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Banksia Woodlands of the Swan Coastal Plain – Draft description and threats

For public consultation as part of the Threatened Species Scientific Committee’s threatened ecological community listing assessment under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).



Banksia Woodlands ecological community © Department of the Environment

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1. DESCRIPTION OF THE ECOLOGICAL COMMUNITY

The ecological community is a woodland associated with the Swan Coastal Plain of southwest Western Australia. It typically has a prominent tree layer of *Banksia* with scattered eucalypts and other tree species present within or emerging above the *Banksia* canopy, and a species rich understorey including sclerophyllous shrubs, graminoids and forbs.

1.1 Name of the ecological community

It is recommended that the ecological community be named **Banksia Woodlands of the Swan Coastal Plain bioregion**. The name appropriately describes the dominant canopy genus, structure¹ and location that characterise the ecological community.

The national ecological community includes ecological communities recognised as threatened in Western Australia.

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 restricted to the Swan Coastal Plain IBRA bioregion² and immediately adjacent areas, including the Dandaragan plateau, from Jurien Bay in the north, to Dunsborough in the south, and north/west on the Whicher and Darling escarpments (Banksia woodlands on these escarpments may be included in the ecological community definition, see *1.5.1 Key diagnostic characteristics*). Sand plains occur further north in the Geraldton Sandplains bioregion, but support a significantly different structure and plant assemblage in a lower rainfall environment.

The Swan Coastal Plain bioregion 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 out to the Ridge Hill Shelf and is composed of alluvial soils. The Ridge Hill Shelf is a narrow strip of land that forms the foothills of the Darling Scarp, and is composed of laterite covered spurs. Finally, the Dandaragan plateau is separated from the other major landform elements by the Gingin Scarp, an ancient shoreline formed by cretaceous marine sediments, and is composed of deep grey or pale brown sands with outcropping laterites (McArthur and Bettenay, 1974; McArthur, 2004).

¹ The term ‘woodland’ has been chosen as the most appropriate term, but the ecological community (or some examples of it) may be considered by some to be a shrubland. 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’. Some areas would also be considered forest under some existing classification systems.

² The Swan Coastal Plain Bioregion is comprised of the Dandaragan Plateau (SWA1) and Perth (SWA2) subregions. Adjacent areas on the Whicher and Darling escarpments are within the Northern Jarrah Forest (JAF01) and Southern Jarrah Forest (JAF02) subregions. IBRA relates to the Interim Biogeographic Regionalisation of Australia v7 (2012).

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The Swan Coastal Plain dune systems are generally composed of well-drained and weathered red/brown (Quindalup), pale yellow (Spearwood) or white (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 system, 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 characterized 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). Surrounding the lower interdunal swamps and lakes, the soils are poorly drained and rich in organic matter.

The Banksia Woodlands ecological community occurs on deep Bassendean and Spearwood sands, or occasionally on Quindalup sands (typically the eastern edge). 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). Some areas, and some types of Banksia Woodlands are very sensitive to variations in groundwater (Groom et al., 2000; Froend and Drake, 2006).

There is a very strong seasonal variation in climate with long periods of summer drought (usually five to six months) coupled with high temperatures. Due to summer drought and vegetation flammability, these are fire prone habitats that include species with resilience to survive fires.

1.3 Vegetation

The principal structural features of the ecological community are:

- A distinctive upper sclerophyllous layer of low trees¹ (occasionally large shrubs more than 2 m tall), dominated or co-dominated 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 be present above the *Banksia* canopy.
- A species-rich understory that consists of:
 - A mid-ground sclerophyllous shrub layer; and/or,
 - A herbaceous ground layer of cord rushes, sedges and perennial and ephemeral forbs, that sometimes includes grasses.

The canopy of the Banksia Woodlands is most commonly dominated or co-dominated by *Banksia attenuata* (candlestick banksia) and/or *B. menziesii* (firewood banksia). Other species may dominate some examples of the ecological community, for instance, *B. prionotes* (acorn banksia) or *B. ilicifolia* (holly-leaved banksia), with *B. burdettii* (Burdett's banksia), more common on the Dandaragan Plateau.

Other trees of a medium height may be present and include *Eucalyptus tottiana* (coastal blackbutt, pricklybark), *Nuytsia floribunda* (Western Australian Christmas tree),

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Allocasuarina fraseriana (western sheoak), *Callitris arenaria* (sandplain cypress) and *Xylomelum occidentale* (woody pear).

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

Key species in the mid-ground sclerophyllous shrub layer of the ecological community include members of the families Asteraceae, Dilleniaceae, Droseraceae, Ericaceae, Fabaceae, Haemodoraceae, Myrtaceae, Orchidaceae, Proteaceae, Restionaceae and "lilies". 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), *Philothea spicata* (pepper and salt), *Stirlingia latifolia* (blueboy) and *Xanthorrhoea preissii* (balga).

Key species in the herbaceous ground layer include members of the families Cyperaceae, Haemodoraceae and Restionaceae. 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 angustatum* (sword 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 (β -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 co-dominated 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.

The diversity in Banksia Woodlands is associated with the understorey, with only 15 native trees associated with the overstorey (Keighery and Keighery, 2016). Surveys have recorded more than 600 native plant taxa from the 233 sampled points on the Swan Coastal Plain that contain 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 occur within the sampled points (100 m²) of Banksia Woodlands in the Perth area.

1.3.1 Variability

The Banksia Woodland ecological community has 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.

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- *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. To the north of the Swan Coastal Plain, where rainfall is lower, Banksia Woodlands 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). To the south of the Swan Coastal Plain, 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 and Dandaragan Plateau where rainfall is higher due to orographic effects of the Gingin Scarp and Darling Scarp.
- *Edaphic gradient.* As described under 1.2 – *Location and physical environment*, the Banksia Woodlands mainly occur on three coastal sand dune systems, particularly on the Bassendean and Spearwood systems. Species richness generally increases in an easterly direction, with the lowest found on the youngest sands (Quindalup) and the greatest on the oldest sands (Bassendean). There are some other floristic differences between the Bassendean and Spearwood dunes, for example, *Eucalyptus gomphocephala* (tuart) occurs only on Spearwood sands. The ecological community does not typically occur on alluvial, granite, limestone, laterite and other lithic substrates. 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.
- *Catenary gradient.* Banksia Woodlands typically occur on the tops and slopes of sand dunes, but do not occur on clay flats. In the north, where rainfall is lower, they are largely confined to sheltered dune slopes and flats, with heathlands occupying the dune crests and upper slopes.

Groundwater levels, groundwater quality, and seasonal fluctuations and flows in groundwater interact with the above factors, to influence the structure and composition of the Banksia Woodlands.

The dominant *Banksia* species in the woodlands are opportunistic phreatophytes (deep-rooted species) and obtain at least part of their water needs from groundwater at the water table, but the depth at which groundwater is exploited varies greatly between species and depends on the depth of the water table. 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

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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 were described on the Swan Coastal Plain, reflecting similarities in geography and soil type (Gibson et al., 1994) (also see 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.

A number of vegetation communities or floristic types are encompassed within the Banksia Woodlands ecological community. Some of these are listed as threatened or priority ecological communities in WA. Further detail on each of these 'sub-communities' will be provided in the final conservation advice document, to provide information to assist with consideration of particular sites of the ecological community.

1.3.2 Fungi

The area is rich in fungi species. There has been no comprehensive survey of fungi in Banksia woodlands across the Swan Coastal Plain, though survey data for fungi are available for a some reserves and sites in the Perth region (Bougher, 2011; Perth Urban Bushland Fungi, 2011) see <http://www.fungiperth.org.au/Reports-all/Fungi-Surveys.html>)

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Table 1: Floristic Community Types (identified in Gibson *et al.*, 1994, and in the System 6 and Part 1 Update, DEP 1996) (adapted from Government of Western Australia, 2000; Urban Bushland Council, 2011).

Note: these Floristic Community Types generally are not mapped and may not describe all types of Banksia Woodlands that are included in the ecological community. Information is being sought on which FCTs occur within the Banksia Woodland ecological community.

Key follows the table.

FCT	FCT name	Distribution	ASR	WA TEC
Supergroup 3 – Uplands centred on Bassendean Dunes and Dandaragan Plateau				
20a	<i>Banksia attenuata</i> woodlands over species rich dense shrublands	PMR+/S	64.5	EN (WA)
20b	Eastern <i>Banksia attenuata</i> and/or <i>Eucalyptus marginata</i> woodlands	PMR+/N	59.7	EN (WA)
20c	Eastern shrublands and woodlands	PMR	60.4	CR (WA); EN (EPBC Act)
20d	Dandaragan Plateau shrublands and woodlands		67.6	
21a	Central <i>Banksia attenuata</i> - <i>Eucalyptus marginata</i> woodlands	PMR/N	52.0	
21b	Southern <i>Banksia attenuata</i> woodlands		57.5	
21c	Low lying <i>Banksia attenuata</i> woodlands or shrublands	PMR+	38.5	P3
22	<i>Banksia ilicifolia</i> woodlands	>PMR/C	30.0	P2
23a	Central <i>Banksia attenuata</i> - <i>Banksia menziesii</i> woodlands	PMR	59.0	
23b	Northern <i>Banksia attenuata</i> - <i>Banksia menziesii</i> woodlands	>PMR/S	47.0	
23c	North-eastern <i>Banksia attenuata</i> - <i>Banksia menziesii</i> woodlands	(PMR)	53.0	
S9	<i>Banksia attenuata</i> 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	
25	Southern <i>Eucalyptus gomphocephala</i> – <i>Agonis flexuosa</i> woodlands	>PMR/S	48.1	P3
28	Spearwood <i>Banksia attenuata</i> or <i>Banksia attenuata</i> - <i>Eucalyptus</i> woodlands	>PMR/S	55.1	

Key

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, sedgeland and herblands after Gibson *et al.* (1994).

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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, less 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.

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

CR = Critically Endangered; EN = Endangered; 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. The Swan Coastal Plain is exceptional in reptile species richness while the bird assemblage is numerically dominated by nectarivores (How and Dell, 2000). The fossorial turtle frog (*Myobatrachus gouldi*) is a highly unusual amphibian species in this ecosystem, and is closely associated with Banksia woodlands due its diet being dominated by termites that feed on Banksia wood (Callaby, 1956).

Some reptile species are endemic to the Swan Coastal Plain, such as *Lerista lineata* (Perth slider, Perth lined lerista) and *Neelaps calonotos* (black-striped snake). Several 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 Banksia woodlands provide key habitat for black cockatoos: Carnaby's (*Calyptorhynchus latirostris*), Baudin's (*Calyptorhynchus baudinii*) and forest red-tailed (*Calyptorhynchus banksii naso*), each of which is listed as nationally threatened. These species occur within the Swan Coastal Plain bioregion, including the Perth urban region, and are known to forage in woodland and heathland dominated by Proteaceae, such as the Banksia Woodland ecological community (DSEWPac, 2012). They breed in eucalypt tree species that may occur as emergents in some patches of the ecological community, especially mature trees old enough to form natural hollows.

Over 70 percent of the native ground mammal fauna known from the Swan Coastal Plain at the time of European settlement has now become regionally extinct (Kitchener et al., 1978),

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and other species have contracted in their range to the north. The larger patches of Banksia Woodlands can still support viable populations of the *Tarsipes rostratus* (Noolbenger, honey possum), and *Pseudomys albocinereus* (Noodji, ash-grey mouse), but fragmentation and increased fire frequency results in the loss of most native mammal species. The often overlapping flowering phenology of the dominant banksia species plays a significant role in maintenance of nectar feeding bird populations. These species mostly rely on all-year-round flowering for their food, successful breeding and persistence, although some species are able to feed on insects for part of the year.

The study of invertebrates is less complete than vertebrates, but 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 plant 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. One key example is that pollination of some rare orchids is dependent on a single, mostly orchid species specific species of thynnid wasp (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 underrepresented in disturbed areas (e.g. garden samples), instead being mostly replaced by introduced species, and introduced species were not found in undisturbed remnants (Abbott, 1982). This suggests that urban development has been detrimental to native earthworm fauna and that remnant vegetation fragments will continue to provide refuges in the future (Abbott and Wills, 2002).

Key species that occur in the ecological community include:

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), usually only where Jarrah or Marri occur

Calyptorhynchus latirostris (Carnaby's cockatoo)

Lichmera indistincta (brown honeyeater)

Phylidonyris niger (white-cheeked honeyeater)

Phylidonyris novaehollandiae (new holland honeyeater)

Zosterops lateralis chloronotus (western silvereye)

Mammals:

Tarsipes rostratus (Noolbenger, honey possum)

Pseudomys albocinereus (Noodji, ash-grey mouse)

Macropus irma (Kwoora, brush-tailed wallaby, black-gloved wallaby)

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Reptiles:

Ctenophorus adelaidensis (western heath dragon, sandhill dragon)

Ctenotus australis (western limestone ctenotus)

Delma concinna (javelin lizard)

Diplodactylus polyophthalmus (spotted sandplain gecko)

Lerista christinae (bold-striped slider)

Lerista lineata (Perth slider, Perth lined lerista)

Morethia lineoocellata (west coast morethia)

Neelaps calonotos (black-striped snake)

Pletholax gracilis (keeled legless lizard)

Simoselaps littoralis (west-coast banded snake)

Frogs:

Heleiporus eyrei (moaning frog)

Limnodynastis dorsalis (pobblebonk)

Litoria moorei (Moore's frog, motorbike frog)

Myobatrachus gouldii (turtle frog)

Invertebrates:

Synemon gratiosa (graceful sun moth)

Endemic *Antichiropus* millipedes

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1.5 Key diagnostic characteristics and condition thresholds

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

National listing focuses legal protection on remaining patches of the ecological community that are most functional, relatively natural (as defined by the 'Description') and in relatively good condition. Key diagnostic characteristics and condition thresholds assist in:

- identifying a patch of the threatened ecological community;
- determining whether the referral, environment assessment and compliance provisions of the EPBC Act are likely to apply to the ecological community; and,
- distinguishing between patches of different quality.

Condition thresholds provide guidance for when a patch of a threatened ecological community retains sufficient conservation values to be considered as a Matter of National Environmental Significance, as defined under the EPBC Act. Patches that do not meet the minimum condition thresholds are excluded from full national protection. This means that the referral, assessment and compliance provisions of the EPBC Act are focussed on the most valuable elements of the ecological community, which may include restored communities.

The Banksia Woodlands ecological community encompasses a number of 'sub-communities', and may also exhibit various degrees of disturbance and degradation. Natural variation and degree of degradation has been taken into account in developing the key diagnostic characteristics and condition thresholds.

1.5.1 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 sub-communities (e.g. Floristic Community Types). Some of these sub-communities have a higher threatened status where listed individually under Western Australian legislation.

Location and physical environment:

- Occurs predominantly within the Swan Coastal Plain IBRA bioregion, which is comprised of the Dandaragan Plateau (SWA1) and Perth (SWA2) subregions. The ecological community also includes some occurrences of Banksia Woodlands outside and adjacent to the mapped Swan Coastal Plain IBRA boundary, for example the lower parts of the Darling and Whicher escarpments to the east and south of the Swan Coastal Plain (Northern Jarrah Forest JAF01; Southern Jarrah Forest JAF02 IBRA subregions).
- Typically occurs on well drained, low nutrient soils on sandplain landforms. In particular, on deep Bassendean and Spearwood sands, or rarely on Quindalup sands.

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Structure:

- The principal structural features of the ecological community are:
 - A distinctive upper sclerophyllous layer of large shrubs or small trees¹ (see footnote 1 on page 3), typically more than 2 m tall.
 - An emergent tree layer of medium or tall (>10 m) height *Eucalyptus* or *Allocasuarina* species may be present above the *Banksia* canopy.
 - A lower shrub and/or ground layer of lower sclerophyllous shrubs, cord rushes, sedges and perennial and ephemeral forbs.

Composition:

- A patch of the ecological community may contain a range of *Banksia* species but must include at least one of the following species:
 - *Banksia attenuata* (candlestick banksia)
 - *Banksia menziesii* (firewood banksia)
 - *Banksia prionotes* (acorn banksia)
 - *Banksia ilicifolia* (holly-leaved banksia)
- The mid and ground layers contain a wide 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 the **Description** section.

1.5.2 Condition thresholds

Condition thresholds are yet to be finalised for the Banksia Woodlands ecological community. They often include parameters such as a minimum patch size, minimum cover of native species and a minimum plant species diversity. For vegetation communities endemic to WA, they could also cross-refer to available and widely used condition scales such as that developed by Keighery (1994) for vegetation around Perth.

1.5.3 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 will influence the state in which a patch of the ecological community is expressed. The surrounding vegetation may also influence how important a patch of the ecological community is in the broader landscape.

A **patch** is defined as a discrete and mostly continuous area of the ecological community that may encompass smaller subpatches of other vegetation communities. Patches can be spatially

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variable and are often characterised by one or more areas within a patch that meet the condition threshold criteria amongst areas of lower condition. Therefore a patch may include small-scale disturbances, such as tracks or breaks (including exposed soil, leaf and other plant litter, cryptogams) or small-scale variations in vegetation that do not significantly alter its overall functionality. Where there is a break in cover from the edge of the upper sclerophyllous layer of less than 30 m, then the gap is part of a single patch.

This 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 (significant impacts from activity within the buffer zone would require EPBC Act approval).

The recommended minimum buffer zone for the ecological community is 30 metres from the outer edge of a patch. 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 to protect groundwater sources.

Restored (revegetated or replanted) sites are considered part of the listed ecological community where such a patch meets the description, key diagnostic characteristics and condition thresholds above, and there is evidence of post-regeneration recruitment or patch longevity. It is recognised that revegetation or restoration requires appropriate techniques as well as long-term management and considerable time for a degraded patch to repair functionality and reach higher 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 least 100 m² (= 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

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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 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;

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- 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); and,
- Occurrence of the patch is:
 - in an area where the ecological community has been most heavily cleared and degraded, or is of a ‘sub-community’ (e.g. WA listed threatened or priority ecological community) that has been heavily cleared and degraded; or
 - at the edge of the range of the ecological community.

1.6 National context and other existing protection

This ecological community encompasses all of the ‘Shrublands and woodlands of the eastern Swan Coastal Plain’, a sub-community listed under the EPBC Act as Endangered in July 2000.

Relationships to State-listed ecological communities

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. ‘*Banksia attenuata* woodlands over species rich dense shrublands’, ‘*Banksia attenuata* and/or *Eucalyptus marginata* woodlands of the eastern side of the Swan Coastal Plain’ and ‘Shrublands and woodland of the eastern side of the Swan Coastal Plain’ (also see Table 1).

This national ecological community draft description also relates to six Western Australian Priority Ecological Communities, a list of ecological communities that are either provisionally identified as threatened or require further survey effort (as determined by the WA Threatened Ecological Communities Scientific Committee).

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Table 2. WA priority listed *Banksia* woodland ecological communities relating to the national ecological community draft description.

Community Name	Region	WA Category
<i>Banksia ilicifolia</i> woodlands, Southern Swan Coastal Plain	Swan	P2
Swan Coastal Plain <i>Banksia attenuata</i> – <i>Banksia menziesii</i> woodlands	Swan	P3
Low lying <i>Banksia attenuata</i> woodlands or shrublands	Swan and Southwest	P3
Southern <i>Banksia attenuata</i> woodlands	Southwest	P3
<i>Banksia</i> woodland of the Gingin area restricted to soils dominated by yellow to orange sands	Swan	P2
West Whicher Scarp <i>Banksia attenuata</i> woodland	Southwest	P1

Listed threatened flora and fauna species associated with the ecological community

As at March 2016, 66 flora and 15 fauna species that are listed nationally, or listed in Western Australia, may occur in the ecological community (see Appendix A – Species lists). They include 54 nationally listed threatened plant species and 15 nationally listed threatened animal species.

2. SUMMARY OF THREATS

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

- Clearing and fragmentation (greatest threat) - including associated urban degradation/disturbance (e.g. rubbish dumping, uncontrolled vehicle access, wildflower and seed harvesting).
- Mining for basic raw materials (road/building materials), mineral sands and silica sands (clearing and hydrological impacts)
- 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)
- Climate change (increasing temperatures, declining rainfall, changing rainfall timing)
- Hydrological degradation (groundwater abstraction, eutrophication, soil acidification)
- Invasive species
- Dieback diseases (especially those caused by *Phytophthora* species)
- Grazing (including overabundance of kangaroos particularly in peri-urban reserves)

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- 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.

See Appendix B – Detailed description of threats, for further details.

3. SUMMARY OF ELIGIBILITY AGAINST LISTING CRITERIA

It is recommended that the *Banksia* Woodlands ecological community merits listing as Endangered, based on initial assessment of data.

It has undergone a substantial to severe decline of at least 60% across the entire Swan Coastal Plain and 67% for the plain south of the Moore River.

The ecological community has transformed in nature from being almost continuous across the plain, to now becoming very highly fragmented with the majority of patches (more than 80%) now less than ten hectares in area. The median patch size has reduced from an estimated pre-European value of 335 ha to a current size of only 1.6 ha.

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.

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APPENDICES

Appendix A – Species lists

Table 3: Listed threatened flora species that are known or likely to occur in the Banksia Woodlands of the Swan Coastal Plain ecological community.

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

Note: Highlighted species are noted as unlikely to occur in Banksia Woodlands. Please provide comments on these and any other species that should be deleted, or added.

Scientific Name	Common Name	EPBC Status	WA Status	Endemic to the Ecological community
<i>Acacia anomala</i>	grass wattle	VU	VU	Yes
<i>Acacia aphylla</i>	leafless rock wattle	VU	VU	Yes
<i>Acacia brachypoda</i>	western wheatbelt wattle	EN	VU	No
<i>Acacia chapmanii</i> subsp. <i>australis</i>		EN	EN	No
<i>Andersonia gracilis</i>	slender andersonia	EN	VU	No
<i>Anigozanthos viridis</i> subsp. <i>terraspectans</i>	dwarf green kangaroo paw	VU	VU	No
<i>Anthocercis gracilis</i>	slender tailflower	VU	VU	Yes
<i>Asterolasia nivea</i>	Bindoon starbush	VU	VU	Yes
<i>Banksia aurantia</i>	orange dryandra	CR	VU	Yes
<i>Banksia mimica</i>	summer honeypot	EN	VU	No
<i>Caladenia dorrienii</i>	cossack spider-orchid	EN	EN	No
<i>Caladenia huegelii</i>	king spider-orchid	EN	CR	No
<i>Caladenia</i> sp. <i>Quindanning</i>	Quindanning spider-orchid	Not listed	CR	No
<i>Calytrix breviseta</i> subsp. <i>breviseta</i>	swamp starflower	EN	CR	Yes
<i>Chamelaucium</i> sp. Gingin	Gingin wax	EN	VU	Yes
<i>Chorizema varium</i>	limestone pea	EN	EN	Yes
<i>Conospermum undulatum</i>	wavy-leaved smokebush	VU	VU	Yes

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Scientific Name	Common Name	EPBC Status	WA Status	Endemic to the Ecological community
<i>Darwinia acerosa</i>	fine-leaved darwinia	EN	EN	No
<i>Darwinia apiculata</i>	scarp darwinia	EN	EN	Yes
<i>Darwinia ferricola</i>	Scott River darwinia	EN	EN	Yes
<i>Dasymalla axillaris</i>	native foxglove	CR	CR	No
<i>Diplolaena andrewsii</i>		Not listed	VU	Yes
<i>Diuris drummondii</i>	tall donkey orchid	VU	VU	No
<i>Diuris micrantha</i>	dwarf bee orchid	VU	VU	No
<i>Diuris purdiei</i>	Purdie's donkey orchid	EN	EN	No
<i>Drakaea elastica</i>	glossy-leafed hammer orchid	EN	CR	No
<i>Drakaea micrantha</i>	dward hammer orchid	VU	EN	No
<i>Eleocharis keigheryi</i>	Keighery's eleocharis	VU	VU	No
<i>Eremophila glabra</i> subsp. <i>chlorella</i>		Not listed	CR	No
<i>Eucalyptus argutifolia</i>	Wabbling Hill mallee	VU	VU	No
<i>Eucalyptus balanites</i>	Cadda Road mallee	EN	CR	No
<i>Frankenia conferta</i>	silky frankenia	EN	VU	No
<i>Goodenia arthrotricha</i>		Not listed	EN	No
<i>Grevillea althoferorum</i> subsp. <i>fragilis</i>		Not listed	CR	Yes
<i>Grevillea bracteosa</i> subsp. <i>bracteosa</i>		Not listed	EN	No
<i>Grevillea christineae</i>	Christine's grevillea	EN	EN	No
<i>Grevillea corrugata</i>		EN	VU	Yes
<i>Grevillea curviloba</i> subsp. <i>curviloba</i>	curved-leaf grevillea	EN	CR	Yes
<i>Grevillea curviloba</i> subsp. <i>incurva</i>	narrow curved-leaf grevillea	EN	EN	Yes
<i>Grevillea flexuosa</i>	zig zag grevillea	VU	VU	Yes

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Scientific Name	Common Name	EPBC Status	WA Status	Endemic to the Ecological community
<i>Hypocalymma sylvestre</i>		Not listed	CR	Yes
<i>Lasiopetalum pterocarpum</i>	wing-fruited lasiopetalum	EN	CR	Yes
<i>Lechenaultia laricina</i>	scarlet leschenaultia	EN	VU	No
<i>Lepidosperma rostratum</i>	beaked lepidosperma	EN	EN	Yes
<i>Leucopogon</i> sp. Flynn		Not listed	CR	Yes
<i>Macarthuria keigheryi</i>	Keighery's macarthuria	EN	EN	No
<i>Marianthus paralius</i>		Not listed	CR	Yes
<i>Paracaleana dixonii</i>	sandplain duck orchid	EN	VU	No
<i>Ptilotus pyramidatus</i>	pyramid mulla-mulla	CR	CR	Yes
<i>Ptychosema pusillum</i>	dwarf pea	VU	VU	No
<i>Pultenaea pauciflora</i>	Narrogin pea	VU	VU	No
<i>Spirogardnera rubescens</i>	spiral bush	EN	VU	No
<i>Stylidium semaphorum</i>		Not listed	CR	Yes
<i>Synaphea</i> sp. Fairbridge Farm	Selena's synaphea	CR	CR	Yes
<i>Synaphea</i> sp. Pinjarra	club-leafed synaphea	CR	CR	Yes
<i>Synaphea</i> sp. Pinjarra Plain		Not Listed	CR	Yes
<i>Synaphea</i> sp. Serpentine		Not listed	CR	No
<i>Synaphea stenoloba</i>	dwellingup synaphea	EN	CR	Yes
<i>Tetraria australiensis</i>	southern tetraria	VU	VU	No
<i>Thelymitra dedmaniarum</i>	cinnamon sun orchid	EN	CR	Yes
<i>Thelymitra stellata</i>	star sun orchid	EN	EN	No

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Scientific Name	Common Name	EPBC Status	WA Status	Endemic to the Ecological community
<i>Thomasia glabripetala</i>	sandplain thomasia	VU	VU	Yes
<i>Tribonanthes purpurea</i>	granite pink	VU	VU	No
<i>Trithuria occidentalis</i>	swan hydatella	EN	CR	Yes
<i>Verticordia fimbriilepis</i> subsp. <i>fimbriilepis</i>	shy featherflower	EN	VU	No
<i>Verticordia plumosa</i> var. <i>ananeotes</i>	tufted plumed featherflower	EN	CR	No

Table 4: Listed threatened fauna species that are known or likely to occur in the Banksia Woodlands of the Swan Coastal Plain ecological community (EC).

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

Please provide comments on any other species that should be deleted from, or added to, this list.

Scientific name	Common name	EPBC Act status	WA status	Endemic to the EC
Mammals				
<i>Bettongia penicillata ogilbyi</i>	woylie	EN	CR	No
<i>Dasyurus geoffroii</i>	chuditch, western quoll	VU	VU	No
<i>Myrmecobius fasciatus</i>	numbat	VU	VU	No
<i>Petrogale lateralis lateralis</i>	black-flanked rock-wallaby	VU	VU	No
<i>Phascogale tapoatafa</i>	brush-tailed phascogale, wambenger	Not listed	VU	No
<i>Pseudocheirus occidentalis</i>	western ringtail possum	VU	VU	No
<i>Setonix brachyurus</i>	quokka	VU	VU	No

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Scientific name	Common name	EPBC Act status	WA status	Endemic to the EC
Birds				
<i>Calyptorhynchus baudinii</i>	Baudin's cockatoo	VU	EN	No
<i>Calyptorhynchus latirostris</i>	Carnaby's cockatoo	EN	EN	No
<i>Calyptorhynchus banksii naso</i>	forest red-tailed black cockatoo	VU	VU	No
<i>Atrichornis clamosus</i>	noisy scrub-bird	VU	EN	No
<i>Botaurus poiciloptilus</i>	Australasian bittern	EN	EN	No
<i>Cacatua pastinator pastinator</i>	Muir's corella	VU	Other - specially protected fauna	No
<i>Falco peregrinus</i>	peregrine falcon	Not listed	Other - specially protected fauna	No
<i>Leipoa ocellata</i>	malleefowl	VU	VU	No
Reptiles				
<i>Aspidites ramsayi</i>	woma	Not listed	Other - specially protected fauna	No
<i>Morelia spilota imbricata</i>	carpet python	Not listed	Other - specially protected fauna	No
Insects				
<i>Leioproctus douglasiellus</i>	A short- tongued bee	CR	EN	Yes
<i>Neopasiphae simplicior</i>	A native bee	CR	EN	Yes

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Table 6: Listed WA priority fauna species that are known or likely to occur in the Banksia Woodlands of the Swan Coastal Plain ecological community (EC).

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	Endemic to the EC
Mammals			
<i>Falsistrellus mackenziei</i>	western false pipistrelle	P4	No
<i>Hydromys chrysogaster</i>	water-rat, rakali	P4	No
<i>Isoodon obesulus fusciventer</i>	quenda	P4	No
<i>Macropus eugenii derbianus</i>	tammar wallaby	P4	No
<i>Macropus irma</i>	western brush wallaby	P4	No
Birds			
<i>Burhinus grallarius</i>	bush stonecurlew	P4	No
<i>Falcunculus frontatus leucogaster</i>	crested shrike-tit (southwestern subspecies)	P4	No
<i>Ninox connivens connivens</i>	barking owl (southwestern population)	P2	No
<i>Tyto novaehollandiae novaehollandiae</i>	masked owl (southwestern subspecies)	P3	No
Reptiles			
<i>Acanthophis antarcticus</i>	southern death adder	P3	No
<i>Ctenotus delli</i>	Dell's skink	P4	No
<i>Ctenotus gemmula</i> (SCP pop.)	jewelled southwest skink	P3	Yes
<i>Ctenotus ora</i>	coastal plains skink	P1	No
<i>Lerista lineata</i>	lined skink	P3	Yes
<i>Neelaps calonotos</i>	black-striped snake	P3	No
Insects			
<i>Austroconops mcmillani</i>	a biting midge	P2	Yes
<i>Austrosaga spinifer</i>	cricket	P3	No
<i>Hylaeus globuliferus</i>	bee	P3	No
<i>Leioproctus bilobatus</i>	bee	P2	No
<i>Leioproctus contrarius</i>	bee	P3	Yes

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Scientific name	Common name	WA status	Endemic to the EC
<i>Synemon gratiosa</i>	graceful sunmoth	P4	Yes
<i>Throscodectes xiphos</i>	cricket	P1	Yes
<i>Trichosternus relictus</i>	beetle	P1	No
<i>Arbanitis inornatus</i>	trapdoor spider	P1	No

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Appendix B – Detailed description of threats

This appendix provides relevant information about the known and potential threats to the Banksia Woodlands ecological community. The Threatened Species Scientific Committee will be using available data to assess the impacts of these threats on the Banksia Woodlands ecological community. Specifically, these impacts will be addressed against listing criteria, to determine eligibility for listing against each criterion. The six listing criteria are outlined in the [Guidelines for nominating and assessing threatened ecological communities](#).

Land clearing and impacts associated with fragmentation

Land clearing, development and intensification of land use, results in habitat loss, fragmentation and modification (DPaW, 2014). 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 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,

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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).

Climate change (increasing temps, declining rainfall, rainfall timing)

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) has been decreasing (CSIRO, 2012; DPaW, 2014). Since 1970 there has been a 17 per cent decline in average winter rainfall in the southwest of Australia. The decline in this region has also been characterised by a lack of very wet winters. The reduction in rainfall is amplified as decreased streamflow in rivers and streams. In the far southwest, streamflow has declined by more than 50 percent 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 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).

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).

Groundwater drawdown

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

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rapid changes in water table elevation, and historically, large numbers of *Banksias* 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 phreatophytic 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 are 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).

Altered fire regimes

Prior to European settlement, some fires occurred through lightning strikes and Aboriginal burning of the landscape. However *Banksia* Woodlands are generally considered to have been excluded from burning, except where routes between significant areas passed through the woodlands.

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, low intensity and high frequency of fires. While many plant taxa and ecosystems are resilient to a range of fire regimes, *Banksia* Woodlands and some component species have specific fire regime requirements including fire-free intervals sufficient to allow a build up of seed resources for species susceptible to

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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).

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, with a skewed distribution of fire frequencies (<7 yr fire frequencies are overrepresented).

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
- Increase in weed abundance, diversity and a decrease in native plant diversity and density
- Changes to the ecological function of Banksia Woodlands
- Feedback loops, promoting weed species e.g. perennial veldtgrass *Ehrharta calycina* which is highly flammable and promotes further fires.

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, 2014).

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, 2014).

Plant pathogens (causing 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

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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. 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, 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, 2014) 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.

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 most common and widespread weeds include *Gladiolus caryophyllaceus*, *Freesia refracta*, *Ursinia anthemoides*, *Hypochaeris glabra* and *Briza maxima*, and perennial veldtgrass (*Ehrharta calycina*). *Gladiolus caryophyllaceus* almost exclusively occurs in Banksia Woodlands.

The weed species with the greatest effect on community composition are freesias, perennial veldtgrass and *Gladiolus caryophyllaceus*, as they not only transform the ecological character of the community but they also reduce the diversity of the native shrubs, herbs, sedges and grasses.

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 *Ehrharta calycina* (perennial veldtgrass). However, perennial veldtgrass 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. 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).

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Common invasive fauna include the European rabbit (*Oryctolagus cuniculus*), red fox (*Vulpes vulpes*), feral cat (*Felis catus*), black rat (*Rattus rattus*), house mouse (*Mus musculus*), rainbow lorikeets (*Trichiglossus haematodus*), laughing kookaburra (*Dacelo novaeguineae*) and the introduced honey bee (*Apis mellifera*) (Reaveley et al., 2009; Stevens et al., 2016). Introduced fauna species affect biodiversity values through habitat modification, predation, grazing and competition.

Whilst native herbivores suppress 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).

Mining, exploration and extraction

The extraction of raw materials can result in the loss of vegetation 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, 2014; 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.

Other disturbances to patches

Other disturbances to patches are particularly common in the urban and peri-urban context (Stenhouse, 2004; Ramalho, 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, 2014). 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.

Key threatening processes

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

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

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