***Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (s266B)**
**Approved Conservation Advice (including listing advice) for the**
**Warkworth Sands Woodland of the Hunter Valley ecological community**

1. The Threatened Species Scientific Committee (the Committee) was established under the EPBC Act and has obligations to present advice to the Minister for the Environment (the Minister) in relation to the listing and conservation of threatened ecological communities, including under sections 189, 194N and 266B of the EPBC Act.
2. The Committee provided its advice on the Warkworth Sands Woodland of the Hunter Valley ecological community to the Minister as a draft of this conservation advice. In 2016, the Minister accepted the Committee's advice and adopted this document as the approved conservation advice.
3. The Minister amended the list of threatened ecological communities under section 184 of the EPBC Act to include the Warkworth Sands Woodland of the Hunter Valley ecological community in the **critically endangered** category. It is noted that the ecological community is also listed as threatened in New South Wales (*Threatened Species Conservation Act 1995*).
4. A draft description and summary of threats for this ecological community was made available for expert and public comment for a minimum of 30 business days. The Committee and Minister had regard to all public and expert comment that was relevant to the consideration of the ecological community.
5. This approved conservation advice has been developed based on the best available information at the time it was approved; this includes scientific literature, advice from consultations, and existing plans, records or management prescriptions for this ecological community.

**Table of Contents**

**CONSERVATION OBJECTIVE**

**The conservation objective is to mitigate the risk of extinction of the Warkworth Sands Woodland of the Hunter Valley; and help recover its biodiversity and function by:**

- **protecting it under the *Environment Protection and Biodiversity Conservation Act 1999;* and**
- **implementing the priority conservation actions for the ecological community** (as outlined in Section 4.2 – 4.4).

The three key approaches to achieve the conservation objective are:

1) PROTECT the ecological community, to prevent further loss of extent and condition;
2) RESTORE the ecological community within its original range, by active abatement of threats, re-vegetation and other recovery initiatives;
3) COMMUNICATE WITH AND SUPPORT researchers, land use planners, landholders, land managers, community members and others - to increase understanding of the value and function of the ecological community and encourage their efforts in its protection and recovery.

These approaches overlap in practice; and form part of an iterative approach to management that includes research, planning, management, monitoring and review. Further details are set out in Section 4 *Priority Conservation Actions*.

# 1 DESCRIPTION OF THE ECOLOGICAL COMMUNITY

## 1.1 Name of the ecological community

The name of the ecological community is Warkworth Sands Woodland of the Hunter Valley (hereafter referred to as Warkworth Sands Woodland and/or the ecological community). It is a mid to low woodland (occasionally forest), typically dominated by *Angophora floribunda* (rough-barked apple) in the canopy and *Banksia integrifolia* subsp. *integrifolia* (coast banksia) and/or *Acacia filicifolia* (fern-leaved wattle) in a sub-canopy; together with other small trees, shrubs and groundcover species that are typical of sandy soils in the Hunter Valley region.

## 1.2 Location and physical environment

Warkworth Sands Woodland occurs in the Hunter River catchment, in the Central Hunter region of the Hunter Valley. It occurs in the Hunter Valley IBRA[1] subregion (SYB02), in the north of the Sydney Basin Bioregion (SYB). In 2016 the ecological community is known to occur in the Hunter Local Land Services region; confined to small areas west of Singleton, in the Singleton Local Government Area, on areas of sandy soil classified as part the Warkworth Land System (Peake et al., 2002; NSW OEH, 2012).

There are four known main occurrences of Warkworth Sands Woodland: Wallaby Scrub Road, Warkworth village, Archerfield and Bulga. The majority of the ecological community occurs within the Warkworth district and this area contains the relatively few large and mostly good condition remnants of the ecological community. It may occur elsewhere in the Central Hunter region.

The ecological community is only known to occur on aeolian sands[2] – on old dune formations and swales between the dunes and on sand sheets ('veneers'); all part of the Warkworth Land System (Story et al., 1963; Kovac and Lawrie, 1991).

Warkworth Sands Woodland mostly occupies linear sand dunes, which are between one and six metres high, typically resting on a river terrace, on the undulating valley floor. As well as these deeper sand deposits, the ecological community also occurs on shallow veneers of sand, separated from the main sand deposit by areas of clay soils developed on Permian sediments.

Further details on the distribution and soil type of the ecological community are in Appendix C *National context and Relationship to other vegetation classification systems*.

### *1.2.1 Climate*

The Sydney Basin Bioregion (SYB) generally has a temperate climate, characterised by warm summers with no dry season (NSW NPWS, 2003). Climatic variations across the bioregion are largely due to increasing altitude and distance from the coast, although latitude also plays a part (NSW OEH, 2011). The ecological community occurs in the warmer, drier parts of the bioregion, in the Hunter Valley region, where average daily temperatures exceed 21 $^{o}$C in

[1] IBRA: Interim Biogeographical Regionalisation of Australia [Version 7 – 2012] in DSEWPAC (2012).

[2] Aeolian sands: Sand transported by the wind; made up of windblown grains of sand.

summer and the average minimum temperature in winter is 4.4 $^{o}$C. January is the hottest month and July the coldest (ATN, 2014). Average annual rainfall is 750 mm, with the heaviest rainfall in summer and a secondary peak just before winter (ATN, 2014).

## 1.3 Vegetative components

The ecological community is a mid to low woodland (occasionally forest), typically dominated by *Angophora floribunda* (rough-barked apple) and *Banksia integrifolia* subsp. *integrifolia* (coast banksia).

Table 1 lists abundant, common and/or characteristic vascular flora species[3]. Whilst the species listed in Table 1 are found regularly in Warkworth Sands Woodland, many also occur in other ecological communities (NSW Scientific Committee, 2011).

The occurrence and composition of an ecological community (the number of species and the above ground relative abundance) at a particular site is influenced by many factors, including: the size of the site, recent rainfall, or drought conditions and by its disturbance history (including clearing, grazing and fire). At any one time, above ground individuals of some species may be absent, but the species may be represented below ground in the soil seed banks or as dormant structures such as bulbs, corms, rhizomes, rootstocks or lignotubers (Preston and Adam, 2004 in Bell, 2012; NSW Scientific Committee, 2011).

### *1.3.1 Canopy*

The canopy of the ecological community is sparse to dense and typically dominated by *Angophora floribunda* (rough-barked apple) on deeper sand. On the shallower sands (e.g. in swales) *Eucalyptus blakelyi* x *E. tereticornis* (Blakely's red gum x forest red gum hybrid) and *E. crebra* (narrow leaved ironbark) may be more numerous. In more disturbed areas, other canopy species, such as *Allocasuarina luehmannii* (bulloak, buloke) and *Callitris endlicheri* (black cypress-pine) may be more numerous (Peake, 2006). Other tree species may include: *Eucalyptus blakelyi* (Blakely's red gum) and *Brachychiton populneus* subsp. *populneus* (kurrajong).

### *1.3.2 Mid layer (Sub-canopy or midstorey)*

Warkworth Sands Woodland midstorey vegetation comprises species more typical of sand or sandstone-based environments (Peake et al., 2002). A sparse sub-canopy of smaller trees is often present, typically dominated by *Banksia integrifolia* subsp. *integrifolia* (coast banksia) and /or *Acacia filicifolia* (fern-leaved wattle); *Allocasuarina littoralis* (black sheoak) is occasionally present (Peake, 2006). A sparse to dense shrub layer is usually present; with *Brachyloma daphnoides* subsp. *daphnoides* and *Breynia oblongifolia* (coffee bush) commonly occurring and occasionally *Hovea linearis* (narrow leaf hovea). *Melaleuca thymifolia* (thyme honey-myrtle)

[3] Not all species are present in every patch and the total species list from all patches of the ecological community is considerably larger than Table 1. A more comprehensive flora list is in Table B1 in Appendix B *Species List.*

may be present at damper sites (Peake, 2006) and may be the dominant shrub cover in a few areas (e.g. shallow drainage lines).

### *1.3.3 Ground layer*

The groundcover varies from very sparse to dense and is dominated in most places by *Imperata cylindrica* (blady grass) and *Pteridium esculentum* (bracken). Other species that commonly occur include: *Chrysocephalum apiculatum* (common everlasting); *Commelina cyanea* (scurvy weed); *Dichondra repens* (kidney weed); *Echinopogon caespitosus* var. *caespitosus* (tufted hedgehog grass); *Glycine clandestina* (twining glycine); *Hibbertia linearis* (guinea flower); *Leucopogon muticus* (blunt beard-heath); *Lomandra confertifolia* (mat rush); *Lomandra leucocephala* (woolly mat rush); *Lomandra multiflora* subsp. *multiflora* (many flowered mat rush); *Microlaena stipoides* var. *stipoides* (weeping grass) and *Pimelea linifolia* subsp. *linifolia* (slender rice flower) (Peake et al., 2002, Peake; 2006; NSW OEH, 2012). On the shallower sands (e.g. in swales) there may be more grasses and herbs typical of the surrounding clay landscapes. The ecological community also comprises lichens, mosses, fungi and micro-organisms. Table 1 lists the abundant, common and/or characteristic vascular flora species.

### *1.3.4 Derived native grassland*

Isolated native grasslands are **not** included in the ecological community, except where they fill a gap in, or at the edge of a patch, or between two patches across a short distance[4].

Derived grasslands can be an important part of the broader ecosystem and may have potential for future restoration (i.e. developing a canopy layer that makes them eligible for inclusion in the nationally protected ecological community)[5]. Derived grasslands may retain some essential elements of the native plant biodiversity of the ecological community and act as a seed bank and source of genetic material. Derived grasslands also act as buffer zones that can protect woodland remnants from adjacent activities; and act as stepping stones that enable the movement of some species between remnant woodlands. For this reason, where not included in a patch, they should be considered as part of the surrounding environment and landscape context for patches of the ecological community (see Section 1.6 *Further information to assist in determining the presence of the ecological community and significant impacts*).

---

[4] In derived grassland the canopy layer has been removed, or thinned to very scattered trees (<10% canopy cover), but a herbaceous ground layer remains largely intact. Where native grassland (whether derived or not) connects discrete patches of the ecological community in close proximity (i.e. edges of the tree canopy up to 30 m apart) then it should be treated as part of a single patch.

Also where native grassland is within a gap in, or at the edge of a patch, (up to 30 m from the edge of the tree canopy) it should be treated as part of the patch to be protected. See also Section 1.6.1 (*Defining a patch*). Native means vegetation 'dominated by native species'; i.e. that 50% or more of the perennial vegetation cover is native.

[5] The Warkworth Sands Woodland intergrades and shares characteristics (e.g. ground layer species) with the nationally listed Critically Endangered White Box - Yellow Box - Blakely's Red Gum Woodland and Derived Native Grasslands ecological community (also referred to as the 'Box - Gum Grassy Woodland'), which also occurs in the Hunter region. Some areas of derived grassland in the Hunter Valley region are protected under the Box - Gum Grassy Woodland listing (TSSC, 2006).

Evidence that a derived grassland originated from a specific woodland or forest type may include: tree stumps, fallen logs, historical records, photographs, surrounding vegetation remnants, underlying substrate, or reliable modelling of pre-European vegetation that a patch of derived grassland formerly contained the ecological community. For example, derived grassland patches on aeolian sand, in the area where the ecological community occurs, that meet the ground layer description of the ecological community, may be reasonably inferred from their location to have been the ecological community in the past (unless conditions or other evidence dictate otherwise).

**Table 1. Abundant, common and/or characteristic flora species of the Warkworth Sands Woodland.** Scientific names are nationally accepted names as per the Australian Plant Census as at March 2016. Source: NSW Scientific Committee (2011); Peake et al. (2002); Peake (2006); Cumberland Ecology (2014).

| Scientific name | Common name |
|---|---|
| **Canopy** | |
| *Allocasuarina luehmannii* | bulloak, buloke |
| *Angophora floribunda* | rough-barked apple |
| *Brachychiton populneus* subsp. *populneus* | kurrajong |
| *Callitris endlicheri* | black cypress-pine |
| *Eucalyptus blakelyi* | Blakely's red gum |
| *Eucalyptus blakelyi* x *E. tereticornis* | red gum hybrid (Blakely's red gum x forest red gum) |
| **Sub-canopy / Mid layer** | |
| *Acacia falcata* | hickory wattle, sally, sickle wattle |
| *Acacia filicifolia* | fern-leaved wattle |
| *Acacia parvipinnula* | silver stemmed wattle |
| *Allocasuarina littoralis* | black sheoak |
| *Amyema pendula* subsp. *pendula* | drooping mistletoe |
| *Banksia integrifolia* subsp. *integrifolia* | coast banksia |
| *Brachyloma daphnoides* | daphne heath |
| *Breynia oblongifolia* | coffee bush |
| *Exocarpos cupressiformis* | native cherry |
| *Exocarpos strictus* | pale-fruit ballart, dwarf cherry |
| *Hovea linearis* | narrow leaf hovea |
| *Indigofera australis* | austral indigo |
| *Melaleuca thymifolia* | thyme honey-myrtle |

| Scientific name | Common name |
|---|---|
| **Ground layer** | |
| *Aristida calycina* var. *calycina* | dark wiregrass |
| *Aristida ramosa* | purple wiregrass |
| *Aristida personata* | purple wiregrass |
| *Aristida vagans* | three-awn speargrass |
| *Aristida warburgii* | (a wire grass) |
| *Cheilanthes sieberi* subsp. *sieberi* | mulga fern, narrow rock fern |
| *Chrysocephalum apiculatum* | common everlasting |
| *Chrysocephalum semipapposum* | clustered everlasting, yellow buttons |
| *Desmodium varians* | slender tick-trefoil |
| *Dianella revoluta* | blueberry lily, blue flax-lily |
| *Dichondra repens* | kidney weed |
| *Echinopogon caespitosus* var. *caespitosus* | tufted hedgehog grass |
| *Echinopogon intermedius* | erect hedgehog grass |
| *Einadia hastata* | berry saltbush, saloop |
| *Entolasia stricta* | wiry panic |
| *Eragrostis brownii* | Brown's lovegrass |
| *Glycine clandestina* | twining glycine |
| *Glycine tabacina* | variable glycine |
| *Hardenbergia violacea* | false sarsaparilla, native lilac |
| *Hibbertia linearis* | guinea flower |
| *Imperata cylindrica* | blady grass |
| *Jacksonia scoparia* | dogwood |
| *Leucopogon muticus* | blunt beard-heath |
| *Lomandra confertifolia* | mat rush |
| *Lomandra glauca* | pale mat-rush |
| *Lomandra leucocephala* | woolly mat rush |
| *Lomandra multiflora* subsp. *multiflora* | many flowered mat rush |
| *Microlaena stipoides* var. *stipoides* | weeping (meadow) grass |
| *Perotis rara* | comet grass |
| *Persoonia linearis* | narrow-leaved geebung |
| *Pimelea linifolia* subsp. *linifolia* | slender rice flower |
| *Pomax umbellata* | pomax |
| *Pteridium esculentum* | bracken |
| *Vittadinia sulcata* | furrowed New Holland / native daisy |

### 1.4 Faunal components

The vertebrate fauna of the ecological community are typical of those of similar woodland and forest environments throughout the Hunter Valley region. Because the ecological community is highly fragmented and part of a mosaic of other woodlands (surrounded by a highly modified landscape) no species are known to be restricted to just this ecological community. Rather, most animal species use the habitats provided by the ecological community as part of larger ranges, which may include numerous remnant vegetation types.

Whilst there is no distinctive faunal assemblage confined solely to the ecological community, it provides habitat to a wide variety of vertebrate and invertebrate fauna. The ecological community provides essential resources such as nesting/breeding sites, shelter from predators (for example logs, tree hollows and thicker undergrowth) and sources of food (for example nectar from flowers or invertebrate prey). For example *Allocasuarina luehmannii* (bulloak) is a potential food tree for *Calyptorhynchus lathami* (glossy black cockatoo) (Umwelt, 2013).

Some fauna may be seasonal transients through the ecological community (for example pollinating birds such as honeyeaters are likely to visit during the local flowering season). Other animals may use the patches of the ecological community as stepping stones to other habitats; such as crossing the valley floor, north to south. The ecological community can be valuable as a refuge and a source of winter-flowering eucalypts for transient threatened species such as *Anthochaera phrygia* (regent honeyeater) and *Lathamus discolor* (swift parrot).

The ecological community supports bat species, for example *Falsistrellus tasmaniensis* (eastern false pipistrelle) and *Saccolaimus flaviventris* (yellow-bellied sheath-tail bat), primarily by providing tree hollows and suitable foraging habitat. The ecological community may not support a diverse reptile component due to the absence of structural elements such as rocky outcrops or deep litter microhabitats. However, it is likely to include various species of lizards (including skinks, dragons, geckoes and monitors) and snakes. The ecological community may provide habitat for various frogs, including the threatened *Litoria aurea* (green and golden bell frog) and *Heleioporus australiacus* (giant burrowing frog).

Some ground-dwelling native animals such as *Vombatus ursinus* (bare-nosed wombat) and *Tachyglossus aculeatus* (short-beaked echidna), as well as bandicoot species, found (or formerly present) in the ecological community play an important ecological role in maintaining soil processes. In other locations in NSW it has been observed that soil disturbances created by these animals can provide benefits by assisting soil aeration, nutrient cycling and water infiltration, as well as the spread and establishment of seedlings (Martin, 2003).

A wide range of fauna taxa, including many species of invertebrates and birds, play an important role in pollination and seed dispersal. Some mammals such as *Antechinus stuartii* (brown antechinus); *Cercartetus nanus* (eastern pygmy possum); *Petaurus breviceps* (sugar glider); and *Rattus fuscipes* (bush rat) are also likely to contribute to these functions in the ecological community.

### 1.5 Guidance for determining when the national ecological community is present

National listing focuses legal protection on patches of this ecological community that are functional and relatively natural, as outlined in the *Description of the ecological community* (Section 1). Key diagnostic characteristics and condition thresholds assist in identifying a patch of the threatened ecological community and determining whether the referral, environment assessment and compliance provisions of the EPBC Act are likely to apply.

Condition categories and thresholds can provide guidance on whether a patch retains sufficient conservation values to be considered as a matter of National Environmental Significance, as defined by the EPBC Act. They can enable the EPBC Act protection provisions to be focussed on the most valuable elements of the ecological community. Where condition thresholds are applied, patches which do not meet the minimum condition thresholds are then largely excluded from national protection.

Condition thresholds have not been applied to this ecological community, because less than 500 ha of this ecological community remain. A minimum patch size of 0.1 ha (1000 $m^2$) has been applied; i.e. patches less than 0.1 ha in size do not trigger the protection provisions of the EPBC Act.

In order to be considered a matter of National Environmental Significance under the EPBC Act, areas of the ecological community must meet:

- the *Key diagnostic characteristics* (in Section 1.5.1); and
- at least the minimum patch size of 0.1 ha (1000$m^2$).

Species composition of this ecological community is influenced by (amongst other things) the size of the patch, recent rainfall, flowering seasons, occurrence of tree hollows, drought conditions and disturbance history (including fire and grazing). Plant surveys conducted during spring and early summer may more easily identify the ecological community. However, the *Key diagnostic characteristics* (Section 1.5.1) and *Other diagnostic considerations* (Section 1.5.2) are designed to allow identification of the ecological community irrespective of the season.

### *1.5.1 Key diagnostic characteristics*

For EPBC Act referral, environment assessment and compliance purposes the protected national ecological community is limited to patches that meet all the following key diagnostic characteristics (and the minimum patch size):

- It occurs in the Central Hunter Valley, in the Hunter Valley IBRA[6] subregion (SYB02) of the Sydney Basin (SYB) Bioregion in New South Wales;
- It occurs on aeolian sands[7] of the Warkworth Land System;
- It is a mid to low woodland (occasionally forest), with a projected crown cover[8] of at least 10%.
- A ground layer is present (although it may vary in development and composition), as a sparse to thick layer of native shrubs, bracken, grasses and/or other native herbs;
- It is characterised by multiple flora species in Table 1, although not all species need be present (see Section 1.3 *Vegetative components* for more details on vegetation structure and flora).

[6] IBRA: Interim Biogeographical Regionalisation of Australia [Version 7 – 2012] in DSEWPAC (2012).

[7] Aeolian sands: Sand transported by the wind; made up of windblown grains of sand. These have not all been conclusively mapped for the Warkworth Land System.

[8] Projected cover of canopy trees is calculated by assuming a solid canopy.

### *1.5.2 Other diagnostic considerations*

- Warkworth Sands Woodland mostly occupies linear sand dunes, which are generally between one and six metres high, typically resting on a river terrace, on the undulating valley floor.
- As well as these deeper sand deposits, the ecological community also occurs on shallow "veneers" of sand separated from the main sand deposit by areas of clay soils developed on Permian sediments.
- It does not occur on clay soils on Permian sediments, nor does it occur on the sandy colluviums[9] of the widespread Triassic Sandstone plateaus.
- The canopy is typically dominated by *Angophora floribunda* (rough-barked apple) on deeper sands.
- On the shallower sands (e.g.in swales) *Eucalyptus blakelyi* x *E. tereticornis* (Blakely's red gum-forest red gum hybrid) and sometimes *E. crebra* (narrow-leaved ironbark) may be more numerous. There may be more grasses and herbs typical of the surrounding clay landscapes, but they are not dominant in the understory.
- In more disturbed areas, other canopy trees such as *Allocasuarina luehmannii* (bulloak, buloke) and *Callitris endlicheri*[10] (black cypress-pine) may be more.
- Other tree species may include *Eucalyptus blakelyi* (Blakely's red gum), as well as *Brachychiton populneus* subsp. *populneus* (kurrajong) in some areas;
- Patches with hybrid eucalypt species are included in the ecological community (i.e. areas should not be excluded on the basis of hybridisation);
- A sparse, sub-canopy layer is likely to be dominated by *Banksia integrifolia* subsp. *integrifolia* (coast banksia) and/or *Acacia filicifolia* (fern-leaved wattle);
- Derived native grasslands are **not** included in patches of this nationally protected ecological community, except where there is a gap, in or at the edge of a patch; or connecting two patches across a short distance (i.e. 30 m)[11].

[9] Colluvial material / Colluvium: A loose deposit of sharp edged rock debris and/or sediment that has moved downhill to the bottom of the slope (or cliff) without the help of running water in streams.

[10] In some areas, regeneration from past disturbance has created monocultures where little else grows; these areas are unlikely meet the *Key diagnostic characteristic* of being "characterised by multiple flora species in Table 1" (See section 1.5.1).

[11] In derived grassland the canopy layer has been removed, or thinned to very scattered trees (<10% canopy cover), but a herbaceous ground layer remains largely intact. Where native grassland (whether derived or not) connects discrete patches of the ecological community in close proximity (i.e. edges of the tree canopy up to 30 m apart) then it should be treated as part of a single patch.

Also where native grassland is within a gap in, or at the edge of a patch, (up to 30 m from the edge of the tree canopy) it should be treated as part of the patch to be protected. See also Section 1.6.1 (*Defining a patch*). Native means vegetation 'dominated by native species'; i.e. that 50% or more of the perennial vegetation cover is native.

### *1.5.3 Condition thresholds*

Condition thresholds have not been applied to this ecological community, because less than 500 ha of this ecological community remains. A minimum patch size of 0.1 ha (1000 $m^2$) has been applied; i.e. patches less than 0.1 ha in size do not trigger the protection provisions of the EPBC Act.

It is acknowledged that:

- small patches (≥ 0.1 ha in size) that remain largely intact have significant conservation value;
- even degraded patches that retain the characteristics of the ecological community need protecting;
- mature locally indigenous trees (and hollow bearing trees) are important for the range of habitats and resources they provide to species in the ecological community and the broader region;
- large intact patches are relatively uncommon in this landscape and;
- larger size and/or connectivity to other native vegetation areas are typically beneficial.

Other indicators of conservation value are detailed in Section 1.6.5 Surrounding environment, landscape context and other significant considerations.

It is not intended to include heavily degraded patches with isolated trees; or small narrow stands of trees over weeds that serve as windbreaks or shelter belts; i.e. where the patch is <0.1 ha and/or the native understorey has been lost and/or the tree canopy is discontinuous (i.e. <10% projected canopy cover) and there is no evidence of native species recruitment or regeneration potential.

## 1.6 Further information to assist in determining the presence of the ecological community and significant impacts

Landuse history will influence the current state of a patch of the ecological community. The structural form of the ecological community will also influence its species richness and diversity. The position of the ecological community and its position relative to surrounding vegetation also influence how important a patch of the ecological community is in the broader landscape.

### *1.6.1 Defining a patch*

A patch is a discrete and mostly continuous area of the ecological community[12]. A patch may include small-scale (<30 m) variations and disturbances, such as tracks, paths or breaks (including exposed soil, leaf litter, cryptogams and watercourses/drainage lines), or localised

[12] Note that NSW vegetation assessment tools have defined a 'patch' as an area of native vegetation, of one or more different communities that occur together, separated by a gap of no greater than a set distance (usually 100 m). However, the Threatened Species Scientific Committee uses the term 'patch' to describe any discrete remnant/area of the ecological community in question.

changes in vegetation that do not significantly alter the overall functionality of the ecological community. Such breaks should not be excluded from patch size calculations.

Where there is a break in native vegetation cover, from the edge of the tree canopy, of 30 m or more (e.g. due to permanent artificial structures, wide roads or other barriers; or due to wide water bodies - e.g. separating the tree canopy by 30 m or more), then the gap indicates that separate patches are present.

### *1.6.2 Buffer zone*

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

The buffer zone is not part of the ecological community; so whilst having a buffer zone is strongly recommended, it is not formally protected as a matter of National Environmental Significance. For EPBC Act approval, changes in use of the land that falls within the buffer zone must not have a significant impact on the ecological community, but there are exemptions for continuing use. If the use of an area (e.g. grazing land) that directly adjoins a patch of the ecological community is going to be intensified (e.g. fertilised), approval under the EPBC Act may also be required.

The recommended minimum buffer zone is 30 m from the outer edge of the patch. This typically accounts for the maximum height of the vegetation and likely influences on the root zone. A larger buffer zone should be applied, where practical, to protect patches of very high conservation value, or if patches are downslope of drainage lines or a source of eutrophication.

### *1.6.3 Reconstructed and revegetated areas and areas of regrowth*

Revegetated or replanted sites (or areas of regrowth) are not excluded from the listed ecological community, so long as the patch meets the *Key diagnostic characteristics* and minimum patch size. It is recognised that reconstruction/revegetation often requires longer-term effort and commitment and results are uncertain. Reconstructing a woodland ecological community to a state that resembles appropriate reference sites can, at best, be extremely slow and may ultimately prove unsuccessful (Wilkins et. al, 2003).

### *1.6.4 Sampling protocols*

Thorough and representative on-ground surveys are essential to accurately assess the extent of the ecological community. Patches can vary markedly in their shape, size and features that appear within a given patch. As a general principle, sampling protocols and the number of sample plots/transects should address the following:

- significant variation in the vegetation, landscape qualities and management history (where known) across the patch; for instance localised weed cover, drainage lines, grazed areas, saline zones; and
- an appropriate size and number of plots or transects to provide a representative sample across the full extent of the patch (taking into consideration the shape and condition across the site, as well as providing a good representation of the species present).

Plots of 0.04 ha (quadrats of 20 x 20 m) may be suitable (Tozer, 2003; Tozer et al., 2010). Recording the search effort (identifying the number of person hours spent per plot and across the entire patch; along with the surveyor's level of expertise) can be useful for future reference.

### *1.6.5 Surrounding environment, landscape context and other significant considerations*

Actions that may have 'significant impacts'[13] on any nationally protected patches of the Warkworth Sands Woodland require referral under the EPBC Act.

Warkworth Sands Woodland occurs near the edges of Wollemi and Yengo National Parks, in a heavily cleared region of Australia. Much of the native vegetation now only remains as small fragmented remnants, in a mosaic with other native vegetation (including other national and state protected ecological communities), amongst a matrix of mining and modified agricultural landscapes.

The ecological importance of a patch is influenced by both its condition and also its surrounding landscape. If a patch is connected to, or near, other native vegetation the patch may contribute substantially to landscape connectivity and function. Similarly, actions beyond the boundary of a patch may have a significant impact on the patch (for example, through changes in hydrology). For this reason, when considering actions likely to have impacts on this ecological community (or when considering priorities for recovery, management and funding), it is important to also consider the following indicators of conservation value:

- Large size and/or a large area to boundary ratio – patches with larger area to boundary ratios are less exposed and more resilient to edge effects (disturbances such as weed invasion and other anthropogenic impacts). However, patches that occur in areas where the ecological community has been most heavily cleared and degraded, may also have importance due to their rarity, genetic significance, or because of the absence of some threats.

[13] A 'significant impact' is an impact which is important, notable, or of consequence, having regard to its context or intensity. Further information regarding 'significant impact' and the EPBC Act is available at http://www.environment.gov.au/epbc/publications/significant-impact-guidelines-11-matters-national-environmental-significance

- Evidence of recruitment of key native plant species and the presence of a range of age cohorts (including through successful assisted regeneration). For example, tree canopy species are present as saplings through to large hollow-bearing trees.
- Good faunal habitat as indicated by: diversity of landscape; diversity of plant species; mature trees (particularly those with hollows); logs; and large rocks.
- High native species richness, possibly including many understorey plant species or native fauna species.
- Patches that contain a unique combination of species and/or rare or important species in the context of the particular ecological community, or local region (e.g. a patch with unique fauna and/or understorey flora composition; or a patch that contains flora or fauna that have largely declined in the ecological community or region; or a patch with national or state listed threatened species).
- Areas with minimal weeds and feral animals, or where these threats can be managed.
- Presence of cryptogams, soil crust and leaf litter on the soil surface, which may indicate
- Low (or no) recent disturbance to the natural soil structure and the potential for good functional attributes such as nutrient cycling; these may be indicated by the presence of cryptogams, soil crust and leaf litter on the soil surface.
- Derived native grasslands, particularly those adjacent to or near forest/woodland remnants. These can be important to the survival of the ecological community in an otherwise fragmented, rural landscape.
- Connectivity to other native vegetation remnants or restoration works (e.g. native plantings) in particular, a patch in an important position between (or linking) other patches in the landscape. This can contribute to movement of fauna and transfer of pollen and seeds.
- Linear road reserves often contain remnant native vegetation in high to moderate condition, representing a diverse range of upper storey, mid-storey and perennial understorey species. These areas also act as important corridor links to larger patches of nearby vegetation. In some instances, linear road reserves can represent the only remnant native vegetation occurring in an area where adjacent land has largely been cleared.

### *1.6.6 Timing of surveys and seasonal variation*

When assessing the quality (including species richness) of an ecological community and its surrounding environment, the timing of surveys can be an important consideration, because the appearance of vegetation can vary throughout the year and between years, depending on drought-rain cycles for example. Seasonal factors can determine the visual dominance of taxa.

Ideally, to maximise the assessment of understorey composition, sites should be assessed during a good season (e.g. within two months of effective rain) and six months after cessation of major disturbance (e.g. fire/grazing/mowing/slashing). At a minimum, it is important to note climate conditions and what kind of disturbance may have happened within a patch and when that disturbance occurred, as far as possible.

### *1.6.7 Area critical to the survival of the ecological community*

All remaining patches that meet the description are critical to the survival of the ecological community. In addition, buffer zones are considered critical to the survival of the ecological community. Original areas of Aeolian sands of the Warkworth Land System and adjoining native vegetation are also important to the survival of the ecological community and should be taken into consideration as part of the surrounding environment and landscape context, as outlined in Section 1.6.5.

### *1.6.8 Geographic extent and patch size distribution*

#### *1.6.8.1 Geographic extent*

Prior to European settlement the extent of the ecological community is estimated to have been 800 - 3040 ha; the current extent of the ecological community is estimated to be 400 - 465 ha (Umwelt, 2011; Bell, 2012). The ecological community has undergone a decline of 50 - 85% (Umwelt, 2011; Bell, 2012). Further losses (72 ha, 15 – 18% of the current extent) have been approved (November 2015) as part of the Warkworth Continuation Project (Umwelt, 2011; Bell, 2012; NSW PAC, 2015a).

#### *1.6.8.2 Patch size*

The ecological community is highly fragmented, with a median average patch size of less than 3 ha; most of the patches (at least 70%) are less than 10 ha in size (DoE, 2016).

## 1.7 Other existing protection

Less than five percent (20 000 ha) of the Hunter IBRA sub-region has the status of terrestrial protected areas (NSW OEH, 2008b; DoE 2013); and most of these are at higher altitudes than the ecological community. There are no known areas of Warkworth Sands Woodland protected in any conservation reserves or in perpetuity conservation areas (Peake, 2006; Bell, 2012).

The ecological community contains habitat for threatened fauna and flora species listed under the EPBC Act and/or NSW state legislation.

### *1.7.1 Relationship to state-listed ecological communities*

The ecological community corresponds to the similarly named New South Wales listed Warkworth Sands Woodland in the Sydney Basin Bioregion ecological community (NSW Scientific Committee, 2011).

### *1.7.2 Listed threatened flora species*

***Table 2.Threatened flora that may occur in the Warkworth Sands Woodland.*** Scientific names and threatened status are current as at March 2016. Source: Peake (2006); Umwelt (2013) Cumberland Ecology (2014); Commonwealth Environment Protection and Biodiversity Conservation Act 1999 Species Profile and Threats Database [EPBC Act SPRAT Database]; NSW Threatened Species Conservation Act 1995 (NSW TSC) Act Database [NSW TSC Act Threatened Species Database].

| Scientific name | Common name | EPBC Act* | NSW TSC Act* |
|---|---|---|---|
| *Cymbidium canaliculatum* | black orchid population in the Hunter catchment | - | Endangered population |
| *Thesium australe* | austral toadflax | V | V |

* V= listed as Vulnerable; E= listed as Endangered; CE= listed as Critically Endangered.

### *1.7.3 Listed threatened fauna species*

***Table 3. Threatened fauna that may occur in the Warkworth Sands Woodland.*** Scientific names and threatened status are current as at March 2016. Source: Cumberland Ecology (2014); Umwelt (2013); EPBC Act SPRAT Database; NSW TSC Act Threatened Species Database.

| Scientific name | Common name | EPBC Act* | NSW Act* |
|---|---|---|---|
| **Amphibians** | | | |
| *Heleioporus australiacus* | giant burrowing frog | V | V |
| *Litoria aurea* | green and golden bell frog | E | V |
| **Birds** | | | |
| *Anthochaera phrygia* | regent honeyeater | E | CE |
| *Callocephalon fimbriatum* | gang-gang cockatoo | - | V |
| *Calyptorhynchus lathami* | glossy black cockatoo | - | V |
| *Chthonicola sagittata* | speckled warbler | - | V |
| *Climacteris picumnus victoriae* | brown treecreeper (eastern subspecies) | - | V |
| *Daphoenositta chrysoptera* | varied sittella | - | V |
| *Grantiella picta* | painted honeyeater | V | V |
| *Hamirostra melanosternon* | black-breasted buzzard | - | V |
| *Lathamus discolor* | swift parrot | E | E |
| *Lophoictinia isura* | square-tailed kite | - | V |
| *Melanodryas cucullata cucullata* | hooded robin (south-eastern form) | - | V |

| Scientific name | Common name | EPBC Act* | NSW Act* |
|---|---|---|---|
| *Melithreptus gularis gularis* | black-chinned honeyeater (eastern subspecies) | - | V |
| *Neophema pulchella* | turquoise parrot | - | V |
| *Ninox connivens* | barking owl | - | V |
| *Ninox strenua* | powerful owl | - | V |
| *Parvipsitta pusilla* | little lorikeet | - | V |
| *Petroica boodang* | scarlet robin | - | V |
| *Stagonopleura guttata* | diamond firetail | - | V |
| *Tyto novaehollandiae* | masked owl | - | V |
| **Mammals** | | | |
| *Cercartetus nanus* | eastern pygmy possum | - | V |
| *Chalinolobus dwyeri* | large-eared pied bat | V | V |
| *Dasyurus maculatus maculatus* | spotted-tailed quoll (south-eastern mainland population) | E | V |
| *Falsistrellus tasmaniensis* | eastern false pipistrelle | - | V |
| *Miniopterus australis* | little bentwing bat | - | V |
| *Miniopterus schreibersii oceanensis* | eastern bentwing bat | - | V |
| *Mormopterus norfolkensis* | eastern freetail bat | - | V |
| *Myotis macropus* | southern myotis | - | V |
| *Nyctophilus corbeni* | Corben's long-eared bat | V | V |
| *Petaurus norfolcensis* | squirrel glider | - | V |
| *Petrogale penicillata* | brush-tailed rock wallaby | E | V |
| *Phascogale tapoatafa* | brush-tailed phascogale, tuan | - | V |
| *Phascolarctos cinereus* | koala | V | V |
| *Pomatostomus temporalis temporalis* | grey-crowned babbler (eastern subspecies) | - | V |
| *Pteropus poliocephalus* | grey-headed flying fox | V | V |
| *Saccolaimus flaviventris* | yellow-bellied sheathtail bat | - | V |
| *Scoteanax rueppellii* | greater broad-nosed bat | - | V |
| *Vespadelus troughtoni* | eastern cave bat | - | V |

*V= listed as Vulnerable; E= listed as Endangered; CE= listed as Critically Endangered.

## 2 SUMMARY OF THREATS

Warkworth Sands Woodland is primarily threatened by clearing, mostly for open cut mining and the construction of mining infrastructure, but also clearing by other private landholders for livestock grazing. Altered fire regimes and weed invasion also pose a threat (Peake, 2006; NSW Scientific Committee, 2011; Bell, 2012).

The key threats affecting the ecological community are:

- Vegetation clearing and landscape fragmentation. Mining continues to be the main driver of clearing; remaining areas of the ecological community are fragmented, isolated and much less resilient to on-going impacts.
- Invasive flora species. Weeds compete with locally indigenous flora species for available resources (water, light, nutrients) and lead to a change in the diversity and regenerative capacity of a native ecosystem.
- Altered fire regimes. These include changed fire intensity, frequency, seasonality and extent of patchiness. These changes influence vegetation composition and structure, as well as the success of plant invasions and subsequent impacts on native biota.
- Climate change. In addition to threatening the species that cannot adapt, climate change can exacerbate existing threats such as habitat loss, altered fire and hydrology regimes and the spread of invasive species.

### 2.1 Summary of Key Threatening Processes (KTPs)

Key threatening processes identified under the NSW TSC Act and EPBC Act that are, or could be, affecting Warkworth Sands Woodland are:

- Land clearance (EPBC Act); Clearing of native vegetation (NSW TSC Act)
- Alteration of habitat following subsidence due to longwall mining (NSW TSC Act)
- Novel biota and their impact on biodiversity (EPBC Act)
- Invasion of native plant communities by exotic perennial grasses (NSW TSC Act); Invasion and establishment of exotic vines and scramblers (NSW TSC Act); Invasion, establishment and spread of Lantana (*Lantana camara*) (NSW TSC Act);
- Competition and land degradation by rabbits (EPBC Act); Competition and grazing by the feral European Rabbit, *Oryctolagus cuniculus* (NSW TSC Act)
- Loss of hollow-bearing trees (NSW TSC Act);
- Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases (EPBC Act); Anthropogenic climate change (NSW TSC Act).
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants (EPBC Act/TSC Act)
- Competition from feral honeybees (NSW TSC Act)
- Predation by the European red fox (*Vulpes vulpes*) (NSW TSC Act and EPBC Act)
- Predation by feral cats (EPBC Act and NSW TSC Act).

## 3 SUMMARY OF ELIGIBILITY FOR LISTING AGAINST THE EPBC ACT CRITERIA

### 3.1 Criterion 1 - Decline in geographic distribution

Available data indicate that the ecological community has undergone a decline of at least 50%. As detailed in Appendix E *Eligibility for listing against the EPBC Act criteria*, the ecological community is considered to have undergone at least a substantial decline in its geographic extent and is therefore **eligible** for listing as **vulnerable** under this criterion.

### 3.2 Criterion 2 - Limited geographic distribution coupled with demonstrable threat

The ecological community has a very restricted distribution because it has: a very restricted extent of occurrence (400 – 465 ha) and area of occupancy (6,000 – 7,000 ha); mostly small remnants (at least 70%) less than 10 ha in size. As detailed in Appendix D (*Description of Threats*), the ecological community is subject to a range of ongoing demonstrable threats.

The ecological community's very restricted distribution, coupled with demonstrative threats, makes it likely that the action of a threatening process could cause the ecological community to be lost in **the immediate future** (i.e. three generations of key canopy species - at least 45 years). Therefore, the ecological community is **eligible** for listing as **critically endangered** under this criterion.

### 3.3 Criterion 3 - Loss or decline of functionally important species

Whilst functionally important species, such as canopy trees, burrowing mammals and nomadic nectarivores, are likely to have been impacted by threats, specific data related to their decline in this ecological community are not available. Also the functional roles of many species in this ecological community are not well documented. As such there is **insufficient information to determine the eligibility** of the ecological community for listing under any category of Criterion 3.

### 3.4 Criterion 4 - Reduction in community integrity

Substantial clearing, fragmentation, weed invasion, and associated changes to vegetation structure and loss of faunal components have very severely reduced the integrity of the ecological community. This may be compounded by climate change. The loss of integrity, coupled with the ongoing threats to the ecological community mean that *restoration* of the Warkworth Sands Woodland is unlikely within the *immediate future*, even with positive human intervention.

The reduction in integrity experienced by the ecological community across most of its geographic distribution is **very severe**, as indicated by **very severe** degradation of the ecological community. Therefore, the ecological community is **eligible** for listing as **critically endangered** under this criterion.

### 3.5 Criterion 5 - Rate of continuing detrimental change

The majority of the area of occupancy of the ecological community occurs within the Warkworth district and this area contains the relatively few, large and mostly good condition remnants of the ecological community. The planned clearance of a further 72 ha of the ecological community in the Warkworth district will remove much of the highest quality Warkworth Sands Woodland (up to half), leaving mostly medium and low condition remnants.

The **severe** projected decline, of up to half of the highest quality patches of the Warkworth Sands Woodland, represents a **severe** rate of continuing detrimental change in the immediate future. Therefore, the ecological community is **eligible** for listing as **endangered** under this criterion.

### 3.6 Criterion 6 - Quantitative analysis showing probability of extinction

There are no quantitative data available to assess this ecological community under this criterion. As such there is **insufficient information to determine the eligibility** of the ecological community for listing under any category of Criterion 6.

| |
|---|
| Further details are at Appendix E *Eligibility for listing against the EPBC Act criteria*. |

## 4 PRIORITY CONSERVATION ACTIONS

### 4.1 Conservation objective

The conservation objective (stated at the front of the document and reproduced here) provides the goal and rationale for the priority actions identified here.

**The conservation objective is to mitigate the risk of extinction of the Warkworth Sands Woodland; and help recover its biodiversity and function - By:**

- **protecting it under the *Environment Protection and Biodiversity Conservation Act 1999;* and**
- **implementing the priority conservation actions for the ecological community** (as outlined in Section 4.2 – 4.4 below).

### 4.2 Priority protection and restoration actions

It is more practical and cost-effective to maintain existing high quality remnants than to allow their degradation and then attempt rehabilitation. The more disturbed and modified a patch of the ecological community is, the greater is the recovery effort required. To gain the most cost-effective outcomes of investments in management, it is important to consider the likely interaction of management actions at any one site, as these may be synergistic or antagonistic. There are also likely to be interactions between sites (Auerbach et al, 2015).

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

Assessments of activities that may have significant impacts to the ecological community should incorporate related actions below when determining recommendations. The information outlined in Section 1.6 *Further information to assist in determining the presence of the ecological community and significant impacts* should also be taken into consideration.

The three key approaches to achieve the conservation objective are:

1) PROTECT the ecological community, to prevent further loss of extent and condition;
2) RESTORE the ecological community within its original range, by active abatement of threats, re-vegetation and other recovery initiatives;
3) COMMUNICATE WITH AND SUPPORT researchers, land use planners, landholders, land managers, community members (including the Indigenous community) and others - to increase understanding of the value and function of the ecological community and encourage their efforts in its protection and recovery.

These approaches overlap in practice; and form part of an iterative approach to management that includes research, planning, management, monitoring and review.

### *4.2.1 PROTECT*

*4.2.1.1 Vegetation clearance and direct habitat damage*

It is more practical and cost-effective to maintain existing high quality remnants than to allow their degradation and then attempt rehabilitation. The more disturbed and modified a patch of the ecological community is, the greater is the recovery effort required; the time required for significant recovery of sustainable flora and fauna composition and function is likely to be at least 50 years.

**Highest priorities**

- Prevent further clearance, fragmentation or detrimental modification of remnants of the ecological community and of surrounding native vegetation (e.g. during mining and infrastructure development). High conservation value, unmodified and older regrowth areas with mature trees are particularly important for retention and management.
    - Overall, the extent of the ecological community should not be further reduced and efforts should be made to increase the remaining extent and connectivity (see 4.2.2.4), including with other surrounding vegetation types.
    - Identify remnants of the ecological community in advance of zoning and development planning decisions and avoid clearing/damaging them.
    - Recognise the landscape position of remnants of the ecological community and ensure that planning supports increased resilience within the landscape (for example, by retaining appropriate connectivity between remnants of all naturally occurring ecological communities in the region).
    - Apply recommended buffers of at least 30m around patches of the ecological community (see Section 1.6.2 *Buffer zone*).
    - Protect mature trees with hollows, including dead tress. If necessary, supplement, but do not replace habitat by placing artificial hollows (e.g. various sized nest boxes) in, or near to, the ecological community. Maintain the boxes and monitor outcomes.
    - Retain other native vegetation remnants, derived native grasslands and mature paddock trees near patches of the ecological community where they are important for connectivity.
    - Fence remnants to exclude indiscriminate or unplanned livestock grazing, protect them from activities and disturbances on adjoining land and encourage regeneration.
- Avoid offsetting. It is not appropriate to offset this ecological community through the use of any other ecological community. Further information is in Section 4.3 *Offsets*.

**Other priorities**

- Seek to increase the level of legislative protection for sites through landuse planning mechanisms and conservation agreements.
- Assess and utilise opportunities for incorporating land supporting the ecological community into formal reserve tenure, biobanking, or other land tenure for biodiversity conservation purposes. Ideally all of the remaining extent of the ecological community should be set aside.

- Protect the soil seed bank by minimising soil disturbance and removal.
- Prevent impacts to native vegetation, native flora, hydrology, or soil structures from any developments and activities adjacent to or near patches of the ecological community by planning for and appropriately mitigating off-site effects. For instance apply buffer zones and avoid activities that could cause significant hydrological changes and eutrophication.
- Retain habitat features for fauna, noting species requirements (e.g. large rocks, logs embedded in the soil or hollow logs).

### *4.2.2 RESTORE*

Integrate restoration and management practices for the ecological community and across the broader landscape; such as invasive species control with fire management and revegetation.

*4.2.2.1 Control invasive species and diseases*

**Highest priorities**

- Implement effective control and management techniques for invasive species currently affecting the ecological community, such as *Lantana camara*, integrating this with alternative habitat provision and predator control.
- Prioritise management of weeds in high quality patches, or where threatened or regionally significant species are known to occur.
- Manage weeds before and after ecological burns, and during revegetation works to maximise success of restoration.
- Monitor for signs of new disease and identify new weed or pest animal incursions early and quickly manage for local eradication.
- Do not introduce or spread known, or potential, environmental weeds, or diseases, within or near the ecological community.
    - Ensure stock do not carry weeds into patches of the ecological community (e.g. hold stock in paddocks free of weeds for an appropriate time prior to introduction).
    - Use appropriate hygiene to minimise the introduction or spread of weeds and diseases at susceptible sites. For example, keep vehicles and machinery to dedicated roads and out of remnants wherever possible. If vehicles must be taken into remnants ensure they are washed first to remove soil and weed seeds.
    - Avoid potentially invasive species and select local native species when landscaping nearby. Promote knowledge about local weeds and keep non-indigenous invasive plant species controlled at all times.

**Other priorities**

- Ensure that actions to control invasive, or other pest, species avoid impacts on non-target species and have no long-term adverse impacts on the ecological community.
    - Ensure workers are appropriately trained in the use of relevant herbicides, pesticides and what to target; and understand the importance of avoiding non-target impacts on native vegetation.
    - Avoid chemical spray drift and off-target damage within, or near to, the ecological community, having regard to minimum buffer zones.
- Control introduced pest animals through consolidated landscape-scale programs.
- Control run-off to prevent infiltration of litter, dispersal of weeds, plant diseases and eutrophication. Use sediment fences as appropriate.

*4.2.2.2 Fire*

- Use a landscape-scale approach and available knowledge of life histories of component species, to identify and implement appropriate fire regimes.
- Implement appropriate fire management regimes for the ecological community taking into account results from research. These may include some of the following actions:
    - extinguish fires from tree bases, after fire front has passed, to retain trees that are old or contain hollows;
    - where weeds dominate in high densities, consider burning to control them - taking into consideration the requirements of resident native flora and fauna species that you aim to protect or encourage (e.g. avoid burns when the natives are seeding/ reproducing);
    - do not burn if soil moisture is very low, or dry conditions are predicted for the coming season;
    - monitor the results for increases in native plants or a decrease in weeds and deal with any post-fire management needs (including predator and weed problems) without delay; take these results into account when implementing future fire regimes.

*4.2.2.3 Grazing*

- Exclude livestock wherever possible - particularly in regrowth and revegetation areas; or from sites with threatened, regionally important, or diverse understorey species.
- Manage populations of feral animals that damage native vegetation, including deer, pigs and rabbits.

*4.2.2.4 Re-vegetation*

**Highest priorities**

- Implement optimal regeneration, revegetation and restoration strategies for the ecological community, across the landscape. In general, use locally collected seed where available, to create an appropriate canopy and diverse understorey. Consider, in particular: the original species composition and vegetation structure (where known); and, the needs of those native species of conservation concern - or the needs of those species known to be functionally important in the ecological community in the area.
- Encourage appropriate use of local native species in developments and revegetation projects through local government and industry initiatives.
- Work with neighbouring mines and other properties to reduce fragmentation and isolation by: developing long-term ecological linkages (such as restoring wildlife corridors); and integrating existing vegetation and rehabilitated vegetation communities - with particular emphasis on threatened ecological communities. Further, ensure that these areas are considered for inclusion in formal reserve tenure, or other conservation related tenure, for protection and management in perpetuity.
- Implement effective adaptive management regimes using information from relevant research. Refer to the National Standards for the Practice of Ecological Restoration in Australia to assist in setting goals, planning actions and monitoring outcomes (Society for Ecological Restoration Australasia, 2015).

### *4.2.3 COMMUNICATION AND SUPPORT*

*4.2.3.1 Education, information and local regulation*

**Highest priorities**

- Develop a communication strategy, education programs, information products and signage to help mine employees and contractors, local communities, planners and managers recognise:
  - the presence and importance of the ecological community (e.g. the use of signs to identify good examples of the ecological community);
  - the appropriate management of patches of the ecological community;
  - responsibilities under state and local regulations and the EPBC Act.
- Promote knowledge about local weeds, means to control them and appropriate alternative native species to plant.

**Other priorities**

- Develop education programs to discourage damaging activities such as the removal of dead timber, the dumping of rubbish, roaming domestic pets, and the use of off-road vehicles in patches of the ecological community.

- Encourage local participation in recovery efforts, in removing threats and actively restoring existing patches, as well as supplementing these efforts. This may be achieved by setting up a recovery team with appropriate expert and local participants; by local conservation groups adopting patches; or by encouraging short term involvement through field days and planting projects, with appropriate follow-up.
    - Ensure planners and participants are aware of:
        - appropriate native species to plant[14] across the range of the ecological community;
        - the best opportunities to restore landscape connectivity and to encourage natural regeneration;
        - the best known techniques for particular site conditions and for species being planted.
    - Ensure commitment to required follow-up after planting, such as care of newly planted vegetation by: watering, mulching, weeding, thinning and the removal of tree guards.
- Promote awareness and protection of the ecological community by relevant agencies and industries. For example to:
    - state and local government planning authorities, to ensure that planning takes the protection of remnants into account, with due regard to principles for long-term conservation;
    - mining and construction industries and land developers, to minimise threats associated with land development;
    - local councils and state authorities - to ensure road widening and maintenance activities (or other infrastructure or development activities), involving substrate or vegetation disturbance, do not adversely impact the ecological community. This includes avoiding the introduction or spread of weeds and avoiding planning new roads or paths through patches of the ecological community;
- Liaise with local fire management authorities and agencies and engage their support in ecologically sensitive fire management of the ecological community.

*4.2.3.2 Incentives and support*

- Support opportunities for traditional owners or other members of the Indigenous community to manage the ecological community.
- Implement formal conservation agreements (for example, covenants) for sites containing the ecological community.

[14] Use appropriate local seed (or other plant germplasm) sourcing strategies that capture suitable genetic diversity and don't negatively impact on remnant populations.

- Develop projects (e.g. through the Green Army and 20 Million Trees programs) to encourage conservation and stewardship on private land, and link up with other programs and activities, especially those managed by regional catchment groups (e.g. Hunter Local Land Services)

### 4.3 Offsets

**Highest priorities**

This ecological community has already been greatly reduced in spatial extent and condition. Any further loss in extent of this ecological community should be avoided. Offsetting is a last resort, used as an attempt to compensate for damage to the ecological community deemed unavoidable. The outcomes of offsetting activities (for example woodland reconstruction) are generally highly uncertain.

Any proposals considering offsets for this ecological community should aim to:

- minimise the need to offset the ecological community;
- retain medium and higher quality[15] patches of the ecological community, rather than offset them;
- focus on retaining remnants of the ecological community with mature trees;
    - offsetting with replanted areas is insufficient - since there is no guarantee that woodland reconstruction will be successful and, given the long ecological lags in the potential recreation of a resilient and functioning patch of the ecological community, the loss of mature eucalyptus and banksias severely compromises the viability of the ecological community;
- manage and protect offset areas in perpetuity in areas dedicated for conservation purposes - avoid reducing their size, condition and ecological function;
- increase the area and improve ecological function of the existing woodlands, for example by enhancing landscape connectivity, habitat diversity and condition;
- focus on the restoration of medium quality patches of the ecological community to achieve high quality condition;
- extend protection to otherwise unprotected sites (e.g. sites that are currently too small or degraded to meet the *Key diagnostic characteristics* for national protection, but can reasonably be restored to a better, more intact condition).

The Warkworth Sands Woodland is distinctly different to all other vegetation communities in the Hunter Valley and it is therefore not appropriate to offset this ecological community through the use of any other ecological community.

[15] In addition to the indicators of conservation value set out in Section 1.6.5 (*Surrounding environment, landscape context and other significant considerations significant considerations*) a deeper sand substrate (e.g. at least one metre) is another indicator of how well a particular site supports the ecological community and contributes to its ongoing viability.

### 4.4 Research and monitoring priorities

Relevant and well-targeted research and other information gathering activities are important to inform the protection and management of the ecological community. Coordination with individuals and groups with responsibilities for planning and on ground management (e.g. through a management technical committee) is important to ensure that research questions and methods are well chosen and that the information gathered is shared and applied to the benefit of the ecological community. Research and ongoing management activities can often be integrated to achieve the best results in the face of ongoing change. It is important that any monitoring is planned before management commences, considering data requirements to address research questions. Monitoring must also be resourced for the duration of the management activities, especially for those using a novel approach.

**Highest priorities**

High priority research and monitoring activities to inform protection, management and restoration of the Warkworth Sands Woodland include the following:

- Improve and update maps of the ecological community across its range.
    - Support field survey (including soil surveys) and interpretation of other data such as aerial photographs and satellite images to more accurately document current extent, condition, threats, function, presence and use by regionally significant or threatened species.
    - Determine the tenure of all remnants of the ecological community and identify relevant stakeholders.
    - Support and enhance existing programs to model the pre-1750 extent across the entire range of the ecological community to inform restoration; identify the most intact, high conservation value remnants and gain a better understanding of variation across the ecological community (for example, in linear road reserves and private landholdings).
    - Determine priority areas for restoration to enhance connectivity and landscape resilience.
- Undertake research to develop fire regimes that are compatible with conservation of biodiversity within the ecological community.
- Review past land use and management practices applied to the ecological community, to inform future conservation management and restoration efforts.
- Monitor changes in condition, including response to different types of management actions and use this information to increase understanding of the ecological community and inform recommendations for future management.
- Conduct research leading to the development of effective landscape-scale restoration techniques for the ecological community:
    - investigate the interaction between disturbance types (such as fire, grazing and invasion by weeds and feral animals) to determine how an integrated approach to threat management can be implemented;

- investigate the most cost-effective options for restoring landscape function, including revegetation priorities (potentially buffering and connecting existing remnants), predator control (potentially including exclusion fencing) and the reintroduction of key fauna;
- assess the vulnerability of the ecological community to climate change and investigate ways to improve resilience through other threat abatement and management actions.

- Investigate seed bank dynamics of key species, including rates of seed production, seed viability, germination, dormancy and longevity (in natural environment and in storage).

### 4.5 Recovery plan recommendation

Recovery of the ecological community is likely to be long-term, due to the range of threats to be addressed and their cumulative impacts. National listing and protection will underpin recovery efforts.

A recovery plan is not recommended for this ecological community. The main threats to the ecological community and actions required to address them are understood. A number of existing strategies, plans and guides are relevant to the management and/or recovery of the ecological community, or its component species.

In addition, the recent approval of the Warkworth Continuation Project requires Rio Tinto Coal Australia Pty Limited to prepare an Integrated Management Plan (IMP) for Warkworth Sands Woodland, in consultation with Wambo and Bulga Mines (both of these mines own and manage significant areas of the ecological community).

This existing guidance and required IMP, together with national listing protection and the priority research and conservation actions identified in the Conservation Advice, if resourced and implemented over the longer term, are a good prescription for recovery of the ecological community.

## APPENDIX A – GLOSSARY

**Aeolian (also spelled eolian) sands**: A type of sediment, which has been transported by the wind; windblown sand grains. Sand dunes are the most noticeable landforms produced by wind deposition.

**Allelopathy:** The chemical inhibition of one plant (or other organism) by another, due to the release of substances acting as germination or growth inhibitors.

**Alluvium:** A general term for clay, silt, sand, gravel or similar unconsolidated (not cemented together into a solid rock) detrital material, deposited during comparatively recent geologic time by a stream or other body of running water, as a sorted or semi-sorted sediment.

**Blowouts**: Sandy depressions in a sand dune ecosystem caused by the removal of sediments by wind. They form when a patch of protective vegetation is lost, allowing strong winds to "blow out" sand and form a depression.

**Carboniferous Period**: A geologic period (298 – 354 Ma). The Carboniferous Period was followed by the Permian Period (251 – 298 Ma). Although European and North American coals were deposited during the Carboniferous Period, virtually no economic Carboniferous coal was deposited in Gondwanaland (the predecessor of Australia and a number of other continents).

**Conglomerate**: A coarse-grained sedimentary rock composed of rounded fragments embedded in a matrix of cementing material such as silica.

**Colluvial** material / **Colluvium**: A loose deposit of sharp edged rock debris and/or sediment that has moved downhill to the bottom of the slope (or cliff) without the help of running water in streams. Gravity and sheetwash[16] during rain storms are the predominant agents of colluvium deposition.

**Dominant:** See Projected canopy cover

**Duplex soil**: A soil with a texture or permeability contrast layer within the top 80 cm of the profile (e.g. a sand layer, over a clay layer). See also Texture contrast (soil).

**Ecological niche:** The role and position a species has in its environment; how it meets its needs for food and shelter, how it survives, and how it reproduces. A species' niche includes all of its interactions with the biotic and abiotic factors of its environment.

**Eutrophication:** An increase in the rate of supply of nutrients into an ecosystem.

**Foodweb:** A network of food chains or feeding relationships by which energy and nutrients are passed on from one species of living organisms to another.

**Functionality** (of an ecological community): This refers to many processes such as: the movement of wildlife and pollinators; the dispersal of spores, seeds and other plant propagules; and the activities of predators.

**Geological Periods over the last 350 million years (Ma):** Quaternary (0 – 2.6 Ma); Tertiary (2.6 – 66 Ma); Cretaceous (66 – 145 Ma); Jurassic (145 – 201 Ma); Triassic (201 – 251 Ma); Permian (251 – 298 Ma); and Carboniferous (298 – 354 Ma).

[16] Sheetwash: Sheets of running water rather than by stream flowing in well defined channels

**Hybrid**: The offspring of two animals or two plants of different breeds, varieties, species, or genera (e.g. when two different species cross pollinate). Examples of possible hybrids in this ecological community include *Eucalyptus tereticornis* x *E. blakelyi* (forest red gum x Blakely's red gum).

**IBRA**: The Interim Biogeographical Regionalisation of Australia (IBRA). The latest version (IBRA7) classifies Australia's landscapes into 89 large geographically distinct bioregions based on common climate, geology, landform, native vegetation and species information. The 89 bioregions are further refined to form 419 subregions which are more localised and homogenous geomorphological units within each bioregion. The bioregions and subregions are the reporting unit for assessing the status of native ecosystems and their level of protection in the National Reserve System.

**Loam**: A rich, friable (crumbly) soil containing a relatively equal mixture of sand and silt and a somewhat smaller proportion of clay.

**Ma:** Million years ago.

**Permian**: The Permian Period is a geologic period (251 – 298 Ma). It is the last period of the Palaeozoic Era; it occurred after the Carboniferous Period and before the Triassic Period (the first period of the Mesozoic Era). The bulk of Australian coal accumulated during the Permian and Tertiary periods; the majority of Australia's resources of metallurgical coking and bituminous thermal coal occur in the Permian deposits of the Sydney and Bowen Basins of NSW and Queensland (Hutton, 2009).

**Projected canopy (or crown) cover**: A way of assessing tree dominance in a patch of woodland/forest. Dominant, in this document means accounting for more than 50% of the projected canopy cover. Projected cover of canopy trees is calculated by assuming a solid canopy. Projected canopy (or crown) cover is the preferred benchmark for dominance; except in regenerating areas with few mature canopy trees; where this is the case, tree basal area is the next best surrogate for assigning dominance, since it measures biomass to some degree.

**SYB**: Designates the Sydney Basin (SYB) IBRA Bioregion.

**Tertiary Period**: A geologic period (2.6 – 66 Ma). It marks the beginning of the Cenozoic Era. The Tertiary Period was followed by the Quaternary Period (0 – 2.6 Ma). The bulk of Australian coal accumulated during the Permian and Tertiary periods (Hutton, 2009).

**Texture contrast (soil)**: A significant increase in texture over a vertical distance of less than 5 cm (referred to by the term 'over'). This is commonly a sand layer over a sandy clay loam to clay layer, or a loam over a clay. Texture contrast soils have a clear, abrupt or sharp boundary between the A and B horizon together with an increase in clay in the B horizon of at least 20% (Isbell, 1996).

## APPENDIX B – SPECIES LISTS

Table B1 lists vascular plant species that may occur in the Warkworth Sands Woodland ecological community. Table B2 lists fauna that may occur in the ecological community. These lists are indicative, rather than comprehensive, lists of species present in the ecological community. Individual patches may not include all species on the list, or may include other species not listed. At any one time, above-ground individuals of some plant species may be absent, but the species may be represented below ground in soil seed banks or as dormant structures such as bulbs, corms, rhizomes, rootstocks or lignotubers.

**Table B1. Flora species that may occur in the Warkworth Sands Woodland.** Scientific names are nationally accepted names as per the Australian Plant Census as at March 2016.
Source: Peake et al. (2002); Peake (2006); Somerville (2009); NSW OEH (2012); Cumberland Ecology (2014).

| Scientific name | Common name |
|---|---|
| *Acacia falcata* | sickle / hickory wattle, sally |
| *Acacia filicifolia* | fern-leaved wattle |
| *Acacia parvipinnula* | silver stemmed wattle |
| *Ajuga australis* | austral bugle |
| *Allocasuarina littoralis* | black sheoak |
| *Allocasuarina luehmannii* | bulloak, buloke |
| *Amyema pendula* subsp. *pendula* | drooping mistletoe, furry drooping mistletoe |
| *Angophora floribunda* | rough-barked apple |
| *Aristida calycina* | dark wiregrass |
| *Aristida personata* | purple wiregrass |
| *Aristida ramosa* | purple wiregrass |
| *Aristida vagans* | three-awn speargrass |
| *Aristida warburgii* | (a wire grass) |
| *Banksia integrifolia* subsp. *integrifolia* | coast banksia |
| *Brachychiton populneus subsp. populneus* | kurrajong |
| *Brachyloma daphnoides* | daphne heath |
| *Breynia oblongifolia* | coffee bush |
| *Callitris endlicheri* | black cypress-pine |
| *Callitris glaucophylla* | white cypress-pine |
| *Calotis cuneifolia* | purple burr-daisy, Lachlan calotis |
| *Cheilanthes sieberi* subsp. *sieberi* | mulga fern, narrow rock fern |
| *Cheilanthes austrotenuifolia* | rock fern |
| *Chrysocephalum apiculatum* | common everlasting, yellow buttons |

| Scientific name | Common name |
|---|---|
| *Chrysocephalum semipapposum* | clustered everlasting, yellow buttons |
| *Commelina cyanea* | scurvy weed |
| *Cymbopogon refractus* | barbed wire grass |
| *Cymbopogon obtectus* | silky heads |
| *Desmodium varians* | slender tick-trefoil |
| *Dianella revoluta* | blueberry lily, blue flax-lily |
| *Dichondra repens* | kidney weed |
| *Echinopogon caespitosus* var. *caespitosus* | tufted hedgehog grass |
| *Echinopogon intermedius* | erect hedgehog grass |
| *Einadia hastata* | berry saltbush, saloop |
| *Einadia trigonos* | fishweed |
| *Eragrostis brownii* | Brown's lovegrass |
| *Entolasia stricta* | wiry panic |
| *Eucalyptus blakelyi* | Blakely's red gum |
| *E. blakelyi / tereticornis* intergrade | Blakely's red gum - forest red gum intergrade |
| *Eucalyptus crebra* | narrow leaved ironbark |
| *E. moluccana* | grey box |
| *Exocarpos cupressiformis* | native cherry |
| *Exocarpos strictus* | pale-fruit ballart, dwarf cherry |
| *Glycine clandestina* | twining glycine |
| *Glycine tabacina* | variable glycine |
| *Grevillea montana* | mountain grey grevillea |
| *Hardenbergia violacea* | false sarsaparilla |
| *Hibbertia linearis* | guinea flower |
| *Hovea linearis* | narrow leaf hovea |
| *Hypoxis hygrometrica* var. *hygrometrica* | golden weather-grass |
| *Imperata cylindrica* | blady grass |
| *Indigofera australis* | austral indigo |
| *Jacksonia scoparia* | dogwood |
| *Leucopogon muticus* | blunt beard-heath |
| *Lomandra confertifolia* | mat rush |
| *Lomandra glauca* | pale mat-rush |
| *Lomandra leucocephala* | woolly mat rush |
| *Lomandra multiflora* subsp. *multiflora* | many flowered mat rush |

| Scientific name | Common name |
|---|---|
| *Melaleuca decora* | white feather, honeymyrtle |
| *Melaleuca thymifolia* | thyme honey-myrtle |
| *Microlena stipoides Var. stipoides* | weeping (meadow) grass |
| *Notelaea neglecta* | - |
| *Panicum effusum* | hairy panic |
| *Persoonia linearis* | narrow-leaved geebung |
| *Perotis rara* | comet grass |
| *Pimelea linifolia* subsp. *linifolia* | slender rice flower |
| *Podolepis hieracioides* | long podolepis |
| *Pomax umbellata* | pomax |
| *Pteridium esculentum* | bracken |
| *Solanum prinophyllum* | forest nightshade |
| *Vittadinia sulcata* | furrowed New Holland / native daisy |

**Table B2. Fauna species that may occur in the Warkworth Sands Woodland.** Scientific names are as at March 2016. Source: Peake (2006); Somerville (2009); Umwelt (2013).

| Scientific name | Common name |
|---|---|
| **Reptiles** | |
| *Hoplocephalus bitorquatus* | pale-headed snake |
| *Varanus varius* | lace monitor |
| **Amphibians** | |
| *Heleioporus australiacus* | giant burrowing frog |
| *Litoria aurea* | green and golden bell frog |
| **Birds** | |
| *Anthochaera phrygia* | regent honeyeater |
| *Acanthiza nana* | yellow thornbill |
| *Acanthiza pusilla* | brown thornbill |
| *Acanthorhynchus tenuirostris* | eastern spinebill |
| *Burhinus grallarius* | bush stone-curlew |
| *Cacatua galerita* | sulphur-crested cockatoo |
| *Callocephalon fimbriatum* | gang-gang cockatoo |
| *Certhionyx variegatus* | pied honeyeater |
| *Chthonicola sagittata* | speckled warbler |
| *Circus assimilis* | spotted harrier |

| Scientific name | Common name |
|---|---|
| *Climacteris picumnus victoriae* | brown treecreeper (eastern subspecies) |
| *Corcorax melanorhamphos* | white-winged chough |
| *Cormobates leucophaeus* | white-throated treecreeper |
| *Cracticus tibicen* | Australian magpie |
| *Daphoenositta chrysoptera* | varied sittella |
| *Dicaeum hirundinaceum* | mistletoe bird |
| *Eopsaltria australis* | eastern yellow robin |
| *Falco subniger* | black falcon |
| *Grantiella picta* | painted honeyeater |
| *Hamirostra melanosternon* | black-breasted buzzard |
| *Hieraaetus morphnoides* | little eagle |
| *Lathamus discolor* | swift parrot |
| *Lophoictinia isura* | square-tailed kite |
| *Manorina melanocephala* | noisy miner |
| *Melanodryas cucullata cucullata* | hooded robin (south-eastern form) |
| *Melithreptus gularis gularis* | black-chinned honeyeater (eastern subsp.) |
| *Neochmia temporalis* | red-browed finch |
| *Neophema pulchella* | turquoise parrot |
| *Ninox connivens* | barking owl |
| *Ninox novaeseelandiae* | southern boobook |
| *Ninox strenua* | powerful owl |
| *Pardalotus punctatus* | spotted pardalote |
| *Parvipsitta pusilla* | little lorikeet |
| *Petroica boodang* | scarlet robin |
| *Petroica phoenicea* | flame robin |
| *Platycercus eximius* | eastern rosella |
| *Pomatostomus temporalis temporalis* | grey-crowned babbler (eastern subspecies) |
| *Rhipidura albiscapa* | grey fantail |
| *Stagonopleura guttata* | diamond firetail |
| *Tyto longimembris* | eastern grass owl |
| *Tyto novaehollandiae* | masked owl |
| **Mammals** | |
| *Antechinus stuartii* | brown antechinus |
| *Cercartetus nanus* | eastern pygmy possum |

| Scientific name | Common name |
|---|---|
| *Chalinolobus dwyeri* | large-eared pied bat |
| *Dasyurus maculatus maculatus* | spotted-tail quoll |
| *Falsistrellus tasmaniensis* | eastern false pipistrelle |
| *Miniopterus australis* | little bentwing bat |
| *Miniopterus schreibersii oceanensis* | eastern bentwing bat |
| *Myotis macropus* | southern myotis |
| *Nyctophilus corbeni* | Corben's long-eared bat |
| *Petaurus australis* | yellow-bellied glider |
| *Petaurus breviceps* | sugar glider |
| *Petaurus norfolcensis* | squirrel glider |
| *Petrogale penicillata* | brush-tailed rock wallaby |
| *Phascogale tapoatafa* | brush-tailed phascogale, tuan |
| *Phascolarctos cinereus* | koala |
| *Pseudomys novaehollandiae* | New Holland mouse |
| *Pteropus poliocephalus* | grey-headed flying fox |
| *Rattus fuscipes* | bush rat |
| *Saccolaimus flaviventris* | yellow-bellied sheathtail bat |
| *Scoteanax rueppellii* | greater broad-nosed bat |
| *Tachyglossus aculeatus* | short-beaked echidna |
| *Trichosurus vulpecula* | brushtail possum |
| *Vespadelus troughtoni* | eastern cave bat |
| *Vombatus ursinus* | common / bare nosed wombat |

**Table B3. Weed species[17] recorded in the Warkworth Sands Woodland**. Scientific names are nationally accepted names as per the Australian Plant Census as at March 2016. Source: Somerville (2009); Bell (2012); Umwelt (2013); Gross and Vary (2014).

| Common Name | Scientific Name |
|---|---|
| - | *Cyperus aggregatus* |
| - | *Juncus cognatus* |
| - | *Plantago myosuros* |
| - | *Verbena quadrangularis* |
| African boxthorn | *Lycium ferocissimum* |
| African lovegrass | *Eragrostis curvula* |
| annual cat's tail | *Rostraria cristata* |
| annual trampweed | *Facelis retusa* |
| bindyi, burrweed, jo-jo, | *Soliva sessilis* |
| blackberry nightshade | *Solanum nigrum* |
| blue heliotrope, wild verbena, turnsole | *Heliotropium amplexicaule* |
| blue/ scarlet pimpernel | *Anagallis arvensis* (syn. Lysimachia arvensis) |
| Brazilian/ Chilean whitlow (wort) | *Paronychia brasiliana* |
| Cape daisy/ dandelion/ marigold/ weed | *Arctotheca calendula* |
| catsear, long-rooted catsear, flatweed, false dandelion | *Hypochaeris radicata* |
| catsear, smooth catsear | *Hypochaeris glabra* |
| century weed | *Centaurium tenuiflorum* |
| clover [(yellow) suckling] | *Trifolium dubium* |
| clover [drooping-flower] | *Trifolium cernuum* |
| clover [haresfoot] | *Trifolium arvense* |
| clover/ trefoil [subterranean/ burrowing] | *Trifolium subterraneum* |
| clover [white eye, Mexican] | *Richardia brasiliensis* |
| cobbler's pegs, farmer's friend | *Bidens pilosa* |
| common prickly pear | *Opuntia stricta* |
| creeping pear | *Opuntia humifusa* |
| cudweed | *Gamochaeta americana* |
| cudweed | *Gamochaeta pensylvanica* |
| cudweed, silky cudweed | *Gamochaeta calviceps* |

[17] Plants, or their seed's, were recorded at Warkworth Sands Woodland sites.

| Common Name | Scientific Name |
|---|---|
| dandelion | *Taraxacum officinale* |
| field madder | *Richardia stellaris* |
| fireweed | *Senecio madagascariensis* |
| fleabane | *Conyza parva* (syn. *Conyza canadensis*) |
| fleabane, flaxleaf fleabane | *Conyza bonariensis* |
| four-leaved / four-leaf allseed | *Polycarpon tetraphyllum* |
| galenia | *Galenia pubescens* |
| greater beggar's ticks | *Bidens subalternans* |
| green cestrum | *Cestrum parqui* |
| jacaranda | *Jacaranda mimosifolia* |
| lantana | *Lantana camara* |
| lesser swinecress, wartcress | *Coronopus didymus* (syn. *Lepidium didymium*) |
| mullein [twiggy/ green] | *Verbascum virgatum* |
| narrow-leaved cotton bush | *Gomphocarpus fruticosus* |
| onion grass | *Romulea rosea* |
| Paddy's lucerne | *Sida rhombifolia* |
| pale pigeon grass | *Setaria pumila* |
| paspalum | *Paspalum dilatatum* |
| peppercress, cut-leaf/ cutleaved/ argentine pepper cress/ weed/ wort, birdseed | *Lepidium bonariense* |
| prairie grass | *Bromus brevis* |
| red Natal grass | *Melinis repens* |
| Rhodes grass | *Chloris gayana* |
| saffron thistle | *Carthamus lanatus* |
| shivery / little-quaking grass | *Briza minor* |
| slender celery | *Cyclospermum leptophyllum* |
| slender pigeon grass | *Setaria parviflora* |
| sour dock, (horse/ sheep) sorrel | *Acetosella vulgaris* (syn. *Rumex acetosella*) |
| sowthistle, prickly sowthistle | *Sonchus asper* |
| spear thistle | *Cirsium vulgare* |
| stinking roger, southern marigold | *Tagetes minuta* |
| tiger pear | *Opuntia aurantiaca* |
| velvet mesquite | *Petrorhagia velutina* (syn *Petrorhagia dubia*) |
| wall fescue | *Vulpia muralis* |
| winter cherry | *Withania somnifera* |

**Table B4. Animal pest species likely to occur in the Warkworth Sands Woodland**. Scientific names are as at March 2016. Source: Bell (2012); Umwelt (2013); Vary and Gross (2012).

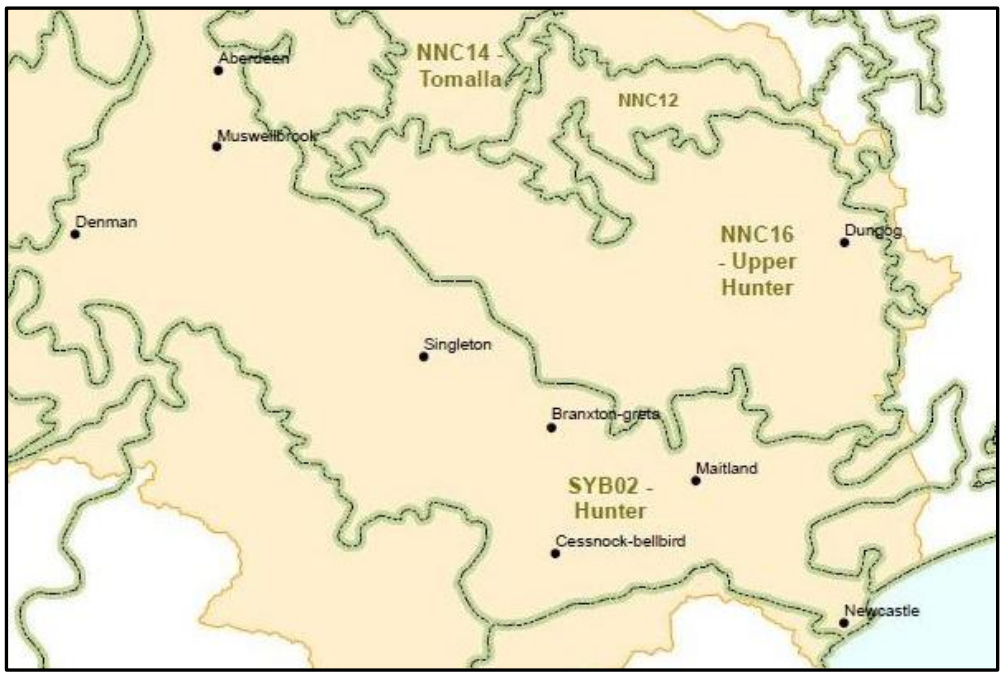
| Common Name | Scientific Name |
|---|---|
| cat | *Felis catus* |
| common hoverfly | *Melangyna viridiceps* |
| common myna | *Acridotheres tristis* |
| common starling | *Sturnus vulgaris* |
| dog | *Canis lupus* |
| European honeybee | *Apis mellifera* |
| European rabbit | *Oryctolagus cuniculus* |
| hare | *Lepus capensis* |
| house mouse | *Mus musculus* |
| red fox | *Vulpes vulpes* |

## APPENDIX C - NATIONAL CONTEXT AND RELATIONSHIP TO OTHER VEGETATION CLASSIFICATION SYSTEMS

### C1 Distribution

The Warkworth Sands Woodland occurs in the Hunter Valley region, in the north east of the Sydney Basin IBRA[18] Bioregion, in the Hunter Valley IBRA subregion (SYB02). It occupies a small area near the town of Warkworth, south west of Singleton (and near Bulga), in the Singleton Local Government Area; it does not occur elsewhere in the Hunter Region, in New South Wales; nor elsewhere in Australia (Peake et al., 2002; Peake, 2006; Bell, 2012; NSW OEH, 2012). This area is in the Hunter River catchment, in the Hunter Local Land Service region.

***Figure C1. The Hunter Valley IBRA subregion***. Source: DSEWPAC (2012).




### C2 Landscape and soils

The Hunter Valley region is at the intersection of a number of bioregions, where ecosystems from the coast, inland and the north and south all meet. The region is bounded on the north east by the Hunter Thrust Fault and on the south by cliffs of Narrabeen Sandstone. It is characterised by low, rolling hills and wide valleys, with a meandering river system on a wide flood plain. The geology of the Hunter Valley region's landscape includes Permian shales, sandstones, conglomerates, volcanics and coal measures. These formations are dissected by unconsolidated alluvial deposits associated with the Hunter River system (Nashar, 1964; Tame, 1992; NSW DMR, 1999). Much of the region, particularly areas with Permian sedimentary bedrock, has extensive coal deposits. There are a variety of harsh texture contrast (duplex) soils on the slopes; and deep sandy alluvial loam on the valley floors (Morgan, 2001 in NSW NPWS, 2003).

[18] IBRA: Interim Biogeographical Regionalisation of Australia [Version 7 – 2012] in DSEWPAC (2012).

The Warkworth Sands Woodland occurs on aeolian sand deposits west of Singleton (Story et al., 1963; Bell, 2012), part of the Warkworth Land System / Warkworth soil landscape. The ecological community occupies linear sand dunes, which are generally between one and six metres high, typically resting on a river terrace; the main dune deposit is aligned NW-SE (Story et al., 1963; Kovac and Lawrie, 1991). The sand dunes at Warkworth likely formed some 18 000 to 15 000 years ago from the sandy alluvium of Wollombi Brook, a tributary of the Hunter River (Galloway, 1963). Story et al. (1963) noted that the dunes are generally stable but are subject to blow-outs[19].

The Warkworth soil landscape is perched on a shallow ephemeral alluvial aquifer, which is perched above a low permeability base of residual clay associated with the underlying strata. The soil has low fertility, is rapidly drained and has a low available water-holding capacity. The ecological community probably extracts groundwater from the underlying shallow aquifer and hence is at risk from activities that impact the sand sheet (Umwelt, 2013).

Benson (1981) notes that as well as the deeper sand deposits, there is a shallow "veneer" of sand continuing southward from the north-west end of the main sand deposit. This is separated from the main deposit by an area of clay soils developed on Permian sediments. An area of similar "sandy veneer" occurs about 2 km north-east of the main deposit (to the north of the intersection between the Golden Highway and Long Point Road) (Benson, 1981 in Bell, 2012 and in Peake et al., 2002). Native vegetation on both areas of sandy veneer are part of the ecological community, with characteristic species such as *Banksia integrifolia* subsp. *integrifolia* (coast banksia), *Acacia filicifolia* (fern-leaved wattle) and *Angophora floribunda* (rough-barked apple); albeit in reduced abundance (Peake et al., 2002).

### C3 Relationship to other vegetation classification systems

Keith (2004) includes the Warkworth Sands vegetation in the broader Sydney Sand Flats Dry Sclerophyll Forests vegetation class and notes that the few communities comprising this particular vegetation class are unique to the Sydney and Hunter regions.

The ecological community wholly or partially corresponds to a range of vegetation / map units identified by a number of surveys, mapping projects and databases covering the Hunter Valley region.

Additional/updated information on vegetation classification, subsequent to publication of this an approved Conservation Advice for this ecological community, may be published on the Species Profile and Threats Database (SPRAT) profile for this ecological community, on the Department's website at: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

[19] Blowouts: Sandy depressions formed when a patch of protective vegetation in a sand dune ecosystem is lost and strong winds "blow out" sand to form a depression.

The ecological community corresponds wholly or partially to the following vegetation/map units:

- **MU14** Warkworth Sands Woodland (Peake, 2006);
- **MU 124** Rough-barked Apple/ Narrow-leaved Ironbark/Blakely's Red Gum/ Bull Oak/ Coast Banksia/Bracken woodland of Warkworth area (Somerville, 2009);
- **HU600** Rough-barked Apple - Coast Banksia shrubby woodland on Warkworth Sands of the central Hunter Valley, Sydney Basin (**Plant Community Type ID 1112** superseded[20]) (NSW OEH, 2008a); and
- **HU872** (PCT ID 1658[21]) Rough-barked Apple - Narrow-leaved Ironbark - Blakely's Red Gum - Bull Oak - Coast Banksia woodland on sands of the Warkworth area (NSW OEH, 2015).

Areas of the vegetation classifications above **that meet the *Key diagnostic characteristics* (in Section 1.5.1)** are considered to be part of the Warkworth Sands Woodland.

***C4 Differences to similar or intergrading national ecological communities***

The Warkworth Sands Woodland occurs on a highly restricted sand mass. Consequently, it is floristically distinct from other vegetation in the local area which is predominantly various associations of *Eucalyptus albens* (white box), *Eucalyptus moluccana* (grey box), *E. crebra* (narrow-leaved ironbark) and *Corymbia maculata* (spotted gum) (Peake et al., 2002). Warkworth Sands Woodland has also been shown to have a different floristic composition, particularly as regards the suite of dominant species, to other sand-based vegetation communities of the Sydney Basin Bioregion.

*Central Hunter Valley eucalypt forest and woodland*

The nationally listed Critically Endangered Central Hunter Valley eucalypt forest and woodland ecological community occurs adjacent to the Warkworth sand dunes, on Permian clays and shares many species with Warkworth Sands Woodland; however, it has an abundance of Permian substrate species, such as *Corymbia maculata* (spotted gum), *Eucalyptus moluccana* (grey box), *Allocasuarina luehmannii* (bulloak, buloke) and *E. crebra* (narrow leaved ironbark) (TSSC, 2015a).

[20] NSW OEH (2008a) 'Biometric Vegetation Types (BVTs) for CMA areas' have been superseded by the NSW Vegetation Information System (VIS) Classification 2.1 BVTs (NSW OEH, 2015).

[21] The NSW Plant Community Type (PCT) classification, established as the NSW master community-level classification, was only recently updated with a new vegetation classification for the Greater Hunter region.

*White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland*

Warkworth Sands Woodland intergrades and shares characteristics (e.g. some ground layer species) with the nationally listed Critically Endangered White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland ecological community (also referred to as the 'Box - Gum Grassy Woodland ecological community'), which also occurs in the Hunter region. However the tree layers of the two ecological communities typically have a different species composition; and the Box - Gum Grassy Woodland ecological community is more typically grassy, with a shrub cover limit of 30% (TSSC, 2006).

The canopy (where present) of Box – Gum Grassy Woodland ecological community is dominated by *Eucalyptus albens* (white box), *E. melliodora* (yellow box), or *E. blakelyi* (Blakely's red gum) (TSSC, 2006).

*Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion*

The nationally listed Endangered Castlereagh Scribbly Gum and Agnes Banks Woodlands ecological community does not occur in the Hunter Valley. It occurs further south; primarily in the Castlereagh area in the north-west of the Cumberland Plain, with other known occurrences just outside the Cumberland sub-region. The ecological community occurs primarily on ancient alluvial soils, the Tertiary sands and gravels of the Hawkesbury-Nepean river system (TSSC, 2015b).

The canopy contains, and is often dominated by, one or more of the following species: *Angophora bakeri* (narrow-leaved apple), *Eucalyptus parramattensis* subsp. *parramattensis* (Parramatta red gum) and *E. racemosa* (syn. *E. sclerophylla*) (scribbly gum, narrow-leaved scribbly gum). *Eucalyptus fibrosa* (red ironbark) is also occasionally prominent in the canopy. In addition, the Agnes Banks vegetation occurs on aeolian sand and can contain a number of species reminiscent of communities closer to the coast, such as *Banksia aemula* (wallum), *Dillwynia glaberrima* and *Ricinocarpos pinifolius* (wedding bush) (TSSC, 2015b).

As well as the different dominant characteristic canopy species, other tree species such as *Callitris endlicheri* (black cypress-pine) and *Exocarpos cupressiformis* (native cherry), *Brachychiton populneus* subsp. *populneus* (kurrajong), *Allocasuarina luehmannii* (bull oak) also make Warkworth Sands Woodland distinct from Castlereagh Scribbly Gum and Agnes Banks Woodlands.

*Elderslie*[22] *Banksia Scrub Forest of the Sydney Basin Bioregion* [23]

This low scrub-forest or woodland is listed under the NSW TSC Act and does not occur in the Hunter Valley. It occurs to the south west of Sydney, south of Camden near the Nepean River. It occurs on older coastal aeolian sand deposits on the Cumberland Plain. Its canopy is dominated by *Banksia integrifolia* subsp. *integrifolia* (coast banksia), or *Eucalyptus botryoides* (bangalay) in some wetter areas, and may contain *Angophora subvelutina* (broad-barked apple), *E. baueriana* (blue box) and/or *Melaleuca decora* (Tozer et al., 2010; NSW Scientific Committee, 2014). Of these, only *Banksia integrifolia* subsp. *integrifolia* is also a characteristic species of Warkworth Sands Woodland.

Other characteristic species of Elderslie Banksia Scrub Forest, which differentiate it from Warkworth Sands Woodland include: *Acacia decurrens* (Sydney green wattle), *A. implexa* (hickory wattle), *A. ulicifolia* (prickly moses), *Aotus ericoides* (common aotus), *Clerodendrum tomentosum* (hairy clerodendrum), *Dillwynia glaberrima* (smooth-leaved dillwynia), *Duboisia myoporoides* (corkwood), *Hibbertia diffusa* (wedge guinea flower), *Gleichenia dicarpa* (pouched coral fern, tangle fern), *Kunzea ambigua* (tick bush), *Platysace lanceolata* (shrubby platysace) and *Ricinocarpos pinifolius* (wedding bush).

[22] Here 'Elderslie' refers to Elderslie of the Cumberland Plain region, not Elderslie of the Hunter Valley.

[23] Under EPBC Act Assessment as a potentially threatened ecological community.

## APPENDIX D – DESCRIPTION OF THREATS

The ecological community has suffered substantial damage in the past, largely associated with loss and degradation of vegetation. A range of ongoing threats interact in complex ways to reduce the integrity, functioning and recovery of the ecological community and its resilience to future impacts.

Mining development and grazing, along with the construction and maintenance of infrastructure have resulted in the clearing, degradation and modification of large areas of the ecological community. These activities continue to impact the ecological community; with clearance associated with mining the primary ongoing threat.

Because of past clearing much of the ecological community is regrowth and thus younger than fully mature woodlands. Immature regrowth provides less habitat resources, such as tree hollows or mature flowering resources. This increases the importance of remaining older regrowth or unmodified areas of this ecological community. Key threats to fauna assemblages include: cumulative habitat loss; fragmentation (affecting species that are unable to cross large open patches, such as the NSW threatened *Pomatostomus temporalis* (grey-crowned babbler); and loss of mature trees with hollows (affecting numerous threatened hollow-dependent species such as *Petaurus norfolcensis* (squirrel glider)). Various other key threatening processes apply to this ecological community (see Section 2.1 *Summary of Key Threatening Processes*).

### D1 Vegetation clearing and landscape fragmentation

Agriculture and mining have been the main drivers of clearing in the Hunter region. Much of the Warkworth Land System that supports the Warkworth Sands Woodland ecological community has been overwhelmingly cleared of native vegetation. Some areas have been lost to mining operations, while other areas are grazing lands (Peake, 2006; Umwelt, 2011; Bell, 2012). The vast majority of the ecological community now occurs on land managed by mining companies (Umwelt, 2011).

The median average size of patches of the ecological community is less than 3 ha; and most patches (at least 70%) are less than 10 ha in size. Small, isolated fragments are less buffered against disturbances, such as invasion by weeds (Tozer, 2003; Cuneo et al., 2009), or other impacts from surrounding activities, such as agricultural spray drift and dust from mining. Small, isolated fragments can also be subject to increased predator pressure on native fauna such as small mammals and lizards (Anderson and Burgin, 2002).

#### *Agriculture*

Pressures from agricultural clearing are an ongoing threat to the ecological community (NSW Scientific Committee, 2011; Bell, 2012). Remaining areas of the ecological community are fragmented, modified and isolated and are now much less resilient to on-going impacts; whereas previously they had been part of more continuous and durable woodland system.

Changes in soil structure, hydrology and nutrient levels as a consequence of land use practices can also lead to more favourable conditions for weeds. The use of herbicides and pesticides to control weeds and agricultural pests can disrupt natural food webs and hence impact many flora

and fauna species. Spray drift from surrounding agricultural activities is a larger potential problem, now that patches of the ecological community are more fragmented.

### *Mining*

Although coal was discovered early on during settlement of the Hunter Valley, it was not until the mid 1900s, with the development of mechanical mining equipment that a major shift in land use began. A global resources boom in the more recent past has lead to significant expansion of mining operations in the Hunter Valley to meet the demand for coal.

Land clearing is the most obvious impact of mining, particularly open-cut mining. Once vegetation is cleared and topsoil stripped these areas cannot easily be recovered to a pre-mining state. In the case of the Warkworth Sands woodland, there is no history of re-establishing the ecological community through post-mine rehabilitation (Umwelt, 2011); however a University of New England research programme supported by Rio Tinto Coal Australia on the restoration of Warkworth Sands Woodland is ongoing.

In addition to mine sites, further clearing and modification occurs in order to provide service infrastructure for mining activities (roads, pipelines, rail etc). More broadly, mining can lead to the disruption of hydrological processes, erosion and changes to soil structure and chemistry, all of which negatively impact the landscape and potentially the ecological community. Direct impacts on flora and fauna, from the heavy machinery employed, include road kills along service roads, felling of habitat trees and crushing of fallen logs during clearing. Indirect impacts include fuel spills, import of weed seed material, erosion, noise, dust and light (Beltana Highwall Mining, 2008).

Mining activities have the potential to introduce new weeds and facilitate the spread of existing ones. Mining and other land clearing activities in the Central Hunter Valley have resulted in the proliferation of exotic species, including: African boxthorn (*Lycium ferocissimum*), African lovegrass (*Eragrostis curvula*), bridal creeper (*Asparagus asparagoides*), fireweed (*Senecio madagascariensis*), galenia (*Galenia pubescens*), kikuyu (Pennisetum *clandestinum*) and Rhodes grass (*Chloris gayana*) (NCC, 2014). Increased runoff from impermeable surfaces (such as road infrastructure) can change stream flow patterns, causing erosion. It can penetrate adjacent bushland and carry high nutrient and sediment loads, which can further encourage weed invasion.

Clearing the ecological community for mining activities continues, despite the ecological community being listed as threatened under the NSW *Threatened Species Conservation Act 1995*. In November 2015, an expansion of the Warkworth mine complex was approved. This approval included clearing 72 ha of the ecological community in the Warkworth district over the next two decades (NSW PAC, 2015b). This represents a 15-18% loss of the total remainder of the ecological community (Umwelt, 2011; Bell, 2012). Further, the area approved for clearance will remove much of the highest quality Warkworth Sands Woodland ecological community (up to half), leaving mostly medium and low condition remnants (Bell, 2012). Clearing large areas (such as the planned removal of 72ha) within the remnant woodland that supports the largest and best occurrences of the ecological community will result in a substantially increased reliance on smaller, less resilient remnants of the ecological community (Umwelt, 2011). The second review of the Warkworth Continuation Project concluded that this loss was likely to increase the risk of

extinction of the ecological community (NSW PAC, 2015a). There is the potential for further clearance as a consequence of decisions made under the Upper Hunter Strategic Assessment for Coal Mines.

**D2 Invasive flora species**

Weed incursion in the region is associated with agricultural activities, mining and residential development. Clearing and grazing over many decades has altered ground cover, diminished perennial native grasses and changed water dynamics in the landscape. This has made the ecological community vulnerable to invasive species.

Weed invasion is a serious threat, particularly given the diversity of non-native species occurring along abutting roadsides and open cut coal mines. Weeds compete with locally indigenous flora species for available resources (water, light, nutrients) and lead to a decline in the diversity and regenerative capacity of a native ecosystem. This in turn, impacts on habitat values for woodland fauna by affecting the type and availability of resources such as food (e.g. nectar, seeds and fruit), shelter from predators, or weather and nesting sites.

A range of woody and herbaceous weeds have become established in the ecological community and surrounding environment including: common prickly pear (*Opuntia stricta*), fireweed (*Senecio madagascariensis*), lantana (*Lantana camara*), Rhodes grass (*Chloris gayana*) and tiger pear (*Opuntia aurantiaca*). Other invasive weed species that threaten the ecological community include: African boxthorn (*Lycium ferocissimum*), catsear (*Hypochaeris radicata*), creeping pear (*Opuntia humifusa*), field madder (*Richardia stellaris*), galenia (*Galenia pubescens*), green cestrum (*Cestrum parqui*), Paddy's lucerne (Sida rhombifolia), red Natal grass (*Melinis repens*) and *Verbena quadrangularis* (Somerville, 2009; Bell, 2012; Umwelt, 2013; Gross and Vary, 2014). A more comprehensive list of weed species recorded in the ecological community is in Appendix B *Species lists* (Table B3).

Invasion of native plant communities by aggressive weedy shrub lantana, exotic perennial grasses (including Rhodes grass) and exotic vines and scramblers are all listed as Key Threatening Processes in NSW because of the impacts they have on native plants and on birds, reptiles and invertebrate species dependent on native vegetation.

Lantana typically forms dense thickets, suppressing native vegetation and seedlings through shading, nutrient competition, smothering and allelopathy. It readily invades disturbed sites. In open forests and woodlands lantana often becomes a dominant understory species if not managed appropriately. Bell (2012) notes that south of Warkworth, extensive aggressive weedy shrubs have dramatically altered the understorey of parts of the Warkworth Sands Woodland ecological community.

African boxthorn is an aggressive invader of pastures, roadsides, reserves, remnant bushland and waterways. It forms impenetrable, spiny thickets that provide a haven for feral animals. Galenia was introduced to Australia as a stabilizing species for mining areas and there is a concentration of the species in the Hunter Valley area. Galenia grows over the top of native vegetation and has the potential to smother plants and prevent germination of other species (DoE, 2014).

Rhodes grass is a common weed of roadsides, having been extensively used in the past for stabilising open-cut mine overburden dumps and rehabilitated areas. It spread into native

pastures and in particular into disturbed woodland areas and causes significant modification of ground cover (Peake, 2006).

Bell (2012) also notes a site, formerly classified as high quality Warkworth Sands Woodland by Bower (2004), as being heavily infested by red ash (*Alphitonia excelsa*). Although native to Australia, red ash was probably planted as part of former land uses, and is aggressively spreading in the local area and altering the structure and floristics of the natural vegetation. Red ash has been reported elsewhere to become invasive from plantings (Daehler and Baker, 2006).

**D3 Altered fire regimes**

The term 'fire regime' describes the average fire characteristics and patterns for a given area during a particular time period. It includes: fire intensity, frequency, seasonality and extent of patchiness. All of these characteristics influence vegetation composition and structure as well as the success of weed invasions and the subsequent impacts on native biota. Reciprocally, the fuel properties of plants within an ecological community affect fire regime characteristics (Mandle et al., 2011).

Fire has been excluded from a number of areas of the ecological community since 1950, including high quality sites (Gross and Vary, 2014); it is likely to have affected the balance of flora species and of fauna species in those areas. Different vegetation types respond to fire in different ways: some plants are killed, others resprout; many plants release seed only post-fire or after plant death; the timing, intensity and duration of fire can be critical to native vegetation (Bell, 2014).

The broader landscape context is also important for ecological response to disturbances such as fire, with unburnt areas providing refuge and source populations for recovery (Recher et al, 2009). Flora and fauna populations in isolated patches may be vulnerable to permanent extinction following severe fire.

Perennial exotic grasses, such as those now infesting the ecological community, produce large amounts of plant matter which dries quickly and causes fuel loads to increase. This fuel load results in fire regimes that favour the spread of these perennial weeds. Hotter fires may lead to changes in the structure of vegetation and in some cases to local extinctions of some plant and animal species (NSW DEC, 2014).

**D4 Climate change**

Climate change poses a serious long-term threat to terrestrial and aquatic ecosystems with the potential to change the ecology of these environments through changes to species composition and function (Dunlop et al., 2012). The very restricted distribution of the ecological community greatly increases its vulnerability to the effects of a changing climate (for example, because movement of native species is limited).

CSIRO (2007) investigated the vulnerability of the Hunter-Central Rivers catchment to the impacts of climate change. The report concluded that changes will have significant impacts on the area's plants and animals. Risks include:

- plants and animals becoming ‘stranded’ in isolated remnants of vegetation as climate zones change, due to a lack of suitable habitat for migration
- changes in the distribution of tree species and associated habitat
- possible increased pest invasions
- more frequent droughts and fires
- increased severe storm events.

Warkworth Sands Woodland is an endemic ecological community. It occurs across a range that is naturally very short (20km) (Umwelt, 2011). Ecological communities with short ranges are naturally more susceptible to landscape-scale changes. They frequently have no place, over time, to migrate to as a result of landscape-scale changes, such as those predicted to occur because of climate change. (Umwelt, 2011).

Further, the long generation time and limited dispersal ability of some key species, such as canopy trees, are likely to limit adaptation through range shift. In addition to threatening species that cannot adapt, climate change could also exacerbate existing threats such as habitat loss and the spread of invasive species.

## APPENDIX E – ELIGIBILITY FOR LISTING AGAINST THE EPBC ACT CRITERIA

### Criterion 1 - Decline in geographic distribution

This criterion refers to a past decline in the geographic distribution of the ecological community, typically since before European settlement in Australia circa 1750. Changes in the extent of the ecological community are difficult to quantify due to poor historical data and changes in mapping techniques between surveys (Peake, 2006; NSW Scientific Committee, 2011; Umwelt, 2011; Bell, 2012). Two of the most recent estimates of pre-European extent, current extent and decline for the ecological community are summarised in Table E1.

**Table E1: Recent estimates of pre-European extent, current extent and decline for Warkworth Sands Woodland.** Source: Umwelt (2011); Bell (2012).

| Source | Estimated pre-European area (ha) | Estimated current area (ha) | Estimated percentage loss / decline in extent |
|---|---|---|---|
| Umwelt (2011) | 3,038 | 465 | 85% |
| Bell (2012) | 800 | 400 | 50% |

Bell considers his overall extent estimates (2012) to supersede those of Umwelt (2011) and explains the discrepancy between the two estimates as being due to further floristic analysis of remnant vegetation and the use of finer scaled mapping of aeolian (windblown) sands in this part of the Central Hunter Valley; the latter resulting in a five-fold reduction in the estimated land area capable of supporting the ecological community.

According to recent estimates, the ecological community has undergone a decline of at least 50% over the long term, see Table E1. The decline in extent of the Warkworth Sands Woodland has been due largely to clearing for grazing and mining activities; this has resulted in fragmentation, weed invasion and degradation of the remaining patches of the ecological community.

#### *Conclusion*

Based on the above estimates, the ecological community is considered to have undergone at least a substantial decline (at least 50%) in its geographic extent and is therefore **eligible** for listing as **vulnerable** under this criterion.

**Criterion 2 - Limited geographic distribution coupled with demonstrable threat**

The purpose of this criterion is to recognise that an ecological community with a distribution that is currently limited has an inherently higher risk of extinction if it is subject to a threatening process.

Thresholds to identify terrestrial vegetation communities with limited distributions are typically based on three indicative measures:

1. extent of occurrence – an estimate of the total geographic range of the ecological community;
2. area of occupancy – an estimate of the area actually occupied by the ecological community (which generally equates with its present extent); and
3. patch size distribution – an indicator of the degree of fragmentation of the ecological community and the vulnerability of small patches to particular threats.

The highest category met (i.e. indicating the most restricted distribution), against any one of these measures, is applied in the assessment of the criteria to determine the conservation status of the ecological community.

***Extent of occurrence***

The ecological community has an estimated total extent of occurrence of 6,000 – 7,000 ha (DoE 2016). This indicates a very restricted geographic distribution (of less than 10,000 ha).

***Area of occupancy***

The estimated area of occupancy of the ecological community is 400 - 465 ha (Umwelt, 2011; Bell, 2012). This indicates a very restricted geographic distribution (of less than 1,000 ha).

***Patch size distribution***

Previously, there were larger patches of the ecological community, such that it was better connected across its extent of occurrence. Clearing has resulted in the ecological community becoming mostly small remnants; with an estimated median average patch size of less than 3 ha (Table E2); most of the patches (at least 70%) are less than 10 ha in size (Table E3) (DoE, 2016). These values indicate that the Warkworth Sands Woodland has a very restricted geographic distribution (patch sizes of less than 10 ha).

**Table E2. Patch size distribution for the Warkworth Sands Woodland.** Source: DoE (2016) based on Peake (2006), Umwelt (2011) and Bell (2012).

| **Number of patches in the size range** | | | **Total number of patches** | **Median average patch size (ha)** |
|---|---|---|---|---|
| **0.1 – 10 ha** | **> 10 - 100 ha** | **>100 ha** | | |
| 20 | 8 | 0 | 28 | 2.6 |

**Table E3. Summary of patch size distribution for the Warkworth Sands Woodland.** Source: DoE (2016) based on Peake (2006), Umwelt (2011) and Bell (2012).

| EPBC Act listing criteria thresholds | | Patch size range (ha) | No. of patches | Percentage of patches |
|---|---|---|---|---|
| **Restricted** | **Very Restricted** | **0.1 - 10** | 20 | 71% |
| | | **> 10 - 100** | 8 | 29% |
| | | **> 100** | 0 | |
| | | **Total** | 28 | |

***Demonstrable and ongoing threats***

The landscape within which the Warkworth Sands Woodland ecological community occurs is subject to a matrix of land uses, primarily: mining, agricultural, livestock and horticultural activities, rural-residential housing and urban use. As detailed in Appendix D (*Description of Threats*), the ecological community is subject to a range of ongoing demonstrable threats; the key threat being land clearing. Several threats are interacting to reduce the integrity and functioning of the ecological community, as well as its resilience to future impacts. Further, the restorability of the ecological community is limited by the restricted area of occupancy of the ecological community, the very short range over which it occurs, the very specific substrate (aeolian sands) on which it occurs and the likely inability for the ecological community to migrate over time as an adaptation to probable climate change impacts.

***Conclusion***

The ecological community has a very restricted extent of occurrence (400 – 465 ha) and area of occupancy (6,000 – 7,000 ha). It has become mostly small and isolated remnants; with an estimated median average patch size of less than 3 ha; most of the patches (at least 70%) are less than 10 ha in size. These indicate a very restricted distribution. As detailed in Appendix D (*Description of threats*), the ecological community is subject to a range of ongoing demonstrable threats. Activities continue to impact the ecological community and the loss of area and condition compounds these impacts.

The distribution of the ecological community is considered to be **very restricted**. It is likely that the action of a threatening process could cause it to be lost in **the immediate future** (considered here as three generations of key canopy species; i.e.at least 45 years). Therefore, the ecological community is **eligible** for listing as **critically endangered** under this criterion.

**Criterion 3 - Loss or decline of functionally important species**

There is a lack of specific information about what ecological functions most species have in the ecological community. Similarly, the significant loss, or declines, of many individual species are largely undocumented; the exception being species that are listed or otherwise considered to be threatened.

Although studies specific to particular functional species in the ecological community are not available, it is known that relationships between species are important to maintain ecosystem functions.

Vegetative components of the ecological community provide food and habitat for faunal components of the ecological community. Canopy trees, such as *Angophora floribunda* (rough-barked apple) and *Eucalyptus blakelyi* (Blakely's red gum) provide nectar, a source of food for many species (including numerous invertebrates and mammals such as *Pteropus poliocephalus* (grey-headed flying fox)) and seed, which is eaten by parrots. Insectivorous birds forage in their foliage and a wide range of fauna utilise the hollows in older trees. Conversely, many of the vegetative components of the ecological community rely on fauna for pollen and seed dispersal.

There are no known locations where the ecological community is in pre-European condition (Umwelt, 2010). As such the ability of the ecological community to provide resources is diminished. For example, larger, more mature trees often contain hollows that provide habitat for fauna, but regrowth areas of the ecological community will have fewer mature trees and thus tree hollows. The delay in creating new hollows limits the functional recovery of the ecological community.

A decrease in patch size and connectivity of the ecological community has reduced its ability to support a natural and complete assemblage of birds; this in turn affects the vegetation. For example, a healthy bird community may remove 50 – 70% of leaf-feeding insects, thus playing an important role in maintaining the canopy of an ecological community (Ford, 1989 in Barrett, 2000).

The loss of mammal species from an ecological community also has negative consequences for ecological function, through the reduction of pollination, seed dispersal and soil engineering (Leary, 2007). Additionally, fundamental changes in nutrient inputs and hydrology (associated with land clearing and agriculture) cause physical, chemical and biological changes to woodland soils. These drive reductions in the abundance of soil and litter dwelling invertebrates, which are another major food source for many woodland birds (Watson, 2011).

***Conclusion***

Whilst threats have impacted functionally important species such as canopy trees, burrowing mammals and nomadic nectarivores, specific data related to the decline of particular species in this ecological community are not available. Also the functional roles of many species in the ecological community are not well documented. As such there is **insufficient information to determine the eligibility** of the ecological community for listing under any category of Criterion 3.

**Criterion 4 - Reduction in community integrity**

The ecological community occurs in an extensively cleared landscape and the primary cause of loss of integrity is clearing (for grazing and mining). Remaining areas of native vegetation in the region are mostly small patches that are severely fragmented and subject to further mine expansion and infrastructure development, as well as invasion by weeds. As in other ecological communities in the region faunal assemblages are depauperate. While little specific information is available on the roles played by species formerly present, it is likely that ecological function has been compromised by the loss of many soil engineers, pollinators and seed dispersers. Further damage to integrity is evident through changes in vegetation structure and the loss of key habitat features, such as large old trees with hollows which support faunal breeding. The long lag time to recover vegetation structure, with adequate representation of large old trees, suggests that recovery is unlikely in the near future. The intractability of other problems, such as the regional loss of fauna, further reduces the potential for recovery.

***Reduction in integrity through clearing and fragmentation***

The ecological community has been extensively cleared, severely compromising its integrity. The total area of the ecological community (estimated to have been 800 - 3,038 ha originally) is now an estimated 400 – 465 ha; a decline in extent of at least 50% (Umwelt, 2011; Bell, 2012). Remnants of the ecological community are generally small and isolated; most patches (at least 70%) are less than 10 ha in size, with an estimated median average patch size of less than 3 ha (DoE, 2016).

Further, there are no known locations where the ecological community is in pre-European condition (Umwelt, 2011). The majority of the area of occupancy of the ecological community is within the Warkworth district in relatively few, large and moderate to good condition remnants.

As discussed under Criterion 3, such a substantial decline is likely to have caused fundamental changes in function, both within the boundaries of the ecological community and in the role it plays in the wider landscape. For example, through the loss of large hollow bearing trees.

The small patch sizes and fragmentation caused by clearing of the ecological community and surrounding vegetation, is likely to: reduce rates of survival and dispersal; interrupt population processes such as genetic exchange; as well as disrupting other ecological processes that sustain the ecological community. Clearance also increases the proportion of the remaining patches susceptible to threats from predation, changed microclimates and weed incursion; for example, invasion by the aggressive weedy shrub Lantana (*Lantana camara*). Additionally, the limited dispersal ability of some canopy species restricts their ability to support regeneration of the ecological community where the gaps between vegetation remnants are wide.

***Reduction in integrity through weed invasion***

The ecological community has undergone a reduction in ecological function as indicated by the invasion and establishment of exotic species. Weeds compete with locally indigenous flora for resources (e.g. water, light, nutrients); and often lead to a decline in the diversity and regenerative capacity of a native ecosystem. There are over 60 weed species recorded in the ecological community (Somerville, 2009; Bell, 2012; Umwelt, 2013; Gross and Vary, 2014).

Amongst the more serious threats are: common prickly pear (*Opuntia stricta*), fireweed (*Senecio madagascariensis*), lantana (*Lantana camara*), Rhodes grass (*Chloris gayana*) and tiger pear (*Opuntia aurantiaca*). Other invasive weed species threatening the ecological community include: African boxthorn (*Lycium ferocissimum*), catsear (*Hypochaeris radicata*), creeping pear (*Opuntia humifusa*), field madder (*Richardia stellaris*), galenia (*Galenia pubescens*), green cestrum (*Cestrum parqui*), Paddy's lucerne (Sida rhombifolia), red Natal grass (*Melinis repens*) and *Verbena quadrangularis* (Somerville, 2009; Bell, 2012; Umwelt, 2013; Gross and Vary, 2014).

Bell (2012) notes that south of Warkworth extensive thickets of the aggressive weedy shrub lantana (*Lantana camara*) have dramatically altered the understorey of parts of the ecological community. Lantana typically forms dense thickets, suppressing native vegetation and seedlings through shading, nutrient competition, smothering and allelopathy. Somerville (2009) reported weed species that occurred in more than 25% of mapped Warkworth Sands Woodland sites. The weeds in Table F4 are considered significantly invasive.

**Table F4. Examples of invasive flora species found at more than 25% of sites in the Warkworth Sands Woodland**. Scientific names are current as at March 2016. Source: Somerville (2009).

| Map unit number and name | Significantly invasive naturalised species | % of sites at which recorded |
|---|---|---|
| MU 124 Rough-barked Apple/ Narrow-leaved Ironbark/Blakely's Red Gum/ Bull Oak/ Coast Banksia/Bracken woodland of Warkworth area | *Opuntia stricta* var. *stricta* (common prickly pear)<br>*Senecio madagascariensis* (fireweed)<br>*Hypochaeris radicata* (catsear) | 71<br>67<br>29 |

***Reduction in integrity through decline in faunal components***

Loss of total area and fragmentation of the ecological community reduces its capacity to support a relatively natural and complete faunal assemblage, removing the ecological services provided by these animals. For example, the simplification of the bird assemblage may increase the risk of defoliation by insects, while other services such as pollination and seed dispersal may also be compromised.

The loss (or significant reduction in numbers) of most native species of mammals, formerly found throughout the region, is likely to have directly reduced the integrity of the ecological community - through the loss of these elements of its original ecological character. In addition, the roles that these mammals may have played as soil engineers, pollinators and seed dispersers will have also been compromised.

***Reduction in integrity through climate change***

As described in Appendix D (*Description of Threats*), climate change is likely to compromise the integrity of the ecological community both directly and by altering the survival rates of constituent species. The ecological community is a short-range endemic community, occurring

across a range that is naturally very short (20km) (Umwelt, 2011). Communities with short ranges and specialist landscape and soil requirements, are naturally more susceptible to landscape-scale changes; and frequently have no other place to migrate to as a result of landscape-scale changes, such as those predicted to occur as a result of climate change (Umwelt, 2011). Further, the long generation time and limited dispersal ability of some key species, such as canopy trees, are likely to limit adaptation through range shift. Climate change is also likely to interact with other threats, such as changed fire regimes or the invasion of weeds.

***Restorability of the ecological community***

There is little evidence that the integrity of the ecological community may be recovered in the immediate future (three generations of canopy species is estimated to be at least 45 years). In the long-term, there is a likelihood that the vegetation can be restored - if disturbance pressures are removed and adequate resources are provided, along with an appropriate monitoring program and feedback/action loop. A University of New England research programme supported by Rio Tinto Coal Australia on the restoration of Warkworth Sands Woodland is ongoing. However, the time required for significant recovery of sustainable flora and fauna composition and function is unknown; it is likely to be at least 50 years (Umwelt, 2011). In particular, if mature trees continue to be removed as areas are cleared, the ecological community will continue to be subject to a loss of diversity and function that will very severely impact long term viability and make restoration less likely in the future.

Despite the community being considered to have good potential for natural regeneration, there are a number of factors that may impede the success of a restoration program - not least being: the restricted area of occupancy of the ecological community; the very short range over which it occurs; the very specific substrate (aeolian sands) on which it occurs; the decline in faunal elements; and, the likely inability for the ecological community to migrate over time as an adaptation to probable climate change impacts. Clearing large areas (such as the planned removal of 72 ha in the Warkworth district), within the remnant woodland that supports by far the largest and best occurrences of the ecological community, is likely to increase the risk of extinction of the ecological community (Umwelt, 2011; NSW PAC, 2015a).

***Conclusion***

Substantial clearing, fragmentation, weed invasion, and associated changes to vegetation structure and loss of faunal components have very severely reduced the integrity of the ecological community. This may be compounded by climate change. The loss of integrity, coupled with the ongoing threats to the ecological community mean that *restoration* of the Warkworth Sands Woodland is unlikely within the *immediate future*, even with positive human intervention.

The reduction in integrity experienced by the ecological community across most of its geographic distribution is **very severe**, as indicated by **very severe** degradation of the ecological community. Therefore, the ecological community is **eligible** for listing as **critically endangered** under this criterion.

**Criterion 5 - Rate of continuing detrimental change**

A continuing detrimental change refers to a recent, current or projected future change - whose causes are either not known, or not adequately controlled, and so is liable to continue unless remedial measures are taken. This rate of change may be indicated by, for example: the rate of continuing decline in its geographic distribution, or the intensification in degradation, or disruption of important community processes.

The Warkworth Sands Woodland has a very restricted area of occupancy. Remnants of the ecological community are generally fragmented; most of the patches (at least 70%) are less than 10 ha in size, with an estimated median average patch size of less than 3 ha. Further, the ecological community has been extensively cleared and there are no known locations where the ecological community is in pre-European condition (Umwelt, 2011). The majority of the area of occupancy of the ecological community occurs within the Warkworth district and this area contains the relatively few, large and mostly good condition remnants of the ecological community. There are no known areas of Warkworth Sands Woodland protected in any conservation reserves or in perpetuity conservation areas.

In November 2015, an expansion of the Warkworth mine complex was approved. This approval included clearing 72 ha of the ecological community in the Warkworth district over the next two decades (NSW PAC, 2015b). This represents a 15-18% loss of the total remainder of the ecological community (Umwelt, 2011; Bell, 2012). Further, the area approved for clearance will remove much of the highest quality Warkworth Sands Woodland (up to half), leaving mostly medium and low condition remnants (Bell, 2012). Clearing large areas within the remnant woodland that supports by far the largest and best occurrences of the ecological community will result in a substantially increased reliance on smaller, less resilient remnants of the ecological community (Umwelt, 2011). The review of the Warkworth Continuation Project concluded that the approved loss was likely to increase the risk of extinction of the ecological community (NSW PAC, 2015a).

In addition to the direct removal of vegetation which will result in the loss of habitat for fauna species, potential indirect impacts of the clearing on adjacent patches of the ecological community, include: increased edge effects, modification of abiotic factors such as light regimes and water flow, fragmentation of the vegetation and isolation of remaining patches of vegetation and the fauna that utilise them (Cumberland Ecology, 2014).

***Conclusion***

The **severe** projected decline, of up to half of the highest quality patches of the Warkworth Sands Woodland, represents a **severe** rate of continuing detrimental change in the immediate future. Therefore, the ecological community is **eligible** for listing as **endangered** under this criterion.

**Criterion 6 - Quantitative analysis showing probability of extinction**

There are no quantitative data available to assess this ecological community under this criterion. As such there is **insufficient information to determine the eligibility** of the ecological community for listing under any category of Criterion 6.

## APPENDIX F – EXISTING PLANS/MANAGEMENT PRESCRIPTIONS

A number of existing strategies, plans and guides are relevant to management and/or recovery of the ecological community, or its component species. These prescriptions were current at the time of publishing. Please refer to the relevant agency's website for any updated versions or new information that has been published.

DITR (2006). Leading practice sustainable development program for the mining industry: Biodiversity management handbook. Department of Industry Tourism and Resources.

Dorrough J, Stol J and McIntyre S (2008). Biodiversity in the Paddock: a land managers guide. Future Farm Industries Co-operative Research Centre. http://www.futurefarmonline.com.au/_literature_53421/Biodiversity_in_the_Paddock

Hunter Catchment Management Trust (2003). Integrated catchment management plan for the Hunter Catchment, 2002. Sydney, NSW Department of Land and Water Conservation.

Hunter-Central Rivers CMA (2007). Hunter-Central Rivers Catchment Action Plan. Hunter-Central Rivers Catchment Management Authority. Paterson, NSW.

Hunter River Management Committee (1998). Building a more secure future for the Hunter. NSW Department of Land and Water Conservation.

Lindenmayer DB, Archer S, Barton PS, Bond S, Crane M, Gibbons P, Kay G, MacGregor C, Manning AD, Michael D, Montague-Drake R, Munro N, Muntz R and Stagoll K (2011). What makes a good farm for wildlife? CSIRO Publishing.

Lindenmayer D, Claridge A, Hazell D, Michael D, Crane M, MacGregor C and Cunningham R (2003). Wildlife on farms — how to conserve native animals. CSIRO Publishing.

Natural Regeneration Australia (undated). Ecological research, planning and management in Australian agricultural landscapes – Publications web page. http://www.naturalregen.com.au/further-readin/publications/

Natural Resource Management Ministerial Council (2010). Australia's Biodiversity Conservation Strategy 2010-2030, Australian Government, Department of Sustainability, Environment, Water, Population and Communities. https://www.environment.gov.au/system/files/resources/58321950-f8b6-4ef3-bb68-6f892420d601/files/biodiversity-strategy-2010.pdf and https://www.environment.gov.au/biodiversity/conservation/strategy

North West Weeds (2015). North West Weeds - Tiger pear. http://www.northwestweeds.com.au/tiger_pear.htm

NSW DPI (undated). Weed Management Guide - Fireweed. Department of Planning and Infrastructure, NSW. http://www.weeds.org.au/WoNS/fireweed/docs/47053%20ERGO%20Weed%20Mgmt%20guide%20FIREWEED_web_FA.pdf

NSW DPI (2012). Upper Hunter Strategic Regional Land Use Plan. NSW Department of Planning and Infrastructure.
http://www.nsw.gov.au/sites/default/files/initiatives/upperhunterslup_sd_v01.pdf

NSW DMR (1999). Synoptic Plan: Integrated landscapes for coal mine rehabilitation in the Hunter Valley of NSW. Report prepared by N Andrews, NSW Department of Mineral Resources.

NSW OEH (undated). Wildlife on your property - Assessing wildlife habitat. Office of Environment and Heritage, Department of Premier and Cabinet NSW.
http://www.environment.nsw.gov.au/resources/cpp/AssessHabitat.pdf.

NSW OEH (2012). Warkworth Sands Woodland in the Sydney Basin Bioregion – profile
http://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10833

NSW OEH (2014). Biodiversity and threatened species resources for local government. Last updated 17/03/2014. Viewed 15/02/2016.
http://www.environment.nsw.gov.au/biodiversity/BiodiversityResources.htm

NSW NPWS (1999). Natural tree hollows - Essential for wildlife. Voluntary conservation on private and public land. Conservation Management Note 5 – 1999. NSW National Parks and Wildlife Service.
http://www.environment.nsw.gov.au/resources/nature/Factsheet5TreeHollows.pdf

RTCA [Rio Tinto Coal Australia Pty Limited] (2014). Local Offset Management Plan Warkworth Mine, NSW.
http://www.riotinto.com/documents/Warkworth_Local_Offset_Management_Plan.pdf

RDA [Regional Development Australia] Hunter (2012). Hunter Regional Plan 2012—2022.
http://rdahunter.org.au/_literature_328/Hunter_Regional_Plan_2012-2022

Society for Ecological Restoration Australasia 2015 Society for National Standards for the Practice of Ecological Restoration in Australia (final draft).
www.seraustralasia.com/pages/SERARestorationStandards_15dec2015.pdf

The following are recovery plans prepared for species occurring in the Warkworth Sands Woodland:

NSW DECCW (2009). Draft National Recovery Plan for the Grey-headed Flying-fox *Pteropus poliocephalus*. Prepared by Dr Peggy Eby. Department of Environment, Climate Change and Water NSW, Sydney.
http://www.environment.nsw.gov.au/resources/threatenedspecies/08214dnrpflyingfox.pdf

VIC DNRE (1999) Regent Honeyeater Recovery Plan 1999-2003. VIC Department of Natural Resources and Environment, Victoria.
http://www.environment.gov.au/resource/regent-honeyeater-xanthomyza-phrygia-recovery-plan-1999-2003

**BIBLIOGRAPHY**


Anderson L and Burgin S (2002). Influence of woodland remnant edges on small skinks (Richmond, New South Wales). Austral Ecology 27(6), 630 – 637.

ATN [Australian Tourism & Travel Network] (2014). Hunter Valley Weather Conditions. Viewed: 27/05/2014. http://www.atn.com.au/nsw/syd/huntervalley-weather.html

Auerbach N, Wilson K, Tulloch A, Rhodes J, Hanson J and Possingham H (2015). Effects of threat management interactions on conservation priorities Conservation Biology 29(6), 1626-1635

Barrett G (2000). Ecological Management for Agricultural Sustainability. Supplement to Wingspan 10(4). Hawthorn East, Victoria: Birds Australia.

Bell S (2012). Expert Report: Bulga Milbrodale Progress Association v Minister for Planning and Infrastructure and Warkworth Mining Limited Land and Environment Court Proceedings No: 10224 of 2012. Report to Environmental Defenders Office NSW. Eastcoast Flora Survey.

Bell S (2014). The Flora of the Hunter Valley - History, Ecology, Diversity. Presentation by Stephen Bell, Workshop on plant identification for flora of the Hunter Valley; Australian Network for Plant Conservation.

Beltana Highwall Mining (2008). Flora and Fauna Management Plan ENVSTD4.3.03.01.009.

Benson DH (1981). Impact of Wambo Colliery Balloon Loop on native vegetation on Warkworth Sands. Unpublished report to National Parks and Wildlife Service. Royal Botanic Gardens, Sydney.

Bower CC (2004). Investigation of Warkworth Sands Woodland and associated soils in the extension area, NDAs, HMAs and on adjacent land. Unpublished Report. FloraSearch. August 2004.

Cuneo P, Jacobson C and Leishman MR (2009). Landscape-scale detection and mapping of invasive African Olive (*Olea europaea* L. subsp. *cuspidata* (Wall ex G. Don Ciferri) in SW Sydney, Australia using remote sensing, Australia. Applied Vegetation Science 12, 145 – 154.

CSIRO (2007). Climate Change in the Hunter-Central Rivers Catchment. A report prepared for the New South Wales Government. NSW Department of Environment and Climate Change, Sydney.

Cumberland Ecology (2014). Warkworth Continuation 2014 Environmental Impact Statement Volume 3 Appendix H. Prepared for Warkworth mining Ltd.

Daehler CC and Baker RF (2006). New records of naturalised and naturalizing plants around Lyon Arboretum, Mānoa Valley, O'ahu. Records of the Hawaii Biological Survey for 2004-2005. Occasional Papers 87: 3-18.

DoE [Australian Government Department of Environment] (2013). Collaborative Australian Protected Areas Database National Reserve System - National Reserve System IBRA subregion protection level. http://www.environment.gov.au/topics/land/national-reserve-system/science-maps-and-data/australias-bioregions-ibra/australias (Viewed 29/03/2015); and http://www.environment.gov.au/system/files/pages/5b3d2d31-2355-4b60-820c-e370572b2520/files/ibraregions-new.pdf

DoE (2014). Weeds in Australia - *Galenia pubescens*. Viewed 13/10/2014. http://www.environment.gov.au/cgi-bin/biodiversity/invasive/weeds/weeddetails.pl?taxon_id=4624

DoE (2016). Data from Peake (2006), Umwelt (2011) and Bell (2012); the latter supplied by NSW Office of Environment and Heritage. Composite dataset compiled by Environmental Resources Information Network (ERIN) - Australian Government Department of the Environment (February 2016).

DSEWPAC [Australian Government Department of Sustainability, Environment, Water, Population and Communities] (2012). Australia's bioregions (IBRA). Last viewed 29/03/2015. http://www.environment.gov.au/land/nrs/science/ibra

Dunlop M, Hilbert DW, Ferrier S, House A, Liedloff A, Prober SM, Smyth A, Martin TG, Harwood T, Williams KJ, Fletcher C and Murphy H (2012). The implication of Climate Change for Biodiversity Conservation and the National Reserve System: Final Synthesis. CSIRO Climate Adaption Flagship, Canberra.

Ford HA (1989). Ecology of Birds: an Australian Perspective. Surrey Beatty: Chipping Norton, NSW.

Galloway RW (1963). Geology of the Hunter Valley. In 'General Report on the Lands of the Hunter Valley. Land Research Series No 8.' pp 81– 89. (eds) R Story, RW Galloway, RHM van de Graaff and A Tweedie. CSIRO, Melbourne.

Gross CL and Vary LB (2014). Arrested recovery in a sandy woodland correlates with a lack of heavy and long seeds in the seed bank. Ecosphere 5(6), 1 – 26. Last viewed 10/02/2016. H at http://onlinelibrary.wiley.com/doi/10.1890/ES14-00020.1/pdf

Hutton AC (2009). Geological Setting of Australasian Coal Deposits. In 'Australasian Coal Mining Practice' (eds) R. Kininmonth and & E Baafi. Australasian Institute of Mining and Metallurgy, Carlton Victoria.

Isbell RF (1996). Australian soil classification. CSIRO Division of Soils, Townsville.

Keith D (2004). Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT. NSW Department of Environment and Conservation, Hurstville.

Kovac M and Lawrie JW (1991). Soil Landscapes of the Singleton 1:250,000 Sheet. Map. Department of Land and Water Conservation, Wellington.

Leary T (2007). Information requested by NSW Scientific Committee on Fauna of the Cumberland Plain Woodland EEC. Unpublished data.

Mandle L, Bufford JL, Schmidt IB and Dachler CC (2011). Woody exotic plant invasions and fire: reciprocal impacts and consequences for native ecosystems. Biological Invasions 13, 1815-1827.

Martin G (2003). The role of small ground-foraging mammals in topsoil health and biodiversity: implications to management and restoration. Ecological Management and Restoration 4, 114 – 119.

Morgan G (2001). Delineation and description of the Eastern Environmental Subregions (provinces) in New South Wales Study. NSW National Parks and Wildlife Service, Hurstville. (Cited in NSW NPWS, 2003).

Nashar B (1964). The geology of the Hunter Valley. Jacaranda Press, Melbourne.

NCC [Nature Conservation Council] (2014). Submission on the listing of the Central Hunter Valley Eucalypt Forest and Woodland Complex as an endangered ecological community under the Commonwealth Environment Protection and Biodiversity Conservation Act (1999).

NSW DEC (2014). Invasion of native plant communities by exotic perennial grasses – profile. Last updated 28/04/2014 – Viewed 09/02/2016. http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=20018

NSW DMR [Department of Mineral Resources] (1999). Lower North East Region 1:250,000 scale equivalent geology [lner5ge_p (polygons) and lner5ge_l (lines or arcs)] geological coverage comprising the area covered by parts of the Dorrigo, Tamworth, Hastings, Singleton and Newcastle 1:250 000 sheet areas, Hunter Coalfield and Newcastle Coalfield Regional Geology 1:100 000 sheet areas and part Sydney 1:250 000 sheet area. CRA

NSW NPWS [National Parks and Wildlife Service] (2003). The Bioregions of New South Wales: their biodiversity, conservation and history. NSW National Parks and Wildlife Service, Hurstville. Last viewed 20/05/2014, via NSW OEH Sydney Basin Bioregion overview (2011). http://www.environment.nsw.gov.au/bioregions/SydneyBasinBioregion.htm

NSW OEH [Office of Environment and Heritage] (2008a). NSW Biometric vegetation database. Definitions of vegetation types for CMA areas. Updated June 2008. http://www.environment.nsw.gov.au/resources/nature/BioMetric_Vegetation_Type_CMA.xls Available from the New South Wales OEH webpage - BioMetric: Terrestrial Biodiversity Tool for the NSW Property Vegetation Planning System. Viewed 02/03/2015, via http://www.environment.nsw.gov.au/projects/biometrictool.htm

NSW OEH (2008b). Terrestrial Protected Areas in Australia by Subregion. Viewed 24/03/2015. http://www.environment.gov.au/system/files/pages/4fe91d68-b097-45ed-aa0b-450c5717438b/files/capad08national.xls

NSW OEH (2011). Sydney Basin – climate. NSW Office of Environment & Heritage. Last updated: 27/02/2011 – Last Viewed 25/01/2016. http://www.environment.nsw.gov.au/bioregions/SydneyBasin-Climate.htm

NSW OEH (2012). Warkworth Sands Woodland in the Sydney Basin Bioregion – profile. Last updated: 07/09/12. Last viewed 29/09/15. http://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10833

NSW OEH (2015). The NSW Vegetation Information System (VIS) Classification 2.0. Accessed 06/10/2015.

NSW PAC [Planning Assessment Commission] (2015a). Second Review Report - Warkworth Continuation Project (SSD 6464). October 2015. State of New South Wales through the NSW Planning Assessment Commission. Last viewed 10/02/2016. http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=6464 and https://majorprojects.affinitylive.com/public/e2fe9189476109eb28ff45ecb0549e3c/04.%20Warkworth%20Continuation%20Project%20-%20PAC%20Second%20Review%20Report.pdf

NSW PAC [Planning Assessment Commission] (2015b). Determination Report - Warkworth Continuation Project (SSD 6464). November 2015. State of New South Wales through the NSW Planning Assessment Commission. Last viewed 10/02/2016. http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=6464 and https://majorprojects.affinitylive.com/public/0bb244424267a3b79ff007cc0c7fa26e/01.%20Warkworth%20Continuation%20Project%20-%20PAC%20Determination%20Report.pdf

NSW Scientific Committee (2011). Warkworth Sands Woodland in the Sydney Basin Bioregion - Determination to make a minor amendment to Part 3 of Schedule 1 of the Threatened Species Conservation Act. Last updated: 14/109/11. Last viewed 25/01/2016. http://www.environment.nsw.gov.au/determinations/warkworthsands36a.htm

NSW Scientific Committee (2013). Castlereagh Scribbly Gum Woodland in the Sydney Basin Bioregion - vulnerable ecological community listing. (Web page). Available on the internet at: http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=20154

NSW Scientific Committee (2014). Preliminary determination [Elderslie banksia scrub forest]. Available on the internet at: http://www.environment.nsw.gov.au/resources/threatenedspecies/determinations/PDElderslie%20BanksiaScrubCEEC.pdf

Peake TC (2006). The Vegetation of the Central Hunter Valley, New South Wales. A report on the findings of the Hunter Remnant Vegetation Project: Volume 1: Main report; and Volume 2: Profiles of Vegetation Communities. Hunter-Central Rivers Catchment Management Authority, Paterson. Downloaded from the HCCREMS website. Viewed 24/03/15. http://www.hccrems.com.au/RESOURCES/HCCREMS-Publications.aspx

Peake T, Bell S, Tame T, Simpson J and Curran T (2002). Warkworth Sands Woodland - An Endangered Ecological Community Distribution, Ecological Significance and Conservation Status. Viewed 29/09/15. http://www.huntergardens.org.au/forms/Warkworth%20Sands%20Woodland.pdf

Preston BJ and Adam P (2004). Describing and listing threatened ecological communities under the Threatened Species Conservation Act, 1995 (NSW): Part 1 – the assemblage of species and the particular area. Environmental Planning Law Journal 250: 250-263.

Recher H, Lunney D, and Matthews A (2009). Small mammal populations in a eucalypt forest affected by fire and drought. I. Long-term patterns in an era of climate change, Wildlife Research 36(2) 143-158.

Society for Ecological Restoration Australasia 2015 Society for National Standards for the Practice of Ecological Restoration in Australia (final draft). www.seraustralasia.com/pages/SERARestorationStandards_15dec2015.pdf

Somerville M (2009). Hunter, Central & Lower North Coast Vegetation Classification & Mapping Project: Vol 1: Vegetation classification technical report; and Vol 2: Vegetation community profiles. Prepared by the HCCREMS, Hunter Councils Environment Division for the Hunter-Central Rivers Catchment Management Authority, Tocal, NSW. Downloaded from the HCCREMS website. Viewed 24/03/15. http://www.hccrems.com.au/RESOURCES/HCCREMS-Publications.aspx

Story R, Galloway RW and van de Graaff RHM (1963). Land Systems of the Hunter Valley. In 'General Report on the Lands of the Hunter Valley. Land Research Series No 8.' pp 12-61. (eds) R Story, RW Galloway, RHM van de Graaff and A Tweedie. CSIRO, Melbourne.

Tame T (1992). Evolution of the Hunter Valley. Hunter Natural History 50: 1 – 7.

TSSC [Threatened Species Scientific Committee] (2006). Commonwealth Listing Advice on White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Viewed 16/02/2016. http://www.environment.gov.au/cgi-bin/sprat/public/publicshowcommunity.pl?id=43 and http://www.environment.gov.au/biodiversity/threatened/communities/box-gum.html

TSSC (2015a). Approved Conservation Advice (including listing advice) for the Central Hunter Valley eucalypt forest and woodland ecological community. Viewed 16/02/2016. http://www.environment.gov.au/cgi-bin/sprat/public/publicshowcommunity.pl?id=130 and http://www.environment.gov.au/biodiversity/threatened/communities/pubs/130-conservation-advice.pdf

TSSC (2015b). Approved Conservation Advice (including listing advice) for Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion. Viewed 16/02/2016. http://www.environment.gov.au/cgi-bin/sprat/public/publicshowcommunity.pl?id=119 and http://www.environment.gov.au/biodiversity/threatened/communities/pubs/119-conservation-advice.pdf

Tozer M (2003). The native vegetation of the Cumberland Plain, western Sydney: systematic classification and field identification of communities. Cunninghamia 8(1), 1 – 75.

Tozer MG, Turner K, Keith DA, Tindall D, Pennay C, Simpson C, MacKenzie B, Beukers P and Cox S (2010). Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. Cunninghamia 11(3): 35 – 406.

Umwelt (2011). Review of Ecological Assessments for Warkworth Extension EA and HVO South Modification Projects. Prepared by Umwelt (Australia) Pty Limited on behalf of Department of Planning & Infrastructure.

Umwelt (2013). Ecological Impact Assessment Bulga Optimisation Project. Umwelt (Australia) Pty Limited.

Vary and Gross (2012). The impact of exotic pollinators on native plant-pollinator networks. Presentation to the ecological Society of Australia 2012 annual conference. Symposium: Plant pollination and mate choice.

Watson DM (2011). A productivity-based explanation for woodland bird declines: poorer soils yield less food. Emu 111, p 10 – 18.

Wilkins S, Keith DA, and Adam P (2003). Measuring success: Evaluating the restoration of a grassy eucalypt woodland on the Cumberland Plain, Sydney, Australia. Restoration Ecology 11(4): 489-503.