than those of many other banksias, taking less than three months to mature. The seeds are rarely destroyed by insects, probably because there is insufficient time for the insects to develop.

In other aspects of its ecology, holly-leaf banksia is like the other banksias. It usually survives fire, unless intense; but it is highly susceptible to the introduced pathogen *Phytophthora cinnamomi*, and to sudden drops in the water table. Large areas of holly-leaf banksia are now locally extinct as a result of water extraction on the coastal plain.

Associated life

The western spinebill, the red and little wattlebirds and the brown and New Holland honeyeaters feed on the flowers as do a variety of native bees, ants and beetles.

Because it flowers throughout the year, holly-leaf banksia is one of the most important sources of food for twig-mound ants (*Iridomyrmex conifer*), which often build their nests of twigs near the base of this tree.

Holly-leaf banksia's foliage supports more insect species than that of candle banksia or firewood banksia.

Cultivation

This distinctive banksia should be grown a lot more on suitable sites.

Common Sheoak – *Allocasuarina fraseriana*

Common sheoak is the large sheoak of Banksia woodlands. On the coastal plain it can grow up to 12 metres, slightly taller than the banksias. Unlike the banksias it lacks showy features, and tends to be overlooked or poorly appreciated. As with most sheoaks, the male and female flowers are borne on separate trees, and the tiny but numerous male flowers give a dusting of rich brown in late winter and early spring. The species is wind-pollinated.

Ecology

Many sheoaks are hardy species that grow in inhospitable environments, but that is not true of common sheoak. It cannot tolerate as dry conditions as candle banksia or firewood banksia, whose range extends to the Murchison River; common sheoak occurs to just north of Perth. In Kings Park, many specimens died or declined in the droughts of 2006 and 2007. Mature specimens will often survive fire if it is not too severe, but often die back to near the base.

Near the coast, common sheoak is less resistant than many of its associated trees to salt winds. Specimens thus affected are picturesque, often with a graceful lean, foliage concentrated into clumps and layers, and a decoration of dead twigs.

Associated life

Common sheoak harbours a great variety of insects, including three species of jewel beetle. A species of sap-sucking bug lives in the twigs, exuding honey-dew through its protruding white, hair-like tube. The honey-dew collects on the branchlets, and falls to the ground to form damp, sticky areas. Ants and wasps eat this honey-dew, and small native cockroaches eat the black smut-fungus that often develops on it. These, along with crickets, also eat the ‘needles’, the slender green branchlets that function as leaves. ‘Witch’s brooms’, the distorted hanging branches found on some specimens of common sheoak, are thought to be a response to the sap-sucking bugs or infection by microorganisms.

Common sheoak provides shade, used by butterflies such as the marbled xenica and common brown for shelter on hot days. Ringneck parrots eat the seeds, which they pluck from the cones.

Human uses

Common sheoak’s timber is prized for its beauty. Although not readily available commercially, it is used to a limited degree for decorative turning or carving.

As a tree, however, common sheoak is rarely cultivated. It should be considered for planting in parks and median strips for its beautiful form, and as a reminder of Perth’s original vegetation.

Bull Banksia – *Banksia grandis*

Bull banksia grows widely on the Swan Coastal Plain but, unlike candle banksia and firewood banksia, occurs most abundantly in places heavily timbered with eucalypts. It is typical of the tuart belt, near the coast; and of areas dominated by marri on the alluvial soils of the plain’s eastern side.

The tree, of similar size to candle banksia, stands out with its elongated and deeply divided leaves, with distinctive large flower spikes and cones, supported by thick stems. It is simple and bold in appearance.

Ecology

Bull banksia can live for 100 to 150 years. Mature specimens are mostly resistant to fire but can be killed if the fire is intense. Saplings can resprout from an underground rootstock.

Bull banksia protects its seeds from attack by insects by producing a thickened stalk on flower spikes that allows them to repair damage caused by moth larvae burrowing through the woody axis. The seed follicles barely protrude from the cone and so do not advertise their presence. They remain very small for a year or so, then develop rapidly and release the seed. The seeds are released in autumn and are carried, usually 5–10 metres, by the wind.

Bull banksia is highly susceptible to the introduced root-rot water mould *Phytophthora cinnamomi*.

Associated life

Bull banksia flowers in spring and early summer, benefiting the abundant insects at this time. The nectar is also of value to birds such as honeyeaters, wattlebirds and the silvereye as well as being a favourite for the once abundant but now rare and locally extinct honeypossum.

The seeds are eaten by Carnaby's black cockatoo, the red-capped parrot and moth larvae. Other moth larvae feed in the flower spikes.

Human uses

Aboriginal people would suck the flower spikes for nectar. The nectar and pollen are now useful to beekeepers, particularly in bridging the gap between the flowering of parrot bush and jarrah.

Marri – *Corymbia calophylla*

Marri occurs widely throughout the southwest of Western Australia. On the Swan Coastal Plain it is most abundant in the alluvial soils near the Darling Scarp; elsewhere it is more localised, favouring spots where the soil is moister or more fertile. It is a large tree, up to 30 metres in the Darling Range but smaller on the coastal plain.

Marri's large, thick, woody, urn-shaped fruits, known as 'honkey nuts', identify it as one of the bloodwood eucalypts, in the genus *Corymbia*. Another bloodwood characteristic is marri's splendid display of flowers in conspicuous terminal clusters, usually seen in autumn.

Associated life

Marri is known to support up to 800 species of invertebrate (chiefly insects), on its foliage, stems, wood, bark and leaf litter. It thus makes an important contribution to the biodiversity of Perth's Banksia woodlands. The larvae of long-horned beetles and other wood-boring insects eat the wood, causing the characteristic bleeding of gum. In autumn, this gum attracts clusters of common brown butterflies.

The seeds are a major food of Baudin's black cockatoo, Carnaby's black cockatoo and various parrots; the ringneck and red-capped parrots chew the soft, immature fruits. The flowers' abundant nectar and pollen attract many birds, such as purple-crowned lorikeets, silvereyes, red and little wattlebirds, and brown and New Holland honeyeaters, as well as insects such as bees, wasps, ants, beetles, butterflies and moths. In fruit-growing districts, parrots and silvereyes are much less apt to eat cultivated fruit when marri is flowering heavily.

Stalked mistletoe readily grows on marri, augmenting the tree's biological value by supporting additional birds and insects.

Marri casts a heavier shade than do most eucalypts, and is of value to wildlife that seek shelter on hot days.

Ecology

Marri's large seeds produce robust seedlings, of which many survive, even on weedy sites. They soon develop a lignotuber, enabling them to resprout after fire. Mature marri trees have fire-resistant bark, and usually resprout after fire.

The native fungus *Quambalaria coyrecup* is responsible for marri canker, causing wounds to develop on the twigs, branches or trunks of stressed marri trees. Since the 1970s far more marri trees have succumbed to the disease, perhaps because of the drying of the climate.

Some care is required in restoration plantings as understorey species can be suppressed by the deep shade cast by marri.

Human uses

Because it provides good shade, marri is valuable on farms as shelter for stock. It is one of the major honey plants of the southwest, with useful pollen and excellent honey. The wood is strong and easily worked. With its light yellowish colour and attractive gum veins, it is popular for furniture.

Tuart – *Eucalyptus gomphocephala*

Tuart is the most typical eucalypt of the coastal dunes and limestone along the western side of the Swan Coastal Plain. It is also the Plain's largest tree, some Perth specimens growing to more than 30 metres tall and two metres across near the base. Its grey-green foliage is glossier than that of most of Perth's eucalypts. Tuarts' bark, compared with that of Perth's other rough-barked species, is noticeably the palest. It has been known as 'white gum', a name preserved in the name of the suburb White Gum Valley.

Ecology

Wherever it occurs, tuart dominates, by growing larger and also much faster than jarrah or marri, and being a good coloniser of disturbed sites. Thick growths of weeds, however, may suppress its regeneration.

Unlike most Perth eucalypts, tuart does not develop a true lignotuber, and relies mostly on its bark to protect it from fire. Many saplings are killed, but some recover by shooting from a slight swelling at the base of the stem.

Tuarts can survive near-coastal exposure though leaves will show salt-scorch following high winds. Tuart in exposed locations will branch low, often right at the base, into two, three or more main stems.

Associated life

Tuart is one of Perth's most biologically valuable trees. Like many eucalypts growing in their natural environment, tuart supports a great diversity of insects and other invertebrates. Being vigorous and growing in more fertile soils than jarrah or marri, it is likely to be even richer in associated insects. Further insects are supported by bracket fungi or mistletoe growing on tuart.

Hollows in mature and old trees are used by tree-martins, red-capped parrots and other native animals. Hollow trunks support ringneck parrots, kestrels, sacred kingfishers, brushtail possums and false pipistrelle bats.

Human uses

Tuart's timber is hard, dense and strong, with an interlocked grain. It was largely used to construct railway wagons, where it had to withstand strains and abrasions. It is no longer available, since the forest at Ludlow from which it was cut is now the Tuart Forest National Park.

Tuart is widely cultivated in southern Australia and many countries overseas, and is especially valued in the Mediterranean for its high tolerance of winds and alkaline soils. In Perth it is sold in nurseries, and in recent years has been planted by local governments in parks and open spaces. Where space permits, this distinctive tree should be grown in its natural belt of occurrence for its beauty and its biological and heritage value.

Jarrah – *Eucalyptus marginata*

Jarrah is the most common eucalypt on the Swan Coastal Plain, where it occurs as a quite open woodland, associated chiefly with banksias and common sheoak. Here jarrah does not grow tall, often less than 15 metres – but older specimens become stout and spreading, with thick, often quite horizontal branches.

Jarrah is famous for its beautiful red timber, hard but easily worked; thus many of the larger trees, both on the Darling Range plateau and on the Swan Coastal Plain, have been felled. The slender specimens seen today on the plateau are subsequent regrowth such as found in the bushland of Kings Park.

Associated life

Jarrah is known to support about 800 insects and other invertebrates, in its foliage, stems, wood, bark and leaf litter, and thus makes an important contribution to the biodiversity of Perth's Banksia woodlands.

On the coastal plain, jarrah's foliage often turns brown in spring, when the larvae of a small moth, the jarrah leaf miner, eat the tissue between the leaves' outer layers. These larvae are eaten by birds such as pardalotes, thornbills and parrots.

Jarrah flowers in the warm days of late spring and early summer. Many adult insects appear at this time and visit the flowers for pollen or nectar, including two common butterflies, the Australian painted lady and the common brown.

Ecology

In the past, jarrah has been a very successful tree, tolerating infertile soils, resisting fire well and reproducing abundantly. Today many trees die from root-rot, caused by the water mould *Phytophthora cinnamomi*, although less so on the western side of the coastal plain. Further trees die when ringbarked by wood-borers – or appear to die, later resprouting from their lignotubers (woody swellings just below ground level). They become susceptible to the borers as a result of stress, perhaps from rapidly dropping water tables. In grassed parks in the limestone belt irrigated by bore water, jarrah trees suffer from chlorosis (chlorotic decline syndrome) if that water is too alkaline.

Cultivation

Although jarrah is admired for the forest it forms on the Darling Plateau, it largely goes unrecognised on the coastal plain. This typical tree, which reflects Perth's natural environment, should be planted much more in our parks and other suitable places, and given conditions to encourage its good health.

Pricklybark – *Eucalyptus todtiana*

Pricklybark is an attractive mallee or small tree, reflecting the infertile soils in which it grows. It is usually much broader than tall, with a height of only 9–15 metres. Its branches often droop, weighed down by large clusters of fruits.

The bark is thick and rough, and composed of distinctive fine, tough fibres giving the tree its common name 'pricklybark'.

Associated life

The various marks on its leaves show that pricklybark supports insects such as leaf miners, sawflies and weevils.

A very visible feature on pricklybark's stems are large spherical galls, sometimes almost the size of ping pong balls. These are made by the females of an eriococcid bug, a species of *Apiomorpha*, which live inside them.

Pricklybark's abundant flowers in late summer are an important source of nectar for honey-eating birds and insects. The seeds are eaten by Carnaby's black cockatoo.

Ecology

Pricklybark often grows in places too infertile or dry for large trees to develop, and its associated trees are chiefly banksias. To obtain plenty of sunlight, it need only grow taller than the banksias, and it often barely does.

Pricklybark survives fire well; if badly damaged it develops new branches from near the base or from a lignotuber. Since pricklybark is not tall, the new branches do not have far to grow before their foliage becomes part of the tree's main canopy. Even if the original trunk is reduced to a stump, the tree still recovers. The size of some such stumps suggests that pricklybark is long-lived.

Like jarrah, pricklybark can suffer from chlorosis in grassed parks in the limestone belt, if the bore water with which the grass is irrigated is too alkaline.

Cultivation

Pricklybark is full of character and, like jarrah, makes an ideal horticultural subject. It is a hardy tree, withstanding dry conditions, and has the further advantage of small size, enabling its use where space is limited or under powerlines. Slow-growing and floriferous when mature, pricklybark nonetheless grows strongly as a sapling if planted in an open position.

Christmas Tree – *Nuytsia floribunda*

Christmas tree is well known for its dense masses of brilliant orange flowers in early summer. The species has no close relatives and is the world's largest mistletoe. In growing from the ground as a tree, it is unlike other members of the family, which parasitise branches of trees.

Ecology

Christmas tree is semi-parasitic. Its roots extract water and nutrients from the roots of nearby trees. Christmas tree is the only mistletoe with dry, winged fruits, dispersed by the wind. From a tree of good size, the fruits usually can disperse many metres. Seeds are shed between early autumn and mid-winter. The single seed of each fruit germinates readily after being soaked by autumn or winter rains.

The seedlings remain shrubby for several years, often dying back to a few twigs in summer. Seven to 20 years after germination, they send up a single stem that grows strongly and develops into a tree. At this stage flowering begins. Christmas tree also reproduces by suckering: new plants sprout from a large network of underground stems. Groups of saplings are thus often seen around mature specimens.

Christmas tree does not have true wood, but rather concentric circles of cork-like material. The trunk and branches, although thick, are not strong, and bend under the weight of the foliage and terminal flowers.

Associated life

During its short period of flowering, Christmas tree is one of the richest sources of pollen and nectar for insects such as bees, wasps, ants and nectar-eating beetles, and is particularly favoured by the spotted jezebel butterfly. The flowers also attract birds such as the red wattlebird, little wattlebird, brown honeyeater, western spinebill, New Holland honeyeater and silvereye. The yellow-rumped thornbill, black-faced cuckoo-shrike and rainbow bee-eater eat insects attracted to the flowers. Up to six bee-eaters have been seen congregating at a single tree, perching nearby and darting out to catch the insects in the air.

Christmas tree's foliage is more nutritious than that of the banksia species with which it associates, and appears to support more insect species.

Cultivation

Only rarely is Christmas tree cultivated. Seedlings take a long time to develop and flower. In cultivation they also need generous watering over the first few summers. Christmas tree would, however, be a lovely addition to many parks and gardens, well worth the time and effort it takes to grow it. It is also possible to transplant mature specimens, though the procedure should be undertaken by a qualified person.

Table B1: Banksia species description and phenology

Main flowering period highlighted by darker shading (reproduced from Johnston, 2013).

Species	Common name	Brief Description	Flowering												*Ref*	Seed maturation (months)
			J	F	M	A	M	J	J	A	S	O	N	D		
B. attenuata	Candlestick Banksia, Slender Banksia	Shrub or tree 2-10m. Leaves broadly linear, truncate, 4-27cm long, 5-16mm wide at flowering. Inflorescence conspicuous, cylindrical, 5-26cm long, 3.5-5cm wide at flowering. Flowers bright yellow. [b]													a,b	12–17 [e]
B. ilicifolia	Holly-leaved Banksia	Tree to 10m. Leaves obovate-elliptic, undulate, truncate or obtuse mucronate, 3-10cm long. Inflorescence on short branchlets, head-like, 7-9cm wide. Flowers cream and pink. [2]													a,b	<3
B. menziesii	Firewood Banksia	Shrub or tree 3-10m. Leaves oblong, truncate, 8-25cm long, 1-4cm wide. Inflorescence ovoid-cylindrical, 4-12cm long, 7-8cm wide at flowering. Flowers deep pink, red and/or yellow. [b]													a,b	unknown
B. prionotes	Acorn Banksia	Shrub or tree to 10m. Leaves broadly linear, obtuse, 15-27cm long, 1-2cm wide. Inflorescence conspicuous, ovoid, 7-15cm long, 7-8cm wide at flowering. Flowers cream and orange. [b]													a	unknown
B. grandis	Bull Banksia	Tree to 10m. Leaves obovate-cuneate, truncate, 10-45cm long, 3-11cm wide. Inflorescence cylindrical, 10-40cm long, 7-9cm wide at flowering. Flowers pale yellow. [b]													a,b,c	12–14 [f,g]
B. sessilis	Parrot Bush	Shrub 0.8-5m. Leaves cuneate-obovate, obtuse or acute, pungent, 1-4cm long, 5-20mm wide. Inflorescence headlike, 2-4cm wide. Flowers cream-yellow. [c]													d	unknown

References: [a] Whelan and Burbidge (1980), [b] George (1984), [c] Marchant et al. (1987), [d] Collins et al. (2008), [e] Stock et al. (1992), [f] Scott (1982), [g] Abbott (1985).

B2. Further relevant biology and ecology

Plant – animal - fungal interactions

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Banksia woodlands are much more than trees. The rich flora of these areas is composed mostly of low shrubs and perennial and annual herbs (small, soft-stemmed plants). Of the 300 plant species that occur naturally in Kings Park, for example, only 12 are trees, and 33 are medium to large shrubs (such as basketbush, *Spyridium globulosum*); all the rest, apart from a few climbers and mistletoes, are low shrubs or herbs.

Of the animals, the vertebrates – mammals, birds, reptiles and amphibians – comprise only a small proportion of the species. The majority, numbering several thousand, are invertebrates, mostly insects but also spiders, springtails, scorpions, mites, centipedes, millipedes, snails and earthworms.

The invertebrates, as a group, contribute far more than the vertebrates to a woodland's ecology. The many invertebrates that live in the soil or leaf litter are vitally important in breaking down dead or discarded remains, animal or vegetable, and returning nutrients to the soil for reuse. The great majority of plant pollinators are insects: native bees, wasps, beetles, moths, butterflies, and so on. Although some plants are adapted for pollination by honey-eating birds, many others rely solely on insects or other invertebrates. Indeed, some plant species require pollination by a particular insect, or group of insects. Some hammer orchids (*Drakaea* spp.), for example, rely on a single species of flower wasp in the family Thynnidae. Invertebrates keep a check on plant growth, as they or their larvae eat leaves, buds, fruits or seeds, helping to maintain a natural balance of plant species. Numbers of the herbivorous invertebrates are themselves controlled by their many invertebrate predators (spiders, dragonflies and many wasp species) and parasites (further wasps and many flies). And all these groups together provide the main food for most of the woodland's vertebrate animals: many of the bird species, plus bats, lizards and frogs.

While some invertebrates use a wide range of plants for their food, others have evolved in close association with particular plants. A typical butterfly of Banksia woodlands, for example, the fringed heath blue (*Neolucia agricola*), breeds only on understorey pea-plants such as rattlepods (*Daviesia divaricata*). A small understorey plant such as common buttercups (*Hibbertia hypericoides*) will not support as many invertebrate species as, say, jarrah (*Eucalyptus marginata*); but collectively, the understorey species enormously increase the numbers and diversity of invertebrates in the woodland. Moreover, the greater diversity of a woodland with rich and healthy understorey layers benefits its vertebrate fauna directly by providing different sorts of site for shelter or nesting, and more nectar at all seasons of the year.

One of the chief reasons why non-local plants such as veld grass (*Ehrharta calycina*), or sugar gum (*Eucalyptus cladocalyx*) often threaten to displace native plants is the absence of many of their normal herbivorous insect associates. However, a dense understorey of the woodland's natural species will compete with these invading plants, reducing their vigour and making it harder for weeds to spread and multiply.

Like invertebrate animals, native fungi too play significant roles in our ecosystems. They are major recyclers, breaking down organic matter into nutrients available to plants as well as attaching themselves to the roots of plants to form mycorrhiza. The fungi act like an additional root system for the plants: they spread through the soil, gathering and passing nutrients to the plants in forms that the plants can use. This service is particularly valuable to plants in Banksia woodlands, where the soils are infertile. The Banksias themselves, however, cope with the low nutrient status of the soils by having what are called cluster (proteoid) roots, which form dense mats near the soil's surface, and absorb nutrients very efficiently.

Like herbivorous insects, even where fungi damage plants they thereby help to keep the vegetation in balance and enhance its value as habitat. Fungi that eat the wood of dead or live trees create hollows, used by birds and other wildlife for nesting or shelter. A common fungus on the stems of coojong (*Acacia saligna*), the gall rust-fungus (*Uromycladium tepperianum*), forms globular swellings where additional insects, such as moths and beetles, can live. The honey fungus (*Armillaria luteobubalina*) can kill trees and shrubs by attacking their roots, opening up the vegetation in places, allowing coloniser plants to establish, thus creating a more diverse vegetation. Only when the vegetation is already disturbed or under stress (for example, from drought or introduced pathogens) can honey fungus or other native fungi cause serious damage to a species or a woodland as a whole.

To sum up, natural Banksia woodlands are rich and complex systems of interdependence between plants, fungi, invertebrate and vertebrate animals. In setting out to restore or rehabilitate Banksia woodland we should keep these interactions in mind as much as possible.

Connectivity

Connectivity is essential as wildlife corridors for seasonal movement of fauna (eg. small bird species, invertebrates), and to act as refugia and corridors for recolonisation after catastrophic events such as fire and hailstorms in a fragmented landscape. For example there are at least twelve species of small birds which move seasonally across the Swan Coastal Plain from east to west and north to south for summer feeding along coastal heathlands, returning east for winter spring feeding and nesting in Banksia Woodlands. Many small bird species need cover of vegetation to safely move across the landscape. Even large birds such as the endangered Carnaby's Cockatoo require corridors of Banksias and Eucalypts for resting and feeding in their longer daily journeys. Invertebrates are also highly dependent on connectivity across the landscape.

B3. Aboriginal (Nyoongar) knowledge and seasons

The Swan Coastal Plain was traditionally abundant in water supplies, and a variety of environmental zones provided rich resources to the Whadjuk, Binjareb and Wardandi Noongar people. Land use patterns of the Nyoongar people were based on seasonal and environmental factors. The rivers and the associated creek systems, the flow of lakes, wetlands and surrounding landscape were not only an important economic resource but were also intricately linked to the Dreaming stories of ancestral beings (O'Connor et al., 1989, 1995; cited in DPaW, 2014a).

In the southwest of Australia, the Nyoongar seasonal calendar includes six different seasons in a yearly cycle. The information below is reproduced from BOM (2016).

These are Birak, Bunuru, Djeran, Makuru, Djilba and Kambarang. Each of the six seasons represents and explains the seasonal changes we see annually. The flowering of many different plants, the hibernation of reptiles and the moulting of swans are all helpful indicators that the seasons are changing.

The Nyoongar seasons can be long or short and are indicated by what is happening and changing around us rather than by dates on a calendar.

This six-season calendar is extremely important to Nyoongar people, as it is a guide to what nature is doing at every stage of the year, as well as understanding respect for the land in relation to plant and animal fertility cycles and land and animal preservation.

There are different ways to spell Nyoongar (e.g. Noongar, Nyungar, Nyoongar, Noongah) and Nyoongar words. Nyoongar language, like all traditional languages in Australia is an oral language. Throughout this calendar, we have maintained the spelling as Nyoongar, and we respectfully include all people in the southwest.

Summaries of each of the six seasons are at Table C3 and the following pages.

Table B2. Nyoongar calendar of six seasons for southwest WA (BOM, 2016).

This table and the following information on each season outlines some of the Aboriginal knowledge of the seasons, food resources, management and plant and animal phenology in the region.

The timing of the six Nyoongar seasons with respect to European months and seasons is approximate. Their timing varies, depending on how nature is responding. A season may be longer or shorter for any given year.

December - January	February - March	April - May	June - July	August - September	October - November
Birak	**Bunuru**	**Djeran**	**Makuru**	**Djilba**	**Kambarang**
Dry and hot	Hottest part of the year	Cooler weather begins	Coldest and wettest time of the year; more frequent gales and storms	Mixture of wet days with increasing number of clear, cold nights and pleasant warmer days	Longer dry periods
Season of the young	Season of adolescence	Season of adulthood	Fertility season	Season of conception	Season of birth

Summaries of each of the six seasons begin on the next page.

Birak

Birak season sees the rains ease up and the warm weather really start to take hold. The afternoons are cooled by the sea breezes that abound from the southwest. This was the fire season, a time to burn the country in mosaic patterns.

An almost clockwork style of easterly winds in the morning and sea breezes in the afternoon, meant that traditionally this was the burning time of year for Nyoongars.

They would burn the country in mosaic patterns for several reasons including fuel reduction, increasing the grazing pastures for some animals, to aid in seed germination for some plants and for ease of mobility across the country.

As for the animals, there are many fledglings now venturing out of nests, though some are still staying close to their parents. Reptiles are looking to shed their old skin for a new one.

With the rising temperatures and the decreasing rainfall, it's also time for the baby frogs to complete their transformation into adulthood.

Bunuru

Bunuru is the hottest time of the year with little to no rain. Hot easterly winds continue with a cooling sea breeze most afternoons if you're close to the coast. Therefore, traditionally this was, and still is, a great time for living and fishing by the coast, rivers and estuaries. Because of this, freshwater foods and seafood made up major parts of the diet during this time of year.

Bunuru is also a time of the white flowers with lots of white flowering gums in full bloom, including Jarrah, Marri and Ghost Gums.

Another striking flower that is hard to go past is the female Zamia (Macrozamia riedlei). Being much larger than that of its male counterpart, the huge cones emerge from the centre of the plant with masses of a cotton wool like substance.

As the hot, dry weather continues the seed upon the cones change from green to bright red, indicating they're ripening and becoming more attractive to animals, particularly the emu, that will eat the toxic fleshy outer.

Djeran

Djeran season at last sees a break in the really hot weather. A key indicator of the change of season is the cool nights that once again bring a dewy presence for us to discover in the early mornings.

The winds have also changed, especially in their intensity, with light breezes being the go and generally swinging from southerly directions (i.e. south east to south west). Many flying ants can be seen cruising around in the light winds.

Djeran is a time of red flowers especially from the Red Flowering Gum (Corimbia ficifolia), as well as the smaller and more petite flowers of the Summer Flame (Beaufortia aestiva). As you travel around the Perth area, you may also notice the red 'rust' and seed cones forming on the male and female Sheoaks (Allocasuarina fraseriana). Banksias start to display their flowers, ensuring that there are nectar food sources for the many small mammals and birds that rely upon them.

Traditionally, foods at this time of year included the seeds that had been collected and stored for treatment from the Zamia last season along with the root bulbs of the Yanget (Bullrushes), fresh water fish, frogs and turtles.

As the season progresses, the nights will become cooler and damper along with some cool and rainy days which also means that traditionally mia mias (houses or shelters) were now repaired and updated to make sure they were waterproofed and facing in the right direction in readiness for the deep wintery months to come.

Makuru

Makaru sees the coldest and wettest time of the year come into full swing. Traditionally, this was a good time of the year to move back inland from the coast as the winds turned to the west and south bringing the cold weather, rains and occasionally snow on the peaks of the Stirling and Porongurup Ranges.

As the waterways and catchments started to fill, people were able to move about their country with ease and thus their food sources changed from sea, estuarine and lake foods to those of the lands in particular the grazing animals such as the kangaroo. As well as a food source, animals provided people with many other things. For example, 'Yongar' or kangaroos not only provided meat but also 'bookas' (animal skin cloaks that were used as the nights became much cooler). Nothing was left; even the bones and sinews were used in the manufacturing of bookas and for hunting tools such as spears.

Makuru is also a time for a lot of animals to be pairing up in preparation for breeding in the coming season. If you look carefully, you might now see pairs of 'Wardongs' (ravens) flying together. You also notice these pairs not making the usual 'ark ark arrrrrk' that these birds are well known for when flying solo. Upon the lakes and rivers of the South West, you'll also start to see a large influx of the Black Swan or 'Mali' as they too prepare to nest and breed.

Flowers that will start to emerge include the blues and purples of the Blueberry Lilly (Dianella revoluta) and the Purple Flags (Patersonia occidentalis). As the season comes to a close, you should also start to notice the white flowers of the weeping peppermint (Agonis flexuosa) as the blues start to make way for the white and cream flowers of Djilba.

Djilba

Djilba season is a time to look for the yellow and cream flowers starting on mass.

Djilba is a transitional time of the year, with some very cold and clear days combining with warmer, rainy and windy days mixing with the occasional sunny day or two.

This is the start of the massive flowering explosion that happens in the South West. This starts with the yellow flowering plants such as the Acacias. Also colours that are around at this time of year are creams, combined with some vivid and striking blues.

Traditionally, the main food sources included many of the land based grazing animals as in the season before. These included the Yongar (kangaroo), the Waitj (emu) and the Koomal (possum).

As the days start to warm up, we start to see and hear the first of the new borns with their proud parent out and about providing them food, guiding them through foraging tasks and protecting their family units from much bigger animals, including people.

The woodland birds will still be nest bound, hence the swooping protective behavior of the Koolbardi (Magpie) starts to ramp up and if watched closely, so to do the Djidi Djidi (Willy Wag Tails) and the Chuck-a-luck (Wattle Birds) to name a couple of others.

As the season progresses and the temperatures continue to rise, we'll start to see the flower stalks of the Balgas (Grass Trees) emerging in preparation for the coming Kambarang season.

Kambarang

During the Kambarang season, we see an abundance of colours and flowers exploding all around us. The yellows of many of the Acacias continue to abound, along with some of the Banksias and many other smaller delicate flowering plants including the Kangaroo Paw and Orchids. Also during this time the Balgas will also start to flower, especially if they've been burnt in the past year or closely shaved.

One of the most striking displays of flowers to be seen during this season will be the "Mooja", or Australian Christmas Tree (Nuytsia). The bright orang/yellow flowers serve to signal the heat is on its way.

For the animals, October is also the most likely time of the year that you'll encounter a snake as the reptiles start to awaken from their hibernation and look to make the most of the warm to assist them in getting enough energy to look for food. It's also a time that many young families of birds will be singing out for their parents to feed them. Koolbardies (Magpies) will also be out protecting their nests and their babies.

Many things are undergoing transformation with the warm change in the weather.

Longer dry periods accompany a definite warming trend.

Appendix C – Detailed description of national context

C1. Relationships to other vegetation classifications

Broad structural units (Beard Vegetation Associations)

A consistent vegetation classification system for Western Australia was developed by John Beard and associated ecologists from the mid 1960s. The available state-wide vegetation datasets are hierarchical and encompass three scales:

- vegetation systems – a broad landscape-level classification that combines elements of vegetation and landscape types;
- vegetation associations – purely vegetation units that share a consistent structure and with the same dominant species in the main vegetation layer; and
- vegetation system–associations – a finer-scale classification that provides more detail about vegetation associations in the context of particular systems.

The Banksia woodlands were mapped using structural criteria at a scale of 1:250,000. Beard recognised that at this broad scale there were major differences in co-dominants from north to south - *Eucalyptus todtiana* north, *Allocasuarina fraseriana* central and *Eucalyptus marginata* south. Differences were also mapped in relation to the understories on the two major dune systems, the Spearwood and Bassendean Dunes (Keighery and Keighery, 2016).

Recent analysis to map the Banksia Woodlands ecological community across the entire Swan Coastal Plain bioregion resulted in the identification of up to 49 system associations as containing some component of the Banksia Woodlands ecological community. Overall, the key *Banksia* species are regarded as a major component of the vegetation for fourteen system-association units, e.g. woodlands clearly dominated by the key *Banksia* species (Table C1-A). Another thirteen units partially correspond to the ecological community in that the key *Banksia* species are present in the canopy as a mix with other tree genera, often expressed as an upper canopy of eucalypts with a lower canopy of *Banksia*, or a mixed canopy (Table C1-B). The remaining units are regarded as minor, since their descriptions do not show the key *Banksia* species as a significant component in the general description (Table C1-C). However, site-specific mapping indicates the presence of some local patches that may be consistent with the description of the ecological community. These minor units generally refer to eucalypt or other woodlands that fall outside the description of the Banksia Woodlands ecological community, for the most part.

Banksia Woodlands were the dominant vegetation type of the Swan Coastal Plain at the time of European settlement. Nineteen vegetation associations across the Swan Coastal Plain bioregion are considered dominant vegetation units, in that they collectively accounted for 85 percent of the pre-European extent of vegetation in each subregion (DPaW, 2014). Of these, nine dominant vegetation associations correspond to major and partial components of the Banksia Woodland ecological community. Altogether, the major and partial components identified in Table C1 collectively account for 46 percent of the pre-European extent of native vegetation in the Swan Coastal Plain.

Broad Scale Geomorphic Classification (Vegetation Complexes)

The mapping of Beard vegetation types and vegetation complexes produce mappable products that show the broad climatic, soil and geographic variation of Banksia Woodlands which are useful in broad scale land use planning. However this mapping does not encompass the understorey variation (total floristic variation) and the location of this variation, or describe any set locality on the ground (Keighery and Keighery, 2016). In addition, the mapping is quite approximate and requires further ground truthing.

Following the Beard classifications, a number of vegetation complexes containing areas of *Banksia* woodlands were mapped for the Swan Coastal Plain from south of the Moore River (Heddle et al., 1980; Havel and Mattiske, 2000). These complexes were identified at a regional and finer scale than was possible for the State-wide Beard vegetation associations. Those containing Banksia Woodlands are shown in Table C2 with the vegetation complexes stratified according to whether they are strongly or moderately associated with the ecological community. Complexes which may include a minor component of Banksia woodlands also are listed. These minor components generally are other vegetation types but may include some patches of Banksia Woodlands, for instance on atypical landscapes within the complex such as elevated areas within a low-lying wetland region. Fourteen vegetation complexes are regarded as strongly associated with the Banksia Woodlands ecological community, four complexes are moderately associated and another six complexes may have a minor component.

Regional Floristic Studies (Floristic Community Types)

To further address the floristic variation in the total flora of plant communities, standard quadrat and bushland area sampling is used. These data are assembled from standard quadrats or relevés of 10m x 10m. Several decades of detailed quadrat and area based on floristic studies has recorded over 1,200 native taxa for the coastal plain around Perth (Gibson et al., 1994; Government of WA, 2000). The principal aims of these studies, and the larger regional study of which they were part, were to understand the patterning, distribution and regional conservation of the native vegetation and flora to inform conservation planning (Government of WA, 2000). These studies form the basis of a substantial database of the many species of Banksia Woodland communities with attached ecological data which can be used to better know the understorey flora of the Banksia Woodlands. The low shrubs, grasses, herbs and sedges of the vegetation layers are vital components of the woodlands (Keighery and Keighery, 2016).

Floristic Community Types that relate to the Banksia Woodlands ecological community are listed in Table 1 and further details on each FCT are below in section *C2 – Detailed information on sub-communities*.

Table C1: Beard Vegetation and System Associations that include a Banksia Woodlands component and occur in the Swan Coastal Plain bioregion (SWA). Corresponding National Vegetation Information System (NVIS) level 6 descriptions are also shown. The system-associations have been split according to the degree to which each corresponds to the description of the Banksia Woodlands ecological community, as Major, Partial or Minor components.

A) Vegetation system-associations likely to comprise a **major component** of the Banksia Woodlands ecological community. Major components have one or more key *Banksia* species as dominant or significant elements of the upper vegetation layer. Most units are confined to the Swan Coastal Plain bioregion, or almost so.

System	System Association	Extent in SWA (%)	Beard Vegetation Association	NVIS Level 6 Description
BARRAMBER	949.0	100	Low woodland; banksia	**U1 +*Banksia*** sp. \tree \6 \i
GINGIN	949.0	99.3	Low woodland; banksia	**U1 +*Banksia*** sp. \tree \6 \i
GUILDERTON	949.0	100	Low woodland; banksia	**U1 +*Banksia*** sp. \tree \6 \i
PINJARRA	949.0	100	Low woodland; banksia	**U1 +*Banksia*** sp. \tree \6 \i
SPEARWOOD	949.0	100	Low woodland; banksia	**U1 +*Banksia*** sp. \tree \6 \i
JURIEN	949.1	100	Low woodland; banksia	**U1 +*Banksia attenuata, Banksia menziesii,*** *Eucalyptus todtiana*, *Nuytsia floribunda*, *Allocasuarina fraseriana* \tree \6 \i; M1 *Calothamnus sanguineus*, *Petrophila brevifolia*, *Eremaea pauciflora*, *Hakea costata*, *Jacksonia hakeoides* \shrub \4 \i; G1 *Hibbertia hypericoides*
BASSENDEAN	949.2	100	Low woodland; banksia	**U1 +*Banksia attenuata, Banksia menziesii,*** *Eucalyptus todtiana*, *Nuytsia floribunda*, *Allocasuarina fraseriana* \tree \6 \i; G1 *Conospermum incurvum*, *Verticordia nitens* \shrub \4 \c
BASSENDEAN	1001.1	100	Medium very sparse woodland; jarrah, with low woodland; banksia & casuarina	**U ^*Banksia attenuata, Banksia ilicifolia,*** *Nuytsia floribunda* \tree \6 \i; M *Philotheca spicata* (syn. *Eriostemon spicatus* \shrub \3 \i
BASSENDEAN	1014.1	100	Mosaic: Low woodland; banksia / Shrublands; teatree thicket	U1 ***Banksia ilicifolia, Banksia attenuata, Banksia menziesii,*** *Eucalyptus todtiana*, *Nuytsia floribunda* \tree \6 \i
DANDARAGAN	1030.0	100	Low woodland; *Banksia attenuata* & *B. menziesii*	U1 +***Banksia attenuata***, +***Banksia menziesii*** \tree \6 \i
GINGIN	1030.0	100	Low woodland; *Banksia attenuata* & *B. menziesii*	U1 +***Banksia attenuata***, +***Banksia menziesii*** \tree \6 \i
BASSENDEAN	1030.2	98.7	Low woodland; *Banksia attenuata* & *B. menziesii*	U1 +***Banksia attenuata***, ***Banksia menziesii,*** *Eucalyptus todtiana*, *Nuytsia floribunda*, ***Banksia ilicifolia*** \tree \6 \i; M1 *Adenanthos cygnorum*, *Allocasuarina humilis*, *Jacksonia furcellata*, *Acacia* sp., *Allocasuarina microstachya* \shrub, *Xanthorrhoea* \4 \r; G1 *Anigozanthus*

System	System Association	Extent in SWA (%)	Beard Vegetation Association	NVIS Level 6 Description
KOOJAN	1030.2	96.1	Low woodland; *Banksia attenuata* & *B. menziesii*	U1 +***Banksia attenuata***, ***Banksia menziesii,*** *Eucalyptus todtiana*, *Nuytsia floribunda*, ***Banksia ilicifolia*** \tree \6 \i; M1 *Adenanthos cygnorum*, *Allocasuarina humilis*, *Jacksonia furcellata*, *Acacia* sp., *Allocasuarina microstachya* \shrub, *Xanthorrhoea* \4 \r; G1 *Anigozanthus*
KOOJAN	1036.0	100	Low woodland; *Banksia prionotes*	U1 **+*Banksia prionotes*** \tree \6 \i

B) Vegetation system-associations likely to **partially correspond** to the Banksia Woodlands ecological community. In partial units the key *Banksia* species are typically present in the upper or mid vegetation layers but occur with other species, notably eucalypts as an emergent or overtopping tree canopy; or expert feedback has indicated the the defined ecological community partially corresponds with the system association. The key *Banksia* species may be locally dominant in some patches within these units. Most units are confined to the Swan Coastal Plain bioregion, or almost so, with the exception of Pinjarra 1181.0. This unit extends into the Whicher Range in a part of the Southern Jarrah Forests (JAF02) subregion adjacent to the Swan Coastal Plain bioregion. These outlying patches are included as part of the Banksia Woodlands ecological community.

System	System Association	Extent in SWA (%)	Beard Vegetation Association	NVIS Level 6 Description
SPEARWOOD	6.1	100	Medium woodland; tuart & jarrah	U1 +*Eucalyptus gomphocephala*, +*Eucalyptus marginata*, *Corymbia calophylla*, *Eucalyptus decipiens* \tree \7 \i; U2 *Agonis flexuosa*, *Allocasuarina fraseriana*, ***Banksia attenuata, Banksia menziesi****i* \tree \6 \i;M1 *Acacia cyanophylla*, *Acacia cyclops*, *Dodonaea aptera*, ***Banksia* spp**.
SPEARWOOD	998.1	100	Medium woodland; tuart	U1 +*Eucalyptus gomphocephala*, *Corymbia calophylla*, *Eucalyptus decipiens* \tree \7 \i; U2 *Agonis flexuosa*, *Allocasuarina fraseriana*, ***Banksia attenuata, Banksia menziesi****i* \tree \6 \i; M1 *Acacia cyanophylla*, *Anthocercis littorea*, *Dodonaea aptera*, ***Banksia sessilis***
GINGIN	999.1	100	Medium woodland; marri	U1 +*Corymbia calophylla* \tree \7 \i; U2 ***Banksia attenuata, Banksia grandis,*** *Nuytsia floribunda* \tree \6 \i; M1 *Acacia cyanophylla*, ***Banksia sessilis***, *Grevillea vestita*, *Jacksonia sternbergiana* \shrub \4 \i; M2 *Xanthorrhoea preissii* \xanthorrhoea \3 \i
SPEARWOOD	1011.1	100	Medium open woodland; tuart	U1 +*Eucalyptus gomphocephala*, *Corymbia calophylla*, *Eucalyptus decipiens* \tree \7 \r; U2 *Agonis flexuosa*, *Allocasuarina fraseriana*, ***Banksia attenuata, Banksia menziesii*** \tree \6 \r; M1 *Acacia cyanophylla*, *Anthocercis littorea*, *Dodonaea aptera*, ***Banksia sessilis***
BASSENDEAN	1016.0	100	Mosaic: Low woodland; banksia / Shrublands; dryandra heath	M1 ***Banksia* sp**. (formerly *Dryandra* sp.) \shrub \3 \c
BASSENDEAN	1017.0	100	Medium open woodland; jarrah & marri, with low woodland; banksia	U1 *Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \i; U2 ***Banksia attenuata, Banksia ilicifolia,*** *Nuytsia floribunda* \tree \6 \i

System	System Association	Extent in SWA (%)	Beard Vegetation Association	NVIS Level 6 Description
GINGIN	1017.0	96.3	Medium open woodland; jarrah & marri, with low woodland; banksia	U1 *Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \i; U2 ***Banksia attenuata, Banksia ilicifolia,*** *Nuytsia floribunda* \tree \6 \i
BASSENDEAN	1018.0	100	Mosaic: Medium forest; jarrah-marri / Low woodland; banksia / Low forest; teatree / Low woodland; *Casuarina obesa*	U1 +*Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \c; M1 *Melaleuca* sp., ***Banksia*** sp., *Casuarina obesa* \tree \6 \c
PINJARRA	1018.1	100	Mosaic: Medium forest; jarrah-marri / Low woodland; banksia / Low forest; teatree / Low woodland; *Casuarina obesa*	U1 +*Eucalyptus marginata*, +*Corymbia calophylla*, +***Banksia attenuata***, *Melaleuca preissiana*, *Casuarina obesa* \tree \6 \i; U2 *Melaleuca rhaphiophylla* \tree \6 \i
GINGIN	1027.1	100	Mosaic: Medium open woodland; jarrah & marri, with low woodland; banksia / Medium sparse woodland; jarrah & marri	U1 *Corymbia calophylla*, *Eucalyptus marginata*, *Eucalyptus rudis* \tree \7 \bi; U2 ***Banksia attenuata, Banksia menziesii,*** *Eucalyptus todtiana*, *Nuytsia floribunda*, ***Banksia ilicifolia*** \tree \6 \i
WARRO	1036.1	99.7	Low woodland; *Banksia prionotes*	U1 +***Banksia attenuata***, +***Banksia prionotes***, ^*Callitris arenaria*, ***Banksia burdettii,*** *Eucalyptus todtiana* \tree \6 \i; M1 *Acacia blakelyi*, *Adenanthos cygnorum*, *Calothamnus quadrifidus*, *Chamelaucium drummondii*, *Daviesia preissii* \shrub \4 \i; G1 *Allocasuarina humilis*
KOOJAN	1038.0	100	Medium open woodland; eucalypts (e2), with low woodland; *Banksia attenuata* & *B. menziesii*	U1 *Eucalyptus* sp. \tree \7 \r; U2 +***Banksia attenuata***, +***Banksia menziesii*** \tree \6 \i
PINJARRA	1181.0	37.2	Medium woodland, jarrah & *Eucalyptus haematoxylon* (Whicher Range)	U1 +*Eucalyptus marginata*, +*Eucalyptus haematoxylon* \tree \7 \i; U2 ***Banksia attenuata, Banksia grandis*** \tree \6 \i; M1 *Allocasuarina humilis*, ***Banksia sphaerocarpa*** \shrub \3 \i

C) Vegetation system-associations likely to include a **minor component** of the Banksia Woodlands ecological community. Minor components are typically dominated by genera other than *Banksia*, and generally are eucalypt woodlands and forest, or shrublands of various species. Site-specific survey and mapping, however, have indicated that some local patches of *Banksia* Woodlands may occur within these vegetation system-associations.

System	System Association	Extent in SWA (%)	Beard Vegetation Association	NVIS Level 6 Description
BASSENDEAN	3.0	85.8	Medium forest; jarrah-marri	U1 +*Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \c
PINJARRA	3.2	87.3	Medium forest; jarrah-marri	U1 +*Eucalyptus marginata*, +*Corymbia calophylla*, *Eucalyptus wandoo*, *Eucalyptus rudis* \tree \7 \i; U2 *Allocasuarina fraseriana*, *Melaleuca preissiana* \tree \6 \i
GINGIN	4.0	93.8	Medium woodland; marri & wandoo	U1 +*Corymbia calophylla*, +*Eucalyptus wandoo* \tree \7 \i; U2 *Acacia acuminata*, *Allocasuarina huegeliana*, ***Banksia grandis, Banksia sessilis*** \tree \6 \i; M1 *Acacia nervosa*, *Gastrolobium* sp., *Hakea lissocarpha*, *Oxylobium* sp., *Trymalium ledifolium* \shrub \4 \i;M2 ***Banksia* spp**.
BASSENDEAN	6.0	100	Medium woodland; tuart & jarrah	U1 +*Eucalyptus gomphocephala*, +*Eucalyptus marginata* \tree \7 \i
BASSENDEAN	51.4	100	Sedgeland; reed swamps, occasionally with heath	U1 *Adenanthos obovatus*, *Hypocalymma angustifolium*, *Pultenaea reticulata*, *Xanthorrhoea preissii* \shrub, xanthorrhoea \4 \c
BASSENDEAN	965.0	100	Medium woodland; jarrah & marri	U1 +*Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \i
PINJARRA	965.0	100	Medium woodland; jarrah & marri	U1 +*Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \i
BASSENDEAN	968.0	100	Medium woodland; jarrah, marri & wandoo	U1 +*Eucalyptus marginata*, +*Corymbia calophylla*, +*Eucalyptus wandoo* \tree \7 \i
PINJARRA	968.3	99.1	Medium woodland; jarrah, marri & wandoo	U1 +*Eucalyptus marginata*, +*Corymbia calophylla*, +*Eucalyptus subangusta* \tree \7 \i; U2 *Allocasuarina fraseriana*, ***Banksia grandis,*** *Persoonia longifolia*, *Persoonia elliptica*, *Nuytsia floribunda* \tree \6 \i; M1 *Acacia* sp., *Adenanthos* sp., *Agonis parviceps*, *Baeckea* sp.
BASSENDEAN	973.0	100	Low forest; paperbark (*Melaleuca rhaphiophylla*)	U1 +*Melaleuca rhaphiophylla* \tree \6 \c
BASSENDEAN	998.0	100	Medium woodland; tuart	U1 +*Eucalyptus gomphocephala* \tree \7 \i
BASSENDEAN	1000.0	100	Mosaic: Medium forest; jarrah-marri / Low woodland; banksia / Low forest; teatree (*Melaleuca* spp.)	U1 +*Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \c; U2 *Agonis flexuosa*, ***Banksia grandis,*** *Persoonia longifolia* \tree \6 \i; M1 ***Banksia sessilis***, *Hakea undulata* \shrub \4 \i
PINJARRA	1000.0	94.4	Mosaic: Medium forest; jarrah-marri / Low woodland; banksia / Low forest; teatree (*Melaleuca* spp.)	U1 +*Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \c; U2 *Agonis flexuosa*, ***Banksia grandis,*** *Persoonia longifolia* \tree \6 \i; M1 ***Banksia sessilis***, *Hakea undulata* \shrub \4 \i

System	System Association	Extent in SWA (%)	Beard Vegetation Association	NVIS Level 6 Description
SPEARWOOD	1000.0	100	Mosaic: Medium forest; jarrah-marri / Low woodland; banksia / Low forest; teatree (*Melaleuca* spp.)	U1 +*Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \c; U2 *Agonis flexuosa*, ***Banksia grandis,*** *Persoonia longifolia* \tree \6 \i; M1 ***Banksia sessilis***, *Hakea undulata* \shrub \4 \i
PINJARRA	1001.0	100	Medium very sparse woodland; jarrah, with low woodland; banksia & casuarina	U1 +*Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \c; U2 *Agonis flexuosa*, ***Banksia grandis,*** *Persoonia longifolia* \tree \6 \i; M1 ***Banksia sessilis***, *Hakea undulata* \shrub \4 \i
SPEARWOOD	1001.0	100	Medium very sparse woodland; jarrah, with low woodland; banksia & casuarina	U1 +*Eucalyptus marginata*, +*Corymbia calophylla* \tree \7 \c; U2 *Agonis flexuosa*, ***Banksia grandis,*** *Persoonia longifolia* \tree \6 \i; M1 ***Banksia sessilis***, *Hakea undulata* \shrub \4 \i
BASSENDEAN	1009.0	100	Medium woodland; marri & river gum	U1 +*Corymbia calophylla*, +*Eucalyptus rudis* \tree \7 \i
GINGIN	1015.1	100	Mosaic: Mixed scrub-heath / Shrublands; dryandra thicket	U1 ***Banksia carlinoides*** \shrub \3 \c
GINGIN	1020.1	94.4	Mosaic: Medium forest; jarrah-marri / Medium woodland; marri-wandoo	U1 +*Corymbia calophylla*, +*Eucalyptus wandoo* \tree \7 \i
JURIEN	1029.1	99.9	Shrublands; scrub-heath dryandra-calothamnus assocication with *Banksia prionotes* on limestone in the northern Swan Region	U1 +***Banksia sessilis***, +*Calothamnus quadrifidus*, *Acacia heteroclita*, *Grevillea thelemanniana*, *Hakea bipinnatifida* \shrub, *xanthorrhoea* \4 \i; G1 *Conospermum stoechadis*, *Lechenaultia linarioides*, *Hibbertia hypericoides*, ***Banksia nivea***, *Hakea prostrata* \shrub, forb
PINJARRA	1136.0	99.9	Medium woodland; marri with some jarrah, wandoo, river gum and casuarina	U1 +*Corymbia calophylla*, *Eucalyptus marginata*, *Eucalyptus wandoo*, *Eucalyptus rudis* \tree \7 \i; U2 *Allocasuarina* sp. \tree \6 \r

Source: The system associations shown here were identified by the WA Department of Parks and Wildlife as corresponding to the ecological community to some degree, based on descriptions of the vegetation units , or mapping indicating they contain patches of Banksia Woodlands floristic community types.

Extent in SWA (%) estimates the proportion of the pre-European extent of each vegetation system-association that originally was present in the Swan Coastal Plain IBRA bioregion. The bioregion encompasses two subregions: SWA01 Dandaragan Plateau and SWA02 Perth. The 2015 dataset released by the Government of Western Australia (2016) was used to determine the bioregional extent.

Table C2: Vegetation Complexes that are associated to some extent with the Banksia Woodland of the Swan Coastal Plain ecological community

a) Strongly associated with the ecological community. The majority of mapped extent comprises Banksia woodlands.

Vegetation Complex	**Brief description**
Bassendean Complex - Central and South	Vegetation ranges from woodland of *E. marginata – A. fraseriana – Banksia spp*. to low woodland of *Melaleuca* spp. and sedgelands on the moister sites. This area includes the transition of *E. marginata to E. todtiana* in the vicinity of Perth. *Banksia attenuata*, *B. menziesii* and *B. grandis* are common on the upper slopes while *B. ilicifolia* and *B. littoralis* are common on low-lying moister soils.
Bassendean Complex - North	Vegetation ranges from a low open forest and low woodland of *Banksia spp. – E. todtiana* to low woodland of *Melaleuca spp*. and sedgelands which occupy the moister sites.
Bassendean Complex - North - Transition Vegetation Complex	A transition complex of low open forest and low woodland of *Banksia spp. – E. todtiana* on a series of high sand dunes. The understorey species reflect similarities with both the Bassendean-North and Karrakatta –North vegetation complexes.
Caladenia Complex	Mosaic of vegetation from adjacent vegetation complexes of Karrakatta, Yanga and Bassendean. The upper dunes suport a low open forest of *Banksia- E. todtiana* with *B. attenuata* and *B. menziesii* being dominant.
Cartis Complex	Low open forest to open forest *of E. marginata – C. calophylla – E. haematoxylon* with a second storey of *Banksia* spp. Vegetation has affinities with the southern Darling Scarp complex. Occurs on the Blackwood Plateau with some occurrences extending into adjacent areas of the Jarrah Forests bioregion (these are included in the ecological community).
Coonambidgee Complex	Vegetation ranges from a low open forest and low woodland of *E. todtiana - B. attenuata - B. menziesii - B. ilicifolia* with localised admixtures of *B. prionotes* to an open woodland of *E. calophylla - Banksia* species. Also extends onto the Dandaragan Plateau (not part of the ecological community).
Cottesloe Complex - North	Predominantly low open forest and low woodland of *B. attenuata - B menziesii - E. todtiana;* closed heath on the Limestone outcrops.
Cullala Complex	A mixture of low open forest of *Banksia*-prickly bark and an open woodland of marri with a well defined second storey of *Banksia attenuata – B. menziesii- B. ilicifolia*.
Karrakatta Complex - North	Predominantly low open forest and low woodland of *Banksia* spp. - *E. todtiana*, less consistently open forest of *E. gomphocephala - E. todtiana - Banksia* species.
Karrakatta Complex - North - Transition Vegetation Complex	A transition complex of low open forest and low woodland of *Banksia* species - *E. todtiana* on the transition zone of a series of high sand dunes between Bassendean-North and Karrakatta-North.
Mogumber Complex South	Dominated by open woodland of marri and well defined second storey of pricklybark-banksia (*Eucalyptus todtiana-Banksia attenuata-B.menziesii-B.ilicifolia*)
Moondah Complex	Predominantly low closed to low open forest of *B. attenuata - B. menziesii - B. prionotes - E. todtiana* on the slopes and *C. calophylla - Banksia* spp. in the valleys. Mostly occurs on the Dandaragan Plateau but >1000 hectares extends into the Perth subregion.
Reagan Complex	Vegetation ranges from low open woodland of *Banksia* species - *E. todtiana* to closed heath depending on the depth of soil. Also extends onto the Dandaragan Plateau.
Yelverton	Woodland of *Allocasuarina fraseriana-Eucalyptus marginata* subsp. *marginata-Xylomelum occidentale-Banksia attenuata* on sandy slopes in the humid zone. Some occurrences extend into adjacent areas of the Jarrah Forests bioregion (these are included in the ecological community).

b) Moderately associated with the ecological community. Up to about half the mapped extent is likely to comprise Banksia woodlands.

Name of Vegetation Complex	Brief description
Cannington Complex	Mosaic of vegetation from adjacent vegetation complexes of Bassendean, Karrakatta, Southern River and Vasse. Uplands support a woodland of *E. marginata* – Banksia spp. Low-lying areas have a range of vegetation from *E. rudis – Melaleuca raphiophylla* woodland to closed scrub of *Melaleuca* spp.
Forrestfield Complex	Vegetation ranges from open forest of *C. calophylla - E. wandoo - E. marginata* to open forest of *E. marginata - E. calophylla - C. fraseriana - Banksia* species. Fringing woodland of *E. rudis* in the gullies that dissect this landform. Some occurrences extend into adjacent areas of the Jarrah Forests bioregion (these are included in the ecological community).
Karrakatta Complex - Central and South	Predominantly open forest of *E. gomphocephala - E. marginata - C. calophylla* and woodland of *E. marginata - Banksia* species. Minor occurrences extend into adjacent areas of the Jarrah Forests bioregion (these are included in the ecological community).
Southern River Complex	Open woodland of *C. calophylla - E. marginata - Banksia* species with fringing woodland of *E. rudis - M. rhaphiophylla* along creek beds. Minor occurrences extend into adjacent areas of the Jarrah Forests bioregion (these are included in the ecological community).

c) Minor association with the ecological community. Only a small proportion of the mapped extent may comprise Banksia woodlands, the remainder being other vegetation types.

Name of Vegetation Complex	Brief description
Bassendean Complex - Central and South - Transition Vegetation Complex	Woodlands of *E. marginata- C. calophylla* with well-defined second storey of *A. fraseriana and B. grandis* on the deeper soils and a closed scrub on the moister sites. The understorey species reflect similarities with the adjacent vegetation complexes.
Bootine Complex	Predominantly low open forest of *E. todtiana - B. attenuata - B. menziesii - B. illicifolia* with a woodland of *E. rudis – M. rhaphiophylla* on lake margins transitioning to sedgelands.
Cottesloe Central and South	Mosaic of woodland of *E. gomphocephala – E. marginata – E. calophylla*; closed heath on the limestone outcrops.
Karamal Complex South	Dominated by an open forest of jarra-marri with a definite second storey of *Banksia grandis* on the gravelly soils and *B. attenuata* and *B. menziesii* on the sandier soils.
Mogumber Complex North	Dominated by open and closed heaths of *Allocasuarina humilis, Banksia sphaerocarpa*, several unnamed *Banksia* species, *Xanthorrhoea preissii*, and many other species, in particular of the families Myrtaceae, Proteaceae, Fabaceae and Ericaceae occur on the low rises.
Pinjar Complex	Vegetation ranges from woodland of *E. marginata - Banksia* species to a fringing woodland of *E. rudis - M. preissiana* and sedgelands

Source: Heddle et al., (1980) and Havel and Mattiske (2000) for descriptions of vegetation complexes; The Western Australian Department of Parks and Wildlife (pers. comm.) for data on extent of complexes and ratings of association with the Banksia Woodlands ecological community.

C2. Detailed information on sub-communities

The following information and descriptions of Floristic Community Types are from Gibson et al. (1994), Government of Western Australia (2000), Keighery et al. (2008) and input from WA Department of Parks and Wildlife. They best correspond to the Banksia Woodlands ecological community and can be regarded as sub-communities of the national ecological community (with the exception of 20c, see below), where they occur within the defined distribution. The information is current at July 2016 and represents known occurrences at that time.

'Central' Swan Coastal Plain:

Banksia woodland of the Gingin area restricted to soils dominated by yellow to orange sands

- WA PEC – P2
- Species-rich Banksia woodlands on deep yellow-red sands that appear restricted to the western Dandaragan Plateau.
- 1302.2 ha mapped in 17 occurrences from Mooliabeenee to Chittering, a distance of about 25km.
- Described as scattered *Eucalyptus todtiana* and *Corymbia calophylla* over *Banksia menziesii* and *Banksia attenuata* low open woodland over *Jacksonia sternbergiana* and *Adenanthos cygnorum* high open shrubland over *Allocasuarina humilis* and *Chamelaucium* sp. Gingin (N.G. Marchant 6) (DRF) open shrubland over *Eremaea pauciflora* and *Astroloma xerophyllum* low shrubland over *Mesomelaena pseudostygia* open sedgeland.

'Southern' Swan Coastal Plain:

Supergroup 3 – Uplands centred on Bassendean Dunes and Dandaragan Plateau

FCT 20a – Banksia attenuata woodlands over species rich dense shrublands (Gibson et al., 1994)

- WA TEC - Endangered
- Occurs on sands at the base of the Darling Scarp in the Forrestfield area and north of Perth in the Koondoola and Chittering areas.
- 585 ha remaining in 69 occurrences from Breera to Orange Grove, a distance of about 62km.
- This community is very species rich (80 spp./100m^2).
- Dominated by *Banksia attenuata* (occasionally with *Eucalyptus marginata*) with *Bossiaea eriocarpa, Conostephium pendulum, Hibbertia huegelii, H. hypericoides, Petrophile linearis, Scaevola repens, Stirlingia latifolia, Mesomelaena pseudostygia* and *Alexgeorgea nitens* common understorey species. This community is very restricted and the richest of any *Banksia* community found on the coastal plain. Sites of community 20a were differentiated from the other two subgroups by occurrences of species such as *Alexgeorgia nitens, Daviesia nudiflora, Synaphea spinulosa, Hibbertia racemosa, Stylidium calcaratum* and a variety of other taxa occurring at low frequency.

FCT 20b – Eastern Banksia attenuata and/or Eucalyptus marginata woodlands (Gibson et al., 1994)

- WA TEC – Endangered
- Community 20b occurs on sands at the base of the Darling Scarp between Guildford and Harvey predominantly on the Pinjarra Plain and Ridge Hill Shelf.
- 286.3 ha remaining in 41 occurrences from Middle Swan to Warawarrup, a distance of about 135km.
- This community is very species rich (75 spp./100m^2).
- Dominated by *Banksia attenuata* and/or *Eucalyptus marginata* with *Mesomelaena pseudostygia, Tetraria octandra, Banksia lindleyana, Desmocladus fasciculatus, and Chamaescilla corymbosa* being common in the understorey. Understorey species such as *Grevillea pilulifera, Babingtonia camphorosmae, Hibbertia vaginata, Caladenia flava, Hakea stenocarpa and Conostylis setosa* differentiate it from related woodland types (type 20a and 20c) as does the absence of *Alexgeorgea nitens*, a common component of community 20a.

FCT 20c – Eastern shrublands and woodlands (Gibson et al., 1994)

- WA TEC – Critically Endangered; EPBC TEC – Endangered
- **This FCT corresponds with a separate EPBC ecological community listing, Shrublands and Woodlands of the eastern Swan Coastal Plain. Occurrences this FCT should be considered under that separate listing (Department of the Environment, 2016).**
- This highly restricted community occurs mainly on the transitional soils of the Ridge Hill Shelf, on the Swan Coastal Plain adjacent to the Darling Scarp, but also extends marginally onto the alluvial clays deposited on the eastern fringe of the Swan Coastal Plain.
- 128.8 ha remaining in six occurrences from Stratton to Maddington, a distance of about 20km.
- This community is species rich (60 spp./100 m^2).
- Occurs as a shrubland, or woodland of *Banksia attenuata* and *Banksia menziesii,* sometimes with *Allocasuarina fraseriana*, over a shrub layer that can include *Adenanthos cygnorum, Hibbertia huegelii, Scaevola repens* var. *repens, Allocasuarina humilis, Bossiaea eriocarpa, Hibbertia hypericoides* and *Stirlingia latifolia.* A suite of herbs including *Conostylis aurea, Trachymene pilosa, Lomandra hermaphrodita, Burchardia congesta* and *Patersonia occidentalis,* and the *sedges Mesomelaena pseudostygia* and *Lyginia barbata* usually occur in the community.

FCT20d – Dandaragan Plateau shrublands and woodlands

- Not listed as threatened or priority in WA
- No detailed description available and boundaries not mapped.
- Known from 11 point locations over about 120km from Red Gully in the north to Martin in the south.

FCT 21a – Central Banksia attenuata - Eucalyptus marginata woodlands (Gibson et al. 1994)

- Not listed as threatened or priority in WA
- This community occurs as a woodland on the Spearwood and Bassendean Dunes and Pinjarra Plain extending from Gingin south to Bunbury. Boundaries not mapped.
- Known from 50 point locations over about 245 km from Yeal in the north to Capel in the south.
- The community has a moderate average species richness (52 spp./100m^2).
- Primarily consists of *Banksia attenuata - Eucalyptus marginata* woodlands, *Corymbia calophylla – B. attenuata* woodlands or *B. attenuata* woodlands. *Allocasuarina fraseriana* and *Eucalyptus gomphocephala* are sometimes present as dominant or codominant. Common shrubs include *Hibbertia hypericoides, Bossiaea eriocarpa, Petrophile linearis, Gompholobium tomentosum,* and herbs *Trachymene pilosa, Lepidosperma squamatum, Burchardia congesta, Dasypogon bromeliifolius* and *Phlebocarya ciliata.*

FCT 21b – Southern Banksia attenuata woodlands (Gibson et al., 1994)

- WA PEC – P3
- This community is restricted to sand sheets at the base of the Whicher Scarp, the sand sheets on elevated ridges or the sand plain south of Bunbury. Boundaries not mapped.
- The community has high species richness (61.3 ssp./100m^2).
- Floristic community description is currently under review.
- Structurally, this community type is usually *Banksia attenuata* or *Eucalyptus marginata – B. attenuata* woodlands. Common taxa include *Acacia extensa*, *Jacksonia* sp. Busselton (G.J.Keighery 4482), *Laxmannia sessiliflora*, *Lysinema ciliatum* and *Johnsonia acaulis*.

FCT 21c – Low lying Banksia attenuata woodlands or shrublands (Gibson et al., 1994)

- WA PEC – P3
- This community is largely restricted to the uplands on the Bassendean system, consisting of low dunes and interwoven wetlands and extends from Gingin to Bunbury.
- Known from 27 point locations over about 230km from Chittering to Gelorup. Boundaries of many point locations are not mapped – 317.5 ha currently mapped.
- This type is significantly less species rich than the other sub-groups (supergroup 20, 22, 23) with an average 40 ssp./100m2).
- Structurally this community type may be either a woodland or occasionally shrubland. This type tends to occupy lower lying wetter sites and is variously dominated by *Melaleuca preissiana, Banksia attenuata, B. menziesii, Regelia ciliata, Eucalyptus marginata* or *Corymbia calophylla* either singly or in combination. Other typical or common flora include *Lyginia barbata, Trachymene pilosa, Patersonia occidentalis, Dasypogon bromeliifolius, Gompholobium tomentosum, Petrophile linearis, Drosera erythrorhiza, Xanthorrhoea preissii, Burchardia congesta, Lomandra caespitosa, Hibbertia subvaginata, Phlebocarya ciliata* and *Stylidium brunonianum.*

FCT 22 – Banksia ilicifolia woodlands *(Gibson et al., 1994)*

- WA PEC – P3
- This community occupies low lying sites, generally consisting of *Banksia ilicifolia – B. attenuata* woodlands, but *Melaleuca preissiana* woodlands and shrubs are also recorded. Mostly occurs on Bassendean and Spearwood systems and south end of the Dandaragan Plateau between Ledge Point and Wannamal in the north, to Pinjarra in the south. Boundaries not mapped.
- Known from 23 point locations over about 175km from Moore River National Park to Ravenswood.
- Mean species richness is medium (52 ssp./per 100m^2).
- The community typically has a very open understorey, and sites are likely to be seasonally waterlogged. Typical or common flora in the community are *Banksia ilicifolia, B. attenuata, Adenanthos cygnorum, Leucopogon conostephioides, Hypocalymma angustifolium, Petrophile linearis, Stylidium repens, Dasypogon bromeliifolius, Drosera paleacea* subsp*. paleacea, Lyginia barbata, Patersonia occidentalis, Phlebocarya ciliata* and *Stylidium piliferum*. There are no other communities identified in Gibson *et al*. 1994 for which quadrats commonly included *Banksia ilicifolia* as a dominant.

FCT 23a – Central Banksia attenuata - Banksia menziesii woodlands (Gibson et al., 1994)

- Not listed as threatened or priority in WA
- The central *Banksia* woodlands are generally restricted to the Bassendean system from Bullsbrook to Woodman Point in the south. Boundaries not mapped.
- Known from 51 point locations over a range of about 95km from Pinjar to Keysbrook.
- Species richness is very high (62 ssp./100m^2).
- Typical or common trees are *Banksia attenuata* and *B. menziesii*. Common shrub layer includes *Bossiaea eriocarpa, Petrophile linearis, Gompholobium tomentosum, Conostephium pendulum, Leucopogon conostephioides, Philotheca spicata* with *herbs Patersonia occidentalis, Burchardia congesta, Lomandra hermaphrodita, Lyginia barbata, Trachymene pilosa* and the grass *Rytidosperma occidentale* (syn. *Austrodanthonia occidentalis*).

FCT 23b – Northern Banksia attenuata - Banksia menziesii woodlands (Gibson et al., 1994)

- WA PEC – P3
- The northern *Banksia* woodlands are a distinct sub group, centred on the Bassendean system north of Perth between Regans Ford and Wanneroo. The community is reasonably extensive and it is likely its distribution will extend further north. Boundaries not mapped.
- Known from 79 point locations from over a range of about 90km from Red Gully to Ellenbrook.
- This group has a lower mean species richness than the subgroup 23a (53 spp./100m2) and a significantly lower mean weed frequency reflecting the more extensive and intact *Banksia* woodlands which still occur north of Perth.

- Typical or common trees in the community are *Banksia attenuata* and *Banksia menziesii* Common shrub layers include *Bossiaea eriocarpa, Calytrix flavescens, Eremaea pauciflora, Petrophile linearis, Philotheca spicata* and sedges and herbs *Alexgeorgea nitens, Anigozanthos humilis, Burchardia congesta, Lomandra hermaphrodita, Lyginia barbata, Patersonia occidentalis, Schoenus curvifolius, Stylidium repens* and *Xanthosia huegelii.*

FCT 23c – North-eastern Banksia attenuata - Banksia menziesii woodlands (Gibson et al., 1994)

- Not listed as threatened oo priority in WA
- Located in the north east outer Perth metropolitan region around Mogumber, Boonnanarring and Wannamal areas. This community is generally restricted to the Bassendean system. Boundaries not mapped.
- Known from 12 point locations over a range of about 60km from Red Gully to Yanchep.
- Typical flora include *Patersonia, occidentalis, Mesomelaena pseudostygia, Anigozanthos humilis, Hibbertia hypericoides, Bossiaea eriocarpa, Alexgeorgea nitens, Stylidium repens, Petrophile linearis, Xanthorrhoea preissii, Hypochaeris glabra, Lomandra hermaphrodita, Hibbertia huegelii, Calytrix angulata, Eremaea pauciflora, Scholtzia involucrata, Synaphea spinulosa*.

FCT S9 – Banksia attenuata woodlands over dense low shrublands (Bush Forever, Government of Western Australia, 2000)

- No further description available. Boundaries not mapped.
- Known from some point locations over a range of about 90km from Red Gully to Ellenbrook.

FCT 24 – Northern Spearwood shrublands and woodlands (Gibson et al., 1994)

- WA PEC – P3
- This community occurs as heaths or heaths with scattered *Eucalyptus gomphocephala* on deeper soils. The community is found on the western Swan Coastal Plain, mostly on the Cottesloe unit of the Spearwood system and extends from Yanchep south to Singleton.
- 1009 ha mapped over a range of about 170km from Nowergup to Binningup. 37 pt locations recorded, some of which do not have boundaries mapped.
- The *Banksias* found in this community include *Banksia attenuata* and *B. menziesii*. Typical flora species may include *Banksia sessilis, Calothamnus quadrifidus, Melaleuca systena, Xanthorrhoea preissii, Lepidosperma squamatum, Hardenbergia comptoniana, Phyllanthus calycinus,* with herbs, sedges and grasses *Conostylis aculeata, Dianella revoluta, Lomandra maritima, Schoenus grandiflorus, Desmocladus flexuosa* and *Austrostipa flavescens*.

FCT 25 – Southern Eucalyptus gomphocephala – Agonis flexuosa woodlands (Gibson et al., 1994)

- WA PEC – P3
- These woodlands are mostly restricted to the south western parts of the Swan Coastal Plain from Woodman Point to Busselton, however there are some outliers north of Perth around Yanchep. The community is mostly represented on soils of the Karrakatta, Cottesloe and Vasse units. Boundaries not mapped.
- Recorded from 25 point locations over a range of about 230km from Two Rocks to Stratham.
- Occasionally dominants other than tuarts were recorded (*Corymbia calophylla* and *Eucalyptus decipiens*) however tuarts are emergent nearby. *Banksias* found in this community include *Banksia attenuata, B. grandis* and *B. littoralis* Typical or common shrubs are *Hibbertia hypericoides, Macrozamia riedlei, Phyllanthus calycinus, Acacia willdenowiana, Hardenbergia comptoniana, Leucopogon propinquus*, with herbs and grasses *Daucus glochidiatus, Sowerbaea laxiflora, Trachymene pilosa, Caladenia flava, Caladenia latifolia, Conostylis aculeata, Microlaena stipoides* and *Austrostipa flavescens*.

FCT 28 – Spearwood Banksia attenuata or Banksia attenuata – Eucalyptus woodlands (Gibson et al., 1994)

- Not listed as priority or threatened in WA
- Boundaries not mapped. Known from 80 point locations over a range of about 150km from Red Gully to Leda.
- This type has a medium-high species richness (56 spp./100m^2).
- This community largely consists of *Banksia attenuata* woodlands with *Eucalyptus marginata* and/or *Corymbia calophylla* with scattered *Eucalyptus gomphocephala*. Sites predominantly occur in the Karrakatta and Cottesloe units of the Spearwood dune system. Recorded from Seabird south to Thompsons Lake. Common shrubs found in the understory include *Hibbertia hypericoides, Xanthorrhoea preissii, Gompholobium tomentosum* and *Acacia pulchella* with sedges, grasses and herbs *Desmocladus flexuosus, Mesomelaena pseudostygia, Conostylis aculeata, Trachymene pilosa, Burchardia congesta, Sowerbaea laxiflora* and *Drosera erythrorhiza.*

Whicher Scarp:

Central Whicher Scarp Mountain Marri Woodland (WHSFCT_A1 in Keighery et al., 2008)

- WA PEC – P1
- This community type is located on Whicher Scarp mid slopes.
- Three mapped occurrences, total 172 ha, one unmapped occurrence. Range ~39ha Acton Park to The Plains.
- A group of taxa identify this group, being: *Ricinocarpos* aff. *cyanescens, Hibbertia ferruginea, Platysace filiformis, Conospermum capitatum* subsp. *glabratum, Thysanotus arbuscula, Schoenus brevisetis, Phlebocarya filifolia, Leucopogon glabellus, Pimelea rosea* subsp. *rosea, Adenanthos obovatus, Stylidium carnosum* and *Gompholobium capitatum.*

<u>North Whicher Scarp Jarrah and Woody Pear woodland</u> (WHSFCT_A2 in Keighery et al., 2008)

- Not listed in WA
- This community type is found on the Whicher Scarp lower slopes and adjacent Plain in the North Whicher Scarp from the Abba to the Dardanup area.
- No intact occurrences located.
- Species groups of interest in forming this group are the group of taxa associated with the damp sands: *Aphelia cyperoides, Centrolepis aristata, Drosera glanduligera, Kunzea rostrata, Siloxerus humifusus, Hydrocotyle callicarpa, Pericalymma ellipticum, Stylidium calcaratum* and *Drosera menziesii* subsp. *menziesii.*

<u>North Whicher Scarp Banksia and Woody Pear woodland</u> (WHSFCT_A3 in Keighery et al., 2008)

- Not listed in WA
- This community type is located in the northern section of the North Whicher Scarp.
- No occurrences mapped.
- The type is a drier representation of Group A and is missing the damp sands group present in A2, A4 and A5 and the group that distinguishes A1

<u>Whicher Scarp Banksia grandis, Jarrah and Marri woodland</u> (WHSFCT_A4 in Keighery et al., 2008)

- Not listed in WA
- Located near the interface of the Swan Coastal Plain and the Whicher Scarp and the unusual nature of this community may reflect its location in an ecotone but, as there is so little vegetated land remaining at the interface of the Plain and Scarp, it may represent a unit of vegetation that has been almost completely cleared.
- No occurrences mapped.

<u>Swan Coastal Plain /North Whicher Scarp Banksia attenuata woodland</u> (WHSFCT_B1 in Keighery et al., 2008)

- Not listed in WA
- No occurrences mapped.
- Majority of the type is described by

  (1) the presence of a group of common taxa of leached sands especially: *Amphipogon turbinatus, Leporella fimbriata, Drosera menziesii* subsp. *penicillaris, Hypolaena exsulca, Dasypogon bromeliifolius, Stirlingia latifolia, Petrophile linearis, Melaleuca thymoides, Adenanthos meisneri, Trachymene pilosa, Pyrorchis nigricans, Lyginia barbata, Phlebocarya ciliata, Banksia attenuata, Conostephium pendulum, Hibbertia vaginata, Bossiaea eriocarpa, and Jacksonia* sp. Whicher and *Stylidium brunonianum, Johnsonia acaulis, Gompholobium tomentosum, Calytrix flavescens, Leucopogon conostephioides, Lysinema ciliatum, Banksia ilicifolia, Kunzea glabrescens, Stylidium neurophyllum* and *Eremaea pauciflora* var. *pauciflora*; and

  (2) very low frequency of taxa principally associated with Jarrah Forest: *Mesomelaena tetragona, Kingia australis, Tetrarrhena laevis, Astroloma ciliatum,*

Xanthorrhoea gracilis, Isopogon sphaerocephalus, Hibbertia cunninghamii, Johnsonia lupulina, Hakea cyclocarpa, Dasypogon hookeri, Hibbertia glomerata, Banksia grandis, Adenanthos barbiger, Calothamnus sanguineus and *Eucalyptus haematoxylon.*

C3. Ramsar sites

The Banksia Woodlands ecological community occurs within the boundary of the 'Forrestdale and Thomsons Lakes' Ramsar Wetland of International Importance. Banksia Woodlands form part of the littoral vegetation. For example, the higher sandy ground on the eastern side of Forrestdale Lake supports open woodland dominated by *Banksia attenuata* (Maher and Davis, 2009).

C4. Other national context and existing protection

Details on the following are summarised in *section 2.4*:

- Relationships to other EPBC-listed ecological communities.
- Relationships to State-listed and priority ecological communities.
- Listed threatened flora and fauna species associated with the ecological community.
- Level of protection in reserves.

Appendix D – Detailed description of threats

This appendix provides relevant information about the known and potential threats to the Banksia Woodlands ecological community. This information helps to explain why this ecological community merits listing as threatened and supports the detailed assessment for listing against criteria at Appendix E. Appendix E, Criterion 4 also discusses further how these threats affect the integrity of the Banksia Woodlands.

D1. Land clearing and impacts associated with fragmentation

Land clearing, development and intensification of land use, results in habitat loss, fragmentation and modification (DPaW, 2014a). Clearing reduces the extent of the ecological community and exacerbates patch isolation, reducing connectivity between remnants. Connectivity between remnants of the ecological community and other native vegetation is an important determinant of habitat quality at the landscape scale for native flora and fauna as well as for overall condition and persistence of the ecological community.

Urbanisation has been the main driver of Banksia Woodland fragmentation, starting shortly after Perth was founded in 1829. Urban growth has been most intense since the 1960s, largely driven by a mining boom, and the population is estimated to reach 3.5 million by 2050, which is an increase of almost 70 per cent on the 2015 population (Weller, 2009; Ramalho et al., 2014; Government of Western Australia, 2015). Banksia Woodlands in Perth and surrounds persist in a few large conservation and Crown Land areas on the current city boundaries, and in urban reserves (most of which are small and isolated), linear strips on roadside verges, and rural private properties (Ramalho et al., 2014).

Fragmentation results in reduced connectivity of the floral and faunal components of the ecological community. It can impede movement and dispersal of plants and animals, especially where unsuitable habitat may separate fragments. Patches in fragmented landscapes also have greater levels of 'edge effects' such as human disturbance, weed invasion and feral animal impact than larger, more connected patches due the greater patch edge to area ratio. In narrow remnants, where the edge to area ratio is larger, it is easier for disturbances to invade relatively further into patches and impact on the 'core' of the patch.

Many *Banksia* spp. require the co-incidence of burnt occupied and unoccupied sites to allow seed dispersal and colonization to occur (Cowling and Lamont, 1987; Cowling et al., 1987, 1990; Enright et al., 1998a,b; Groom and Lamont, 2015). Fragmentation creates barriers for plant (Banksia) dispersal and colonisation where land in between remnants is primarily urban or used for intensive agriculture. Consequently there are fewer opportunities for colonisation due to rare long-distance dispersal events, which are required to adapt to rapid climate change (Yates et al., 2010).

Fragmentation impacts may take some time to become evident, however are generally more rapid in smaller remnants. Ramalho et al. (2014) found that richness of native herbaceous species in Banksia Woodlands declined with time since isolation, mainly in the smaller remnants, and this was associated with altered soil properties. In small remnants the native plant species richness in small remnants halved in only a few decades after isolation. Furthermore, increased litter depth (possibly indicating higher productivity) and increased abundance of non-native herbaceous species in the older and smaller remnants was associated with a decline in the abundance of native herbaceous species (Ramalho et al., 2014).

Mining, exploration and extraction

The extraction of raw materials results in the loss of vegetation, hydrological impacts and the introduction and spread of dieback and weeds. Demand for basic raw materials such as gravel, shale, clay, sand, limestone and rock for construction and infrastructure development will increase in the future to support population growth (DPaW, 2014a; EPA, 2015). Extraction of mineral sands, in particular, can result in the removal of and/or disturbance to Banksia Woodlands, due to their association with the sand dune systems.

<u>D2. Climate change (increasing temperatures, declining rainfall, rainfall timing)</u>

Long-term climate variability is affecting the southwest of Western Australia, which is experiencing a trend of increasing temperatures and declining rainfall. The number of days per year hotter than 40°C has been increasing since the 1990s, and late autumn and winter rainfall (the period of most importance for native plant growth in this region, as well as for agriculture/horticulture) has been decreasing (CSIRO, 2012; DPaW, 2014a). Mean annual temperatures have risen by approximately 1°C over the past century and mean annual rainfall has declined by 15% in southwestern Australia between the mid 1970s and 2010 (Steffen and Hughes, 2013). The decline in rainfall is associated with decreases both in the frequency of daily precipitation occurrence and in wet-day amounts (Bates et al., 2010). Decline in this region has also been characterised by a lack of very wet winters since the mid-1970s (Bates et al., 2008). There is strong evidence that these changes are caused by anthropogenic climate warming, resulting in a southern shift of the Southern Annular Mode which brings rain-bearing fronts from the Indian Ocean to the Western Australian coast (Steffen and Hughes, 2013).

The reduction in rainfall is amplified as decreased streamflow in rivers and streams. In the far southwest, streamflow has declined by more than 50 % since the mid-1970s (CSIRO, 2014). This is having an impact on plant reproduction and seedling recruitment (Keith et al., 2014).

Further decreases in average rainfall are expected over southwest Western Australia compared with the climate of 1980 to 1999. Based on modelling of carbon emission scenarios, a zero to 20 per cent decrease in rainfall is expected by 2070 for low emissions with a 30 per cent decrease to 5 per cent increase by 2070 for high emissions, with largest decreases in winter and spring (CSIRO, 2014).

Although fire is an important process in Banksia Woodlands, species such as *B. prionotes*, where adults are killed by fire but fire stimulates seeds to germinate, will be particularly vulnerable to high frequency or unseasonal fires. Resprouters such as *B. attenuata*, *B. grandis* and *B. menziesii* where adult trees can survive low to medium intensity fire and regenerate from lignotubers may also be subject to local extinction due to depletion of carbohydrates, but at a much slower rate than species where adults are killed by fire (Enright et al., 1998; Wilson et al., 2014).

Urban heat islands can affect local climates and have effects on nearby remnants. Urban heat islands are caused by three factors in urban development - built materials trapping heat, urban machinery producing waste heat and the removal of trees and vegetation (and their associated shading and cooling functions) (Brown et al., 2013). If there is ongoing clearing of native vegetation remnants in the Perth metropolitan region, then this is likely to exacerbate urban heat island effects.

<u>D3. Groundwater drawdown</u>

Direct effects

One of the most significant threats to wetland and woodland ecosystems in the Swan Coastal Plain is the reduction of groundwater levels as a result of an increase in groundwater abstraction (including production bores), patterns in water regulation and decreased rainfall and subsequent recharge to the groundwater system. The dominant, deep-rooted Banksia species of the ecological community are considered to be groundwater dependant and are therefore particularly susceptible to impacts from groundwater drawdown (Canham et al., 2009). Impacts related to groundwater drawdown range from a gradual change in the structure and composition of the ecological community to sudden and widespread vegetation death (Groom et al., 2000).

Risk to Banksia Woodlands depends on the floristic community type present and its corresponding dependence on groundwater resources in the region (Groves, 2014). Previous studies comparing Banksia woodlands where groundwater extraction was occurring to those in unaffected areas show that deep-rooted tree and shrub species are more susceptible to water and temperature stress than shallow-rooted species (Groom et al., 2000; Horwitz et al., 2009). The high degree of groundwater dependence makes Banksias highly vulnerable to rapid changes in water table elevation, and historically, large numbers of *Banksia* plants have died near water supply production bores due to rapid water table decline caused by groundwater pumping during exceptionally hot summers (Groom et al., 2000).

Where impacts of decreased groundwater availability on the ecological community result in a change in plant composition and structure, there is a shift in plant community composition from phreatophytic to vadophytic species (or deep-rooted to shallow-rooted) as groundwater resources become unavailable (Groves, 2014).

Groundwater decline is not only influenced by extraction but also by declining recharge/rainfall rates as a result of climate change. Climate data has shown a decrease in average annual rainfall since 1970, dominated by reduced winter rainfall (CSIRO, 2014). Climate change may also result in temporal and spatial changes in hydrology within the Swan Coastal Plain. Changes in soil temperature and distribution of surface water as a result of a warming climate may have implications for *Banksia* species that are restricted to lower-lying areas, such as *B. ilicifolia* (Groves, 2014). Those species restricted to waterlogged areas rely heavily on subsurface soil moisture and groundwater during periods of summer drought. Climate change may reduce the number of seasonally waterlogged areas, as well as increasing the depth to groundwater, resulting in a decrease in the number of deep-rooted species in these areas (Groom, 2004).

Groundwater acidification and related effects

Groundwater decline may also result in flow on effects due to decreased access to the water table, which can impact fauna species dependent on seasonal wetlands (e.g. amphibians; Mitchell et al., 2013)

Banksias may be susceptible to death or decline due to increased acidity and soluble aluminium concentrations in subsoil porewater in areas of rapid decline of the water table in areas underlain by Bassendean dunes. Soils in these areas have a low buffering capacity and are known to contain sufficient pyrite to create acid sulfate soil conditions when the water table declines (Prakongkep et al., 2012; Clohessy et al., 2013) (Figure D1). Additionally, soils are being subject to calcium depletion in areas where the water table is undergoing rapid decline due to drought (Appleyard and Cook, 2009), a condition that is known to have caused widespread impacts on forest and woodland ecosystems in North America and Europe (Schaberg et al., 2001; Schaberg et al., 2010).

Figure D1 on next page

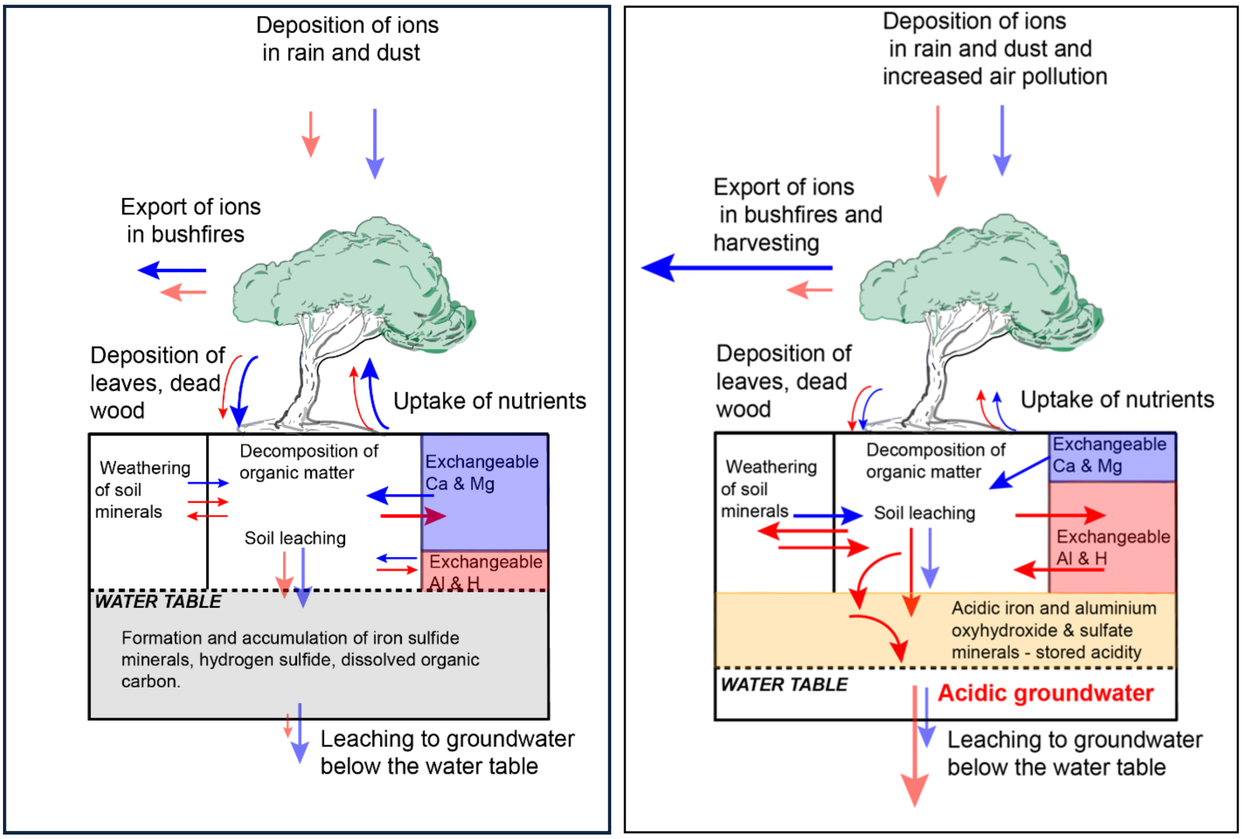


Figure D1 – Acid-base balance on Bassendean Sands (Appleyard, 2005) – Acid and base inputs and outputs from soil due to geochemical interactions between the atmosphere, vegetation, groundwater and the soil. Acid inputs and outputs are shown as red arrows, and base inputs and outputs are shown as blue arrows. The size of each arrow is approximately proportional to the magnitude of each flux.

The left diagram shows the situation before European settlement – Under natural conditions, soils typically have a large "pool" of exchangeable calcium and magnesium (blue compartment) which help buffer the soil against large changes in acidity. Conversely, there is usually only a limited amount of exchangeable acids (hydrogen and aluminium ions) available to acidify soil (red compartment).

The right diagram shows the situation after European settlement, showing processes for acidification of groundwater – The lowering of the water table by pumping and low rainfall leads to progressive drying of the soil which accelerates the oxidation and loss of organic matter and increases soil acidity. This is usually exacerbated by the increased frequency and intensity of bushfires (and timber harvesting) which increases the rate of loss of calcium and magnesium from the soil. The rate of leaching of calcium and magnesium in soil also increases, and these ions are replaced by exchangeable aluminium and hydrogen ions. As the water table falls, iron sulfide minerals are oxidised, creating a large amount of stored acidity that progressively leaches to groundwater together with large amounts of nitrogen and phosphorus, and metals.

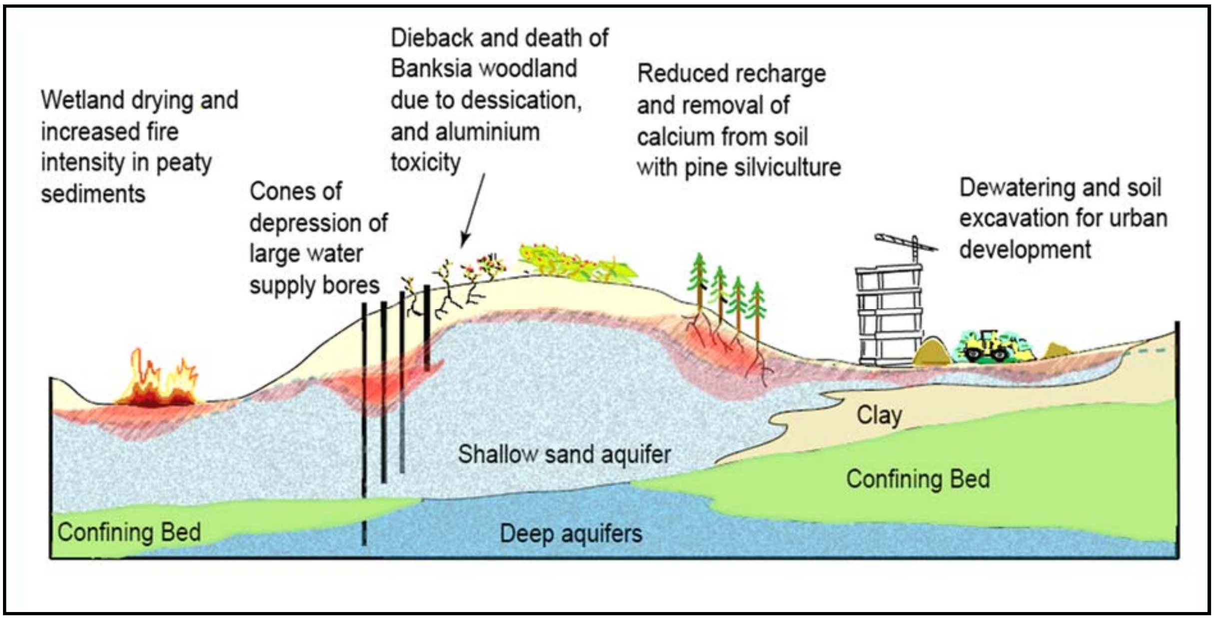


Figure D2 – Triggers for acidification on the Gnangara Mound and elsewhere on the Swan Coastal Plain (Appleyard, pers. comm., 2016).

D4. Altered fire regimes

Prior to European settlement, some fires occurred through lightning strikes and Aboriginal burning of the landscape. It is likely the Swan Coastal Plain experienced a mosaic of burning regimes such that some areas were regularly burnt while other sites may have been long unburnt. It is unclear what fire regimes specifically applied to Banksia Woodlands across its entire range.

Certain fire regimes are inappropriate for the long-term survival of the ecological community and these are a major threat to the diversity, viability and long-term conservation of communities, habitats and populations of many species on the Swan Coastal Plain. These fire effects are the result of cool-season prescribed burning, and high overall frequency of fires. While many plant taxa and ecosystems are resilient to a range of fire regimes, Banksia Woodlands and some component species have particular responses to fire (Table D1) and specific fire regime requirements including fire-free intervals sufficient to allow a build up of seed resources for species susceptible to fire, and sensitivity of geophytic life forms to cool season fires. It is unlikely that any single fire prescription is optimal for all species (Burrows, 2008; Burrows et al., 2008; Wilson et al., 2014).

More recently, fires have occurred as a result of fire management practices, escapes from prescribed burning operations, arson, and accidental ignition from a range of sources. As a result there has been a fire regime change in many parts of the ecological community's distribution, with a skewed distribution of fire frequencies (e.g. <7 yr fire frequencies are overrepresented in the Gnangara Groundwater System region, Wilson et al., 2014).

Table D1: Reproductive responses of *Banksia* species to fire (reproduced from Johnston, 2013).

<table>
<tr><th>Species</th><th>Fire Response</th><th>Fire comparisons between species</th></tr>
<tr><td>B. attenuata</td><td>Resprouter[a]</td><td rowspan="4">B. attenuata can begin to resprout after fire once they have reached 5 years of age, with the proportion of survivours increasing with age, while other resprouters become tolerant once they start flowering[b].

B. menziesii is less tolerant of fire than B. attenuata[b].

Seedlings of B. grandis require >18 years to reach first fruiting[c].</td></tr>
<tr><td>B. grandis</td><td>Resprouter[a]</td></tr>
<tr><td>B. ilicifolia</td><td>Resprouter[a]</td></tr>
<tr><td>B. menziesii</td><td>Resprouter[a]</td></tr>
<tr><td>B. prionotes</td><td>Obligate reseeder[d]</td><td rowspan="2">B. prionotes is usually killed by fire but has a stronger degree of serotiny than B. sessilis[f].</td></tr>
<tr><td>B. sessilis</td><td>Obligate reseeder[e]</td></tr>
</table>

References: [a]Lamont and Markey (1995); [b]Lamont and Van Leeuwen (1988); [c]Abbott (1985); [d]George (1984); [e]Lamont et al. (1999); [f]Cowling et al. (1987).

Higher frequency fire regimes and fire management practices that result in burning during the growing season (late autumn to late spring) and during the seeding season (for most native species in Banksia Woodlands this is from November to December) result in the following changes to Banksia Woodlands (Fisher et al., 2009 a, b; Stevens et al., 2016):

- Structural change, e.g. reduction in canopy cover, loss of native resprouting shrub cover;
- A shift from native species to introduced species, notably increased weed abundance and diversity;
- Decrease in native plant cover, richness and diversity;
- Changes to the ecological function of Banksia Woodlands; and,
- Feedback loops that promote weed species at the expense of native plants e.g. perennial veldgrass *Ehrharta calycina* is highly flammable and infestations promote further fires. Higher fire frequencies, in turn, reduces the cover and regeneration capacity of many native plants.

The richness and diversity of fauna taxa is generally maximised by avoiding widespread intense bushfires and by maintaining a diversity of post-fire vegetation successional stages to provide habitat diversity (Bamford and Roberts, 2003). The fire responses of native fauna will also vary depending on the extent of, and interaction of fire with, habitat fragmentation and other ecological disturbances (for example the effects of weeds, disease and introduced animals). The response of reptiles to fire in the region has been found to be dependent on vegetation type and fire ages with some species disadvantaged by current prescribed burning practices (Valentine et al., 2012; DPaW, 2014a).

Areas of remnant Banksia Woodlands that are small in scale and isolated from other remnants are also particularly sensitive to fire. A high intensity fire that affects the entirety of such a remnant may result in changes in structure of the ecological community, and/or the loss of populations of rare and endemic flora, due to depressed seeding rates or impacts of weeds.

Such remnants also tend to experience higher impediments to post-fire recovery, such as kangaroo grazing and invasion of weeds (Fisher et al., 2009a, b; DPaW, 2014a).

D5. Plant pathogens (dieback)

'Dieback' here generally refers to the effects of a plant disease caused by the water mould *Phytophthora cinnamomi* and other *Phytophthora* species, although it can be related to a number of plant pathogens. Other common pathogens affecting the Banksia Woodlands ecological community include aerial cankers (e.g. *Botryosphaeria ribis*), gall rust (*Uromycladium tepperianum*) (restricted to only some *Acacia* species) and the native parasitic honey fungus (*Armillaria luteobubalina*).

The consequences of infection range from localised infection affecting one or more individual plants, to a dramatic modification of the structure and composition of the native plant communities; a significant reduction in primary productivity; and, for dependent flora and fauna, habitat loss and degradation. For Banksia Woodlands, impacts are typically towards the severe extreme of this range.

Dieback disease caused by *Phytophthora cinnamomi* continues to spread and affect the distribution and abundance of many native southwest Australian plant species and their associated fauna (Shearer et al., 2004, 2007, 2009). This plant pathogen and a number of related *Phytophthora* species present a significant threat to the health and vitality of many ecosystems on the Swan Coastal Plain, including the Banksia Woodlands. *Phytophthora cinnamomi* can alter species composition and ecosystem functioning (Shearer et al., 2009), by impacting susceptible species and vegetation types, some of which may be rare or threatened, and by increasing the vulnerability of impacted areas to invasion by weeds (DPaW, 2014a) through opening up of the canopy and creation of soil voids.

Transmission of plant pathogens occurs through various vectors such as humans and kangaroos, and on larger scales, through contaminated vehicles and machinery. Effective hygiene practices can help to manage human and mechanical transmission.

D6. Invasive flora and fauna

Most exotic plant species of the Banksia Woodlands are herbs and grasses and originate from the Mediterranean Basin, California and South Africa (Dodd and Griffin, 1989; Gibson et al., 1994; Stevens et al., 2016). There are many herb and grass weeds in Banksia Woodlands with this system being vulnerable to new weeds due to their proximity to major population centres (Stevens et al., 2016).

The main weed families that invade Banksia Woodlands are the Poaceae, Asteraceae, Iridaceae, Caryophyllaceae and Papilionaceae (Keighery et al., 2012). The most common perennial weeds include: perennial veldt grass *(Ehrharta calycina),* freesia *(Freesia* sp.), hottentot fig *(Carpobrotus edulis),* gladiolus *(Gladiolus caryophyllaceus),* pelargonium *(Pelargonium capitatum),* arum lily *(Zantedeschia aethiopica),* onion grass *(Romulea rosea)* and *Moraea flaccida*. Bulbous weeds are often common, especially *Gladiolus*, *Morea* and *Freesia* spp. The main annual weeds are: catsear *(Hypochaeris glabra),* ursinia *(Ursinia* *anthemoides),* quaking grass *(Briza maxima),* silvery hairgrass *(Aira caryophyllea)* and common sowthistle *(Sonchus oleraceus).*

The weed species with the greatest effect on community composition are African perennial grasses (e.g. perennial veldgrass), and bulbous weeds such as *Gladiolus caryophyllaceus*, as they not only transform the ecological character of the community but they also reduce the diversity of the native shrubs and herbs.

About 564 introduced plants are recorded from the Gnangara groundwater system area, which makes up nearly 30% of all plant taxa in the area (Reaveley et al., 2009). Thirty of these introduced plants are identified and have significant ecological impacts due to real or potential invasiveness.

In areas of significant disturbance, Banksia woodlands in the Perth area are altered structurally by the presence of a perennial grass layer dominated by perennial veldgrass. However, perennial veldgrass is also present in a significant number of the most intact areas as it was recorded in 23% of the sample points that were located in the most intact areas of each plant community sampled (Keighery and Keighery, 2016). This grass not only competes with native taxa, but it changes the fuel loads in bushland, resulting in bushland being more prone to arson and promoting higher fire frequencies (Stevens et al., 2016).

Common invasive fauna include the European rabbit (*Oryctolagus cuniculus*), red fox (*Vulpes vulpes*), black rat (*Rattus rattus*), house mouse (*Mus musculus*), long-billed corella (*Cacatua tenuirostris*), little corella (*Cacatua sanguinea gymnopis*), rainbow lorikeets (*Trichoglossus haematodus*), laughing kookaburra (*Dacelo novaeguineae*) and the introduced honey bee (*Apis mellifera*) (DEC, 2009; Reaveley et al., 2009; Stevens et al., 2016). Introduced fauna species affect biodiversity values through habitat modification, predation, grazing and competition.

Whilst native herbivores supress non-native herbaceous species abundance in Banksia Woodlands, non-native herbivores such as the European rabbit promote non-native herbaceous species abundance (Ramalho et al., 2014) as a result of their digging activities that promote germination of the weed soil seed bank (Fisher et al., 2009b; Hopper, 2009; Ramalho et al., 2014).

D7. Other disturbances to patches

Other disturbances to patches are particularly common in the urban and peri-urban context (Stenhouse, 2004; Ramalho et al., 2014). Common anthropogenic disturbances to urban remnants include the influx of exotic plant species, especially in the understorey vegetation, dumped rubbish, access by unauthorised vehicles, paths from trampling through the vegetation, illegal cutting of vegetation, firewood collections, bare patches of ground where vegetation cover has been destroyed, erosion, feral animals and domestic animals (Stenhouse, 2004; DPaW, 2014a). These impacts are likely to spread out into remnants that are currently in peri-urban and rural areas, with future urban development plans for the Swan Coastal Plain.

D8. Key threatening processes

EPBC-listed key threatening processes relevant to this ecological community as at March 2016 are:

- Land clearance
- Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*)
- Novel biota and their impact on biodiversity
- Competition and land degradation by rabbits
- Predation by European red fox
- Predation by feral cats
- Predation, habitat degradation, competition and disease transmission by feral pigs
- Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases

Appendix E – Detailed assessment of eligibility for listing against the EPBC Act criteria

This appendix presents a detailed assessment of how the Banksia Woodlands of the Swan Coastal Plain ecological community meets each of the six listing criteria. It forms the listing advice from the Threatened Species Scientific Committee to the Minister.

Criterion 1 – Decline in geographic distribution

Criterion 1. Decline in geographic distribution			
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%

Eligible under Criterion 1(a) for listing as Vulnerable

Evidence:

The Banksia Woodlands of the Swan Coastal Plain ecological community occurs mostly within the Swan Coastal Plain bioregion with some patches extending into adjacent areas of the Jarrah Forests bioregion. The ecological community has been mapped at a number of scales within its distribution (see *Appendix C – Relationships to other vegetation classifications*).

The most comprehensive coverage is the mapping of vegetation associations undertaken by John Beard and associates across Western Australia. There are 27 system-association units that best correspond to the Banksia Woodlands of the Swan Coastal Plain (Table C1). It is noted that system-associations are mapped at a reasonably coarse scale and include some units that only partially correspond to the ecological community because they are mosaic units that include elements which are not *Banksia*-dominated woodlands (e.g. jarrah or marri woodlands). These data may, therefore, overestimate the actual extent. However, the percentage decline is interpreted as indicative of the actual decline for the ecological community given the general loss of native vegetation in the subregion, especially around the Perth metropolitan region.

The data on vegetation complexes by Heddle et al. (1980) and Havel and Mattiske (2000) represents finer-scale mapping that better represents the Banksia Woodlands ecological community. However, these studies are limited to areas south of the Moore River, only, so do not apply to the entire range of the ecological community. Remnants in the northern part of the Swan Coastal Plain, many of which remain as larger patches, were not included. There are eighteen vegetation complexes that correspond to the ecological community, to a strong or moderate degree (Table C2). Some of the vegetation complexes also represent mosaic units so may also overestimate the actual extent of the ecological community within the area covered by these studies. Floristic Community Types are not mapped comprehensively and therefore do not provide sufficient quantitative data for assessment against criteria.

The available data on system-associations and vegetation complexes show the following trends for the extent and decline of the Banksia Woodlands of the Swan Coastal Plain ecological community.

- The range of the ecological community has not contracted, i.e. patches continue to be scattered across the Swan Coastal Plain and immediately adjacent areas. However, the extent of the ecological community within its range has declined.
- Vegetation system-associations are the only dataset that covers the full range of the ecological community. These have been analysed on the basis of individual system-associations (Table E1), and by local government area (Table E2). The pre-European extent is estimated to be about 706,000 to 708,000 hectares. The estimated extent remaining in 2015 is about 336,000 to 337,000 hectares. This indicates an overall decline in extent of about 52 % across the entire Swan Coastal Plain.
- Estimates of decline based on the finer-scale vegetation complexes is higher than for system-associations, in the order of 58.6 % overall (Table E3). However, the data for vegetation complexes only applies to occurrences south of the Moore River.
- There are patterns of variable decline across the Swan Coastal Plain: Some individual system associations and vegetation complexes have declined extensively. Of the 27 system associations in Table E1, eleven have declined by more than 70 percent. Similarly, of the eighteen vegetation complexes in Table E3, six have declined by over 70 percent.
- Patterns of declines by local government area showed that decline is greatest around the Perth metropolitan region (Table E2), about 72 percent. The ecological community has declined by over 90 % within nineteen LGAs, or about 65.5 % of all LGAs with Banksia Woodlands in the Perth metropolitan region.
- Decline was lowest for the LGAs north of the Perth metropolitan region, including the Dandaragan Plateau, being about 45 % (Table E2). The system-association data inicates that decline in Peel/Harvey to Bunbury/Busselton regions is also lower than the metropolitan region, about 55 to 58 % (Table E2).
- Patterns of total vegetation decline are similar to that for the Banksia Woodlands ecological community in that certain LGAs show extensive total vegetation loss of over 90 percent, particularly in the Perth metropolitan region. A comparison of declines for the ecological community and for total vegetation indicates no consistent patterns of comparison (Table E2).

Overall, the available data indicate that the ecological community has declined by about 50 to 60 % overall across its range. It occurs as a relictual landscape (i.e. more than 90 % cleared) in the centre of its distribution in the Perth metropolitan region. This indicates a high degree of disconnectivity that is likely to disrupt any north-south movements and migration of flora and fauna along the Swan Coastal Plain.

The ecological community formerly occurred as a continuous or near continuous expanse of discrete Banksia Woodlands, grading into mosaics of Banksia with eucalypt or other woodland types across the Swan Coastal Plain. Most (>99 percent) of the pre-European extent comprised large patches of over 100 hectares (Table E4). Fragmentation has resulted in only

37.6 % of the original distribution now present as larger patches over 100 ha in size. Much of the ecological community has been cleared or reduced to small fragments under 5 hectares in size. Smaller patches are less likely to maintain their native species diversity to be able to persist in a reference condition in the near future (defined as within 20 years or 5 generations up to 100 years). Ramalho et al. (2014) showed that the smaller patches, defined as less than 5 ha in the study, showed a general trend of local extinction, where the richness of native woody and herbaceous plants was halved 50 years after fragmentation. Table E4 shows that there has been a large increase in the number and proportion of small patches under 5 ha: 72.5 % of the number of patches are now less than 5 ha. Conversely, the proportion of larger patches over 100 hectares in size has markedly declined (Table E4). While the majority of patches and extent in the original distribution comprised such large remnants, fragmentation is such that only 3.7 % of remnants are now over 100 hectares in size. Numerous disconnected and smaller fragments that occur in a matrix of intensive, mostly urban and peri-urban land uses, are less likely to survive intact into the near future.

It should also be noted that some component sub-communities of the Banksia Woodlands ecological community are separately recognised as threatened by the Western Australian government, being listed as endangered or critically endangered.

Conclusion:

Overall, the Committee considers that there has been a substantial decline in geographic extent overall across the Swan Coastal Plain, in the order of 50 to 60 percent. The Committee also notes patterns of very severe regional declines, fragmentation into smaller patches, especially in the central distribution of the ecological community around the Perth metropolitan region, and recognition of separate components as threatened under State legislation. These contribute to the overall impacts of decline in extent and are consistent with a decline in geographic distribution that is **substantial**. Therefore, the ecological community has been demonstrated to have met the relevant elements of Criterion 1 to make it **eligible** for listing as **Vulnerable**.

<u>Table E1</u>. Extent and decline of the Banksia woodlands of the Swan Coastal Plain ecological community for the most corresponding vegetation <u>system-association</u> units.

System	Vegetation Association	System-Association	Pre-European extent (ha)	2015 Extent (ha)	Decline (%)
a) Major components of the ecological community					
BARRAMBER	949	949.0	163.6	30.6	81.31
GINGIN	949	949.0	25,012.6	15,869.8	36.6
GUILDERTON	949	949.0	3,360.8	1,110.9	66.95
PINJARRA	949	949.0	1,053.5	179.4	82.97
SPEARWOOD	949	949.0	13,222.0	6,797.7	48.59
JURIEN	949	949.1	52,223.2	26,410.6	49.43
BASSENDEAN	949	949.2	115,119.2	69,921.3	39.26
BASSENDEAN	1001	1001.1	53,283.5	11,586.0	78.26
BASSENDEAN	1014	1014.1	41,064.2	22,767.5	44.56
DANDARAGAN	1030	1030.0	1,383.5	572.6	58.61
GINGIN	1030	1030.0	13,028.8	4,541.5	65.14
BASSENDEAN	1030	1030.2	114,505.5	79,636.3	30.45
KOOJAN	1030	1030.2	6,104.7	1,351.1	77.87
KOOJAN	1036	1036.0	128.6	8.8	93.12
Sub-total – Major			*439,653.5*	*240,784.1*	*45.23*
b) Partial components of the ecological community					
SPEARWOOD	6	6.1	54,427.1	13,335.5	75.50
SPEARWOOD	998	998.1	48,293.2	17,768.9	63.21
GINGIN	999	999.1	11,489.4	910.2	92.08
SPEARWOOD	1011	1011.1	1,081.8	706.2	34.72
BASSENDEAN	1016	1016.0	1,523.5	411.2	73.01
BASSENDEAN	1017	1017.0	418.4	186.1	55.52
GINGIN	1017	1017.0	5,463.2	2,386.6	56.32
BASSENDEAN	1018	1018.0	8,008.4	1,187.0	85.18
PINJARRA	1018	1018.1	6,051.0	1,258.9	79.20
GINGIN	1027	1027.1	39,809.2	23,329.6	41.40
WARRO	1036	1036.1	85,397.9	31,688.9	62.89
KOOJAN	1038	1038.0	1,715.0	376.2	78.07
PINJARRA	1181	1181.0	3,396.1	2,160.6	36.38
Sub-total - Partial			*267,074.2*	*95,705.8*	*64.17*
TOTAL Major + Partial			**706,727.7**	**336,489.9**	**52.39**

Sources: Government of Western Australia (2016). The WA Department of Parks and Wildlife identified several vegetation system-associations as potentially corresponding to the ecological community across the entire Swan Coastal Plain, based on their descriptions and subsequent surveys/mapping (see Table C1). Data shown only considers those vegetation system-associations that most likely correspond to the description of the Banksia Woodlands ecological community. **Major** components are units where the key *Banksia* species are dominant or significant elements of the upper vegetation layer, while **Partial** components are units where the key *Banksia* species are typically present but other species occur in the canopy. The data shown here reflects the extimated extent across the entire Swan Coastal Plain IBRA bioregion (SWA) plus outlier patches that extend into adjacent areas of the Jarrah Forests bioregion (JAF).

Table E2. Extent and decline of the Banksia Woodlands of the Swan Coastal Plain ecological community based on the most corresponding vegetation system-associations (SAs) by local government area (LGA). LGAs are grouped into four broad regions based on their north-south occurence on the Swan Coastal Plain: North of Perth; Perth Metropolitan; Peel–Harvey immediately south of Perth; and Bunbury–Busselton at the southernmost extent.

Local Govt. Authority Name	Pre-European extent (ha)	2015 Extent (ha)	Decline of SAs (%)	Decline of total vegetation (%)
North of Perth (including Dandaragan Plateau)				
Chittering, Shire of	30,920.9	19,279.0	37.65	61.81
Dandaragan, Shire of	178,654.5	99,624.5	44.24	55.79
Gingin, Shire of	235,945.5	132,846.8	43.70	44.72
Moora, Shire of	28,242.6	11,382.7	59.70	85.02
Victoria Plains, Shire of	9,388.7	1,950.4	79.23	85.01
Subtotal – North of Perth	*483,152.2*	*265,083.4*	*45.13*	*64.76*
Perth Metropolitan				
Armadale, City of	3,332.9	1,121.0	66.37	23.95
Bassendean, Town of	645.5	2.0	99.70	96.95
Bayswater, City of	2,773.2	23.7	99.15	98.14
Belmont, City of	3,638.2	265.8	92.69	92.36
Cambridge, Town of	1,764.1	466.6	73.55	74.54
Canning, City of	5,104.6	336.3	93.41	93.49
Claremont, Town of	494.9	3.7	99.25	99.25
Cockburn, City of	14,079.5	3,496.8	75.16	71.25
Cottesloe, Town of	301.9	1.9	99.38	98.28
East Fremantle, Town of	329.8	3.1	99.06	99.06
Fremantle, City of	1,374.3	25.4	98.15	98.18
Gosnells, City of	5,173.5	600.6	88.39	71.84
Joondalup, City of	6,345.5	700.9	88.95	89.11
Kalamunda, Shire of	1,924.0	151.0	92.15	27.78
Kwinana, City of	10,472.9	3,804.8	63.67	65.51
Melville, City of	5,246.2	309.8	94.10	94.10
Mosman Park, Town of	341.9	11.8	96.54	94.99
Mundaring, Shire of	51.3	6.8	86.75	32.96
Nedlands, City of	1,882.8	182.5	90.30	86.88
Peppermint Grove, Shire of	105.1	1.6	98.48	98.48
Perth, City of	750.4	2.5	99.67	98.44
Rockingham, City of	5,740.6	1,947.7	66.07	71.59
South Perth, City of	547.2	25.1	95.42	97.18
Stirling, City of	9,118.1	488.5	94.64	94.20
Subiaco, City of	696.5	4.8	99.31	99.31
Swan, City of	31,412.9	11,370.8	63.80	57.13
Victoria Park, Town of	1,583.6	10.5	99.34	99.17
Vincent, City of	1,084.1	0.9	99.92	99.92
Wanneroo, City of	56,095.1	23,462.1	58.17	55.74
Subtotal – Perth Metropolitan	*172,410.5*	*48,828.8*	*71.68*	*53.55*

Local Govt. Authority Name	**Pre-European extent (ha)**	**2015 Extent (ha)**	**Decline of SAs (%)**	**Decline of total vegetation (%)**
South of Perth – Peel-Harvey				
Harvey, Shire of	17,520.8	6,043.6	65.51	48.33
Mandurah, City of	8,540.7	4,017.2	52.96	53.15
Murray, Shire of	310.3	103.4	66.68	48.67
Serpentine-Jarrahdale, Shire of	4,430.6	2,148.1	51.52	47.75
Waroona, Shire of	9,548.0	5,596.6	41.39	47.04
Subtotal – Peel-Harvey	*40,350.4*	*17,908.8*	*55.62*	*48.29*
South of Perth – Bunbury-Busselton				
Bunbury, City of	1,301.6	320.9	75.34	76.33
Busselton, City of	2,445.0	306.7	87.45	58.89
Capel, Shire of	7,624.8	4,177.6	45.21	66.66
Dardanup, Shire of	744.3	153.8	79.34	52.06
Donnybrook-Balingup, Shire of	150.8	150.0	0.54	43.79
Subtotal – Bunbury-Busselton	*12,266.5*	*5,109.0*	*58.35*	*53.68*
Total	**708,179.5**	**336,930.1**	**52.42**	**58.90**

Source: Government of Western Australia (2016). The values shown here collate data for the most corresponding vegetation system associations (SAs), identified in Tables C1 and E1 as Major and Partial units.

Note: LGAs were included if they occur in the Swan Coastal Plain bioregion and originally contained *Banksia* woodlands vegetation. As some LGA boundaries extend beyond the SWA bioregion, the estimates of extent include outlying patches that occur in adjacent bioregions, within the limits of each LGA.

Table E3. Extent and decline of the Banksia Woodlands of the Swan Coastal Plain ecological community by vegetation complexes with a strong to moderate association with the ecological community (see Table C2). Vegetation complexes represent a finer-scale vegetation classification than the system-associations shown in Table E1.

Vegetation complex	Pre-European extent (ha)	2015 extent (ha)	Decline to 2015 (%)
a) Strongly associated with the ecological community			
Bassendean Complex - Central and South	87,520.6	22,575.1	74.21
Bassendean Complex – North	79,094.0	56,607.3	28.43
Bassendean Complex - North - Transition Complex	20,865.7	18,558.2	11.06
Caladenia Complex	9,663.6	5,377.0	44.36
Cartis Complex	3,281.3	492.4	84.99
Coonambidgee Complex	6,275.7	2,855.7	54.50
Cottesloe Complex - North	43,489.5	25,189.8	42.08
Cullala Complex	25,177.1	13,241.0	47.41
Karrakatta Complex - North	44,289.1	20,002.1	54.84
Karrakatta Complex - North - Transition Complex	5,263.1	4,680.9	11.06
Mogumber Complex South	13,243.4	5,284.6	60.10
Moondah Complex	17,758.8	7,250.9	59.17
Reagan Complex	9,101.4	3,051.3	66.47
Yelverton Complex	2,439.9	1,362.7	44.15
Sub-total – strongly asosciated	*367,463.1*	*186,529.0*	*49.24*
b) Moderately associated with the ecological community			
Cannington Complex	16,669.3	1,986.9	88.08
Forrestfield Complex	22,477.1	2,646.2	88.23
Karrakatta Complex - Central and South	53,105.4	12,599.1	76.28
Southern River Complex	58,810.3	10,912.0	81.45
Sub-total – moderately asosciated	*151,062.0*	*28,144.1*	*81.37*
TOTAL	**518,525.1**	**214,673.1**	**58.60**

Source: Heddle et al., (1980) for descriptions of vegetation complexes; The Western Australian Department of Parks and Wildlife (pers. comm.) for data on extent of complexes and ratings of association with the Banksia Woodlands ecological community.

Note mapping of vegetation complexes is limited to the Swan Coastal Plain and Jarrah Forests bioregions south of the Moore River, so does not cover the northern extent of the ecological community.

Table E4. Relevant patch size measures for the Banksia Woodlands ecological community based on mapping of system-associations across the entire Perth subregion of the Swan Coastal Plain

Patch size measure	Pre-European	Current (2013)	Change to 2013
Median size (ha)	146.09	1.60	99 % decrease
No. of patches	132	12,609	9,452 % increase
Maximum patch size	111,312.1	15,991.4	85.6 % decrease
Patches < 5 ha – Number	39	9,144	23,346 % increase
Patches < 5 ha – % of total number	29.6	72.5	Increased
Patches < 5 ha – % of pre-European extent	<0.1	48.1	Increased
Patches > 100 ha – Number	68	461	578 % increase
Patches > 100 ha – % of total number	51.5	3.7	Decreased
Patches > 100 ha – % of pre-European extent	99.9	37.6	Decreased

Source: Government of Western Australia (2014)

Note: Patches below 0.1 hectares were excluded from the analyses, due to their potential to be artefacts of data processing. Data for the most corresponding system- associations identified in Table E1 were used for analyses.

Criterion 2 – Limited geographic distribution coupled with demonstrable threat

Criterion 2 - Limited geographic distribution coupled with demonstrable threat			
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

A number of patch size measures may be applied here, depending on what data are available.
1) The mean or the median patch area. In cases where the ecological community is highly fragmented and the patch data distribution is skewed towards mostly small patches, the median would be a more appropriate measure. Otherwise, the smaller of the mean or median should be referred to.
2) The proportion of patches that fall within each size class.
3) Changes in patch size and distribution between the modelled pre-European and currently mapped occurrences.

Criterion 2 aims to identify ecological communities that are geographically restricted to some extent. It is recognised that an ecological community with a distribution that is small, either naturally or that has become so through landscape modification, has an inherently higher risk of extinction if it continues to be subject to ongoing threats that may cause it to be lost in the future. That there are demonstrable and ongoing threats to the Banksia Woodlands of the Swan Coastal Plain ecological community has been detailed in *Appendix D – Description of threats*.

The indicative measures that apply to this criterion are:

- extent of occurrence, an estimate of the total geographic range over which the ecological community occurs;
- area of occupancy, an estimate of the area actually occupied by the ecological community, which generally equates with its present extent;
- patch size and size distribution, an indicator of the degree of fragmentation of the ecological community and the vulnerability of small patches to particular threats; and
- an assessment of timeframes over which threats could result in loss of the ecological community.

Eligible under Criterion 2 for listing as Endangered

Evidence:

Extent of occurrence

The Banksia Woodlands ecological community is mostly occurs in the Swan Coastal Plain bioregion, with occurrences extending across the entire bioregion, from north of Jurien to west of Busselton and onto the Dandaragan Plateau. Some occurrences also extend into neighbouring areas of the Jarrah Forests bioregon. The extent of occurrence is best approximated by the area of Swan Coastal Plain bioregion, which is about 1,526,000 hectares. This exceeds the threshold for a limited geographic distribution.

Area of occupancy

The likely area of occupancy for the Banksia Woodlands ecological community is best approximated by data on vegetation system-associations, since this information relates to the entire extent of the ecological community. The data on vegetation complexes only refers to a part of the range that occurs south of the Moore River. On the basis of the most corresponding system-associations (Tables E1, E2), the area of occupancy is estimated to be up to 337,000 hectares. This exceeds the threshold for a limited geographic distribution.

Patch size distribution

Available data allow a comparison between a modelled pre-European patch size distribution of Banksia Woodland patches with their current size distribution (Tables E4; E5). The pre-European mapping indicates that the Banksia Woodlands had an almost continuous distribution across the Swan Coastal Plain characterised by mostly large remnants. However, the current distribution (data as at 2013) is characterised by intensive fragmentation into numerous smaller remnants (Tables E4; E5).

- About 85 % of the ecological community's extent originally occurred as very large patches over 10,000 hectares in size (Table E5). Only two very large patches now remain, and they account for 7.6 % of the ecological community's current extent.
- Less than 1 % of the pre-European extent comprised patches under one hundred hectares in size. As a result of fragmentation, about 21.8 % of the current extent involves patches under one hundred hectares in size (Table E5).
- The number of patches has increased from 132 to over 12,000 patches. About half of the pre-European patches were over 100 hectares in size. Fragmentation of the ecological community has resulted in almost all patches (96 percent) being under one hundred hectares, with most (82 percent) being less than ten hectares.
- The number of patches under five hectares in size increased by several orders of magnitude, from 39 to over 9000 patches (Table E4). This is a measure of critical functionality such that patches below this threshold may have decreased viability into the future (Ramalho et al, 2014).
- The median patch size has reduced over time by about 99 percent, from 146 hectares to only 1.6 hectare (Table E4). At the same time, the number of patches has also increased

markedly from an estimated 132 generally larger patches to over 12,000 mostly small patches.

These changes in patch size distribution are consistent with a geographic distribution that is very restricted.

The patterns of decline highlighted above (Table E2), indicate that the patterns of clearing and fragmentation are not evenly spread across the Swan Coastal Plain. Clearing is more extensive around Perth in the central part of the Swan Coastal Plain, where fragments are surrounded by intensive urban land use. There has been relatively less clearing (and less urbanisation) in the region north of Perth, where some larger remnants still remain. Smaller remnants are more likely to be impacted by disturbance, lose plant species richness (Ramalho et al., 2014) or provide unsuitable habitat requirements for certain fauna due to edge effects and the proximity of high level threats (e.g. from encroaching suburban developments, lack of regenerative fire regimes). These pressures are likely to continue, especially in the central and southern Swan Coastal Plain, but are likely to expand as future developments extend into the northern part of the ecological community that at present are relatively less impacted.

Timeframes

Given the key *Banksia* species are long-lived dominant and characteristic trees of the ecological community, their mean generation lengths are likely to be measured in decades. The timeframes relating to generations are, therefore, likely to approach the maximum timeframe stated for this criterion, i.e. up to 100 years. The geographic distribution of the ecological community is presently very restricted, due to intensive fragmentation into numerous very small patches, which is in marked contrast to the nature of the ecological community's original distribution as near-continuous remnants. Such fragmentation coupled with intensive threat of clearing and other threats, particularly in the central Swan Coastal Plain around Perth, but also further south, suggest that the ecological community could be lost across much of its range within the near future.

Conclusion:

The Committee considers that the heavily fragmented nature of its geographic distribution plus the nature of the threats to the ecological community over the near future indicates that the ecological community has met the relevant elements of Criterion 2 to make it **eligible** for listing as **Endangered**.

<u>Table E5.</u> Changes in patch size distribution for the Banksia Woodlands of the Swan Coastal Plain ecological community.

a) Size distribution based on number of patches per category

Patch size category	**Pre-European**		**Current – 2013**	
	No. of patches	**% no. of patches**	**No. of patches**	**% no. of patches**
0.1 – 1.0 ha	25	18.94	4,627	36.70
>1.0 – 10.0 ha	15	11.36	5,767	45.74
>10.0 – 100 ha	24	18.18	1,754	13.91
>100 – 1000 ha	24	18.18	409	3.24
>1000 – 10 000 ha	27	20.45	50	0.40
>10 000 ha	17	12.88	2	0.02
Total	**132**	**100.0**	**12,609**	**100.0**

b) Size distribution based on area per category

Patch size category	**Pre-European**		**Current – 2013**	
	Area (ha)	**% total area**	**Area (ha)**	**% total area**
0.1 – 1.0 ha	7.7	<0.01	2,324.0	0.68
>1.0 – 10.0 ha	36.7	<0.01	18,969.6	5.56
>10.0 – 100 ha	997.0	0.14	53,049.8	15.55
>100 – 1 000 ha	7,289.9	1.03	107,746.6	31.59
>1000 – 10 000 ha	97,250.2	13.72	133,025.2	39.00
>10 000 ha	603,185.4	85.10	26,009.1	7.62
Total	**708,766.8**	**100.0**	**341,124.4**	**100.0**

Source: Government of Western Australia (2014). The values shown here are based on the most corresponding vegetation system-associations identified in <u>Table E1</u>.

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

Criterion 3 – Loss or decline of functionally important species

Criterion 3 - Loss or decline of functionally important species			
Category	**Critically Endangered**	**Endangered**	**Vulnerable**
For a population of a native species likely to play a major role in the community, there is a:	very severe decline	severe decline	substantial decline
3.1 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
3.2: *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.

Insufficient information available for listing under Criterion 3.

Evidence:

The four dominant key *Banksia* species that occur in the ecological community are most likely to be considered as functionally important across the entire range of the ecological community. However, these species individually remain common and are not considered to be threatened across the range of the ecological community. A large number of threatened species occur in the ecological community but none are identified as of particular functional significance for the ecological community across its range.

Given the high species richness of vegetation right across southwestern Australia and the high local endemism of *Banksia* floristic communities, it may be that loss or decline of entire floristic or faunal suites from a locality, instead of the decline of individual species, better characterises functional loss in this ecological community. Keighery and Keighery (2016) note that 1130 native flowering plant taxa occur on the Swan Coastal Plain and that 86 % of plant species in the Banksia Woodlands are endemic to those woodlands. The species richness of Banksia woodlands in the Perth area is typically high, averaging at least 30 to 65 species per 10x10 m quadrat, depending on floristic community type. However, there is no consistent quantitative data that documents losses of local endemism across the ecological community.

Conclusion:

There is insufficient information to determine the eligibility of the ecological community for listing in any category under this criterion.

Criterion 4 – Reduction in community integrity

Criterion 4 - Reduction in community integrity			
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:			

Reference should also be made to the indicative restoration timeframes as outlined under Criterion 3, above.

Eligible under Criterion 4 for listing as Endangered

Remnants of the Banksia Woodlands of the Swan Coastal Plain ecological community are subject to a number of ongoing threats, as described in *Appendix D – Detailed Description of threats*. The ecological community is also known to be intolerant of frequent disturbance. A reduction in the integrity of the ecological community is evident from the effects of various threats including clearing and fragmentation, loss or decline of native flora and fauna, presence of invasive flora and fauna, hydrological degradation, altered fire regimes, dieback due to plant pathogens and climate change.

Fragmentation and degradation affect the integrity of the remaining patches of the Banksia Woodlands. The extensive and rapid urban sprawl, particularly around the Perth Metropolitan region and Swan Coastal Plain has had large impacts on native vegetation and species through habitat loss, disturbances that allow non-native species to be introduced and establish, the spread of plant diseases, and alteration of natural hydrological and disturbance regimes (Stenhouse, 2004; Fisher et al., 2009a; Ramalho et al., 2014). Integrity is more likely to be affected in smaller and isolated remnants but can still apply to larger, less fragmented remnants of the ecological community as they remain subject to threats such as altered fire regimes, weeds, climate change and groundwater decline.

A reduction in community integrity results in changes to both the species composition and ecological processes that maintain the ecological community, as outlined in *Appendix B – Biology and ecological processes*. If these changes are ongoing, it will lead to further decline and could lead to the eventual loss of the ecological community.

Reduction in integrity due to impacts associated with fragmentation and associated degradation

As detailed above, Criterion 1 showed the degree of decline and loss of the ecological community, while Criterion 2 demonstrated that fragmentation of the ecological community has increased markedly with time.

When developments remove or severely fragment the original native vegetation, and replace or surround them by modified landscapes, it represents a loss of habitat and corridors that can alter the abundance of species that depend on these features, and their ability to disperse (Davis et al., 2008, Davis et al., 2013). Even though populations of flora and fauna may persist or be relatively stable in the short-term, their ability to escape from or recolonise remnants after a disturbance (e.g. fire) can be hindered by fragmentation if they are unable to successfully disperse across landscapes that are modified and unsuitable.

Disturbances are more likely to occur to patches in urban and peri-urban areas due to their proximity to humans. Such remnants are prone to impacts such as rubbish dumping (including garden waste as a source of weeds), access by unauthorised vehicles or paths created by people trampling through the vegetation, illegal removal of vegetation (including for firewood), increased patches of bare ground where vegetation cover has been destroyed, inappropriate fire regimes and introduction of domestic and feral animals (Stenhouse, 2004; DPaW, 2014; Ramalho et al., 2014). These impacts are likely to spread out into other remnants as future urban developments encroach into the remaining native vegetation of the Swan Coastal Plain.

Few studies document the direct impacts of fragmentation on the Banksia Woodland ecological community. Native plant species richness within isolated patches of Banksia Woodland were found to generally decrease with time since isolation, particularly in smaller remnants (Ramalho et al., 2014). This was associated with altered soil properties.

For birds, Davis et al. (2013) showed that the amount of native or other vegetation in the immediate surroundings (within 2km) was the most important factor for determining occurrences of bushland birds in the Perth region. Occurrences of these species declined as the landscape changed from variegated to fragmented to relictual, according to the percentage of vegetation cover remaining.

An analysis of reptile assemblages in urban bushland remnants of the Swan Coastal Plain (most of which were Banksia Woodlands) showed that larger areas of urban bushland retained larger assemblages of reptiles for all groups, except skinks (How, unpublished). The assemblages in smaller patches of Banksia Woodland differed due to the loss of some original species from the assemblages. This indicates fragmentation into smaller, presumably more degraded patches also limits faunal species richness.

There also is indirect evidence about loss of integrity based on general impacts to native vegetation in the Swan Coastal Plain along roadside verges. It is inferred that, 1) given Banksia Woodlands were the dominant vegetation type in the Perth subregion of the Swan Coastal Plain, the patterns evident for native vegetation generally apply; and 2) that the patterns evident in native vegetation along roadsides also reflect those in non-roadside remnants, as these are subject to similar threats. The information for native vegetation in roadside verges shows the following (Table E6).

- Roadside native vegetation verges are typically narrow, mostly five metres or less wide. This pattern is most evident in the southern part of the Swan Coastal Plain (Capel and Busselton shires) but less evident in the northern part of the plain (Dandaragan shire), where roadside verges are typically 5 to 20 metres wide (Table E6a).
- The majority of roadside remnants adjoin agricultural land use that has been entirely cleared or sometimes has scattered native vegetation. Only a low proportion of roadside

remnants (about 11 to 24 percent) adjoins uncleared native vegetation (Table E6b). This means that the remnants are mostly no wider than the narrow roadsides and this corroborates the patterns of decline and fragmentation presented under Criteria 1 and 2, that the ecological community is now fragmented into smaller patches. It also means that most remnants are in close proximity to modified lands that are more prone to the influence of disturbances such as weeds, fertiliser applications, introduction of dieback or human actions.

- Native vegetation is able to retain some degree of structural integrity. Only just over half the roadside reserves surveyed in the Swan Coastal Plain retained more two or more native vegetation layers (Table E6c). Even of greater concern, many roadside remnants demonstrated low native plant species richness. In the Shires of Capel and Serpentine-Jarrahdale a majority of roadside reserves showed only five native species or fewer present (Table E6d). This represents a marked loss of species, in light of the noted high biodiversity of Banskia Woodlands that is typically in the order of 30–60 native plant species. The decline in integrity is therefore more evident though a decline in the native plant species present than as outright loss of complete vegetation layer(s). However, over 35% of the remnants had only one layer, for instance, when *Banksia* trees remain as an overstorey above weeds instead of over a diverse assemblage of native shrubs and herbs. In the Dandaragan Shire, the northernmost part of the Swan Coastal Plain, most roadside remnants had a less complex vegetation structure with fewer vegetation layers (Table E6b) though more roadside remnants retained a higher richness of plant species. These observations may reflect a shift to a lower, less dense woodland structure due to a declining rainfall gradient from south to north along the coastal plain.

In summary, there is evidence of ongoing degradation and fragmentation of native vegetation within the Swan Coastal Plain, evident from the reduced size of remnants, proximity to highly modified landscapes, altered vegetation structures and loss of species richness. This appears more marked in the central and southern parts of the Perth subregion that has undergone more intensive development. The Perth metropolitan area effectively bisects the Swan Coastal Plain and represents a significant, often impenetrable barrier to the remnant populations of many species that prevents sustainable evolutionary process necessary for their future survival (How, unpublished). There is an ‘extinction debt’ inherent in all smaller fragments that is likely to result in ongoing local extinctions and changes in species assemblages.

Table E6. Characteristics of native vegetation along roadside reserves from four local government areas in the Perth subregion of the Swan Coastal Plain. Numbers show the proportion of surveyed roadside kilometres within each category while Table a) also shows the number of kilometres surveyed along roadsides for each local government area.

a) Width of vegetation roadside reserves.

Reserve width category	Dandaragan (%)	Serpentine-Jarrahdale (%)	Capel (%)	Busselton (%)
1 to 5 metres	9.7	76.2	95.0	85.6
5 to 20 metres	41.5	4.5	5.0	8.0
Over 20 metres	28.6	0.0	0.0	1.4
Unknown	20.2	19.3	-	5.0
Total kilometres surveyed	1837.0	869.1	596.8	1140.1

b) Land use adjoining surveyed roadside reserves.

Adjoining land use to road reserve	Dandaragan (%)	Serpentine-Jarrahdale (%)	Capel (%)	Busselton (%)
Agriculture – completely cleared	50.6	37.2	40.0	36.9
Agriculture – scattered vegetation	28.6	30.9	33.0	41.2
Uncleared native vegetation	17.3	23.9	11.0	11.5
Urban-Industrial	<0.1	1.8	10.0	2.5
Plantation of non-natives	3.5	0.2	3.0	3.7
Other (including rail, drains)	0.0	6.1	3.0	4.2

c) Native vegetation structure within surveyed roadside reserves.

No. native vegetation layers present	Dandaragan (%)	Serpentine-Jarrahdale (%)	Capel (%)	Busselton (%)
0 vegetation layers (destroyed)	8.6	13.0	13.0	7.4
1 vegetation layer (degraded)	78.2	24.6	31.0	35.2
2-3 vegetation layers (more intact)	13.2	62.4	55.0	57.5

d) Native plant species richness within surveyed roadside reserves.

No. of native species present	Dandaragan (%)	Serpentine-Jarrahdale (%)	Capel (%)	Busselton (%)
0-5 native plant species	17.5	51.5	58.0	23.0
6-19 native plant species	43.5	29.0	36.0	42.3
20+ native plant species	39.0	19.5	6.0	34.7

Source: WA Roadside Conservation Committee (2006-2011) Technical reports from roadside surveys for the four local government areas listed in the tables. Shires were selected based on whether *Banksia* woodland vegetation associations were known to be present and a roadside flora survey had been undertaken within the last ten years. Selected shires are taken to be representative of the northern (Dandaragan), Perth (Serpentine-Jarrahdale) and southern (Capel and Busselton) parts of the Swan Coastal Plain.

Reduction in integrity due to loss or decline of native fauna

Threats also have resulted in decline of the faunal component of the Banksia Woodlands. This, in turn, feeds back into the decline of native vegetation because fauna are integral to ecological functions of the ecological community. Many animal species have habitat or dispersal requirements that are no longer available due to loss, fragmentation and degradation of the natural vegetation and remnants now occurring amongst highly modified, often unsuitable landscapes. The greatest decline in native fauna has been in urban and peri-urban areas, notably the Perth metropolitan region, and this is likely to worsen with the ongoing urban sprawl of Perth and other major centres on the Swan Coastal Plain, such as Bunbury.

Mammals are one of the key faunal groups for which there is reasonable information about their biology and decline. Mammals appear to be the most affected group with 52% of the original mammal fauna of the Perth region now considered extinct (Davis et al., 2008). A state government report in 2000 suggested thirty-three native mammals were thought to have occurred on the Swan Coastal Plain prior to European settlement, and it is likely that only 16 species persist (Government of Western Australia, 2000). A detailed bioregional analysis by Burbidge et al (2009) identified 40 indigenous mammal species were once present in the Swan Coastal Plain bioregion and that ten species are now extinct from the bioregion with another eight species in decline or serious decline. Bioregionally extinct mammals include iconic species such as the numbat, bilby and woylie but also five species of native mice and rats. The decline of marsupials resulted from a combination of the threats outlined in *Appendix D* (Stevens et al., 2016) that operate across the Swan Coastal Plain, and generally across southwestern WA. However, which of these factor(s) were most important in causing decline differed among particular species (Abbott, 2008).

An example of a mammal species that has not become extinct but declined due to loss of Banksia Woodlands is *Tarsipes rostratus* (noolbenger, honey possum). The honey possum is a very important pollinator of *Banksia* and other nectar-rich Proteaceae (Bradshaw, 2014). They prefer long unburnt Banksia Woodlands that have been undisturbed for 20 to 25 years or longer (Bradshaw, 2014) and their abundance in these areas is almost double that of recently burnt sites. They are vulnerable to disturbances that affect their key *Banksia* food resources, such as dieback, more frequent fires, groundwater changes and climate change. Their suitable habitat consequently declines when Banksia Woodland remnants are lost outright, fragmented or poorly managed. Climate change modelling predicts potential future declines in the abundance of honey possums of 20 to 50%, depending on rainfall decline scenarios.

Native marsupials would have played a key role in trophic interactions, pollination, seed dispersal, decomposition, mineral nutrient cycling and fuel load reduction in Banksia Woodlands (Stevens et al., 2016). The most common native mammals that now remain in urban bushland remnants are those species able to adapt to human habitations, such as *Macropus fuliginosus* (western grey kangaroo) and *Trichosurus vulpecula* (common brushtail possum). *Isoodon obesulus fusciventer* (quenda) is possibly the only medium-sized ground-dwelling native mammal that survives in the Perth metropolitan region. However, it is subject to ongoing habitat loss and predation by foxes and cats (Davis et al., 2008).

Birds have also been affected by the loss or declining condition of Banksia Woodlands. Across the Swan Coastal Plain, nearly 50% of the passerines and 40% of the non-passerines have declined or have become locally extinct since European settlement (Government of Western Australia, 2000). These include species that are habitat specialists and generalists. The impacts of urbanisation are also demonstrated at a local scale by the decline or extinction of bird species from the large, isolated bushland remnant at Kings Park between 1928 and 1995. The major extinctions in Kings Park have involved insectivores, such as *Eopsaltria griseogularis* (western yellow robin), *Petroica boodang* (scarlet robin), *Acanthiza inornata* (western thornbill) and *Pachycephala pectoralis* (golden whistler). Similarly, in Whiteman Park 4200 ha native vegetation remnant containing significant areas of Banksia Woodlands, *Melanodryas cucullata* (hooded robin) have recently disappeared from where they were regularly recorded between 1990 to 2003 (Davis et al., 2013).

A major concern about birds refers to likely impacts of habitat losses to the iconic black cockatoos of the Swan Coastal Plain, particularly the nationally endangered *Calyptorhynchus latirostris* (Carnaby's black cockatoo). In particular, the clearing of feeding habitat on the Swan Coastal Plain, as Banksia Woodlands and commercial pine plantations provide a significant food resource (DPaW, 2013). Carnaby's black cockatoos breed in trees of the wheatbelt region but migrate to the coast each year. On the Swan Coastal Plain, Carnaby's black cockatoo show a strong preference for food resources from *Banksia* and *Hakea* shrubs (Johnston, 2013), so the Banksia Woodlands provide a key resource for these birds. With the decline in Banksia Woodlands, however, they have adapted to roosting in pine plantations. The Great Cocky Counts that are regularly organised by Birdlife Australia WA to monitor the populations of these cockatoos, noted that a substantial proportion of Carnaby's black cockatoos sighted in the greater Perth-Peel region are now associated with the Gnangara pine plantation north of Perth (Byrne et al., 2015). In previous years between 27 to 59 % of sighted cockatoos occurred in this pine planatation. The 2015 Great Cocky Count found significant declines in the fraction of occupied roosts and flock size over the last six years to 2015. Based on these observations, the current rate of decline was estimated as 15% per year of the total number of Carnaby's black cockatoos on the Perth-Peel Coastal Plain (Byrne et al., 2015). This indicates Carnaby's black cockatoo remains in serious decline. The decline of cockatoos will only be exacerbated if the Perth Green Growth Plan removes substantial areas of remnant Banksia Woodlands as well as continuing to reduce the existing pine plantations in the Perth-Peel region, as proposed. Further removal of pines as feeding habitat will place greater reliance on the remaining (but also declining) patches of Banksia Woodlands as habitat.

As noted above, reptile species assemblages in the Swan Coastal Plain depend on the size of the bushland remnant (How and Dell, unpublished). The long-term persistence of reptile populations may be affected by the presence of barriers to dispersal and, consequently, a reduced ability to recolonise a patch if local extinction occurs (Davis et al., 2008). For many species of reptiles, roads, buildings and other infrastructures are effective barriers to dispersal. Fossorial snakes such as *Lerista lineata* (Perth slider, Perth lined lerista) and *Neelaps calonotus* (black-striped snake) are unlikely to cross these barriers and are more prone to desiccation, car strike and increased predation (Davis et al., 2008).

Indicative for amphibians, the terrestrial breeding *Myobatrachus gouldii* (turtle frog) is affected by the clearing of the sandy Banksia woodland habitats that it occupied throughout the metropolitan region (Davis, 2008; Mitchell, 2011). Their diet consists almost entirely of termites that feed on the wood of *Banksia* trees. Therefore, processes that remove these trees or affect the capacity of termites to utilise *Banksia* will affect turtle frogs via a decline in their food source. Groundwater declines also affect turtle frogs by affecting the health of Banksia trees and by the potential loss of soil-bound moisture required for the frog's survival and reproduction during dry periods (Mitchell, 2011).

Impacts to the invertebrate component of the Banksia Woodland community are poorly studied. Within the Perth metropolitan region, the native earthworm fauna has been mostly replaced by introduced species in disturbed soils, such as gardens. However, introduced species of earthworm were not found in undisturbed bushland remnants (Abbott, 1982). This suggests that the loss of native vegetation remnants has led to a decline of the native earthworm fauna and that remnant vegetation fragments will continue to provide refuges in the future (Abbott and Wills, 2002).

In summary, there have been substantial changes to the fauna of the Swan Coastal Plain bioregion, associated with the loss of native vegetation remnants, that has resulted in the localised extinction or decline of particular species.

Reduction in integrity due to invasive flora and fauna

Weeds are a major ongoing problem, particularly in urban areas with significant weed seed banks and the urban interface representing an ongoing source of weed invasion (Stevens et al., 2016). Weeds Australia identified 139 taxa of significant weeds that occur in the Swan Coastal Plain bioregion. Stenhouse (2004) found that weed invasion was evident in all 71 bushland reserves surveyed in the Perth region. Surveys of roadside vegetation in certain local government areas of the Swan Coastal Plain indicate that a substantial proportion, overall 31 % of roadside reserves, are impacted by weeds to a high degree and another 29 % of roadside reserves are modertately affected by weeds (Table E7a). These observations all confirm that the Swan Coastal Plain is affected to high degree by weed invasion and that, by implication, the Banksia Woodlands are similarly impacted by weeds.

Table E7. Weed infestations along roadside reserves in local government areas in the Swan Coastal Plain. Numbers show the proportion of surveyed roadside kilometres within each category

a) Extent of weed infestations within roadside reserves.

Local GovernmentAuthority	Total km surveyed	Weed infestation category [1] (% of roads surveyed)		
		Light (<20%)	Medium (20-80%) [2]	High (>80%)
Dandaragan	1837.0	51.0	17.6	31.4
Serpentine-Jarrahdale	869.1	28.9	28.7	42.4
Capel [2]	596.8	40.0	37.0	23.0
Busselton	1140.1	26.0	29.9	44.1
Total km / Median % weeds	**6080.0**	**41.3**	**29.3**	**31.6**

b) Significant weeds targeted by roadside flora surveys.

Weed species	Dandaragan (%)	Serpentine (%)	Capel (%)
African lovegrass (*Eragrostis curvula*)		37.7	46.4
Arum lily (*Zantedeschia aethiopica*)			14.5
Bridal creeper (*Asparagus asparagoides*)	5.8		
Cape tulip (*Moraea flaccida, M. miniata)*	6.1	14.3	2.2
Gladiolus *(Gladiolus* sp.)	25.2		
Kikuyu *(Cenchrus clandestinus)*		12.1	
Lavender *(Lavandula dentata)*		5.3	
Paterson's curse (*Echium plantagineum*)	41.2		
Spiny rush (*Juncus acutus*)	16.5		
Thistles (Asteraceae)			12.1
Watsonia *(Watsonia meriana)*		30.5	
Wild radish (*Raphanus raphanistrum*)			22.2

Source: WA Roadside Conservation Committee (2006-2011) Technical reports from roadside surveys of the shires listed above. Shires were selected based on whether Banksia Woodland vegetation associations were known to be present and a roadside flora survey had been undertaken within the last ten years.

Notes: For Table a): [1] Weed infestation category is based upon the estimated percentage of total plants identified as being weeds. [2] The categories applied for the Shire of Capel are: Light <30%, Medium 30-70% and Heavy >70%.

For Table b): Each survey targeted a different suite of weeds considered significant in each shire. Weeds that were targeted but present in less than 5% of any shire roadsides surveyed are not shown. These include: Victorian Tea Tree (*Leptospermum laevigatum*), Boneseed (*Chrysanthemoides monilifera* subsp.m*onilifera*), Evening Primrose *(Oenothera stricta) and* Apple of Sodom (*Solanum linneaenum* syn. *S. sodomaeum*). Similar data for Busselton were not included because the targeted survey grouped a number of the key surveyed weeds that did not allow direct comparisons at the species level.

Many weeds that occur in Banksia Woodlands can alter community composition through competitive effects that reduce the diversity of native shrubs and herbs in the understorey.

Other weeds can produce a substantial annual biomass that increases fuel loads in bushland, resulting in native remnants becoming more prone to fire, especially higher frequencies of fire (Stevens et al., 2016). Examples of such weeds include perennial veldgrass *(Ehrharta calycina)*, wild oats (*Avena* species), ursinia *(Ursinia* species) and fleabane *(Conyza* species). Increased fire frequency creates feedback loops that promote the greater presence of weed species due to their shorter generation lengths, higher seedbanks and faster response to post-fire ash-bed nutrients than many native species (Fisher et al., 2009 a, b). Invasive grassy weeds are present in many patches of Banksia Woodland including some of the more intact remnants. For instance, 23% of sites described in Keighery and Keighery (2016) had perennial veldtgrass present while 37 to 46 % of roadside remnants surveyed in Serpentine-Jarrahdale and Capel shires were invaded to some degree by African lovegrass (*Eragrostis curvula*) (Table E7b). Patches of Banksia woodland with an understorey dominated by perennial veldgrass exhibit very little seed production, seedling recruitment and seedling survival of the key Banksia species despite the prominent presence of a mature canopy of *Banksia* (Stevens et al., 2016).

Introduced fauna species affect biodiversity values through habitat modification, predation and competition. The small to medium sized ground mammals that now dominate fauna species on the Swan Coastal Plain, especially in urban and peri-urban areas, include the cat, fox, house mouse and black rat (Keighery et al., 2006). There are also many European rabbits (*Oryctolagus cuniculus*) and kangaroos in small fragmented reserves, and wild pigs in wetland areas. Feral fauna are difficult to control, particularly in urban settings, due to safety considerations for non-target species and the public (Stevens et al., 2016). Foxes and cats now are the primary predators on remaining native fauna species (e.g. quenda) and have contributed to local extinctions of other native fauna species, as noted above.

Non-native herbivores promote non-native herbaceous species, possibly through the disturbance of top soil through their digging habits (Ramalho et al., 2014). Given that small to medium native mammals are now largely absent from the ecological community, digging by non-native mammals such as the European rabbit now results in weed invasion, due to the large weed seed banks present at many sites. Disturbance of this thin layer in the ancient and impoverished soils of the southwestern Australia is known to promote invasion (Hopper, 2009), as it provides an opportunity for establishment by non-native species, which are abundant in the topsoil seed bank, and germinate and grow faster than native species (Fisher et al., 2009b).

Studies in the Gnangara groundwater system area identified predation by foxes and cats as the main threat to the declining mammal fauna, though habitat destruction and competition by pigs, rabbits, feral bees and other introduced species also affect biodiversity values in the area (Reaveley et al., 2009).

In summary, there is a considerable presence of introduced plants and animals across the Swan Coastal Plain that impacts upon the flora and fauna of the Banksia Woodlands ecological community.

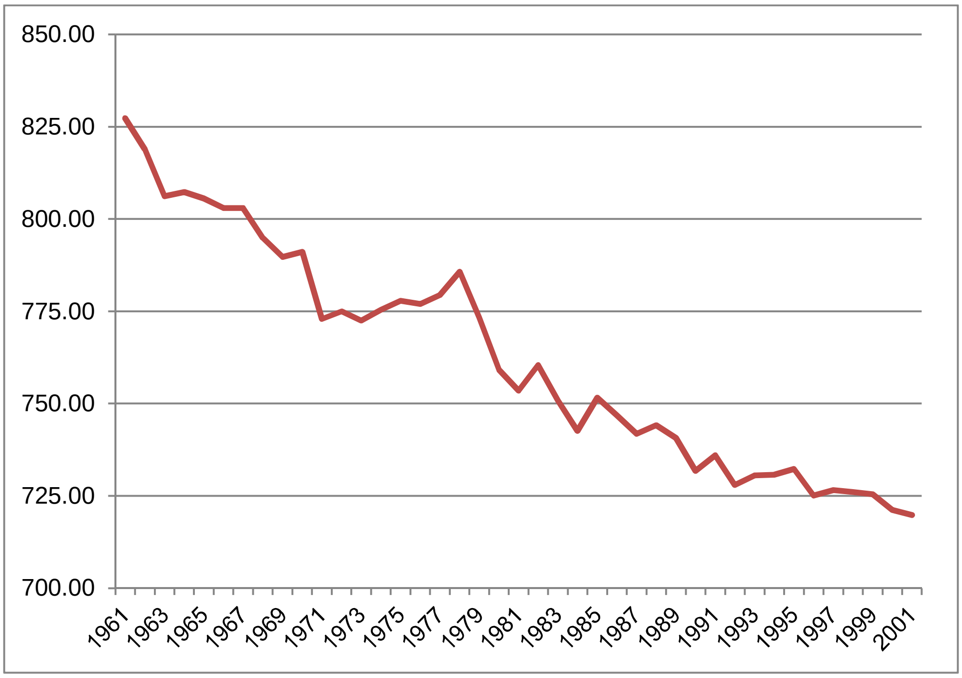
Reduction in integrity due to declining water availability and quality

The dominant *Banksia* species of the ecological community tend to be deep-rooted and are dependant primarily on groundwater for survival. As such, they are susceptible to impacts from groundwater drawdown (Canham et al., 2009; Sommer and Froend, 2011) and declining rainfall, which limits the potential recharge to the water table, on which the ecological community relies.

There are documented changes to the availability of water and patterns of usage in the Swan Coastal Plain.

- Mean annual rainfall has declined across southwestern Australia by approximately 15 % since 1975 (Steffen and Hughes, 2013). For example, rainfall records at Perth Airport, in the centre of the Swan Coastal Plain, show a generally progressive decline in rainfall, based on 30-year running means, since the late 1970s (Figure E1).
- The region of the Gnangara Groundwater System (GGS), north of Perth, also has experienced declining annual rainfall, with a 9% decline from 1976 to 2007, and a 13% decline in rainfall from 1997 to 2007 (Government of Western Australia, 2009).
- A 15 % decline in rainfall may translate into substantially decreased runoff and water inflows. For instance, total annual stream flow into Perth dams declined from an average of 338 GL between 1911-1974 to 117 GL in 1975-2000 to only 58 GL in 2006-2010 (Steffen and Hughes, 2013). Although this measure refers to human requirements (dams), it also reflects the declining amount of water available for environmental uses.

Figure E1. Rainfall patterns for Perth Airport between 1946 and 2015 based on 30-year running means calculated for records from 1946 to 2015. Y-axis shows annual rainfall in millimetres; X axis shows the central year for each 30 year interval starting at 1946-1975 and ending 1986-2015.



Source: BoM (2016)

- At the same time that there is reduced rainfall, there has been increasing use of groundwater sources. There is some variation in the allocation of groundwater throughout the Swan Coastal Plain, depending on the amount of water available in local systems, for example, the allocation limit of the Gnangara mound groundwater area in 2011 (279.9 GL/yr) greatly exceeded that of the Murray groundwater area in 2012 (60.8 GL/yr). Water abstraction from aquifers generally increased from 200GL in 1985 to 600 GL in 2007 (Ali et al., 2012). Allocation of groundwater resources by the Department of Water in the Gnangara Groundwater System increased by over 45 GL between 2009 and 2011 (Department of Water, 2009).
- A trend of declining groundwater levels has been recorded over the last thirty years across two shallow, unconfined aquifers of the Swan Coastal Plain: the Gnangara Mound and the Jandakot Mound (DoW, 2014). Declines are predominately attributed to reduced rainfall, increased groundwater abstraction for domestic, industrial and agricultural needs and recharge limitation by pine plantations (DEC, 2009; DoW, 2014). Groundwater levels in the Gnangara Mound during 2015 were the lowest on record.
- In the Wheatbelt, Perth North, Perth South and Peel subregions, almost all surface water and shallow, middle and deep groundwater areas that are on the Swan Coastal Plain show declining trends in annual stream flow (for surface water) or water level (for groundwater) (WA DoW inventory, 2014).
- Groundwater has been shown to become more acidic in the water table where there is a high rate of extraction of water table.

Banksia and other native species show various adaptations to water availability, as noted in *Appendix B – Biology and ecological processes*. A key consideration relates to how dependent key species are on groundwater resources and their rooting depth capabilities (i.e. if they are deep-rooted or phreatophytic species vs shallow-rooted or vadophytic species). It is expected that long-term reductions in the water table are likely to shift community composition to favour more deeper-rooted species that are better able to access groundwater. The impacts of changing patterns of water availability to the Banksia Woodlands ecological community, and native vegetation in southwestern WA generally, requires further study and long-term monitoring to fully understand responses. However, some findings and observations have been made that point to potentially significant impacts on the vegetation.

- Low rates of groundwater drawdown (9cm year^{-1}) caused a gradual change in the Banksia Woodland flora since the mid-1970s while higher rates (50cm year^{-1}) of drawdown, as is experienced near bores, caused mass mortality events of the flora (Groom et al., 2000; Froend and Sommer, 2010). Groom et al. (2000) found that three species of banksia, but particularly *Banksia ilicifolia*, were severely impacted by drought stress within the GGS area. This was attributed to a significant lowering of the watertable caused by the cumulative effects of groundwater abstraction and below-average rainfall.
- A progressive reduction in canopy foliage cover and change in floristic composition of the Banksia woodlands was observed on the Gnangara groundwater system as the regional watertable declined (Sommer and Froend, 2011).

- Whilst the severity of declines in integrity of the ecological community will vary across its range, composition is likely to shift from deep rooted to shallow rooted, as depth to groundwater increases beyond the maximum rooting depth to deep rooted species.
- Over the Gnangara and Jandakot mounds, an estimated 43 000 ha of remnant vegetation containing Banksia Woodlands is vulnerable to changes in superficial aquifer levels (WA DoW data, defined as depth to water table using peak levels <10.5 m).
- Over the last 20 years, groundwater levels steadily declined in Lowlands Reserve and Koondoola Regional Bushland, but were relatively stable in Melaleuca Park (Groves, 2014). The deep-rooted *Banksia ilicifolia* was observed to decline within Lowlands Reserve due to declining groundwater depths. However, abstraction rates in Melaleuca Park have not yet decreased the watertable to depths below the maximum rooting depths of key species.
- Banksia Woodlands located in groundwater areas that are utilised heavily for abstraction, can be greatly affected when abstraction rates exceed recharge rates, causing a lowering of the groundwater table (Groves, 2014).
- *Banksia ilicifolia* Woodlands, identified as FCT 22 and also recognised as a priority ecological community in WA, is associated with some Bassendean dune seasonally waterlogged sandy flats. This floristic community is declining due to decreased periods or absence of seasonal waterlogging, as a consequence of declining rainfall and water tables, plus the infection of these habitats with *Phytophthora* dieback (DEC, 2010c; Stevens et al., 2016).
- Fauna species reliant on *Banksia*, such as *Tarsipes rostratus* (noolbenger, honey possum) do not directly rely on high groundwater levels but may be influenced by corresponding changes to vegetation. Declining rainfall and a lowering watertable may affect the flowering period of banksias upon which nectar feeding species such as noolbengers feed. As these animals typically live for only 1–3 years, successive dry years could affect the persistence of noolbenger populations by limiting key food resources (Wilson et al., 2012). Deaths of *Banksia* trees on the Scott River plains on the south coast of Western Australia, which may also be due to lowered watertables, are thought to be the cause of a corresponding decrease in noolbenger populations (Phillips et al., 2004).

In summary there is evidence that water availability has, and is likely to continue to decline across the Swan Coastal Plain. Although further longer-term studies would provide additional data, declining water availability is likely to be having severe detrimental impacts upon the Banksia Woodlands ecological community.

Reduction in integrity due to altered fire regimes

Patterns of fire histories and regimes vary across the Swan Coastal Plain, but evidence shows that altered fire regimes are affecting the integrity of Banksia Woodlands at least in substantial areas, and in particular types of Banksia Woodlands (e.g. certain patch sizes).

Ramalho et al. (2014) found that Banksia Woodland remnants in the Perth metropolitan region were burnt more frequently in areas with a higher incidence of human activities. Higher frequency fire regimes and fire management practices that result in burning during the peak growing seasons (late autumn to late spring) and during the seeding season (for most native species in Banksia Woodlands this is from November to December) result in the following changes to Banksia Woodlands (Fisher et al., 2009 a, b; Stevens et al., 2016):

- Structural change, e.g. reduction in canopy cover, loss of native resprouting shrub cover;
- A shift from native species to introduced species, notably increased weed abundance and diversity;
- Decrease in native plant cover, richness and diversity;
- Changes to the ecological function of Banksia Woodlands; and,
- Feedback loops that promote weed species at the expense of native plants e.g. perennial veldgrass *Ehrharta calycina* is highly flammable and infestations promote further fires. Higher fire frequencies, in turn, reduces the cover and regeneration capacity of many native plants.

Fire history and fire management are also important determinants of Banksia Woodland's habitat suitability for various animal communities, including reptiles, mammals and birds (Valentine et al., 2012; Wilson et al., 2014). In general, many native fauna groups in Banksia Woodlands prefer long-unburnt areas, and become more abundant with increasing time since fire. Studies from the Perth and Gingin regions have shown increasing abundance of species such as the *Pseudomys albocinereus* (ash-grey mouse) and *Tarsipes rostratus* (honey possum, noolbenger) as time since fire increased (Bamford, 1986; Davis, 2008; Valentine et al., 2009). Some species such as the *Sminthopsis dolichura* (little long-tailed dunnart) are most abundant 0 – 3 years following fire (Bamford, 1986; Davis, 2008). Feral species, such as the house mouse (*Mus musculus*), were also most abundant in the three years following fire.

Current fire prescriptions in many areas are reducing the availability of longer unburnt habitats (>16 years since fire) (Valentine et al., 2014). For the Banksia Woodlands overall, the recommended fire intervals based on life history traits of key Banksia Woodlands flora and fauna species, derived from studies in the Gnangara Groundwater System region, are: minimum (8–16 years) and maximum (40 years) fire frequency, with an ideal fire cycle of 24–28 years (Wilson et al., 2014). However, the distribution of post-fire ages of Banksia Woodlands (51 914 ha present in this area) is skewed to one to six years since last fire. Greater than 60% of the area was burnt within the last seven years, and less than a third was at >10 year intervals since fire (Valentine et al., 2014; Wilson et al., 2014). Twenty-eight of these sites were last burnt by a prescribed fire (mostly during spring) with 3 being burnt by wildfires or of unknown origin (Valentine et al., 2014). This distribution of post-fire ages is highly skewed and does not approximate the idealised distribution based on plant life history attributes (Valentine et al., 2014; Wilson et al., 2014). The average number of times an area was burnt was 3.13 over a 39 year period (Wilson et al., 2014).

At a finer scale, there was little evidence of unburnt patches within an individual burn, with the amount of unburnt habitat estimated at 2.5–5.9% of the burnt area between 1990–1999 and 2000–2009 respectively, indicating burns are relatively homogeneous within a burn area and not resulting in mosaic fire patterns. This reduces the chance of an area of suitable habitat for particular flora and fauna being available at any one time. Given the high frequency and large area of burns remnants such as these, smaller and more isolated remnants that escape frequent burns are increasingly important.

The responses of reptile species and assemblages to fire frequencies provide strong support for the maintenance of a range of post-fire aged habitat and maintaining or increasing long-unburnt Banksia Woodlands and other habitat types (Table E8; Valentine, 2012; Wilson et al., 2014).

Table E8: Key fire response fauna species and preferred fire age.

Species	**Common name**	**Preferred fire age (Years Since Last Fire)**
Invertebrates		
Synemon gratiosa	graceful sun moth	unknown
Reptiles		
Pseudemydura umbrina	western swamp tortoise	unknown
Ctenophorus adelaidensis	western heath dragon	< 11 YSLF
Aprasia repens	sandplain worm lizard	>16 YSLF
Delma concinna concinna	west coast javelin lizard	< 11 YSLF
Demansia reticulata	yellow-faced whip snake	>16 YSLF
Lerista elegans	west coast four-toed lerista	>16 YSLF
Menetia greyii	common dwarf skink	>16 YSLF
Morethia obscura	southern pale-flecked morethia	>16 YSLF
Neelaps calonotus	black-striped burrowing snake	>16 YSLF
Pletholax gracilis gracilis	keeled legless lizard	unknown
Tiliqua occipitalis	western bluetongue	>16 YSLF
Tiliqua rugosa	bobtail	>16 YSLF
Overall reptile abundance		**>16 YSLF**
Calyptorhynchus latirostris	Carnaby's black cockatoo	Long unburnt (10-30 YSLF)
Acanthiza chrysorrhoa	yellow-rumped thornbill	Recently burnt
Malurus splendens	splendid fairy-wren	Long unburnt
Mammals		
Tarsipes rostratus	honey possum	20-26 YSLF

Species	Common name	Preferred fire age (Years Since Last Fire)
Isoodon obesulus fusciventer	southern brown bandicoot	unknown
Hydromys chrysogaster	water rat	unknown
Rattus fuscipes	bush rat	unknown
Mus musculus (*introduced)	house mouse	<7 YSLF

Source: Wilson et al. (2014)

As *Banksia attenuata* and *B. menziesii* are characteristic components of the Banksia Woodlands of the Swan Coastal Plain, the ecological community is considered habitat critical to the survival of Carnaby's Cockatoo, being important feeding habitat (DPaW, 2013). There is often a time-lag following fire before the reproductive outputs of *Banksia* species resume. It can take up to 8 years following a fire for half of *B. attenuata* and *B. menziesii* plants present at a site to be flowering (Valentine et al., 2014; Wilson et al., 2014).

For both *B. attenuata* and *B. menziesii* the number of cones per plant increases with time since fire. For example, *B. attenuata* produced more cones at sites aged 10–30 years since fire and *B. menziesii* was highest in sites >35 years since fire (Valentine et al., 2014). Time since fire was the principal variable when estimating the numbers of Carnaby's cockatoo that can be supported by Banksia Woodlands, with greater numbers of birds supported by vegetation that is 14–30 years since fire, with numbers peaking in 20–25 years post-fire aged vegetation (Valentine et al., 2014). Approximately 3.5% of vegetation was between 20–25 years since fire (Valentine et al., 2014).

Areas of remnant vegetation that are of small size and isolated from other remnants are particularly sensitive to the effects of altered fire regimes. A high intensity fire that affects the entirety of such a remnant may result in the loss of entire populations of rare and endemic flora where the soil seed bank is depleted or there is excessive competition from weeds. Such remnants also tend to experience significant impediments to post-fire recovery, such as kangaroo grazing and invasion of weeds (Fisher et al., 2009 a, b; DPaW, 2014). As described under sections outlining the effects associated with fragmentation, even though populations of flora and fauna may persist or be relatively stable in the short-term, their ability to recolonise remnants after a fire can be hindered by fragmentation if they are unable to successfully disperse across landscapes that are modified and unsuitable. Most patches of the ecological community now occurs as small remnants (see Criterion 2).

Reduction in integrity due to plant pathogens

The key *Banksia* species in the ecological community are moderately (50–75% deaths) to highly (75–100% deaths) susceptible to dieback from *P. cinnamomi* (Johnston, 2013). Many other plant species that are part of the Banksia Woodland community, including those in the Proteaceae, Ericaceae, Fabaceae families, and *Xanthorrhoea*, are susceptible to the disease (Shearer et al., 2004).

There is a strong correlation between disease centres and geomorphic elements. Half of the disease centres on the Swan Coastal Plain are associated with the Bassendean Dune System with fewer disease centres on soils of the Spearwood and Quindalup Dune Systems (Shearer and Dillon, 1996), This means species that are common on Bassendean Dunes are more affected than those that primarily occur on the Spearwood and Quindalup Dune Systems, e.g. *B. prionotes* and *B. sessilis*. Dieback is also less common in areas with lower soil moisture content and on elevated parts of the landscape (Shearer and Dillon, 1996). As approximately 55 % of the current extent of corresponding vegetation associations occurs in the Bassendean land system (Table E1), much of the ecological community is potentially susceptible to dieback.

Shearer et al. (2009) found in most study areas (*Banksia* woodland and *Eucalyptus marginata* vegetation types in southwest WA) that canopy closure, basal area and number of plant species were significantly lower in old diseased compared with adjoining healthy areas, with diseased front intermediate between the two. In half of the study areas, percentage ground cover and total plant species cover were significantly lower in old diseased compared with adjoining healthy areas, with diseased front intermediate between the two.

As well as much reduced survival rates and changes to structure and composition, a functional consequence of dieback and the presence of *Phytophthora cinnamomi* is reduced flowering and fruiting of affected plants (Johnston, 2013). This means *Banksia* trees in dieback-affected areas produce fewer flower and fruit cones. Dieback could consequently affect those animals that rely on *Banksia* nectar and seeds as food - nectivores such as the western spinebill (*Acanthorhynchus superciliosus*) and honey possum / noolbenger. Any decline in these animals affects their pollination services for other species of plants they may visit, e.g. other genera of Proteaceae.

Davis et al. (2014) examined vegetation and bird communities in Banksia Woodland with, and without, *Phytophthora* dieback, in an area with >20,000 ha infected by *P. cinnamomi* (Wilson et al., 2009). Vegetation assessments showed that diseased sites had reduced plant species richness, litter, shrub, tree and canopy cover, high bare ground and significantly lower flowering scores, than healthy sites. Bird community composition differed significantly between diseased and healthy sites, and this was associated with habitat structural changes influencing bird community composition. Average species richness of birds per survey and the abundance of brown honeyeaters, western spinebills and silvereyes was lower in diseased than healthy sites. The tawnycrowned honeyeater had higher abundances in diseased sites. These results suggest that *Phytophthora* is potentially a serious threat to avian biodiversity and especially for nectarivores, and populations in fragmented landscapes, with implications for pollination webs.

Reduction in integrity due to climate change (increasing temperatures, declining rainfall, rainfall timing)

Banksia Woodlands of the Swan Coastal Plain occur within a region that in recent decades has undergone the most major and rapid change in climate on the Australian continent, and is one of the most rapidly drying regions in the world. Mean annual rainfall has declined by 15% in southwestern Australia between the mid 1970s and 2010 and mean annual temperatures have risen by approximately 1°C over the past century (Steffen and Hughes, 2013).

Multiple lines of evidence indicate that the ecological integrity of Banksia Woodlands of the Swan Coastal Plain is declining in response to the new climate regimes. For example, declining flower production in Banksias is closely linked to downward trends in winter-spring rainfall of the preceding year across western and southern Australia (Keith et al., 2014). Reduced flower production related to declining winter-spring rainfall result in less food for nectar-feeding birds and mammals, and slower accumulation of smaller seedbanks, making Banksia populations less resilient to fires, disease, seed predation and other threats. Climatic drying also impacts on the success of seedling recruitment, which is highly sensitive to soil moisture levels (Enright and Lamont, 1992). Adult plants of many species in Banksia Woodlands are deep-rooted phreatophytes sensitive to changes in groundwater (Groom et al., 2000). Reduced rainfall is expected to result in reduced recharge of groundwater. However, runoff into water storages is declining at a more rapid rate than rainfall: annual inflow has declined from more than 330 GL prior to 1970 to 177 GL during 1975-2000, to 92 GL during 2000-2005, to 58 GL during 2006 to 2010 (Steffan and Hughes, 2013). This is increasing the reliance of Perth's growing population on groundwater as a source of potable water, which will lead to increased rates of watertable drawdown and increased stress on the standing vegetation. Hence extensive mortality of Banksia Woodlands (Groom et al., 2000) will rapidly become a more frequent phenomenon as the climate dries and the population of greater Perth increases.

Figure E2: Catastrophic canopy loss in the iconic Banksia woodland in Kings Park, Perth following the 2014 drought. Major losses of she-oak, *Allocasuarina fraseriana* (seen here) a co-dominant with Banksia in Kings Park woodland occurred alongside large-scale losses of the two co-dominant *Banksia* species (*B menziesii* and *B. attenuata*) (photo: K. Dixon).

Banksias are less able to sustain tree growth forms and spontaneous seed release as rainfall declines along the climatic gradient on the west coast sandplains (Cowling and Lamont, 1985). These patterns suggest a functional shift in Banksia Woodland vegetation as drier climates encroach from the north. Yates et al. (2010) show that more than half of the area currently occupied by three of the four dominant Banksia species in this ecological community is likely to be climatically unsuitable by 2070. The fourth species (*B. ilicifolia*) is also projected to lose more than a third of its climatically suitable range.

Most of the decline in the bioclimatic suitability for Banksia Woodlands will occur in the northern part of the current distribution so that the northern Swan Coastal Plain will become less capable of sustaining Banksia Woodland vegetation in the coming decades. This threatens the integrity of the largest remaining areas of Banksia Woodland that have thus far been least impacted by clearing and fragmentation. It also has important policy implications, as investments in protection and restoration of Banksia Woodlands are very unlikely to be successful or sustainable offsets for losses of Banksia Woodlands in the southern higher-rainfall part of their current distribution. Risks of offset are only likely to be acceptable if strong like-for-like policies are implemented to ensure that offset sites are projected to have similar future rainfall levels to the development sites they are intended to offset (*see section 5.4*).

Further declines in ecological integrity of Banksia Woodland are resulting from an interaction between climatic warming, drying and increased bushfire risk (Enright et al., 1998a,b, 2015). This process, known as “interval squeeze” involves increased extinction risks of woody plants, including Banksias, under the warming and drying climate (Enright et al., 2015). The enhanced extinction risks are associated with reduced intervals between successive fires on one hand, and reduced rates of seedbank accumulation and seedling recruitment on the other. For example, many Banksia spp. require the co-incidence of burnt occupied and unoccupied sites to allow seed dispersal and colonisation to occur (Cowling and Lamont, 1987; Cowling et al., 1987, 1990; Enright et al., 1998a,b), and this becomes less likely as habitats become fragmented due to significant barriers for dispersal and colonisation. Consequently, a smaller proportion of the rare long-distance dispersal events needed to keep pace with rapid climate change may result in colonisation (Yates et al., 2010).

Restorability

There is little evidence that the integrity of the ecological community as a whole may be recovered in the immediate future (mean generation lengths of the key Banksia species are likely to be measured in decades. The timeframes relating to generations are, therefore, likely to approach the maximum timeframe stated for this criterion, i.e. up to 100 years), although recent advances in restoration of disturbed remnant Banksia Woodlands have increased the success of restoration in some cases, for example through implementation of topsoil salvaging and weed control (Stevens et al., 2016).

Restoration practices need to be tailored to match the floristic richness of these woodlands that occur in a harsh environment of infertile, low water-holding soils and high seasonality including long hot and dry summers. Disturbances, particularly since European settlement, amplify this complexity: major past disturbances (e.g. land clearing, logging, grazing) combine with ongoing threats associated with urbanisation (e.g. fragmentation, invasive species, arson, off-road vehicles) and contemporary stressors (e.g. climate change) (Stevens et al., 2016).

Conclusion:

There has been a severe decline in integrity of the Banksia Woodlands ecological community, as detailed in the sections above. Furthermore the combined effects of threats have a compounding detrimental effect on the integrity of the ecological community and increase the complexity of appropriate management requirements at various scales. For example, types of the ecological community, such as those dominated by *Banksia ilicifolia* are declining at a higher rate due to the effects of clearing, lowered water tables and *Phytophthora* disease (Stevens et al., 2016). In particular, the patterns of fragmentation, degradation and invasive species plus what is likely to be a long-term shift in water availability (the impacts of which are yet to become fully evident) indicate that community has – and will continue to – experience a serious reduction in its integrity. Given the very high diversity and complexity of this ecological community, full restoration is unlikely to be possible over a short time-frame.

The Committee considers that the available information indicates the ecological community has met the relevant elements of Criterion 4 to make it **eligible** for listing as **Endangered**.

Criterion 5 – Rate of continuing detrimental change

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

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

Not eligible for listing under Criterion 5.

Broad comparisons can be made between estimates of extent made in 2009 and 2015 based on vegetation system-associations that correspond to the ecological community (Government of Western Australia 2010; 2016). It is noted that some differences in mapping methods may apply between the two periods. In order to account for these, the pre-European estimates for each system-association identified in Table E1 were compared and checked to highlight any differences. Estimates did not generally alter between 2009 and 2015 except for some boundary issues where the same vegetation association had been allocated to a different system, as indicated by declines and increases of similar amounts across adjoining systems during the period. As all these systems were recognised as part of the ecological community, these boundary issues were factored into the broad analysis.

Data collated for the 27 most corresponding system-associations estimated an indicative decline of almost 7000 hectares over the six years between 2009 and 2015. This is equivalent to an overall rate of about 11,602 hectares or a 3.4 percent loss per decade. However, the indicative overall rate of continuing decline masks some more severe declines evident at a regional level (Table E9).

The highest clearing of the ecological community between 2009 and 2015 was in the Perth metropolitan region with 3700 hectares removed, a rate of almost twelve percent per decade across the region. It is not surprising that a majority of the loss to the ecological community occurred in the Perth region given the high pressure for urban development. Clearing appears to be ongoing in some metropolitan LGAs, despite the small extent (<500 hectares) remaining and past high clearing rates of the ecological community (Table E2).

The Peel-Harvey and Bunbury-Busselton regions also had relatively high rates of decline, expressed as a percentage loss per decade in the order of 7.9 to 10.5 percent. Rates of decline were lowest in the region north of Perth, where extensive patches of Banksia Woodlands still remain. Despite low clearing rates of about 1.2 percent per decade, a substantial extent of almost 2000 hectares was lost since 2009 (Table E9).

Table E9 Estimated change in extent and rate of change for the *Banksia* woodlands of the Swan Coastal Plain ecological community between 2009 and 2015, by local government area (LGA) region.

Local Govt. Authority region	Extent - 2009 (ha)	Extent – 2015 (ha)	Loss 2009-2015 (ha)	Rate per decade (%)
North of Perth and Dandaragan Plateau	267,069.7	265,083.4	1,986.3	1.24
Perth Metropolitan	52,571.6	48,828.8	3,742.8	11.87
South of Perth – Peel-Harvey	18,796.9	17,908.8	888.1	7.87
South of Perth – Bunbury-Busselton	5,453.0	5,109.0	344.0	10.51
Total	**343,891.2**	**336,930.1**	**6,961.1**	**3.37**

Sources: Government of Western Australia (2010; 2016). The analysis grouped the major and partially coresponding vegetation system associations identified in Table E1, above.

Notes: The boundaries of some LGAs extend beyond the boundary of the Swan Coastal Plain IBRA bioregion, so include some minor patches of *Banksia* woodland that extend in the adjacent parts of neighbouring bioregions. LGAs were grouped into four broad regions, as detailed in Table E2.

Rate of loss over the six year period was expressed as a percentage loss per decade by the formula:

([Loss 2009-2015 / Extent - 2009] x 100) x (10/6).

The data for corresponding vegetation complexes also confirms ongoing recent clearing. At least 2700 hectares equivalent to the ecological community was cleared in the one year between 2013 and 2014 (Table E10). This represents a higher rate of decline than was evident for system-associations, about 14.9 percent per decade.

However, although these estimates for rates of detrimental change are high and justify concerns about the potential impacts of further development upon the ecological community, the data are insufficient to trigger the thresholds for this criterion.

<u>Table E10:</u> Recent decline of the Banksia Woodlands of the Swan Coastal Plain ecological community by <u>vegetation complexes</u> with a strong to moderate association with the ecological community (see Tables C2 and E3). Note these data for vegetation complexes only relate to the Perth IBRA sub-region of the Swan Coastal Plain bioregion, as mapped south of the Moore River.

Vegetation complex	**Change 2013 to 2014 (ha)**
a) Strongly associated with the ecological community	
Bassendean Complex - Central and South	-1,037.7
Bassendean Complex - North	-293.4
Bassendean Complex - North -Transition Complex	-61.6
Caladenia Complex	No data available
Cartis Complex	No data available
Coonambidgee Complex	-6.3
Cottesloe Complex - North	-40.7
Cullala Complex	No data available
Karrakatta Complex - North	-72.6
Karrakatta Complex - North -Transition Complex	2.7
Mogumber Complex South	No data available
Moondah Complex	No data available
Reagan Complex	-20.7
Yelverton Complex	No data available
Sub-total – available strongly asosciated units	*1,530.4*
b) Moderately associated with the ecological community	
Cannington Complex	-78.9
Forrestfield Complex	-55.1
Karrakatta Complex - Central and South	-702.6
Southern River Complex	-398.7
Sub-total – moderately asosciated units	*1,235.3*
TOTAL – all available units	**2,765.7**

Source: WALGA (2013, 2014) for extent data. Heddle (1980) and Havel and Mattiske (2000) for classification and descriptions of the vegetation complexes.

Further clearance of the ecological community continues and ongoing likelihood of clearing is demonstrated through proposed projects. For example, Stage 1 Swan Valley Section of the Perth-Darwin National Highway is likely to directly impact on approximately 175 ha of Banksia Woodlands, to the west of Whiteman Park, around ‘Cullacabardee’; and near Ellenbrook (Main Roads WA, 2015). Indirect impacts are likely to occur to a greater area adjacent to the road corridor, through isolation, edge effects and reduced connectivity across the broader landscape. After construction, further infrastructure and housing is likely to be proposed alongside the road corridor that would result in further clearance and fragmentation.

The Neerabup Industrial Estate project, 32 km north of the Perth central business district, involves basic raw material extraction and subsequent industrial development. Most of the

89.5 ha development footprint and adjacent bushland are identified as Banksia Woodlands (Eco Logical Australia, 2016).

In addition to these individual projects, planned expansion of the Perth and Peel regions will impact the ecological community through direct (e.g. clearing) and indirect effects (e.g. fragmentation). Approximately 12 668 ha of Banksia Woodlands coincide with classes of action that are planned to 2050 (classes of action in order of area of intersect with Banksia Woodlands are shown in Table E11). These intersect areas therefore provide an early indication of the scale of potential impacts and the Government of Western Australia (2015) state that these areas should be interpreted as a worst-case scenario. However, it is expected that the classes of action will place additional pressures on the Banksia Woodlands ecological community (Government of Western Australia, 2015). 12 668 ha of Banksia Woodlands represents:

- 3.8 percent of the ecological community, based on the 2015 total extent of equivalent vegetation system-associations across the entire Swan Coastal Plain (see Table E1);
- 5.9 percent of the ecological community, based on the 2015 extent of equivalent vegetation complexes as mapped south of the Moore River (see Table E3); and
- 19.0 percent of remnant Banksia Woodlands within the Perth Metropolitan plus Peel-Harvey regions, based on the 2015 extent of equivalent vegetation system-associations (see Table E2).

Table E11. Green Growth Plan classes of action that intersect with Banksia Woodlands (Government of Western Australia, 2015).

Class of action	Area (ha)
Urban	6713
Industrial	2067
Infrastructure	1487
Basic raw materials	1413
Rural residential	988
Total	**12668**

These rates of decline again indicate that a potentially large proportion of the ecological community could be impacted, especially within the Perth-Peel region, but the values still fall below the minimum 30 percent threshold required to trigger this criterion.

Conclusion:

In conclusion, the available information indicates that, in the recent past and projected into the immediate future, there is considerable ongoing and planned clearing of Banksia Woodlands in the Swan Coastal Plain, especially in the region around Perth.

The guidelines for listing against this criterion require a minimum detrimental change of at least 30 percent over the immediate past, or suspected for the immediate future. The available information indicates that the degree of past and projected future losses falls below this minimum indicative value. The ecological community is therefore **not eligible** for listing under any category for this criterion.

Criterion 6 – Quantitative analysis showing probability of extinction

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

Not eligible for listing under Criterion 6.

There are no quantitative data available to assess this ecological community under this criterion. Therefore, it is **not eligible** for listing under this criterion.

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