Department of **Biodiversity, Conservation and Attractions**

GOVERNMENT OF WESTERN AUSTRALIA

| Section 1 – Eligibility for Listing | | |
|---|---|---|
| **1.** Name of the ecological community | | |
| Shrublands on southern Swan Coastal Plain Ironstones (on WA and EPBC TEC list) | | |
| **2.** Listing Category for which the ecological community is nominated | | |
| | WA Biodiversity Conservation Act | EPBC Act |
| Current listing category<br><br>(Please check box) | ☐ Critically endangered<br>☐ Endangered<br>☐ Vulnerable<br>☐ Priority 1-5<br>☐ Data Deficient<br>☐ None – not listed | **Name:** Shrubland Association on Southern Swan Coastal Plain Ironstone (Busselton area) (Southern Ironstone Association)<br><br>☒ Critically endangered<br>☐ Endangered<br>☐ Vulnerable<br>☐ None – not listed |
| Proposed listing category<br><br>(Please check box) | ☐ Collapsed<br>☒ CR: Critically endangered<br>☐ EN: Endangered<br>☐ VU: Vulnerable<br>☐ Priority 1-5<br>☐ Data Deficient | |
| Select one or more of the following criteria under which the community is to be nominated for BC Act listing. (Please check box). For further details on these criteria please refer to the Attachment to this form. The information you provide in Section 3 should support the criteria you select here. | ☒ Criterion A – Reduction in geographic distribution<br>☒ Criterion B – Restricted geographic distribution<br>☐ Criterion C – Environmental degradation based on change in an abiotic variable<br>☐ Criterion D – Disruption of biotic processes or interactions based on change in a biotic variable<br>☐ Criterion E – Quantitative analysis that estimates the probability of ecosystem collapse | |

Section 2 – Description, Condition, Threats & Recovery

Please answer all the questions, providing references where applicable. If no or insufficient information exists to answer a question, you must indicate this instead of leaving the question blank. The answers may be provided within this form or as attachments, ensuring that responses clearly indicate which question number they refer to.

*Classification*

By nominating a broader community, you will enable the Committee to consider the national extent and condition of the community and determine the limits of the listed ecological community.

**3.** What is the name of the ecological community in other jurisdictions?

Note any other names that have been used recently, including where different names apply within different jurisdictions. For example, is it known by separate names in different States or regions?

The community is also known as the Busselton Ironstone community, floristic community type 10b (FCT10b) as described in Gibson *et al.* (1994), as the Southern Ironstone Association or as Swan Coastal Plain community type 10b (SCP10b).

**Much of the text in this nomination form is taken directly from English and Keith (2015).**

**4.** What authorities/surveys/studies support or use the name?

The community was originally described in Gibson *et al*. (1994). The community type has been recognised since the publication of that report, and was endorsed for listing as a critically endangered TEC by the WA Minister for Environment in 2001, but was ranked as CR using ranking criteria developed in WA, that do not match those used for the IUCN RLE. The community was ranked EN under the Endangered Species Protection Act 1992 that didn't recognise the category of critically endangered, also using other ranking criteria. The community was then listed as endangered under the name 'Shrublands on southern Swan Coastal Plain ironstones' when the EPBC Act was enacted, but has not been re-ranked using the new criteria recognised under that Act that also differ from the raking criteria used for the IUCN RLE. Gibson *et al*. (2000) called the community the 'Busselton Ironstone Community'.

**5.** How does the nominated ecological community relate to other ecological communities that occur nearby or that may be similar to it?

Does it intergrade with any other ecological communities and, if so, what are they and how wide are the intergradation zones?
Describe how you might distinguish the ecological community in areas where there is overlap (also see Description section below).

Restricted 'islands' of ferricrete soils occur across the southwest of Western Australia including locations near Kalbarri, Eneabba, Scott River, Albany, Gingin and Busselton, with each containing distinctive assemblages of flora (Department of Conservation and Land Management (CALM) 2005; Gibson *et al.* 2000). The Scott River assemblage is the most similar to the Shrublands on southern Swan Coastal Plain Ironstones but differs in the suite of endemic flora, and more common flora that comprise and distinguish each assemblage. The Scott River Ironstone community occurs on the Scott Coastal Plain, whereas the Busselton Ironstone community occurs on the Swan Coastal Plain.

The Busselton and Scott Ironstone communities are highly distinctive assemblages that occurs on a very restricted ironstone (ferricrete) substrate within the Busselton Augusta National Biodiversity Hotspot.

*Legal Status*

**6.** What is its current level of protection under Australian State/Territory Government legislation?

Please record whether there is an existing State listing for all or part of the nominated ecological community, its listing category (e.g. critically endangered, vulnerable) and its title.
If not listed as threatened, specify any other form of protection under State/Territory legislation?

The community is ranked endangered under the EPBC Act, and as critically endangered on the list of TECs endorsed by the WA Minister for Environment.

*Description*

**7.** List the main features that distinguish this ecological community from all other ecological communities?

Characteristic (or diagnostic) features can be biological (e.g. taxa or taxonomic groups of plants and animals characteristic to the community; a type of vegetation or other biotic structure), or associated non-biological landscape characteristics (e.g. soil type or substrate, habitat feature, hydrological feature). Please limit your answer to those features that are specific to the ecological community and can be used to distinguish it from other ecological communities.

This species-rich plant community is a seasonal wetland on ironstone sheet rock overlain by shallow loam soils on the Swan Coastal Plain and Whicher Scarp near Busselton. Much of the species diversity comes from annuals and geophytes (plants with an underground storage organ). Typical and common shrubs include *Kunzea rostrata*, *Pericalymma ellipticum* (swamp teatree), *Hakea oldfieldii, Hemiandra pungens* (snakebush) and *Viminaria juncea* (swishbush). *Aphelia cyperoides* (hairy aphelia) and *Centrolepis aristata* (pointed centrolepis) also commonly occur. Many taxa in the community are endemic to this unusual geology including a suite of threatened flora. The community is also known as "floristic community type 10b" as originally described in Gibson N., Keighery B.J., Keighery G.J., Burbidge A.H. and Lyons M.N. (1994) "A floristic survey of the southern Swan Coastal Plain" (unpublished report for the Australian Heritage Commission prepared by the Department of Conservation and Land Management and the Conservation Council of Western Australia (Inc.)).

The geographically restricted taxa as listed in Table 1 below are either totally confined or largely confined to this ecosystem (Gibson *et al.* 2000; CALM 2005). Many of these flora are listed as threatened under State and federal legislation (Department of Biodiversity, Conservation and Attractions (DBCA) 2017; Department of Environment and Energy (DEE) 2018) (see Table 1). There are few accessible data about the vertebrate and invertebrate fauna that are associated with the ecosystem, and its uniqueness is therefore ascribed to the flora.

This shrubland is distinguished from most other ecosystems on the Swan Coastal Plain by its shallow soils over massive ferricrete (or ironstone). The ferricrete substrate is highly restricted, occurring as isolated patches surrounded by deeper sandy soils. The ferricrete occurs on the plain and adjacent footslopes of the Whicher Range and consists of cemented iron rich mineral crusts formed by processes of chemical deposition and can be several metres thick overlying sand (Gibson *et al.* 2000; English *et al*. 2012).

**TABLE 1:** Taxa totally or largely confined to ironstone soils (Gibson *et al.* 2000; [redacted], personal communication )

| Taxon | Priority Listing (from Atkins | Busselton ironstone areas | Scott Coastal Plain | Wildlife Conservation Act | EPBC Act Status | Obligate seeder |
|---|---|---|---|---|---|---|
| *Andersonia ferricola* ms | P1 | + | | | | + |
| *Brachyscias verecundus* | DRF | + | | CR | - | + |
| *Calothamnus lateralis* var. *crassus* | P3 | + | + | | | + |
| *Calothamnus quadrifidus* subsp. *teretifolius* | P4 | + | | | | + |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Calytrix retrorsifolia* Nge & Keighery | P2 | + | | | | ? (known to reshoot from base) |
| *Chamelaucium* sp. S coastal plain (R.D. Royce 4872) | DRF | + | | VU | VU | + |
| *Darwinia ferricola* | DRF | | + | EN | EN | + |
| *Darwinia whicherensis* | DRF | + | | CR | EN | + |
| *Banksia nivea* subsp. *uliginosa* | DRF | + | + | EN | EN | + |
| *Banksia squarrosa* subsp. *argillacea* | DRF | + | | VU | VU | + |
| *Gastrolobium modestum* | DRF | + | | VU | VU | + |
| *Gastrolobium papilio* | DRF | + | | CR | EN | + |
| *Grevillea elongata* | DRF | + | | EN | VU | + |
| *Grevillea maccutcheonii* | DRF | + | | CR | EN | + |
| *Hakea oldfieldii* | P3 | + | | | | + |
| *Lambertia echinata* subsp. *occidentalis* | DRF | + | | CR | EN | + |
| *Loxocarya striata* subsp. *implexa* | P1 | + | | | | + |
| *Loxocarya magna* | P3 | + | + | | | + |
| *Petrophile latericola* ms | DRF | + | | CR | EN | + |
| *Stylidium squamellosum* | P2 | + | | | | + |

Definitions of DRF and Priority ratings for plant taxa occur in the Glossary.
CR=Critically Endangered; EN=Endangered; VU=Vulnerable
BJK=Bronwen Keighery, GJK =Greg Keighery, NG=Neil Gibson

**8.** Give a description of the biological components of the ecological community.

For instance, what species of plants and animals commonly occur in the community; what is the typical vegetation structure (if relevant).

The Shrublands on southern Swan Coastal Plain ironstone are winter-wet shrublands consisting of sclerophyllous species that form a dense mixed heath or may occur under a sparse woodland of trees such as *Eucalyptus patens, E. rudis* or *Melaleuca preissiana*. Typical and common native flora include the shrubs *Kunzea micrantha*, *Pericalymma ellipticum*, *Hakea oldfieldii*, *Hemiandra pungens* and *Viminaria juncea*, and the herbs *Aphelia cyperoides* and *Centrolepis aristata* . Many species of geophytes and annual forbs contribute to the high species diversity of the ecosystem (Gibson *et al.* 1994).

**9.** Give a description of the associated non-biological landscape characteristics or components of the ecological community.

For instance, what is the typical landscape in which the community occurs? Note if it is associated with a particular soil type or substrate; what major climatic variables drive the distribution of the ecological community (e.g. rainfall). Note particular altitudes, latitudes or geographic coordinates

Groundwater levels in the community come very close to or may reach the surface in the wetter months (Tille and Lantzke 1990) and may be associated with seasonal shallow fresh surface water due to impermeable outcrops of ferricrete and heavy-textured soils.

Characteristic very high moisture levels in the winter months and much lower moisture availability during summer months is a key contrast with other ecosystems that occur on deep sands in the region. Although

wetlands in claypans of the region are also wet in winter (Gibson *et al*. 1994), these claypans do not contain any of the endemic and threatened flora that are confined to this ferricrete ecosystem.

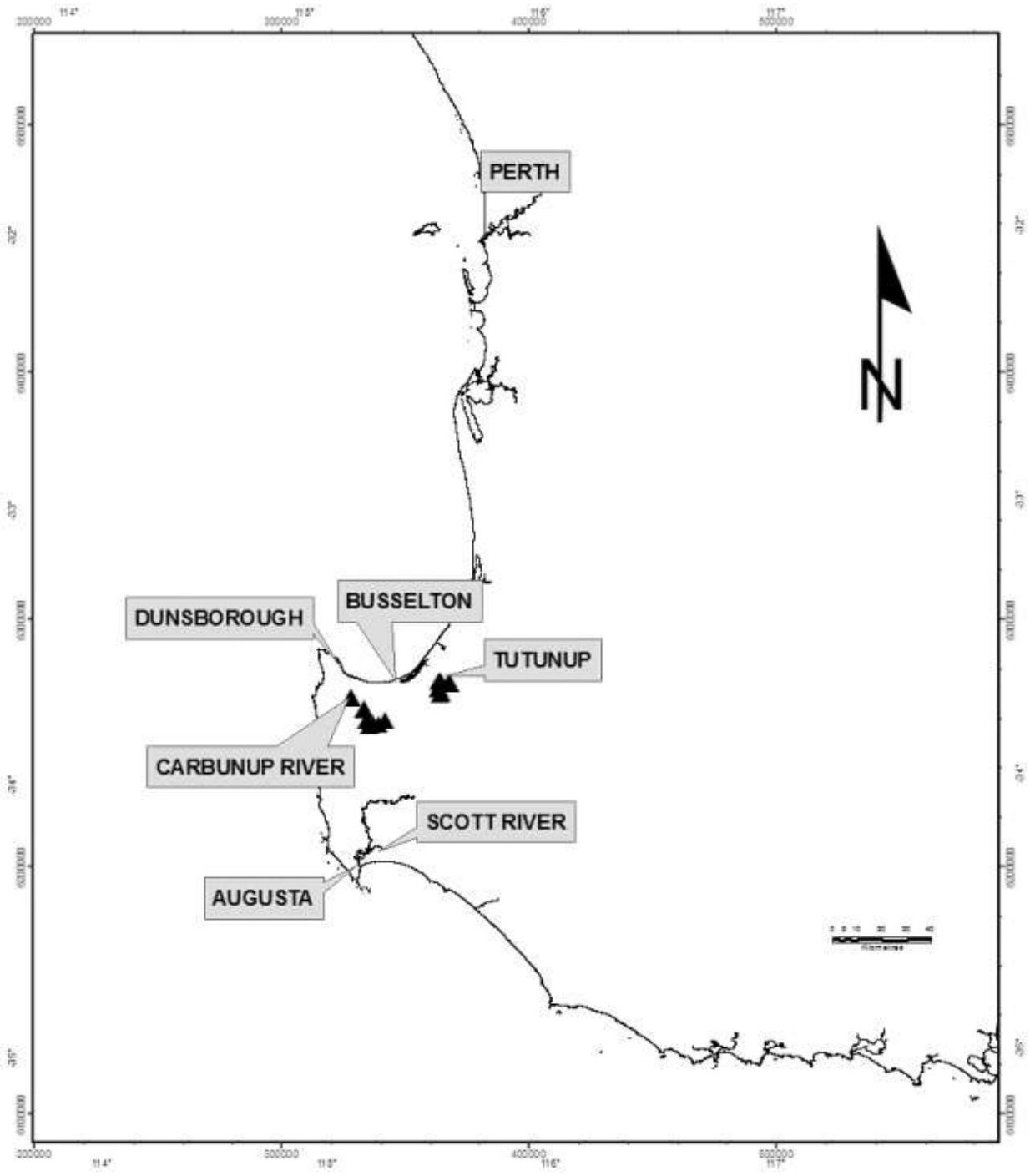
**10.** Provide information on the ecological processes by which the biological and non-biological components interact (where known).

Many of the plant taxa including the threatened flora present in the Shrublands on Swan Coastal Plain ironstone ecosystem are restricted to sites that experience shallow seasonal inundation (Gibson *et al*. 2000). The ecosystem has been identified as groundwater dependant and any significant changes in the watertable have the potential to impact on its ecology (Fig. 2) (CALM 2005; Department of Water (DoW) 2008; Loomes *et al*. 2008; Wilson and Froend 2010).

There are three main aquifers in this area of the Swan Coastal Plain; the superficial, Leederville and Yarragadee. The superficial aquifer is less than 3m from the ground surface, is the main aquifer accessed by the vegetation, and is recharged by rainfall and potentially from upward pressure from underlying aquifers (DoW 2008). The Leederville aquifer occurs at about 12m below ground, but can be as shallow as 7m in vicinity of the ecosystem (DoW 2008) so may be accessed by some deeper rooted perennial species. The thick Yarragadee aquifer sits below the Leederville aquifer and there is generally little vertical flow between these two lower aquifers (DoW 2010). The relationship between the watertable and rainfall, or pressures in the deeper aquifers is not clear however, especially in eastern locations of the ecosystem (Fig. 1). Some deep rooted perennial species in the ecosystem may therefore indirectly depend on the lower aquifers if they recharge the superficial aquifer (EPA 2006; DoW 2008).

Fire regimes play a key role in maintaining the diversity of the system, particularly as many of the rare and restricted flora that ascribe the ecosystem's uniqueness are killed by fire and rely on seedling establishment to maintain their populations.

**Fig. 1:** Map showing the current distribution of the Shrublands on southern Swan Coastal Plain ironstone ecosystem in Western Australia




Legend

▲ Shrublands on Southern SwanCoastal Plain Ironstone ecosystem

**11.** Does the ecological community show any consistent regional or other variation across its national extent, such as characteristic differences in species composition or structure?

If so, please describe these.

The structural units recorded by Gibson *et al*. (1994) included: dense heath B, scrub, low scrub A, open scrub and open low scrub A. The composition varies between sites depending on soil depth and probably chemistry, local hydrology, fire history, and possibly other factors.

**12.** Does the ecological community provide habitat for any listed threatened species and/or endemic species?

If so, please note the species and whether the species is listed on State/Territory and/or national lists and the nature of its dependence on the ecological community.

See Table 1 above.

**13.** Identify major studies on the ecological community (authors, dates, title and publishing details where relevant).


CALM (2005) *Southern Swan Coastal Plain Ironstone (Busselton Area) (Busselton or Southern Ironstone Association). Interim recovery plan no 215: 2005- 2010.* Department of Conservation and Land Management, Perth, Western Australia.

DEC (2009) *Phytophthora Disease Interpretation Report Busselton Ironstone TECs 2009*. Forest Management Branch, Department of Environment and Conservation, Bunbury, Western Australia.

DoW (2014) Water INformation (WIN) database - discrete sample data. Cited 4 February 2014. Department of Water, Water Information section, Perth Western Australia.

EPA (2006) *EPA Bulletin 1245. Report and Recommendations of the EPA. South West Yarragadee Water Supply Development.* Environmental Protection Authority, Perth, Western Australia.

Froend, R. & Loomes, R. (2006). Determination of *Ecological Water Requirements for wetland and terrestrial vegetation – Southern Blackwood and eastern Scott Coastal Plain.* Report to the Department of Water. CEM report no. 2005-07. Centre for Ecosystem Management, Edith Cowan University, Joondalup, Western Australia.

Gibson, N., Keighery, B., Keighery, G., Burbidge, A & Lyons, M. (1994) *A floristic survey of the Southern Swan Coastal Plain.* Unpublished report for the Australian Heritage Commission prepared by the Department of Conservation and Land Management and the Conservation Council of Western Australia (Inc.). Perth, Western Australia.

Gibson, N., Keighery, G. & Keighery, B. (2000) Threatened plant communities of Western Australia 1. The ironstone communities of the Swan and Scott Coastal Plains. *J. R. Soc. Western Aust.*, **83**, 1-11.

Loomes, R., Wilson, J. & Froend, R. (2008) *Vegetation Monitoring Swan Coastal Plain (Bunbury, Busselton-Capel Groundwater Areas). A Report to the Department of Water.* Centre for Ecosystem Management. Edith Cowan University, Joondalup. CEM report no. 2007-15. Joondalup, Western Australia.

Tille P.J. & Lantzke N.C. (1990) *Busselton Margaret River Augusta land capability study. Land Resource Series No. 5. Technical Report 109*. Western Australian Department of Agriculture. Perth.

URS Australia Pty Ltd (2003) *Establishment of interim ecological water requirements for the Blackwood groundwater area, WA – Stage 1. Volume 1 of 2. Prepared for Department of Environmental Protection and Waters and Rivers Commission*. Perth, Western Australia.

Webb, A. (2013). *Preliminary Review of the SWCC funded FCT10b sampling project.* An unpublished report by Department of Environment and Conservation for the South West Catchments Council, Bunbury, Western Australia.

Wilson, J. & Froend, R. (2010) *Vegetation Monitoring Swan Coastal Plain (Bunbury, Busselton-Capel Groundwater Areas). A Report to Water Smart Australia and the Department of Water*. CEM report no. 2010-9. Centre for Ecosystem Management. Edith Cowan University, Joondalup, Western Australia.

*Distribution*

**14.** Describe the distribution nationally and across WA.

State the appropriate bioregions where the ecological community occurs. Attach or provide any maps showing its distribution with details of the source of the maps, or explain how they were created and the datasets used.

The Shrublands on Swan Coastal Plain ironstone ecosystem occurs on the far southern portion of the Swan Coastal Plain about 120-150 km south of Perth, in the southwest of Western Australia (Fig. 1). The ecosystem occurs sporadically over a distance of about 40 km between Carbunup River and Tutunup, about eight to twenty kilometres from the coast (Tille and Lantzke 1990; Gibson *et al*. 1994; CALM 2005). The ecosystem is known from a total of about 225 ha at the 20 separate sites at which the community has been mapped (Note: *these area figures have been updated since English and Keith 2015 that were utilised for the assessment against IUCN RLE criteria below, however identity, condition and extent of three newly located occurrences requires verification*). These occurrences are distributed in an eastern and western cluster that are separated by about 25 km (Fig. 1).

**15.** What is the area of distribution of the ecological community?

For answers to parts a, b, c & d: please identify whether any values represent extent of occurrence or area of occupancy (as described in the Attachment); provide details of the source(s) for the estimates and explain how they were calculated and the datasets used.

15 a. What is the current distribution (in ha)? 225ha

15 b. What is the pre-European extent or its former known extent (in ha).

Based on the extent of relevant land units in Tille and Lantzke (1990) with some corrections, the ecosystem historically covered about 2400 $\pm$ 480 ha hectares (allowing $\pm$ 20% for mapping errors). Relative to the estimated current area (189 ha).

15 c. What is the estimated percentage decline of the ecological community?

This represents a loss of more than 90% (91-94%) of the area of the ecosystem.

15 d. What data are there to indicate that future changes in distribution may occur?

Historically land clearing was probably the greatest threat to the Shrublands on southern Swan Coastal Plain ironstone ecosystem, but various regulatory controls now mean that other less tractable issues such as weed invasion, too frequent or severe fires, and dieback disease caused by *Phytophthora* species threaten the ecosystem now and in the future (CALM 2005).

**16.** Is the ecological community considered to be naturally rare or restricted, based on its original (e.g. pre-European) distribution?

An ecological community is considered to be naturally restricted if it has a pre-European area of occupancy that is less than 10 000 ha or a pre-European extent of occurrence that is less than 100 000 ha (refer to the Attachment A).

Based on the extent of relevant land units in Tille and Lantzke (1990) with some corrections, the ecosystem historically covered about 2400 $\pm$ 480 ha hectares (allowing $\pm$ 20% for mapping errors) (ie area of occupancy). This is less than the 10,000ha threshold and is therefore considered naturally rare or restricted.

*Patch size*

**17.** What is the typical size (in ha) for a patch of the ecological community (if known)?

| |
|---|
| Explain how it was calculated and the datasets that are used. Relevant data includes the average patch size, the proportion of patches that are certain sizes, particularly proportions below 10 ha and below 100 ha, (but also below 1 ha and above 100 ha, for example). |
| The mean size of a patch is 11ha (20 occurrences totalling 225ha i.e. 225/20) = 11ha |
| **18.** Quantify the smallest percentage or area required for a patch of the ecological community to be considered viable.<br>This refers to the minimum size of a remnant that can remain viable without active management. It may be determined through the requirements for dominant native species, level of species diversity, or the nature of invasive weeds. |
| As the community generally occurs within patches of other vegetation, and not in isolation, there is no minimum area specified for a remnant that could remain viable without active management. In addition, as the patches are all small and most require management such as weed and dieback control, this question is not relevant for community. |
| *Functionality*<br>**19.** Is the present distribution of the ecological community severely fragmented?<br>If so, what are likely causes of fragmentation?<br>If fragmentation is a natural or positive characteristic of this ecological community, please explain this and state the reason.<br>*Severely fragmented* refers to the situation in which increased extinction risk to the ecological community results from most remnants being found in small and relatively isolated patches. |
| From English and Keith (2015) 'The southwest of Western Australia was identified as a global biodiversity hotspot due to its high numbers of endemic species, many of which face high risks of extinction (Mittermeier *et al.* 2004). Within the region, diversity is expressed primarily at and below the species level (Byrne 2007), indicating relatively recent diversification within genera such as *Acacia, Banksia, Eucalyptus, Grevillea, Hakea, Melaleuca* and *Stylidium* (Paczkowska & Chapman 2000). The mechanisms responsible for this diversity are complex and thought to be related to post-Miocene climatic instability resulting in cycles of expansion and contraction of mesic and arid conditions across an edaphically and hydrologically varied landscape. The resulting fragmentation and isolation of plant populations promoted genetic divergence, local adaptation and speciation in localised refugia (Hopper 1979, Byrne 2007). As a consequence, high levels of diversity are expressed within local sites, across environmental gradients and at landscape scales (Hopper & Gioia 2004). The extremely high beta-diversity within the region is related in part to the turnover of species along climatic and edaphic gradients, with contrasting substrates supporting distinctive assemblages of flora (Hopper 1979). This is well illustrated by restricted 'islands' of ferricrete soils across the southwest of Western Australia including locations near Kalbarri, Eneabba, Scott River, Albany, Gingin and Busselton, with each containing distinctive assemblages of flora (Department of Conservation and Land Management (CALM) 2005; Gibson *et al.* 2000).<br>Shrublands on southern… Swan Coastal Plain ironstone is a highly distinctive system that occurs on a very restricted ironstone (ferricrete) substrate within the Busselton Augusta National Biodiversity Hotspot. The growing human population of the region has the potential to impact upon this ecosystem, introducing and exacerbating stresses including modification of hydrological processes, introduction of disease, altering fire regimes, introduction of invasive species, and fragmentation of habitats.<br>Historically the most significant pressures were probably land clearing and fragmentation (CALM 1990; Keighery and Trudgen 1992).<br>The most severe of the current pressures are weed invasion, too frequent fire, dieback disease caused by *Phytophthora* species. |

**20.** Has there been a loss or decline of functionally important species?

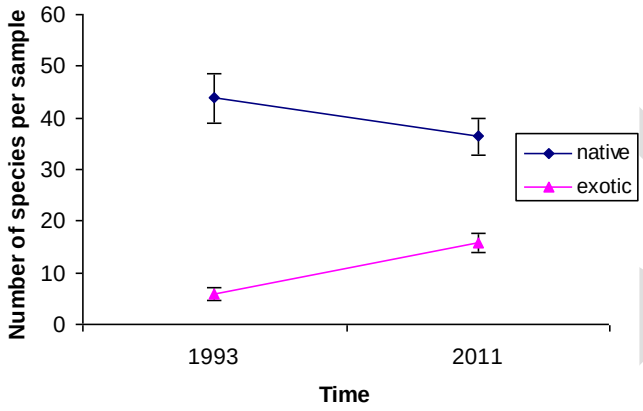
This refers to native species that are critically important in the processes that sustain or play a major role in the ecological community and whose removal has the potential to precipitate change in community structure or function sufficient to undermine the overall viability of the community.

The endemic species that occur in the community are significant in that they are major part of characterising and differentiating the community. They are particularly well adapted to the very specific characteristics of the ironstone substrate and are a key part of the assemblage.

20 a. If yes, which species are affected?

English and Keith 2015 notes that native species declined and exotic plant species increased in number between 1993 and 2011, see below.

**'Fig. 2**. Trends in the numbers of native and exotic plant species in Shrublands on southern Swan Coastal Plain ironstone ecosystem over an 18 year period (n=11).




**20 b. How are the species functionally important and to what extent have they declined?**

The remaining patch of the TEC that supported *Grevillea maccutcheonii* declined such that it no longer occurred in intact ironstone vegetation habitat, rather it comprises a very narrow roadside strip of very poor condition.

***Reduction in community integrity***

**21. Please describe any processes that have resulted in a reduction in integrity and the consequences of these processes, e.g. loss of understorey in a woodland. Include any available information on the rate of these changes.**

This recognises that an ecological community can be threatened with extinction through on-going modifications that do not necessarily lead to total destruction of all elements of the community. Changes in integrity can be measured by comparison with a benchmark state that reflects as closely as possible the natural condition of the community with respect to the composition and arrangement of its abiotic and biotic elements and the processes that sustain them. Please provide a description of the benchmark state where available. For further information please refer to the Guidelines.

The occurrences that are closest to the benchmark state are occurrences 1, 2, 3, 4, 5, 7, 10, 16 and 19 (see Table 2 below), that were in excellent condition when last surveyed. They are characterised by the following:

- Few weed taxa, and low weed cover
- All previously recorded natural strata of the vegetation present
- Connectivity with other intact vegetation
- Highly diverse flora including numerous herbaceous species
- Intact populations present in patches where rare and priority flora were historically recorded

***Survey and Monitoring***

**22. Has the ecological community been reasonably well surveyed?**

Provide an overview of surveys to date and the likelihood of the ecological community's current known distribution and/or patch size being its actual distribution (consider area of occupancy and area of extent, including any data on number and size of patches).

A combination of 12 years survey of the Swan Coastal Plain for the surveys mentioned below:

- Gibson *et al.* (1994). A floristic survey of the southern Swan Coastal Plain. (3 years survey of Swan Coastal Plain)
- Government of WA (2000). Directory of Bush Forever Sites Volume 2.
- Surveys for Bush Forever, undertaken in 1994-1998 by B. Keighery and other staff from DEP.
- DEP (1996). System 6 and Part System 1 Update Program

Since 1994, various people including Environmental Consultants and district staff have searched for the community in likely areas and found a number of new occurrences that were not known in 1994.

**23. Where possible, please indicate areas that haven't been surveyed but may add to the information required in determining the community's overall viability and quality.**

Most likely areas have been surveyed.

**24. Is there an ongoing monitoring program? If so, please describe the extent and length of the program.**

The quadrats that were established in 1993 for Gibson *et al* (1994) were re-monitored in 2011 (Webb 2013). The change between 1993 and 2011 in the proportion of native species present (relative to the total native and exotic) were calculated for each of eleven vegetation samples (Webb 2013). These samples were distributed across the range of the ecosystem. The quadrats are likely to be re-monitored on an opportunistic basis.

***Condition Classes and Thresholds***

**25. Do you think condition classes/thresholds apply to this ecological community? If not, give reasons.**

The Committee recognises that ecological communities can exist in various condition states. In reaching its decision the Committee uses condition classes and/or thresholds to determine the patches which are included or excluded from the listed ecological community (see the Guidelines for details of the process of determining condition classes).

**Table 2. Condition and extent of occurrences**

| Number | Occurrence name | Area | date last surveyed | Condition when last surveyed |
|---|---|---|---|---|
| 1 | WIL01 | 6.7527 | 1994 | Excellent |
| 2 | WIL03 | 6.5360 | 1994 | Excellent |
| 3 | PAYNE02 | 14.2697 | 12/03/2003 | Excellent |
| 4 | YIRON01 | 9.8642 | 07/11/2006 | Excellent |
| 5 | SMITH01 | 36.9301 | 1994 | Excellent |
| 6 | JACKA01 | 8.5382 | 1995 | Excellent 35% (2.98ha), Very good 45% (8.988ha), Good 20% (1.71ha) |
| 7 | IRON01 | 6.4807 | 1994 | Excellent |
| 8 | WONNEW1 | 0.9181 | 1994 | 80% excellent (0.73ha), 20% very good (0.184ha) |
| 9 | YIRON02 | 1.2211 | 07/11/2006 | Good |
| 10 | SMITH04 | 1.7754 | 08/11/2006 | Excellent |
| 11 | NEG01 | 77.8548 | 19/11/2013 | 75% excellent (58.41ha), 25% Very good (19.46ha) |
| 12 | CHAMBERS01 | 3.6321 | 22/09/2016 | Excellent 90% (3.27ha), 10% very good (0.363ha) |
| 13 | HairPinRd | 0.3159 | 14/10/2013 | Good 40% (0.12ha), very good 30% (0.096ha), degraded 30% (0.096ha) |
| 14 | WONN06 | 2.6300 | 1994 | 80% excellent (3.43ha), 20% very good (0.523ha) |
| 15 | WONN05 | 2.4062 | 1994 | 90% excellent (2.17ha), 10% very good (0.24ha) |
| 16 | OATES01_Webb | 7.3012 | 01/11/2011 | Excellent |
| 17 | SWR18 | 1.3407 | - | - |
| 18 | SWR9 | 0.53 | 2017 | Good |
| 19 | SWR19 | 5.57 | | Rehabilitation area? |
| 20 | SWR21 | 30.62 | | |

Approximately 98% of the mapped area of the community for which condition has been recorded is in Good or better condition on Bush Forever (2000) scales. The threshold that is generally applied to 'extant' occurrences of TECs is 'Good', with vegetation in poorer condition than 'good' not being considered to be representative of the TEC.

**26. If so, how much of the community would you describe as in relatively <u>good condition</u>,**

i.e. likely to persist into the long-term with minimal management?

Approximately 65% of the mapped area of the community for which condition has been recorded is in Excellent condition on Bush Forever scales.

**27. What features or variables do you consider to be most valuable for identifying a patch of the ecological community in relatively <u>good condition</u>?**

Variables for establishing the highest condition class may include: patch size; connectivity; native plant species composition; diversity and cover (for example in overstorey; mid-shrub and/or understorey layers); recognised faunal values; and cover of weeds or other invasive species.

- Few weed taxa, and low weed cover (eg <20%)
- All previously recorded natural strata of the vegetation present
- Connectivity with other intact vegetation
- Highly diverse native flora in relation to previously recorded diversity, including a number of herbaceous species
- Intact populations of rare and priority flora for locations previously recorded as habitat of such flora.

**28. How much of the community would you describe as in relatively <u>medium condition</u>**, i.e. likely to persist into the long-term future with management?

Approximately 33% of the mapped area of the community for which condition has been recorded is in Very Good to Good condition on Bush Forever scales.

**29. Please describe how you would identify areas in <u>medium condition</u> using one or a combination of indicators such as species diversity, structure, remnant size, cover of weeds or other invasive species, etc.**

- Moderate cover of weed taxa (eg <50%)
- Most previously recorded natural strata of the vegetation present
- Connectivity with other intact vegetation
- Moderate diversity of native flora in relation to previously recorded diversity, including herbaceous species

**30. How much of the community would you describe as in relatively <u>poor condition</u>,** i.e. unlikely to be recoverable with active management?

Approximately 0.05% of the mapped area of the community for which condition has been recorded is in poorer than Good condition on Bush Forever scales. However, the threshold that is generally applied to 'extant' occurrences of TECs is 'Good', with vegetation in poorer condition not being considered to be representative of the TEC. Therefore when TEC boundaries are mapped, the poor condition areas are not included within mapped boundaries.

**31. Please describe how you would identify area in <u>poor condition</u> using one or a combination of indicators such as species diversity, structure, remnant size, cover of weeds or other invasive species, etc.**

- High level cover of weed taxa (eg >50-70%)
- Evidence of impacts of dieback disease such as deaths of a number of susceptible species
- One or more previously recorded natural strata of the vegetation now absent
- No connectivity with other intact vegetation
- Very low diversity of native flora in relation to previously recorded diversity

***Threats***

Note: If you plan to identify <u>climate change</u> as a threat to the ecological community, please refer to the Guidelines for information on how this should be addressed.

**32. Identify <u>PAST</u> threats to the ecological community indicating whether they are *actual* or *potential*.**

| |
|---|
| Historically land clearing and fragmentation were probably the greatest threats to the Shrublands on southern Swan Coastal Plain ironstone ecosystem. Some patches were historically grazed, and this would have contributed to weed invasion. Grazing by stock has ceased across the range of the community. |
| **For <u>each</u> threat describe:**<br>**32 a. How and where the threat impacts on this ecological community.** |
| Land clearing has resulted in decline from approximately 2400 ± 480 ha hectares (allowing ± 20% for mapping errors) to ~ 189 ha. This clearing has occurred across the historical range of the community from Carbunup to Tutunup, a range of about 30km. |
| **32 b. What its effects have been so far.** Indicate whether they are known or suspected; provide supporting information or research. |
| Data from aerial photography and land unit mapping were used to estimate the ecosystem's original extent, and current boundaries were determined using information from on-ground surveys. |
| **32 c. What its expected effects are in the future.** Include or reference supporting research or information. |
| Various regulatory controls now mean that the threat from land clearing has declined and other less tractable processes threaten the ecosystem now and in the future (CALM 2005). |
| **32 d. Is the threat only suspected? Give Details.** |
| No, actual |
| **32 e. Does the threat only affect certain patches? Give Details.** |
| This clearing has occurred across the historical range of the community from Carbunup to Tutunup. In some cases whole patches have been cleared, in other cases, parts of existing occurrences were cleared. |
| **33. Identify <u>CURRENT</u> threats to the ecological community indicating whether they are *actual* or *potential*.** |
| Major threatening processes currently affecting the community are hydrological change (potential), root rot disease caused by *Phytophthora cinnamomi* (actual), too frequent fire (actual) and weed invasion (actual). |
| **For <u>each</u> threat describe:**<br>**33 a. How and where it impacts on this ecological community.** |
| Various regulatory controls now mean that other less tractable processes threaten the ecosystem now and in the future (CALM 2005) and have replaced land clearing as the main threat. The most severe of these appears to be weed invasion which is steadily replacing the native flora, most likely as a legacy effect of past clearing and fragmentation combined with current ongoing disturbances such as fire. Weed invasion affects all occurrences to varying degrees. All except two locations of the ecosystem are infected with dieback disease caused by Phytophthora spp. (Department of Environment and Conservation (DEC) 2009). The disease can kill species susceptible species, including many of the endemic flora that occur in the community. |
| **33 b. What its effects have been so far.** Indicate whether they are known or suspected; provide supporting information or research. |
| From English and Keith (2015) |

Multiple threats are associated with potential changes in hydrology. Altered periods of inundation by surface water may affect the timing of growth of herbs, and may also affect species composition by favouring different suites of flora taxa. Extraction of water from deep or shallow aquifers on which the ecosystem relies also has the potential to impact water regimes in the ecosystem (CALM 2005), with water demand in the region growing due to urban and agricultural pressures (DoW 2010). Water extraction has been correlated with decline of groundwater dependent Banksia communities on the Swan Coastal Plain near Perth (eg Groom *et al.* 2008) and with dewatering adjacent to the Shrublands on Swan Coastal Plain ironstone ecosystem causing decline (A. Webb unpublished data).

Widespread abstraction of water from the Leederville aquifer (DoW 2008) has potential to impact the ecosystem if upward pressure from this aquifer provides supports the water levels in some locations of the ecosystem, unless compensated by recharge from rainfall, minor streams and from other groundwater movement. Although only relatively small amounts of groundwater are currently abstracted close to the eastern locations of the ecosystem, some water licence allocations nearby are potentially large enough to impact water levels in the area. However, bore data indicate groundwater levels do not appear to be affected by current abstraction (DoW 2008).

Groundwater modelling by DoW (2008) indicates future groundwater levels are likely to fall only slightly with the proposed licensing limits for groundwater abstraction, and that two-thirds of the decline will be associated with drying climate. It is also probable that trends of reduced rainfall will result in declining water levels in superficial aquifers, and that any additional impacts of lowering of groundwater as a consequence of abstraction will exacerbate these changes (URS Australia Pty Ltd 2003; DoW 2008).

The water mould *Phytophthora cinnamomi* is a soil-borne pathogen that causes root rot in a wide variety of woody plants and can cause plant deaths by preventing flora from absorbing water and nutrients (Environment Australia 2001). The disease can change the composition of ecosystems by causing declines in susceptible plant species and resulting increases in the abundance of resistant flora (Shearer *et al.* 1989; Wills & Keighery 1994; Environment Australia 2001). A number of component flora are very susceptible to the disease, including eight of the threatened flora (Environment Australia 2001). All except two locations of the ecosystem are infected with the disease (Department of Environment and Conservation (DEC) 2009). The disease could result in removal of a suite of flora that essentially distinguish the ecosystem from others, and could also alter the composition of the ecosystem to dominance by resistant species such as sedges and annual flora.

It is not known to what extent fire has influenced the ecosystem's past or present structure or composition, however, variations in fire frequency, intensity and season may result in changes in species composition (Abbott and Burrows 2003; CALM 2005; Enright *et al*. 2012). Weed invasion in smaller remnants has also been correlated with high frequencies of fire (eg Milberg and Lamont 1995; CALM 2005). The risk of fire is generally increased by the presence of grassy weeds in the understorey, as they are likely to be more flammable than many of the native species in the herb layer (Milberg and Lamont 1995; Setterfield *et al.* 2013). Increased fire frequency as a consequence of predicted drying climate and increased temperatures (Sullivan *et al*. 2012) are likely to affect regeneration of serotinous, non-seeder species (Enright *et al*. 2012), including a suite of flora that are almost entirely restricted to this ecosystem. In addition, fire increases plant mortality in communities already infected with root rot disease (eg Moore *et al*. 2007).

All occurrences of this ecosystem are close to agricultural areas, roads and other infrastructure that act as weed sources, and are vulnerable to weed invasion. Weed cover in most locations of the ecosystem was low in 1994 (Gibson *et al*. 1994; CALM 2005) but weeds are increasing in species richness and abundance (Webb 2013).

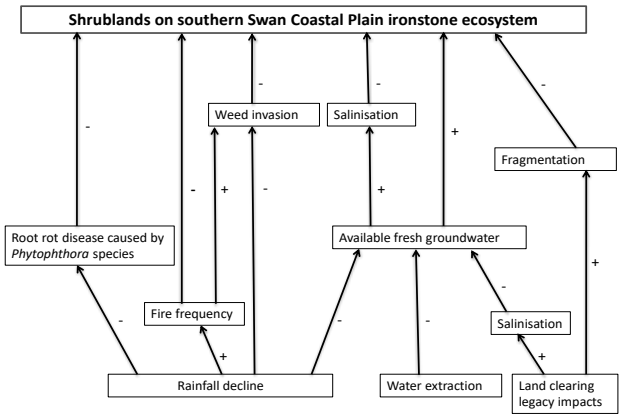
Tille & Lantzke (1990) report that salinisation is degrading the soil and landscape units that support the ecosystem while Short & McConnell (2000) also indicate that the area is at medium to high risk in terms of dryland salinity

within the next 50 years. The anticipated reduction in rainfall in the region will, however, be likely to counteract the impacts of this process by reducing waterlogging and watertable rise.

**33 c. What its expected effects are in the future.** Include or reference supporting research or information.

Potentially synergistic interactions between threatening processes are complex and unpredictable, but may be highly significant in terms of the consequences for the ecosystem's future persistence (Fig. 2). For example, reduced rainfall and increased temperatures may result in increased fire frequency and intensity, and increased weed levels (Milberg & Lamont 1995: Setterfield *et al*. 2013). Increased fire frequency may also amplify impacts of root rot disease (Moore *et al.* 2007), but reduced rainfall is also likely to reduce the rate of spread and manifestation of disease impacts in the ecosystem (Department of Environment and Heritage 2006). The timing of rainfall will also be crucial to the manifestation of the disease, however, as summer rainfall results in increased disease impacts (Lucas *et al*. 2003).

**Fig. 3:** A conceptual model of ecological processes for Shrublands on southern Swan Coastal Plain ironstone ecosystem. Arrows indicate major relationships that either promote the system at which the arrow is directed (+), or inhibit/reduce its effects (-).




**33 d. Is the threat only suspected? Give Details.**

Hydrological change associated with climatic drying remains a concern (DoW 2008), but currently available projections and empirical evidence suggest that the superficial aquifer may be less sensitive to rainfall than previously expected, possibly due to the legacy of rising watertables as a consequence of historical land clearing. In addition, water abstraction from the aquifers may also largely be controlled through regulation. Root rot disease caused by *Phytophothora* species and increased fire frequency and intensity are newly emerging threats that may not reach their potential for some time. Aerial spraying with the chemical phosphite has helped to reduce impacts of root rot disease since the mid 1990s (CALM 2005, Crane & Shearer 2013) but this is highly resource intensive and in the longer term may in itself result in other adverse impacts associated with eutrophication (Lambers *et al*. 2013).

**33 e. Does the threat only affect certain patches? Give Details.**

Weed invasion impacts all known occurrences, as does dieback disease. Too frequent fire impacts most occurrences.

**34. Identify FUTURE threats to the ecological community indicating whether they are *actual* or *potential*.**

Weed invasion and hydrological change are current and ongoing threats. Root rot disease caused by *Phytophothora* species and increased fire frequency and intensity are newly emerging threats that may not reach their potential for some time.

**For <u>each</u> threat describe:**

**34 a. How and where it impacts on this ecological community.**

All occurrences are impacted to some degree by weed invasion. All occurrences except two are infested with dieback disease.

<u>Occurrences 1 and 2</u> occur on road, and rail reserve (reserve 12969) and extend onto adjacent private land and nature reserve. Cleared agricultural lands surround all other Ruabon-Tutunup Road occurrences. Neither of the privately owned areas is currently grazed. The northern part of Occurrence 2 occurs on shallow, fast drying sandy loam soils over ironstone. It extends into a CALM Nature Reserve and partly into private property. The southern part of the occurrence extends into adjacent private land, owned by a mining company. Occurrence 1 extends into adjacent private property.

<u>Occurrences 3-5</u> are located on disused railway reserve 12969, and on the adjacent road reserve along Ruabon-Tutunup Road that is managed by the Shire of Busselton. The rail reserve is vested in Public Transport Authority of Western Australia, but has been leased by the Shire of Busselton since 1998, and the Ruabon-Tutunup Rail Reserve Preservation Group manages the site. The rail and road reserves were burnt in a hot fire in April 1993. Many of the species in occurrences on these reserves are obligate seeders and taxa could be lost through too frequent fire. In 2004, an area of the road reserve had a heavy mineral spill as a consequence of a truck accident, however this did not affect any part of the ironstone occurrence.

<u>Occurrence 6</u> is located on a degraded road reserve on Oates Road managed by the Shire of Busselton. Few of the species that originally occurred at the site remain, so the community is considered very highly modified. This site is managed for species conservation. Adjacent land on Sussex locations 4049 and 5162 were purchased as part of a program for germination and translocation trials for ironstone taxa being conducted by DBCA staff.

<u>Occurrences 7 and 8</u> occur on the boundary of State Forest in Abba block. Cleared agricultural lands occur to the north of both occurrences. A mineral sands mine occurs immediately to the west and north of Occurrence 8. This area was burnt in a hot fire in 1992 when a controlled burn escaped from adjacent areas of State Forest. Deaths caused by *Phytophthora* species have been detected in both of these occurrences. Also, canker probably caused by *Armillaria luteobubalina* has swept through Occurrence 8 resulting in massive deaths of *Dryandra nivea* subsp. *uliginosa*.

<u>Occurrences 9, 10, 11 and 12</u> are in Treeton block of State Forest. Cleared agricultural lands occur to the north of Occurrences 10 and 11. Occurrence 9 extends into private property. A buffer area of native vegetation surrounds Occurrence 12, which is located in an area called Ironstone Gully. Occurrence 9 was burnt in a hot fire in 1993. Much of occurrence 10 was been mined for gravel and an area was recently burnt. However, portions of the site are regenerating well from seed and rhizomes. About half of Occurrence 10 is on private land. Most of Occurrence

11 and some of Occurrence 10 were mistakenly cleared to mineral earth in 1995 for road widening. At Occurrence 11, topsoil was then redistributed over the site and it was fenced. The site has since regenerated quite well.

Occurrence 13 is located on Sussex Location 5114 (previously part Sussex Location 2650), which was purchased in 1999 with funds from CALM and Environment Australia. Cleared agricultural lands surround this site. The occurrence was last burnt in the late 1960s ([redacted][1], personal communication).

Occurrence 14 is located in Kaloorup. The ironstone community occurs on soils that range from surface rock with shallow pockets of clay soil to grey sandy soils over ironstone rock at varying depth. The property was purchased in 2004 with CALM and Environment Australia funds, with some contribution from Cable Sands Pty Ltd. The occurrence extends into the adjacent property to the east and is surrounded by agricultural land including vineyards. Remnant vegetation surrounds the occurrence within the reserve. The occurrence extends into adjacent private property.

Occurrence 15 is located on private property. It is a small occurrence with shallow clay soil over sheet rock. The occurrence was discovered when the landowner enquired about a Conservation Covenant. Cleared Agricultural lands surround the occurrence to the north and south. The occurrence has recovered well since grazing ceased five years ago.

**34 b. What its effects have been so far**. Indicate whether they are known or suspected; provide supporting information or research.

**34 c. What its expected effects are in the future.** Include or reference supporting research or information.

Future management could promote persistence of the ecosystem by maintaining land clearing and water extraction at low levels under a drying climate, by mitigating the invasion of weeds and their effects on native species and by a range of disease prevention and mitigation measures.

Groundwater modelling by DoW (2008) indicates future groundwater levels are likely to fall only slightly with the proposed licensing limits for groundwater abstraction, and that two-thirds of the decline will be associated with drying climate. It is also probable that trends of reduced rainfall will result in declining water levels in superficial aquifers, and that any additional impacts of lowering of groundwater as a consequence of abstraction will exacerbate these changes (URS Australia Pty Ltd 2003; DoW 2008).

Projections for future annual rainfall in the region vary from a decline of 20-40% to an increase of +5 to +10% by 2070 (BOM 2014b). Declining rainfall coupled with increasing temperatures could impact on surface water and levels in watertables through reduced runoff and increased evaporation rates (Fig. 2; DoW 2010). However, modelling of the most likely future rainfall scenario for 2050 suggests that this will only result in a slight fall in watertables in the vicinity of the ecosystem (DoW 2008). Based on the modelled abstraction scenario and rainfall projections, DoW (2008) predicted watertable levels to decline by 0.01m over a 25 year period from 2008. Over a 50 year period, an extrapolated linear decline is in the order of 0.02m. DoW (2008) predicts that such changes pose low risks of changes to ecosystem processes, species abundance and water quality. Other studies of risk to groundwater dependent ecosystems by Froend *et al*. (2004) also indicate that this rate of drawdown would place such ecosystems at low risk of impact. These studies were conducted on deep sands that have different

[1] Russell Smith, Plant Ecologist, CALM South West Region

hydrological properties to massive ironstone overlaying sands (Wösten *et al*. 2001), but the outcomes of projected impacts of watertable declines are similarly small. Even allowing for substantial errors in future projections, a 1% decline in watertable levels over the next 50 years corresponds to a relative severity of less than 5%.

Assuming that the trends observed during 1993-2011 continue until 2043, the relative severity of the decline in the native component of the biota was projected to be 60% (plausible range 38-88%) over a 50 year future period.

Historically land clearing was probably the greatest threat to the Shrublands on southern Swan Coastal Plain ironstone ecosystem, but various regulatory controls now mean that other less tractable processes threaten the ecosystem now and in the future (CALM 2005). The most severe of these appears to be weed invasion which is steadily replacing the native flora, most likely as a legacy effect of past clearing and fragmentation combined with current ongoing disturbances such as fire. Hydrological change associated with climatic drying remains a concern (DoW 2008), but currently available projections and empirical evidence suggest that the superficial aquifer may be less sensitive to rainfall than previously expected, possibly due to the legacy of rising watertables as a consequence of historical land clearing. In addition, water abstraction from the aquifers may also largely be controlled through regulation. Root rot disease caused by *Phytophothora* species and increased fire frequency and intensity are newly emerging threats that may not reach their potential for some time. Aerial spraying with the chemical phosphite has helped to reduce impacts of root rot disease since the mid 1990s (CALM 2005, Crane & Shearer 2013) but this is highly resource intensive and in the longer term may in itself result in other adverse impacts associated with eutrophication (Lambers *et al*. 2013).

Potentially synergistic interactions between threatening processes are complex and unpredictable, but may be highly significant in terms of the consequences for the ecosystem's future persistence (Fig. 2). For example, reduced rainfall and increased temperatures may result in increased fire frequency and intensity, and increased weed levels (Milberg & Lamont 1995: Setterfield *et al*. 2013). Increased fire frequency may also amplify impacts of root rot disease (Moore *et al.* 2007), but reduced rainfall is also likely to reduce the rate of spread and manifestation of disease impacts in the ecosystem (Department of Environment and Heritage 2006). The timing of rainfall will also be crucial to the manifestation of the disease, however, as summer rainfall results in increased disease impacts (Lucas *et al*. 2003).

**34d. Is the threat only suspected? Give Details.**

Weed invasion, dieback disease and too frequent fire are actual threats, hydrological change is suspected.

**34 e. Does the threat only affect certain patches? Give Details.**

All patches are subject to weed invasion. A number of component flora are very susceptible to root rot disease, including eight of the threatened flora (Environment Australia 2001). All except two locations of the ecosystem are infected with the disease (Department of Environment and Conservation (DEC) 2009).

Fire has affected a number of patches.

All occurrences are potentially subject to hydrological change, especially as a consequence of climate change.

**35. Identify any natural catastrophic event/s**

Explain its likely impact and indicate the likelihood of it occurring (e.g. a drought/fire in the area every 100 years). Catastrophic events are those with a low predictability that are likely to severely affect the ecological community.

Major bushfires can occur any time and have potential for major impacts to the ecosystem.

Dewatering for a mine adjacent to the Shrublands on Swan Coastal Plain ironstone ecosystem was implicated in sudden major water stress and decline in the ecosystem in 2004 ([redacted] unpublished data).

**36. Additional biological characteristics**

Identify and explain any additional biological characteristics particular to the community or species within it that are threatening to its survival (e.g. low genetic diversity). Identify and explain any models addressing survival or particular features.

**36 a. How does it respond to disturbance?**

The ecosystem recovers from occasional fire, but too frequent fire could potentially result in loss of fire-sensitive species. Fire also results in increased weed invasion. Historical grazing is implicated in weed invasion.

**36 b. How long does it take to regenerate and/or recover?**

Endemic and other flora recovered after several years following massive die off likely resulting from dewatering from an adjacent mine. Similarly component flora in the community require several years to regenerate and reproduce following bush fires. Within about eight months of the major water stress event in 2004 monitoring indicated that species in the community, particularly *Pericalymma, Corymbia calophylla*, *Restio* and *Xanthorrhoeas* had a remarkable capacity to respond to total defoliation and/or browning caused by drought stress, and had regenerated well.

***Threat Abatement and Recovery***

**37. Identify key management documentation available for the ecological community,** e.g. recovery plans, conservation plans, threat abatement plans or site specific management plans (e.g. for a reserve).

CALM (2005) *Southern Swan Coastal Plain Ironstone (Busselton Area) (Busselton or Southern Ironstone Association). Interim recovery plan no 215: 2005- 2010.* Department of Conservation and Land Management, Perth, Western Australia.

Ecosystem Solutions Pty Ltd (2007). Management Plan for the Ruabon-Tutunup Rail Reserve. Prepared for the Ruabon Tutunup Rail Reserve Preservation Group. Dunsborough, WA.

Department of the Environment (2014). *Threat abatement plan for disease in natural ecosystems caused by* Phytophthora cinnamomi. Canberra, ACT: Commonwealth of Australia. Available from: http://www.environment.gov.au/resource/threat-abatement-plan-disease-natural-ecosystems-caused-phytophthora-cinnamomi. In effect under the EPBC Act from 31-Jan-2014.

**38. Give an overview of how threats are being/potentially abated and other recovery actions underway and/or proposed.** Identify who is undertaking these activities and how successful the activities have been to date.

Regulations that control land clearing under the WA *Environmental Protection Act 1986* and the *Environment Protection and Biodiversity Conservation Act 1999* have reduced land clearing in the ecosystem to negligible levels since about 2001.

Occurrences of the ecosystem have been treated with the chemical phosphite since the mid 1990s to mitigate symptoms of the disease, and on ground observations indicate that the rate of plant deaths associated with impacts of the disease have declined since then ([redacted] unpublished data). Deaths of the highly susceptible threatened flora taxon *Lambertia echinata* subsp *occidentalis,* for example, have declined since the spraying program began ([redacted] unpublished data).

Key measures required to mitigate risks to the ecosystem include seeking secure conservation tenure in areas where the ecosystem is not currently managed for conservation, management of the most serious weeds and of root rot disease, minimising the impacts of hydrological changes from sources other than climatic drying, and managing fire (Gibson *et al*. 2000; CALM 2005). The lands on which the ecosystem occurs are mainly private tenure, State forests, nature reserves, and road and rail reserves, and effective management of threatening processes across the ecosystem's range will require coordination, and the cooperation of land managers with different land management objectives.

**39. What portion of the current extent of the ecological community is protected in a reserve set aside for conservation purposes?**

Currently, almost half of the ecosystem occurs on lands managed for conservation, including nature reserves and State forest (DPaW 2014), while a small proportion is on other public lands including rail and road reserves and the remainder is on private land.

**39 a. Which of these reserves are actively managed?**

All locations in reserves and state forests managed by DBCA are actively managed. The small proportion that is on other public lands including rail and road reserves is also actively managed.

**39 b. Give details including the name of the reserves, and the extent the ecological community is protected within these reserves and whether the reserves are permanent.**

**Table 3 Tenure and extent of occurrences**

| Number | Occurrence | Area | Tenure | Permanence of tenure |
|---|---|---|---|---|
| 1 | WIL01 | 6.7527 | State Forest (SF) - Abba block | Excellent |
| 2 | WIL03 | 6.5360 | State Forest - Abba block | Excellent |
| 3 | PAYNE02 | 14.2697 | Nature Reserve (NR) and adjacent private land | Excellent for portion in NR |
| 4 | YIRON01 | 9.8642 | Nature Reserve | Excellent |
| 5 | SMITH01 | 36.9301 | State Forest - Treeton block | Excellent |
| 6 | JACKA01 | 8.5382 | State Forest - Treeton block and adjacent private land | Excellent for portion in SF |
| 7 | IRON01 | 6.4807 | State Forest - Treeton block | Excellent |
| 8 | WONNEW1 | 0.9181 | Rail and road reserves | Good for portion in rail reserves |
| 9 | YIRON02 | 1.2211 | Nature Reserve | Excellent |

| | | | | |
|---|---|---|---|---|
| 10 | SMITH04 | 1.7754 | State Forest - Treeton block, road reserve | Excellent for portion in SF |
| 11 | NEG01 | 77.8548 | Nature reserve, road and rail reserve, private land | Excellent for portion in NR, good for portion in rail reserves |
| 12 | CHAMBERS01 | 3.6321 | Private land | Insecure tenure |
| 13 | HairPinRd | 0.3159 | Road reserve | |
| 14 | WONN06 | 2.6300 | Rail and road reserves | Good for rail reserves |
| 15 | WONN05 | 2.4062 | Rail and road reserves | Good for rail reserves |
| 16 | OATES01_Webb | 7.3012 | Road reserve and Nature Reserve | Excellent for NR |
| 17 | SWR18 | 1.3407 | Rail and road reserves | Good, for rail reserves |
| 18 | SWR9 | 0.53 | Road reserve | |
| 19 | SWR19 | 5.57 | Conservation reserve | Excellent |
| 20 | SWR21 | 30.62 | State Forest 33 | Excellent |

**39 c. Note which, if any, reserves have management plans and if they are being implemented**.

There is a Management Plan for the Ruabon-Tutunup Rail Reserve and the Ruabon Tutunup Rail Reserve Preservation Group actively manage the area??

**40. Give locations of sites for proposed management, preferably that have been identified in recovery plans and key sites considered to demonstrate those remnants of highest quality and/or most under threat.**

**41. Give details of recovery actions that are or could be carried out at the local and regional level,** e.g. develop and implement management plan for the control of specific weed species (regional), undertake weeding of known sites (local).

Refer to recovery plan. Not relevant for ranking.

**42. Is there an existing support network for the ecological community that facilitates recovery?** e.g. an active Landcare group, Conservation Management Network.

The Tutunup Rail Reserve Preservation Group is active in managing occurrences along the disused rail line.

**43. Describe methods for identifying the ecological community including when to conduct surveys,**

For example, season, time of day, weather conditions; length, intensity and pattern of search effort; and limitations and expert acceptance; recommended methods; survey-effort guide. Include references.

The best way to determine the floristic community types (FCTs) present at a new survey site on the southern Swan Coastal Plain is to repeat methods as described in the Gibson et al. (1994) report. That is, to establish 10 by 10m quadrats in vegetation in best condition and not in ecotones, and score them (ie record all the flora species present) at least twice at appropriate times. A form that provides standard format for recording quadrat-based data occurs in Keighery (1994). Permanent markers such as fence droppers or cut down star pickets should be used to mark corners, and corner locations preferably recorded with a Differential GPS. A photo of the quadrat should be taken from a specified corner; typically the north east corner, using a standard lens.

The scoring of quadrats should be planned around the flowering times of the majority of the species present. This will vary depending on whether the site is a wetland, and will also depend on the latitude, and specific characteristics of the season (late or early rains etc). Spring and late spring are usually best (September, and late October /early November). A third or even fourth scoring was sometimes undertaken for quadrats established for Gibson *et al*. (1994), especially in wetlands. In addition, some quadrats were scored over a series of years for Gibson *et al.* (1994), due to poor seasonal rains. It is therefore possible that climate will influence results for quadrats established, and scorings across a series of additional seasons or even years may be indicated.

Taxonomy should be reconciled between datasets to current or historic species names. The species data from quadrats established should then be compared and analysed against quadrat data held in Gibson *et al*. (1994) or Keighery *et al*. (2012) using appropriate statistical techniques and parameters (eg PATN, Primer or PC-ORD). The reporting should note the closest matches for FCTs present at the new site.

Analyses should be carried out against the quadrat data from Gibson *et al.* (1994) so that conclusions are logical and valid. That is, full species lists for all quadrats available through Parks and Wildlife should be utilised for these comparisons not partial species lists held in the tables in the hard copy Gibson *et al*. (1994) report. Gibson *et al*. (1994) utilised the quadrat-based data collected during that survey and PATN was used to sort the quadrat data into a series of FCTs using specified parameters. To validly compare new data collected for new sites on the southern Swan Coastal Plain, these methods should be repeated.

There are quite a number of ways the statistical analysis can be done. The new quadrat data can be inserted, the classification rerun and examined with cluster (some minor typological changes might be expected) or ordination techniques. Nearest neighbour distances of the new quadrats to the Gibson *et al*. (1994) data can be examined, or some form of multivariate discriminate analysis can be applied, such as CAP - canonical analysis of principal coordinates, in the Primer package. Regardless of the methods used, the most reliable outcomes will be from comparison of adequately sampled quadrat data.

Critical analysis of the logic of the outcomes of analysis is required. For example, the typical habitat features such as soil and landform, and hydrological status of quadrats established for Gibson *et al*. (1994) should be explicitly discussed and compared in reporting. Comparison of 'typical' floristics and structure of the FCTs as defined by Gibson *et al*. (1994) may also be relevant. If results of statistical analysis do not indicate a 'logical' outcome in this regard then the reasons for this should be discussed. The most logical conclusion regarding FCTs present in the new quadrats should be stated and reasoning should be explicit.

Species lists for vegetation units can be collected and analysed using other methods where native species richness is inadequate to provide good quality data for statistical analysis; for example where vegetation is not in suitable condition. Substrate can be very useful in verifying the FCT present in this case.

The flora and vegetation can be surveyed along a series of transects or relevés across the site, with species recorded for different vegetation units being compiled in separate lists. Detailed notes should be recorded about

| |
|---|
| the species present, vegetation condition on Bush Forever scales, and soils and landform. Plant species that may be particularly significant in differentiating the floristic community types should also be noted. |
| **44. Are there other any aspects relating to the survival of this ecological community that you would like to address?** |
| |

**Section 3 - Justification for this nomination**

In order for the nomination to be considered further, one or preferably more of the following criteria need to be fulfilled and substantiated. A clear case for why the ecological community is eligible for listing under the criteria is required, including evidence as to how it meets the requirements for listing under a particular listing category, e.g. ' David et al. (1999) finding of 95% decline in geographic distribution suggests it should be listed as critically endangered'. The type of data available will determine which criteria will be used to justify the application of a listing category.

At least one criterion must trigger the thresholds of a listing category as indicated in the Attachment. Criteria may be of different levels of listing category e.g. Criterion 1 = CR and Criterion 3 = VU.

**45. Provide data that demonstrates why the ecological community meets at least one of the following criteria for the nominated listing category.**

Please use data, provided in previous sections, to demonstrate how it specifically meets at least one of the following criteria. Advice on how to interpret the listing criteria is in Attachment A. Provide a response for every sub-criterion.

**Criterion A:** Reduction in geographic distribution.

| | | | | | |
|---|---|---|---|---|---|
| **A1** | ☒ **CR** | ☐ **EN** | ☐ **VU** | ☐ Not Evaluated | ☐ Does not meet |
| **A2a** | ☐ **CR** | ☐ **EN** | ☐ **VU** | ☐ Not Evaluated | ☒ Does not meet |
| **A2b** | ☒ **CR** | ☐ **EN** | ☐ **VU** | ☐ Not Evaluated | ☐ Does not meet |
| **A3** | ☒ **CR** | ☐ **EN** | ☐ **VU** | ☐ Not Evaluated | ☐ Does not meet |

**Full explanation for Criterion A:**

*Ranking data and assessment information were taken directly from English and Keith (2015) (not updated).*

For criteria A and B, the community was assumed to collapse when the mapped distribution declines to zero.

Recent rates of decline in distribution (criterion A) were estimated from 1:40,000 scale 1967 black and white aerial photographs, in combination with land unit mapping by Tille and Lantzke (1990), and 2012 colour orthophoto mosaics.

The total remaining vegetated area of the ecosystem in 2012 is approximately 189 ha at 17 sites. In 1967, the extent of the ecosystem was estimated to be approximately 1300 ± 260 ha (allowing ± 20% for mapping errors for 1967). Assuming a constant rate of decline, this translates to a decline in extent of at least 85% and up to 88% due to land clearing over the past 50 years. Based on this, the ecosystem meets criterion A1 for critically endangered (≥80% reduction in the last 50 years).

Regulations that control land clearing under the WA *Environmental Protection Act 1986* and the *Environment Protection and Biodiversity Conservation Act 1999* have reduced land clearing in the ecosystem to negligible levels since about 2001. If the current policies continue to be effective for the next 50 years, then it is unlikely that the distribution of the ecosystem will decline, through land clearing, by more than 30% over the next 50 years. The Shrublands on southern Swan Coastal Plain ironstone is therefore Least Concern under criterion A2.

Based on the extent of relevant land units in Tille and Lantzke (1990) with some corrections, the ecosystem historically covered about 2400 ± 480 ha hectares (allowing ± 20% for mapping errors). Relative to the estimated current area (170 ha), this represents a loss of more than 90% (91-94%) of the area of the ecosystem. The Shrublands on southern Swan Coastal Plain ironstone ecosystem therefore qualifies for Critically Endangered under criterion A3.

**Table 4.** Estimated relative severity of decline (%) in geographic distribution over three time frames based on change relative to recent trends, range standardised by thresholds of collapse (see text).

| Time frame (criterion) | best estimate | lower bound | upper bound | Status | Assumptions |
|---|---|---|---|---|---|
| Current 1962-2012 (A1) | 89 | 86 | 91 | CR | Tille and Latzke (1990) land unit mapping largely reflects original distribution |
| Future 2012-2062 (A2) | 0 | 0 | 5 | LC | Trends observed 1994 to 2013 will continue |
| Historic since 1750 (A3) | 93 | 91 | 94 | CR | Current distribution is well known |

**Criterion B:** Restricted geographic distribution.

| | | | | | |
|---|---|---|---|---|---|
| **B1** | ☒ **CR** | ☐ **EN** | ☐ **VU** | ☐ Data Deficient | ☐ Not Evaluated |
| **B2** | ☐ **CR** | ☒ **EN** | ☐ **VU** | ☐ Data Deficient | ☐ Not Evaluated |
| **B3** | ☐ **CR** | ☐ **EN** | ☒ **VU** | ☐ Data Deficient | ☐ Not Evaluated |

**Full explanation for Criterion B:**

For criterion B, extent of occurrence (EOO) was derived from a minimum convex polygon drawn around the current digital mapping of the ecosystem (DPaW 2014). The number of 10 by 10km grid cells for calculating area of occupancy (AOO) was estimated from current digital mapping of the ecosystem (DPaW 2014). The number of locations was derived from an assessment of distributional data for the ecosystem (DPaW 2014), and from assessment of the number of management units likely to be represented by individual remnants in which the ecosystem occurs.

The Extent of Occurrence is currently estimated at 357 $km^2$. Continuing declines in ecological processes are occurring due to a complex of interacting threatening processes including weed invasion (Fig. 2). Even allowing for plausible mapping errors of 10%, the ecosystem meets Critically Endangered status under criterion B1.

Shrublands on southern Swan Coastal Plain ironstone ecosystem is estimated to occupy four 10 × 10 km square grid cells. As for criterion B1, there is evidence of continuing decline in ecological processes inferred from changes in weed abundance, therefore the status under criterion B2 is Endangered.

The eastern and western occurrences of Shrublands on Swan Coastal Plain ironstone may be significantly linked through similar hydrological processes associated with deeper aquifers (DoW 2008, EPA 2006). Possible concurrence of the origin of hydrological processes indicates that the ecosystem plausibly occurs at one or two locations. The effects of human activities or stochastic events may cause the ecosystem to collapse within a very

short period of time, given its highly restricted distribution, ongoing threats posed by changes in hydrology, weed invasion and adverse fire regimes. The ecosystem therefore meets Vulnerable status under criterion B3.

**Table 5.** Estimated geographic distribution from a convex polygon, number of grid cells, and number of locations coupled with decline (see text).

| Criterion | best estimate | lower bound | upper bound | Status | Assumptions |
|---|---|---|---|---|---|
| Current EEO $km^2$ (B1) | 357 | 320 | 393 | CR | Current distribution is well known |
| Current AOO grid cells (B2) | 4 | 3 | 5 | EN | Current trends in threatening processes will continue |
| Number of Locations (B3) | 5 | 2 | 10 | VU | Tille and Latzke (1990) land unit mapping largely reflects original distribution |

**Criterion C:** Environmental degradation based on change in an abiotic variable.

| | | | | | | |
|---|---|---|---|---|---|---|
| **C1** | ☐ **CR** | ☐ **EN** | ☐ **VU** | ☐ Data Deficient | ☐ Not Evaluated | ☒ Does not meet |
| **C2** | ☐ **CR** | ☐ **EN** | ☐ **VU** | ☐ Data Deficient | ☐ Not Evaluated | ☒ Does not meet |
| **C3** | ☐ **CR** | ☐ **EN** | ☐ **VU** | ☐ Data Deficient | ☐ Not Evaluated | ☒ Does not meet |

**Full explanation for Criterion C (abiotic degradation):**

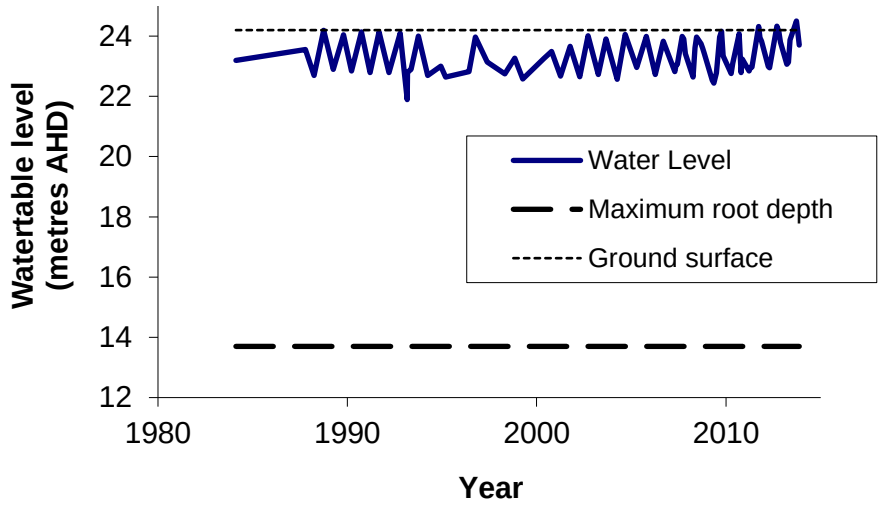
For criterion C, the assessment of decline in abiotic processes focussed on hydrological change using data on the depth of the watertables. It was assumed conservatively that the community would collapse if the watertable depth fell to about 10.5 m below ground surface based on the maximum water depth accessed by deep rooted phreatophytic taxa in nearby areas (Froend & Loomes 2006), and observations that the vigour of canopies declined in groundwater dependent trees in association with declining watertable levels (Wilson & Froend 2010).

There is little licensed groundwater abstraction in the vicinity of the eastern locations of the ecosystem (DoW 2008). Since monitoring began in 1984, bores in the superficial aquifer have been relatively stable or slightly increasing in the area, with seasonal fluctuations of around 1 m metre (Fig. 3). A linear regression fitted to the data had a slope that was not significantly different from zero ($P>0.10$, Fig. 3). Watertable stability was observed despite a decline of 13% $\pm$ 3% in annual rainfall between 1970 and 2013, based on rainfall means for the 30-year prior periods prior to those dates (BOM 2014a). In addition, there is no qualitative evidence to suggest that water levels had declined prior to 1984. The water levels at the BN21 bore in the Leederville aquifer were also relatively stable between 1984 and 2013 (DoW 2008, 2014). The relative severity of declines in water levels were therefore inferred to be close to zero over the past 50 years indicating a status of Least Concern under criterion C1.

Projections for future annual rainfall in the region vary from a decline of 20-40% to an increase of +5 to +10% by 2070 (BOM 2014b). Declining rainfall coupled with increasing temperatures could impact on surface water and levels in watertables through reduced runoff and increased evaporation rates (Fig. 2; DoW 2010). However, modelling of the most likely future rainfall scenario for 2050 suggests that this will only result in a slight fall in watertables in the vicinity of the ecosystem (DoW 2008). Based on the modelled abstraction scenario and rainfall projections, DoW (2008) predicted watertable levels to decline by 0.01m over a 25 year period from 2008. Over a 50 year period, an extrapolated linear decline is in the order of 0.02m. DoW (2008) predicts that such changes pose low risks of changes to ecosystem processes, species abundance and water quality. Other studies of risk to groundwater dependent ecosystems by Froend *et al*. (2004) also indicate that this rate of drawdown would place such ecosystems at low risk of impact. These studies were conducted on deep sands that have different hydrological properties to massive ironstone overlaying sands (Wösten *et al*. 2001), but the outcomes of projected impacts of watertable declines are similarly small. Even allowing for substantial errors in future projections, a 1% decline in watertable levels over the next 50 years corresponds to a relative severity of less than 5%. Therefore, unless rates of water abstraction increase or rainfall declines much more rapidly than projected, the status of the ecosystem is Least Concern under criterion C2.

Relevant watertable data available for one location within the ecosystem for the period 1984 to 2013 (DoW 2008, 2014) indicate no statistically significant changes to watertable for that period. Data for watertables in the ecosystem are not available for a longer time series, but would have to indicate large declines in the watertable levels prior to 1984 for the ecosystem to qualify for threatened status under criterion C. There is no qualitative evidence of trends in watertable levels prior to the commencement of monitoring in 1984. Based on the relative stability of water levels since 1984, we therefore assume that no declines have occurred since 1750, and the ecosystem meets Least Concern under criterion C3.

**Fig. 4.** Trends in watertable levels for the superficial aquifer at Bore BN21 near Tutenup between 1984 and 2013, relative to the assumed threshold of ecosystem collapse (base of superficial aquifer). A linear regression fitted to the data has a slope of 0.013 ± 0.016 (95% confidence limit, P>0.10).




**Criterion D:** Disruption of biotic processes or interactions based on change in a biotic variable.

| | | | | | | |
|---|---|---|---|---|---|---|
| **D1** | ☐ **CR** | ☐ **EN** | ☐ **VU** | ☐ Data Deficient | ☐ Not Evaluated | ☒ Does not meet |

| | | | | | | |
|---|---|---|---|---|---|---|
| **D2** | ☐ **CR** | ☒ **EN** | ☐ **VU** | ☐ Data Deficient | ☐ Not Evaluated | ☐ Does not meet |
| **D3** | ☐ **CR** | ☐ **EN** | ☒ **VU** | ☐ Data Deficient | ☐ Not Evaluated | ☐ Does not meet |

**Full explanation for Criterion D:**

An analysis of weed invasion was carried out to assess severity of changes to biotic components of the community under criterion D, based on changes in floristic composition between 1993 and 2013 reported by Webb (2013). The severity of weed invasion associated with collapse is uncertain, but we assumed conservatively that the community reaches a collapsed state when only 10% (plausible range 0–20%) of its plant species are native.

The shublands have been undergoing composition changes, with increases in exotic and declines in native taxa (Fig. 3, Table 4). There was a net decline of 20.3 ± 7.4% in the number of plant native species as a proportion of total native and exotic species between 1993 and 2011, although there was a slight increase in one of the eleven samples (Webb 2013). Assuming that no net invasion occurred between 1961 and 1993, and range-standardising these estimates against the respective threshold values for collapse, the relative severity of the decline in the native component of biota was 23% (plausible range 13-35%). the status of the ecosystem under criterion D1 is therefore Least Concern (plausible range Least Concern to Vulnerable).

Assuming that the trends observed during 1993-2011 continue until 2043, the relative severity of the decline in the native component of the biota was projected to be 60% (plausible range 38-88%) over a 50 year future period. The status of the ecosystem under criterion D2 was therefore estimated to be Endangered (plausible range Vulnerable - Critically Endangered).

Assuming that all weed invasion observed in 2011 had occurred since European settlement, there was a 32% (plausible range 25-39%) decline in the native component of the biota since 1750, producing an estimated status of Vulnerable (plausible range Least Concern - Vulnerable) under criterion D3.

Positive soil and plant tissue samples of the pathogen *Phytophthora cinnamomi* were taken from eight of the ten occurrences of the ecosystem in 2009 (DEC 2009). The disease is also likely to occur in a ninth site, although it could not be detected there (P. Blankendaal unpublished data). Thus, disease potentially affects 80-90% of the extent of the ecosystem. Data to assess the severity of those effects are currently unavailable, however current impacts appear to be limited. Occurrences of the ecosystem have been treated with the chemical phosphite since the mid 1990s to mitigate symptoms of the disease, and on ground observations indicate that the rate of plant deaths associated with impacts of the disease have declined since then ([redacted] unpublished data). Deaths of the highly susceptible threatened flora taxon *Lambertia echinata* subsp *occidentalis,* for example, have declined since the spraying program began ([redacted] unpublished data).

**Fig. 5**. Trends in the numbers of native and exotic plant species in Shrublands on southern Swan Coastal Plain ironstone ecosystem over an 18 year period (n=11).

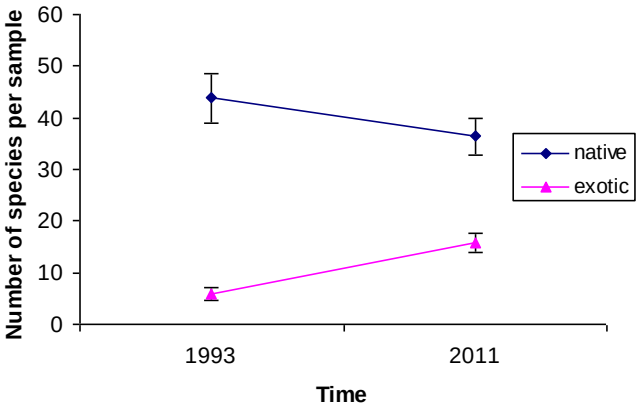



**Table 6:** Estimated relative severity of decline (%) in native component of the biota over three time frames based on changes in the proportion of native species present relative to the total native and exotic species, range standardised by thresholds of collapse (see text). Status is the best estimate with plausible bounds in parentheses.

| Time frame (criterion) | best estimate | lower bound | upper bound | Status | Assumptions |
|---|---|---|---|---|---|
| Current 1961-2011 (D1) | 23 | 13 | 35 | LC (LC-VU) | No weed invasion occurred between 1961 and 1993 |
| Future 1993-2043 (D2) | 60 | 38 | 88 | EN (VU-CR) | Weeds invade at same rate 2011-2043 as observed in 1993-2011 |
| Historic since 1750 (D3) | 35 | 24 | 48 | VU (LC-VU) | All weeds have invaded since 1750 |

**Criterion E:** Quantitative analysis that estimates the probability of ecosystem collapse.

☐ **CR** ☐ **EN** ☐ **VU** ☐ Data Deficient ☒ Not Evaluated

**Full explanation for Criterion E:**

**SUMMARY of Criteria under which community is eligible for listing (as stated at question 2):**

| Criterion A | |
|---|---|
| ☒ CR<br>☐ EN<br>☐ VU<br>☐ not eligible | ☐ **A1**<br>☐ **A2a**<br>☒ **A2b**<br>☒ **A3** |

| | |
|---|---|
| Criterion B<br>☒ CR<br>☐ EN<br>☐ VU<br>☐ not eligible | ☒ **B1** (specify at least one of the following) ☐ **a)(i)** ☐ **a)(ii)** ☒ **a)(iii)** ☐ **b)** ☐ **c); OR**<br>☐ **B2** (specify at least one of the following) ☐ **a)(i)** ☐ **a)(ii)** ☐ **a)(iii)** ☐ **b)** ☐ **c); OR**<br>☐ **B3** (only for Vulnerable Listing) |
| Criterion C<br>☐ CR<br>☐ EN<br>☐ VU<br>☒ not eligible | ☐ **C1 OR**<br>☐ **C2 OR**<br>☐ **C3** |
| Criterion D<br>☐ CR<br>☒ EN<br>☐ VU<br>☐ not eligible | ☐ **D1 OR**<br>☒ **D2 OR**<br>☐ **D3** |
| Criterion E<br>☐ CR<br>☐ EN<br>☐ VU<br>☒ not evaluated | |

**Section 4 – References/Standard of Scientific Evidence**

Note: The opinion of appropriate scientific experts may be cited (with their approval) in support of a nomination. If this is done the names of the experts, their qualifications and full contact details must also be provided in the reference list below. Harvard style of referencing is preferred.

**46. Please provide copies of key documentation/references used in the nomination.**


Abbott, I. & Burrows, N. (eds) (2003) *Fire in ecosystems of south-west Western Australia: impacts and management.* Bachhuys Publishers, Leiden, Netherlands.

BOM (2014a) *Climate statistics for Australian locations.* Australian Government, Canberra. [Cited 23 January 2014] Available from URL: http://www.bom.gov.au/climate/averages/tables/cw_009515.shtml.

BOM (2014b) *Climate change data.* Bureau of Meteorology, Canberra. [Cited 20 January 2014.] Available from URL: http://www.bom.gov.au/climate/change/.

Byrne M (2007). Phylogeography provides an evolutionary context for the conservation of a diverse and ancient flora. *Aust. J. Botany* **55**, pp. 316–325.

CALM (1990) Data on the Conservation of Vegetation Associations on the Swan Coastal Plain. Department of Conservation and Land Management, Perth.

CALM (2005) *Southern Swan Coastal Plain Ironstone (Busselton Area) (Busselton or Southern Ironstone Association). Interim recovery plan no 215: 2005- 2010.* Department of Conservation and Land Management, Perth, Western Australia.

Crane, C.E & Shearer, B.L. (2013) Comparison of phosphite application methods for control of *Phytopththora cinnamomi* in threatened communities. *Aust. Plant Pathology* [Cited 20 January 2014.] Available from URL: http://link.springer.com/search?facet-author=%22B.+L.+Shearer%22#page-1 .

DEC (2009) *Phytophthora Disease Interpretation Report Busselton Ironstone TECs 2009*. Forest Management Branch, Department of Environment and Conservation, Bunbury, Western Australia.

Department of Environment and Heritage (2006) *Management of Phytophthora cinnamomi for Biodiversity Conservation in Australia. Part 2 – National Best Practice Guidelines. Appendix 3.* Australian Government,

Canberra. [Cited 27 January 2014.] Available from URL: http://www.environment.gov.au/system/files/resources/23925ac2-8fda-4036-aa56-5451f5d8b06d/files/appendix3.pdf.

Department of the Environment (2014a) *Australia's 15 National Biodiversity Hotspots*. Australian Government, Canberra. [Cited 27 January 2014.] Available from URL: http://www.environment.gov.au/topics/biodiversity/biodiversity-conservation/biodiversity-hotspots/national-biodiversity-hotspots.

Department of the Environment (2014b) *EPBC Act List of Threatened Ecological Communities*. Australian Government, Canberra. [Cited 28 January 2014.] Available from URL: http://www.environment.gov.au/cgi-bin/sprat/public/publiclookupcommunities.pl.

Department of the Environment (2014c) *EPBC Act List of Threatened Flora.* Australian Government, Canberra. [Cited 28 January 2014.] Available from URL: http://www.environment.gov.au/cgi-bin/sprat/public/publicthreatenedlist.pl?wanted=flora

Department of the Environment (2014d) *Shrublands on southern Swan Coastal Plain ironstones. Advice to the Minister for the Environment and Heritage from the Endangered Species Scientific Subcommittee (ESSS) on a proposal to add an ecological community to Schedule 2 of the Endangered Species Protection Act 1992 (ESP Act).* Australian Government, Canberra. [Cited 27 January 2014.] Available from URL: http://www.environment.gov.au/node/14557.

DPaW (2013a) *List of threatened ecological communities in Western Australia endorsed by the Minister for the Environment*. Department of Parks and Wildlife, Kensington, Western Australia. [Cited 27 January 2014.] Available from URL: http://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/Listings/threatened-ecological-communities-endorsed-by-the-minister-for-the-environment-may-2013.pdf.

DPaW (2013b) Wildlife Conservation (Rare Flora) Notice 2013. *Government Gazette 17 September 2013.* Government of Western Australia. [Cited 27 January 2014.] Available from URL: http://www.dpaw.wa.gov.au/images/documents/plants-animals/threatened-species/Listings/Sept_2013_Flora_Notice.pdf.

DPaW (2014) *Threatened Ecological Community Geographic Information System Database*. Accessed January 2014. Department of Parks and Wildlife, Kensington, Western Australia.

DoW (2008) *Management triggers and responses for groundwater-dependent ecosystems in the South West groundwater areas. Department of Water Report no. 31 December 2008*. Perth, Western Australia.

DoW (2010) *Predicting the future demand for water resources in Western Australia*. Department of Water, Perth, Western Australia. [Cited 20 January 2014.] Available from URL: http://www.water.wa.gov.au/PublicationStore/first/90953.pdf.

DoW (2014) Water INformation (WIN) database - discrete sample data. Cited 4 February 2014. Department of Water, Water Information section, Perth Western Australia.

English, P., Lewis, S., Bell, J., Wischusen, J., Woodgate, M., Bastakov, E., Macphail, M., & Kilgour, P. (2012) *Waterlines. Water for Australia's arid zone – identifying and assessing palaeovalley groundwater resources: summary report*. *Waterlines Series No. 86*. National Water Commission, Canberra.

Enright, N., Keith, D.A., Clarke, M., & Miller, B.P. (2012) Fire regimes in Australian sclerophyllous shrubby ecosystems: heathlands, heathy woodlands and mallee woodlands. In: *Flammable Australia. Fire Regimes, Biodiversity and Ecosystems in a Changing World* (eds R.A. Bradstock, R.A., A.M Gill, & R.J. Williams) pp 215-234. CSIRO Publishing Collingwood, Victoria.

Environment Australia (2001) *Threat Abatement Plan for Dieback Caused by the Root-rot Fungus Phytophthora cinnamomi.* Commonwealth Government of Australia, Canberra. [Cited 20 January 2014.] Available from URL: http://www.deh.gov.au/biodiversity/threatened/publications/tap/phytophthora/.

EPA (2006) *EPA Bulletin 1245. Report and Recommendations of the EPA. South West Yarragadee Water Supply Development.* Environmental Protection Authority, Perth, Western Australia.

Froend, R., Loomes, R., Horwitz, P.,Bertuch, M., Storey, A. & Bamford, M. (2004) *Study of Ecological Water Requirements on the Gnangara and Jandakot Mounds under Section 46 of the Environmental Protection Act. Task 2: Determination of Ecological Water Requirements*. Prepared for: The Water and Rivers Commission. Centre for Ecosystem Management, Edith Cowan University, Joondalup, Western Australia.

Froend, R. & Loomes, R. (2006). Determination of *Ecological Water Requirements for wetland and terrestrial vegetation – Southern Blackwood and eastern Scott Coastal Plain.* Report to the Department of Water. CEM report no. 2005-07. Centre for Ecosystem Management, Edith Cowan University, Joondalup, Western Australia.

Clarke, K.R., Gorley, R.N. (2006). PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth.

English, V. and Keith, D.A (2015). Assessing risks to ecosystems within biodiversity hotspots: a case study from southwestern Australia. Austral Ecology. 40: 411-422.

Gibson, N., Keighery, B., Keighery, G., Burbidge, A & Lyons, M. (1994) *A floristic survey of the Southern Swan Coastal Plain.* Unpublished report for the Australian Heritage Commission prepared by the Department of Conservation and Land Management and the Conservation Council of Western Australia (Inc.). Perth, Western Australia.

Gibson, N., Keighery, G. & Keighery, B. (2000) Threatened plant communities of Western Australia 1. The ironstone communities of the Swan and Scott Coastal Plains. *J. R. Soc. Western Aust.*, **83**, 1-11.

Government of Western Australia (2000) *Bush Forever*. Western Australian Planning Commission, Perth.

Government of Western Australia (2013) *2013 Statewide Vegetation Statistics incorporating the CAR Reserve Analysis (Full Report)*. *Current as of June 2013*. WA Department of Parks and Wildlife, Perth. [Cited 20 January 2014.] Available from URL: https://www2.landgate.wa.gov.au/web/guest/downloader

Groom, P. K., Froend, R.H., & Mattiske, E. M. (2008). Impact of groundwater abstraction on a Banksia woodland, Swan Coastal Plain, Western Australia. *Ecol. Manage. & Restor*, **1:** 117-124.

Hopper, S.D. (1979) Biogeographical aspects of speciation in the southwest Australian flora. *Annu. Rev. Ecol. Syst.* **10,** 399–422.

Hopper, S. D. & Gioia, P. (2004). The Southwest Australian Floristic Region: evolution and conservation of a global hot spot of biodiversity. *Annu. Rev. Ecol. Syst.* **35**, 623–650.

Keighery. B. & Trudgen, M. (1992) Remnant Vegetation on the Alluvial Soils of the Eastern Side of the Swan Coastal Plain. Unpublished report for Department of Conservation and Land Management, Australian Heritage Commission and Heritage Council of WA.

Keith D.A., Rodríguez J.P., Rodríguez-Clark K.M., Nicholson E., Aapala K. *et al*. (2013) Scientific Foundations for an IUCN Red List of Ecosystems. PLoS ONE 8(5): http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0062111;jsessionid=72585D3F4732020B5A9F217BA76B641C

Lambers, H., Ahmedi, I., Berkowitz, O., Dunne, C., Finnegan, P. M., Hardy, G. E., Jost, R., Laliberte, E., Pearse, S. J., & Teste, F. P. (2013) Phosphorus nutrition of phosphorus-sensitive native plants: threats to plants communities in a global biodiversity hotspot. *Conserv. Phys*. **1**: 1-21.

Lindenmayer, D. B. & Likens, G. E. (2010). *Effective ecological monitoring*. CSIRO, Melbourne.

Loomes, R., Wilson, J. & Froend, R. (2008) *Vegetation Monitoring Swan Coastal Plain (Bunbury, Busselton-Capel Groundwater Areas). A Report to the Department of Water.* Centre for Ecosystem Management. Edith Cowan University, Joondalup. CEM report no. 2007-15. Joondalup, Western Australia.

Lucas, A., McComb, J. A., Colquhoun, I. J. and Hardy, G. E. St. J. (2003) Summer rainfall and the development of disease caused by *Phytophthora cinnamomi* in droughted *Eucalyptus marginata* plants. In: *Phytophthora in Forests and Natural Ecosystems: 2nd International IUFRO Working Party* Meeting, 30 September - 5 October, 2001, Albany, Western Australia.

Milberg, P. & Lamont, B. B. (1995) Fire enhances weed invasion of roadside vegetation in southwestern Australia. *Biol. Conserv.* **73,** 45-49.

Keighery, B. (1994). *Bushland plant survey: a guide to plant community survey for the community.* Wildflower Society of WA (Inc.), Nedlands, WA.

Keighery, B., Keighery, G., Longman, V.M., and Clarke, K.A. (2012). Weed and native flora quadrat data compiled between 1990 - 1996 for the Southern Swan Coastal Plain. Data compiled for the Departments of Environmental Protection and Conservation and Land Management. Perth.

Keighery, B. and Trudgen, M. (1992). *Remnant vegetation on the alluvial soils of the eastern side of the Swan Coastal Plain.* Report prepared for the Department of Conservation and Land Management. Perth, Western Australia.

Mittermeier, R. A, Robles Gil, P., Hoffman, M., Pilgrim, J., Brooks, T., Goettsch Mittermeier, C., Lamoreux, J. & da Fonseca. G.A.B. (2004) *Hotspots Revisited: Earth's Biologically Richest and Most Threatened Terrestrial Ecoregions.* Cemex Books on Nature, Mexico City.

Moore N., Barrett, S., Shearer, B. & Hardy, G (2007). The role of fire on *Phytophthora* dieback caused by the root pathogen *Phytophthora cinnamomi* in the Stirling Range National Park, Western Australia. *Proceedings of the MEDECOS XI Conference*. Perth, Western Australia.

Paczkowska, G. & Chapman, A. R. (2000). The western Australian flora: a descriptive catalogue. Wildflower Society of Western Australia, Western Australian Herbarium and Botanic Gardens and Parks Authority, Perth.

Pate J.S. & Beard J.S. (1984). Kwongan, plant life of the sandplain: biology of a south-west Australian shrubland ecosystem. University of Western Australia Press, Nedlands.

Rouget M., Jonas Z., Cowling, R. M., Desmet P. G., Driver A., Mohamed B., Mucina L., Rutherford M. & Powrie L. W. (2006) Ecosystem status and protection levels of vegetation types. In: *The vegetation of South Africa, Lesotho and Swaziland* (eds L. Mucina & M. C. Rutherford) pp 725-737. Stelitzia 19. South Africa National Biodiversity Institute, Pretoria.

Setterfield S.A., Rossiter-Rachor, N.A., Douglas, M.M., Wainger, L., Petty, A.M., Barrow, P., Shepherd, I.J. & Ferdinands, K.B. (2013) Adding fuel to the fire: the impacts of non-native grass invasions on fire management at a regional scale. *PLoS One* **14,** 8. [Cited 25 January 2014.] Available from URL: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3653883/.

Shearer B. L. & Tippett J. T. (1989) *Jarrah Dieback: the dynamics and management of Phytophthora cinnamomi in the Jarrah (Eucalyptus marginata) Forest of Western Australia. Research Bulletin No. 3.* Department of Conservation and Land Management, Como, Western Australia.

Short R. & McConnel C. (2000) *Extent and Impact of Dryland Salinity in Western Australia. Western Australian Department of Agriculture and National Land and Water Resources Audit*. Department of Agriculture, Perth, Western Australian.

Sullivan, A.L., McCaw, W.L., Miguel, G.C., Matthews, S & Ellis, S.M (2012) Fuel, fire weather and fire behaviour in Australian ecosystems. In: *Flammable Australia. Fire Regimes, Biodiversity and Ecosystems in a Changing World.* pp51- 77. (eds R. A. Bradstock, A. M. Gill, & R. J. Williams) CSIRO Publishing, Collingwood, Victoria.

Tille P.J. & Lantzke N.C. (1990) *Busselton Margaret River Augusta land capability study. Land Resource Series No. 5. Technical Report 109*. Western Australian Department of Agriculture. Perth.

URS Australia Pty Ltd (2003) *Establishment of interim ecological water requirements for the Blackwood groundwater area, WA – Stage 1. Volume 1 of 2. Prepared for Department of Environmental Protection and Waters and Rivers Commission*. Perth, Western Australia.

Webb, A. (2013). *Preliminary Review of the SWCC funded FCT10b sampling project.* An unpublished report by Department of Environment and Conservation for the South West Catchments Council, Bunbury, Western Australia.

Wills R. T. & Keighery G. J. (1994) Ecological impact of plant disease on plant communities. *J. R. Soc. Western Aust.* **77,** 127-131.

Wilson, J. & Froend, R. (2010) *Vegetation Monitoring Swan Coastal Plain (Bunbury, Busselton-Capel Groundwater Areas). A Report to Water Smart Australia and the Department of Water*. CEM report no. 2010-9. Centre for Ecosystem Management. Edith Cowan University, Joondalup, Western Australia.

Wösten J. H. M., Pachepsky, Ya. A. & Rawls, W. J. (2001) Pedostransfer functions: bridging the gap between available basic soil data and missing soil hydraulic characteristics. *J. Hydrol.* **251,** 123-150

**47. Statement on the Standard of Scientific Evidence**

Published data on the Shrublands on southern Swan Coastal Plain ironstone were limited, but when combined with unpublished information and local monitoring programs, were sufficient to apply the Red List of Ecosystem criteria. There are likely to be inaccuracies in various aspects of the assessment, particularly with distinguishing recently cleared lands using historical black and white aerial photographs, and approximations based on Tille and Lantzke (1990). However, the outcomes of the assessment are robust, even if substantial errors (± 20%) are assumed in the original and current extent.

Key uncertainties exist in aspects of the hydrological status, effects of fire regimes, and impacts of disease and invasive species. A well designed, systematic, long term monitoring program (Lindenmayer & Likens 2010) with spatially and temporally linked data for parameters including floristics, hydrology, fires, and invasive species is required to better understand the relationships between changes in the ecosystem and the most significant threatening process. Such a program would be resource intensive but could provide the necessary data to help guide future management of this unique and highly threatened ecosystem.

**48. Has this document been reviewed and/or have relevant experts been consulted?**
If so, indicate by whom and provide their contact details.

The data used in ranking were taken directly from the peer reviewed publication English and Keith (2015). A draft of this nomination was provided to Regional DBCA staff for comment.

**Section 5 - Nominator Details & Declaration**

**49. Contact Details**

Note: Nominator details are subject to the provision of the *Privacy Act 1988*

| | |
|---|---|
| **Title/Full Name** | Principal Ecologist |
| **Organisation or Company name** | DBCA |
| **Postal address** | DBCA Kensington |
| **Email** | |
| **Phone** | |
| **Fax** | |

**50. Declaration**

| | |
|---|---|
| **Signature** (Or insert electronic signature) | ***I declare that the information in this nomination form and any attachments is true and correct to the best of my knowledge.*** |
| **Date signed** | |

## Section 6 – Completed nomination form checklist

Please check all items on this list have been completed or are included with your nomination.

- ☐ I have read and applied the further information and guidelines for completing this nomination form in Attachment A
- ☐ Nominator details including name, address contact phone number included
- ☐ Name of the EC
- ☐ Any other names it is known by
- ☐ Map included or attached
- ☐ References cited
- ☐ If questions are left unanswered, a statement indicating that insufficient information is available

A description of:

- ☐ Biological components of the ecological community
- ☐ Non biological components of the ecological community
- ☐ Key interactions and functional processes
- ☐ Characters distinguishing it from other ecological communities
- ☐ Key species (dominant, characteristic or diagnostic, threatened etc)
- ☐ Known or estimated current extent of the ecological community
- ☐ Past/current/future threats including actual/potential, how/ where, how being/how could be abated
- ☐ Which listing category/categories it should be listed under and why

| **How to lodge your nomination** |
|---|
| Completed nominations may be lodged either:<br>1. by email to: communities.data@dbca.wa.gov.au<br>*If submitting by email, please also mail hard copies of attachments that cannot be emailed.*<br>OR<br>2. by mail to: Species and Communities Branch<br>Department of Biodiversity, Conservation and Attractions, WA Government<br>Locked Bag 104, BENTLEY DELIVERY CENTRE WA 6983<br><br>***If submitting by mail, please include an electronic copy on memory stick or CD.*** |
| |