***Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)**
Approved Conservation Advice (including listing advice) for
Shale Sandstone Transition Forest of the Sydney Basin Bioregion (EC25R)

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 *Shale Sandstone Transition Forest of the Sydney Basin Bioregion* ecological community to the Minister as a draft of this approved conservation advice. In 2014, the Minister accepted the Committee's advice, adopting this document as the approved conservation advice.

3. The Minister amended the list of threatened ecological communities under section 184 of the EPBC Act to remove Shale/Sandstone Transition Forest from the endangered category and include the *Shale Sandstone Transition Forest of the Sydney Basin Bioregion* ecological community in the critically endangered category. It is noted that the equivalent ecological community *Shale Sandstone Transition Forest in the Sydney Basin Bioregion* is listed under the New South Wales *Threatened Species Conservation Act 1995*.

4. A draft conservation advice 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 prepared; this includes scientific literature, advice from consultations, existing plans, records or management prescriptions for this ecological community.

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1 DESCRIPTION

1.1 Name of the ecological community

Shale Sandstone Transition Forest of the Sydney Basin Bioregion ecological community

The Shale Sandstone Transition Forest of the Sydney Basin Bioregion ecological community (hereafter referred to as Shale Sandstone Transition Forest or the ecological community) was listed in 2001 under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as Shale/Sandstone Transition Forest. The definition and extent of the ecological community under the EPBC Act has been refined (and presented here in 2014) by research undertaken since 2001.

1.2 Location and Physical environment

Shale Sandstone Transition Forest occurs only in New South Wales, within the Sydney Basin Bioregion, as defined by version 7 of the Interim Biogeographic Regionalisation of Australia (IBRAv7, 2012). As the name implies, this ecological community occurs between other ecological communities found respectively on shale or sandstone substrates. The ecological community is found to the west of Sydney, on the edges of the Cumberland Plain, (particularly the southern edge), as well as on the sandstone-dominated Hornsby, Woronora, and Lower Blue Mountains plateaux that adjoin the plain (although less prevalent on the latter).

Shale Sandstone Transition Forest is found on soils that are primarily derived from shale substrates and thus tend to have a clay texture, but also have some influence from weathered sandstone substrates. This most commonly occurs where the Wianamatta Group shale underlying the Cumberland Plain grades into sandstone, mainly from the Hawkesbury Group, which dominates the surrounding elevated plateaux. In some cases the ridges of the uplifted Hornsby, Woronora and Blue Mountains plateaux also have remnant shale caps, where Shale Sandstone Transition Forest is also found. Less often, the ecological community occurs on Hawkesbury shale lenses within the otherwise sandstone-dominated Hawkesbury Group; on Hawkesbury shale caps; on sites dominated by Hawkesbury sandstone but significantly enriched by colluvium derived from upslope shale; where watercourses have eroded the overlying shale to expose the underlying sandstone; and in association with relatively rare outcrops of Wianamatta Group sandstone (e.g. Minchinbury Sandstone) amongst otherwise predominantly Wianamatta shale geology. Shale Sandstone Transition Forest is also strongly associated with the Mittagong Formation, which is the transitional beds between the Wianamatta and Hawkesbury Groups, and which support unique soil landscapes, with the most relevant being the Lucas Heights landscape.

In summary, the ecological community is found in a range of situations across the gradient between shale based and sandstone-based soils, with its expression reflecting the level of sandstone influence on the otherwise primarily shale-associated vegetation.

1.2.1 Climate

Shale Sandstone Transition Forest generally occurs in areas receiving between 800mm and 1100mm mean annual rainfall (Tozer et al., 2010). Typically, it occurs at elevations less than 200 m Above Sea Level (ASL), although it may occur up to 350 m ASL in parts of the Lower Blue Mountains and western Woronora Plateau that are associated with the rainshadow extending south-west of the Cumberland Plain. It also may occur at approximately 600 m ASL at its southern limit in the Southern Highlands.

1.3 Vegetation

The vegetation of the ecological community is forest or woodland with an overstorey dominated by various Eucalypt species and an understorey comprising of sclerophyll shrubs, grasses and herbs. The structure and composition of vegetation are primarily determined by the transitional geology between Wianamatta shale and Hawkesbury sandstone and vary considerably depending on the degree and the source of shale influence (Wianamatta or Hawkesbury Group, or Mittagong Formation). The vegetation is also influenced by other environmental variables such as rainfall, topographic shelter, slope, proximity to the coast and elevation.

The structure of the ecological community may vary from tall to open forest or woodland, and may include minor areas of scrub associated with disturbance or drainage lines and seepage zones. Sites that are near to sandstone outcrops may have a more shrubby understorey, while those with less sandstone influence may have more herbs and grasses in the understorey (Tozer et al., 2010).

While the transitional nature of the ecological community means that its character is not simply described, some of its constituent plant species are considered to be strongly indicative. The presence of considerable numbers of these species, together with the context provided by landscape, substrate and adjacent ecological communities assist in a positive identification of Shale Sandstone Transition Forest.

Canopy

The canopy is composed of trees with a mature height of approximately 20 m (can vary between 10-30 m). The canopy typically has a projective foliage cover of approximately 20%.

The canopy is a mix of native tree species typically including two or more of the following: *Eucalyptus punctata* (grey gum), *E. crebra* (narrow-leaved ironbark), *E. fibrosa* subsp. *fibrosa* (broad-leaved ironbark), *E. tereticornis* subsp. *tereticornis* (forest red gum), *E. resinifera* subsp. *resinifera* (red mahogany), *E. eugenioides* (or *E. globoidea* depending on local species present and degree of sandstone influence) and *Angophora bakeri* (narrow-leaved apple).

Understorey

Mid layer

A small tree stratum may be present in the mid layer, with a mean height of 10.9 m (Tozer, 2010). It is most often dominated by Eucalypt species as well as *Allocasuarina littoralis* (black she-oak) with *Syncarpia glomulifera* (turpentine) occurring less frequently in the ecological community.

Where present, the shrub layer is typically well-developed, diverse and dominated by *Bursaria spinosa* (blackthorn) in areas with low sandstone influence. Other common species include *Kunzea ambigua* (tick bush), *Persoonia linearis* (narrow-leaved geebung), *Ozothamnus diosmifolius* (rice flower, sago bush, white dogwood), *Hibbertia aspera* (rough guinea flower), *Leucopogon juniperinus* and *Pultenaea villosa* (Tozer, 2003; Tozer et al., 2010). Benson and Howell (2002) describe the rapidity with which the structure of understorey layers of woodlands on the Cumberland Plain can change in response to influences such as rainfall, fire or grazing.

Ground layer

The ground layer is often diverse and dominated by grasses and herbs including *Aristida vagans* (three-awned spear grass), *Austrostipa pubescens* (spear grass), *Cheilanthes sieberi* subsp. *sieberi* (poison rock fern), *Dichondra repens* (kidney weed), *Echinopogon ovatus* (forest hedgehog grass), *Entolasia marginata* (bordered panic), *Entolasia stricta* (wiry panic), *Lepidosperma laterale* (saw sedge), *Lomandra multiflora*, *Microlaena stipoides* var. *stipoides* (weeping grass), *Oxalis perennans* (wood-sorrel), *Pimelea linifolia* subsp. *linifolia*, *Phyllanthus hirtellus, Pomax umbellata, Pratia purpurascens* (white root), *Solanum prinophyllum* (forest nightshade) and *Themeda triandra* syn *T. australis* (kangaroo grass) (Tozer, 2003; Tozer et al., 2010).

Appendix A, Table A1 lists more plant species that are characteristic of the ecological community.

<u>Derived Native Grasslands or Shrublands</u>

Some patches of the ecological community now occur in management-induced states that may vary from the typical vegetation description, above. For example, in derived grassland or derived shrubland forms, the canopy layer has been substantially degraded, removed or thinned to very scattered trees but the ground layer with or without a shrub layer is intact and retains some of the native biodiversity components characteristic of this layer. Evidence that a patch of derived grassland or shrubland formerly contained the ecological community can include tree stumps, fallen logs, historical records, photographs, surrounding vegetation remnants, or reliable modelling of pre-European vegetation. For example, derived grassland or shrubland patches surrounded by woodland could be reasonably inferred from their location to have formerly been of the ecological community.

Derived grasslands or shrublands are not recognised as part of the nationally protected ecological community. Nonetheless, derived grasslands or shrublands are an important part of the broader ecosystem and may have potential for restoration, possibly to a condition that in the future will make them eligible for inclusion in the nationally protected ecological community. They contain much of the native plant biodiversity of the ecological community and act as a seed bank and source of genetic material. Derived grasslands or shrublands also act as buffer zones, that protect the woodland remnants from adjacent activities, and stepping stones that enable the movement of fauna between remnant woodlands. For this reason they should also be considered as part of the "Surrounding environment, landscape context and other significant considerations" for patches of Shale Sandstone Transition Forest.

1.4 Fauna

Whilst there is no distinctive faunal assemblage confined solely to Shale Sandstone Transition Forest, the ecological community contributes substantially to the habitat used by the fauna of the region. Part of the regional fauna of the Cumberland Plain is a characteristic avifaunal assemblage of the broader shale-associated grassy woodlands and forests (including Shale Sandstone Transition Forest) (often referred to as shale birds) (Hoskin, 1991; Keast, 1995; Leary, 2007). The assemblage comprises a mixture of coastal species and birds whose main distribution occurs west of the Great Dividing Range. Characteristic species include: *Pyrrholaemus saggitatus* (speckled warbler); *Climacteris picumnus victoriae* (brown treecreeper); *Lichenostomus fuscus* (fuscous honeyeater); *Melanodryas cucullata cucullata* (hooded robin); and *Psephotus haematonotus* (red-rumped parrot) (Leary, 2007). Several of the shale bird species are listed as threatened in NSW and/or nationally (Appendix A, Table A2).

Other threatened fauna associated with the ecological community include *Saccolaimus flaviventris* (yellow-bellied sheathtail bat), *Varanus rosenbergii* (Rosenberg's monitor) and *Pseudophryne bibroni* (Bibron's or Brown toadlet). *Pommerhelix duralensis* (Dural land snail) is also known to be associated with Shale Sandstone Transition Forest (Ridgeway, in prep.) while *P. corneovirens* (Cumberland land snail) may also use some of the more shale-influenced forms of the Shale Sandstone Transition Forest that border Cumberland Plain Woodland communities.

Further details on flora and fauna species and other relevant biology and ecological interactions and processes can be found at Appendices A and B.

1.5 Key diagnostic characteristics and condition thresholds

National listing focuses legal protection on remaining patches of the ecological community that are most functional, relatively natural (as described by the 'Description') and in relatively good condition. Key diagnostic characteristics and condition thresholds assist in identifying a patch of the threatened ecological community, determine when the EPBC Act is likely to apply to the ecological community and to distinguish between patches of different quality. The ecological community may exhibit various degrees of disturbance and degradation. This degree of degradation has been taken into account in developing the condition thresholds.

1.5.1 Key diagnostic characteristics

The key diagnostic characteristics presented here summarise the main features of the ecological community. These are intended to aid the identification of the ecological community, noting that a broader description is given in the other sections. Key diagnostic characteristics for describing the Shale Sandstone Transition Forest are:

- Limited to the Sydney Basin Bioregion (IBRA v7).
- Occurs at the transition between shales and sandstones of the Wianamatta and Hawkesbury Groups, including the transitional Mittagong Formation.
- Occurs as forest or woodland, and may have a primarily shrubby or primarily grassy understorey, or be a mixture.
- Canopy is a mix of species typically including two or more of the following: *Eucalyptus punctata* (grey gum), *E. crebra* (narrow-leaved ironbark), *E. fibrosa* subsp. *fibrosa* (broad-leaved ironbark), *E. tereticornis* subsp. *tereticornis* (forest red gum), *E. resinifera* subsp. *resinifera* (red mahogany), *E. eugenioides* (or *E. globoidea* depending on local species present and degree of sandstone influence) and *Angophora bakeri* (narrow-leaved apple).
- Where present the mid layer of the understorey varies in structure and floristics.
    - Where present, the small tree layer is likely to be dominated by Eucalypt species and *Allocasuarina littoralis* (black she-oak).
    - Where shrubs are present, the mid layer is likely to be dominated by *Bursaria spinosa* (blackthorn) in areas with low sandstone influence, with other common species including *Leucopogon juniperinus*, *Kunzea ambigua* (tick bush), *Persoonia linearis* (narrow-leaved geebung), *Ozothamnus diosmifolius* (rice flower, sago bush, white dogwood) and *Hibbertia aspera* (rough guinea flower).
- Where present, the ground layer of the understorey is typically diverse and dominated by grasses and herbs including: *Aristida vagans* (three-awned spear grass), *Austrostipa pubescens* (spear grass), *Cheilanthes sieberi* subsp. *sieberi* (poison rock fern), *Dichondra repens* (kidney weed), *Echinopogon ovatus* (forest hedgehog grass), *Entolasia marginata* (bordered panic), *Entolasia stricta* (wiry panic), *Lepidosperma laterale* (saw sedge),*Lomandra multiflora*, *Microlaena stipoides* var. *stipoides* (weeping grass), *Oxalis perennans* (wood-sorrel), *Pimelea linifolia* subsp. *linifolia*, *Pomax umbellata*, *Phyllanthus hirtellus*, *Pratia purpurascens* (white root), *Solanum prinophyllum* (forest nightshade) and *Themeda triandra* syn. *T. australis* (kangaroo grass). The ground layer may also contain small shrubs, including *Hibbertia aspera* (rough guinea flower).
- May contain fauna species presented in Appendix A, Table A2.

1.5.2 Condition thresholds

Condition classes and thresholds provide guidance for when a patch of a threatened ecological community retains sufficient conservation values to be considered as a Matter of National Environmental Significance, as defined under the EPBC Act. This means that the referral, assessment and compliance provisions of the EPBC Act are focussed on the most valuable elements of the ecological community. Very degraded patches that do not meet the condition thresholds will be largely excluded from national protection.

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

For Shale Sandstone Transition Forest, categories A and B are considered moderate quality condition class and the minimum thresholds for a patch of the ecological community to be subject to the referral, assessment and compliance provisions of the EPBC Act. Categories C and D are considered high condition class and the minimum thresholds for a patch of Shale Sandstone Transition Forest to be regarded as an example of high quality condition.

<table>
<tr><th>Category and Rationale</th><th colspan="3">Thresholds</th></tr>
<tr><td rowspan="2">A. Moderate condition class
Represented by medium to large-size patch as part of a larger native vegetation remnant and/or with mature trees</td><td colspan="3">Patch size ≥0.5ha
And
≥30% of the perennial understorey vegetation cover is made up of native species.
And</td></tr>
<tr><td>The patch is contiguous with a native vegetation remnant (any native vegetation where cover in each layer present is dominated by native species) ≥1ha in area.</td><td>Or</td><td>The patch has at least one tree with hollows or at least one large locally indigenous tree (>80cm dbh).</td></tr>
<tr><td>B. Moderate condition class
Represented by medium to large size patch with high quality native understorey</td><td colspan="3">Patch size ≥0.5ha
And
≥50% of the perennial understorey vegetation cover is made up of native species.</td></tr>
<tr><td>C. High condition class
Represented by medium to large size patch with very high quality native understorey</td><td colspan="3">Patch size ≥0.5ha
And
≥70% of the perennial understorey vegetation cover is made up of native species.</td></tr>
<tr><td>D. High condition class
Represented by larger size patch with high quality native understorey</td><td colspan="3">Patch size ≥2ha
And
≥50% of the perennial understorey vegetation cover is made up of native species.</td></tr>
<tr><td colspan="4">Perennial understorey vegetation cover includes vascular plant species of both the ground layer and mid/shrub layer (where present) with a lifecycle of more than two growing seasons. Measurements of perennial understorey vegetation cover exclude annuals, cryptogams, leaf litter or exposed soil.
Contiguous means the patch of the ecological community is continuous with, or in close proximity (within 100 m) to another area of vegetation that is dominated by native species in each vegetation layer present.</td></tr>
</table>

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

Land use history will influence the state in which a patch of the ecological community is currently found. The structural form of the ecological community will influence its species richness and diversity. The following information should also be taken into consideration when applying the key diagnostic characteristics and condition thresholds (to assess a site that may include the ecological community and determine the potential impacts on a patch).

Defining a patch

A patch is defined as a discrete and mostly continuous area of the ecological community.[1] Permanent man-made structures, such as roads and buildings, are typically excluded from a patch. A patch may include small-scale disturbances, such as tracks or breaks, watercourses or small-scale variations in vegetation that do not significantly alter its overall function (processes such as the movement of wildlife and pollinators, the dispersal of plant propagules, activities of seed and plant predators and many others). Where derived native grassland/shrubland connects discrete patches of the ecological community that are in close proximity (up to 100m apart), the whole area should be considered a single patch of the ecological community rather than individual patches.

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 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 or changed to cropping or urbanised), approval under the EPBC Act may also be required.

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

Sampling protocol

On-ground surveys are essential to accurately assess the extent and condition of the ecological community. The recommended sampling protocol involves developing a simple map of the vegetation, landscape qualities and management history (where possible) of the site. The site should then be thoroughly and representatively sampled for vegetation cover and species richness. This should include the areas with the highest level of structural and species richness of native species.

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[1] Note that NSW vegetation assessment tools define 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 100m)). However, the Threatened Species Scientific Committee uses the term 'patch' to describe any discrete remnant/area of the ecological community in question.

The number of plots required will depend on the size of the patch: the plots should provide a good representation of the species present across the whole patch. The survey plot dimensions may also vary with the patch size, shape and variability but plots of 0.04ha (quadrats of 20m x 20m) are suggested as likely to be suitable (after Tozer, 2003; Tozer et al., 2010). Search effort should be recorded identifying the number of person hours spent per plot and across the entire patch.

Tozer et al. (2010) identify species considered to be particularly distinctive to the ecological community (refer Appendix A, Table A1). If the total species recorded in a 0.04 ha survey plot contains a high representation of these distinctive species, there is a strong indication that Shale Sandstone Transition Forest is present. This indication is only valid where plots have sufficiently high species richness.[2]

Seasonal variation

Timing of surveys is an important consideration because the ecological community can be variable in its appearance through the year and between years depending on drought-rain cycles. Assessment should occur in spring and summer to early autumn, when the greatest number of species is likely to be detectable and identifiable. Ideally, surveys should be undertaken during more than one season to maximise the chance of detecting all species present. In years of low rainfall, assessment should recognise that many species may not be detected. In these situations it is preferable that surveys are carried out over more than one year. Presence and detectability of some species may also be affected by the time since disturbance such as fire or grazing so surveys should be planned to occur after an adequate time for some recovery (for example, at least 18 months post fire).

Surrounding environment, landscape context and other significant considerations

Actions that may have 'significant impacts' on any patches of Shale Sandstone Transition Forest that meet the condition thresholds require consideration under the EPBC Act. The ecological importance of a patch is also influenced by its surrounding landscape, for example, if connected or nearby to other native vegetation it may contribute substantially to landscape connectivity and function. Similarly, actions beyond the boundary of any patch of Shale Sandstone Transition Forest may have a significant impact on the patch. For this reason, when considering actions likely to have impacts on this ecological community, it is important to also consider the environment that surrounds any patches that meet the condition thresholds.

Other patches that meet the condition thresholds may occur in isolation and in addition to requiring protection may also require management of the surrounding area to link them with other native vegetation.

In some cases patches do not currently meet condition thresholds, and so are not considered as part of the nationally protected ecological community (as a Matter of National Environmental Significance). However, in the context of their surroundings, recovery may be possible, so these areas should be considered as a priority for management and funding.

The following indicators of the ecological context provided by the areas surrounding patches of Shale Sandstone Transition Forest should be considered both when assessing the impacts of actions or proposed actions under the EPBC Act, or when considering priorities for recovery, management and funding.

- Large size and/or a large area to boundary ratio – patches with larger area to boundary ratios are less exposed and more resilient to edge effects (disturbances such as weed invasion and other anthropogenic impacts). However, patches that occur in areas where the

[2] The diagnostic test proposed by Tozer, et al. (2010) applied to randomly selected plots with species richness greater than 39 containing more than 26 diagnostic species. Thus, this list of species should be considered as indicative in other circumstances.

ecological community has been most heavily cleared and degraded, or that are at the natural edge of its range may also have importance due to their rarity, genetic significance or because of the absence of some threats.

- Evidence of recruitment of key native plant species or the presence of a range of age cohorts (including through successful assisted regeneration). For example, tree canopy species are present as saplings through to large hollow-bearing trees.
- Good faunal habitat as indicated by diversity of landscape, patches containing mature trees (particularly those with hollows), logs, natural rock outcrops.
- High native species richness, possibly including many understorey plant species or native fauna species.
- Presence of EPBC or NSW *Threatened Species Conservation Act 1995* 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 indicating low disturbance and potential for good functional attributes such as nutrient cycling.
- Derived native grasslands/shrublands, particularly those adjacent or near to 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.

Additional information on ecological processes can be found in Appendix B. Information on differences to similar or intergrading ecological communities can be found in Appendix C.

Area critical to the survival of the ecological community

Areas that meet the minimum (moderate class) condition thresholds or are within the buffer zone are considered critical to the survival of the ecological community. Additional areas such as adjoining native vegetation and areas that meet the description of the ecological community but not the condition thresholds are also considered important to the survival of the ecological community, for example, as buffers for higher condition areas, and should be considered as part of the surrounding environment, landscape context and other significant considerations.

Geographic extent and patch size distribution

Shale Sandstone Transition Forest has been subjected to substantial clearing, fragmentation and degradation. Several documents estimate the former and current extent of previously defined vegetation units that correspond closely with the ecological community. The methods used to define these vegetation units and quantify their extent may vary slightly, for example in the approach to defining condition thresholds. Some estimates of the ecological community's area are presented in Table 1, including the extent of vegetation before 1750 (pre-clearing), remaining extent and the level of protection through formal reservation. The listing of Shale Sandstone Transition Forest under the NSW *Threatened Species Conservation Act 1995* (NSW TSC Act) refers to the estimate of decline by Tozer et al. (2010). The map unit 'p2' described by Tozer et al. (2010) refers to (Cumberland) Shale Sandstone Transition Forest. The description of the ecological community in this conservation advice is consistent with that described for the 'p2' unit. While Tozer et al. (2010) provide an estimated range of remaining extent, they do not provide a single figure for the pre-clearing extent. Estimates of pre-European extent are provided by several other New South Wales government publications, including the 'Cumberland Plain Recovery Plan' (DECCW, 2010), which is the figure reflected in the NSW TSC Act listing.

Note that the various extent estimates of vegetation units in Table 1 may include low quality remnants that do not meet the condition thresholds for the national ecological community. Thus the current extent remaining in moderate or high condition is likely to be less than that shown.

The total area of occupancy (indicated by the estimated extent) is, for each of these estimates, less than 1000 ha. The decline that has occurred since European settlement was estimated in 2010 as 79% (DECCW, 2010).

Further to this, the majority of remnants of the ecological community are very small (<10ha). The mean patch size is approximately 9.6 ha and median size is 2.8 ha. Many occurrences of Shale Sandstone Transition Forest are as linear stands (NSW Scientific Committee, 2012). It has been identified as one of the most fragmented communities in the Sydney region, with substantial exposure of edges to cleared or degraded land (NSW Scientific Committee, 2014).

Table 1. Estimates of decline and extent for Shale Sandstone Transition Forest based on vegetation units that correspond with the ecological community.

Vegetation Community	Estimated area pre-clearing (ha)	Estimated area extant (ha)	% original extent	Estimated area reserved (ha)	% of current extent reserved
a) Cumberland SSTF Map unit p2 (Tozer et al., 2010)		9600	20-40[3]	240	<2
b) Map unit GW04 (DECCW, 2009)	24 000-48 000	9600	20-40	240	<2
c) DEC, 2005	43 990	9950	22	284	0.6
d) DECCW, 2010	45 355	9642[4]	21	420[5]	4
e) Map units 1 and 2 (Tozer, 2003)	45 355	9960[6]	23		

a) 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.

b) DECCW (2009). The native vegetation of the Sydney Metropolitan Catchment Management Authority Region. Department of Environment, Climate Change & Water, Hurstville, NSW.

c) DEC (2005). Recovering Bushland on the Cumberland Plain: Best practice guidelines for the management and restoration of bushland. Department of Environment and Conservation (NSW), Sydney.

d) DECCW (2010). Cumberland Plain Recovery Plan. Department of Environment, Climate Change, and Water (NSW), Sydney.

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

[3] Approximate generic bounds of +/- 10% were estimated for all map units in the study.
[4] In condition classes A,B,C identified in NPWS (2002) as having a relatively intact tree canopy.
[5] On DECCW estate in condition classes A,B,C.
[6] Estimated extent in 1997.

1.6 Other existing protection

Relationship to State-listed ecological communities

Shale Sandstone Transition Forest in the Sydney Basin Bioregion is listed under the NSW *Threatened Species Conservation Act 1995* as a critically endangered ecological community. The state listed ecological community does not explicitly include condition thresholds.

Listed threatened flora species

Table 2. Threatened flora species associated with Shale Sandstone Transition Forest

Scientific name	Common name	TSC Act*	EPBC Act*
Dillwynia tenuifolia[7]		E	-
Epacris purpurascens var. *purpurascens*		V	-
Grevillea parviflora subsp. *parviflora*	small-flowered Grevillea	V	V
Melaleuca deanei	Deane's paperbark	V	V
Persoonia bargoensis	Bargo geebung	E	V
Persoonia glaucescens	Mittagong geebung	E	V
Persoonia hirsuta	hairy geebung	E	E
Pimelea curviflora var. *curviflora*	curved riceflower	V	V
Pomaderris brunnea		V	V
Pultenaea pedunculata	matted bush pea	E	-
Pterostylis saxicola	Sydney plains greenhood	E	E

*V – Vulnerable, E-Endangered, CE- Critically Endangered

Listed threatened fauna species

Table 3. Threatened fauna species associated with Shale Sandstone Transition Forest

Scientific name	Common name	TSC Act*	EPBC Act*
Anthochaera phyrgia	regent honeyeater	CE	E
Callocephalon fimbriatum	gang gang cockatoo	V	-
Calyptorhynchus lathami	glossy black cockatoo	V	-
Climacteris picumnus victoriae	brown treecreeper	V	-
Dasyurus maculatus maculatus	spotted tail quoll (SE mainland population)	V	E
Lathamus discolour	swift parrot	E	E
Lophoictinia isura	square-tailed kite	V	-
Melanodryas cucullata cucullata	hooded robin	V	-
Melithreptus gularis gularis	black-chinned honeyeater	V	-
Neophema pulchella	turquoise parrot	V	-
Petaurus australis	yellow-bellied glider	V	-
Petroica boodang	scarlet robin	V	-
Phascolarctos cinereus	koala	V	V
Petroica phoenicea	flame robin	V	-
Pseudophryne australis	red-crowned toadlet	V	-

[7] The population of *Dillwynia tenuifolia* in The Hills Shire (formerly Baulkham Hills Shire) is listed as endangered under the NSW TSC Act.

Scientific name	Common name	TSC Act*	EPBC Act*
Pteropus poliocephalus	grey-headed flying fox	V	V
Pyrrholaemus saggitatus	speckled warbler	V	-
Saccolaimus flaviventris	yellow-bellied sheathtail bat	V	-
Scoteanax rueppellii	greater broad-nosed bat	V	-
Stagonopleura guttata	diamond firetail	V	-
Varanus rosenbergii	Rosenberg's monitor	V	-

*V – Vulnerable, E-Endangered, CE- Critically Endangered

2 SUMMARY OF THREATS

The landscape within which the ecological community occurs is subject to a matrix of land uses, primarily rural-residential housing and urban use. The key threats that have had a major impact in the past and/or are affecting the ecological community now are:

- vegetation clearing and fragmentation, particularly for urban development
- invasion by exotic species
- inappropriate grazing regimes (and mowing)
- inappropriate fire regimes
- inappropriate recreational use
- rubbish dumping (as a source of weeds and pollutants)
- removal of wood
- soil salinisation.

2.1 Key Threatening Processes

Key threatening processes identified under the NSW TSC Act and EPBC Act that are affecting Shale Sandstone Transition Forest are:

- Land clearance (EPBC Act); Clearing of native vegetation (NSW TSC Act)
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants (NSW TSC Act/EPBC Act); Invasion of native plant communities by exotic perennial grasses (NSW TSC Act); Invasion of native plant communities by African olive (NSW TSC Act); Invasion and establishment of exotic vines and scramblers (NSW TSC Act); Invasion, establishment and spread of Lantana (*Lantana camara* L. sens. Lat) (NSW TSC Act)
- Infection of native plants by *Phytophthora cinnamomi* (NSW TSC Act); Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*) (EPBC Act)
- Introduction and establishment of Exotic Rust Fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae (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)
- Removal of dead wood and dead trees (NSW TSC Act)
- Competition from feral honeybees (NSW TSC Act)
- Aggressive exclusion of birds from woodland and forest habitat by abundant Noisy Miners *Manorina melanocephala* (NSW TSC Act)

- Predation by European red fox (EPBC Act); Predation by the European red fox (*Vulpes vulpes*) (NSW TSC Act)
- Predation by feral cats (EPBC Act); Predation by the feral cat (*Felis catus*) (NSW TSC Act)
- Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases (EPBC Act); Anthropogenic climate change (NSW TSC Act)
- High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition (NSW TSC Act).

Further details about the threats to the ecological community can be found at Appendix D.

3 SUMMARY OF ELIGIBILITY FOR LISTING AGAINST EPBC ACT CRITERIA

Criterion 1 - Decline in geographic distribution

The Shale Sandstone Transition Forest ecological community is estimated to have undergone a decline ranging from 60% to 80% of its original pre-European extent. The areas of extant vegetation included in the estimates are likely to include low quality remnants that do not meet the condition thresholds for the national ecological community. Thus, the current extent remaining in good condition is likely to be less than that shown. The decline in the area of occupancy of the ecological community is due largely to past and ongoing clearing and degradation of remaining patches for grazing, agriculture and urban development.

DECCW (2010) estimates the remaining extent of the ecological community to be approximately 20% of the original extent. Based on this estimate, the ecological community is considered to have undergone a 'severe' decline (> 70%) in geographic extent and is therefore **eligible for listing as endangered** under this criterion.

Criterion 2 - Limited geographic distribution coupled with demonstrable threat

Maps of the ecological community and associated data from DECCW (2009) and Tozer et al. (2010) indicate that the present geographic distribution of the ecological community is 'restricted' with the total area of occupancy <10,000 ha. The ecological community is also highly fragmented with a mean patch size of 9.6 ha and median size of 2.8 ha, considered to be 'very restricted' (analysis of data from Tozer et al., 2010). Almost all patches (81%) have a size of less than 10 ha. Gaps between patches are likely to limit regeneration opportunities as some key species have restricted distribution of seeds.

The ecological community is subject to a range of ongoing threats including clearing, fragmentation and other damage associated with urbanisation; loss of ecological services associated with populations of fauna that have been lost or reduced; and inappropriate fire regimes. Climate change is likely to increase the severity of many existing threats, as well as adding new stress to the ecological community.

The ecological community is considered to be 'very restricted' and the fragmented nature of its distribution makes it likely that threatening processes could cause it to be lost in the immediate future (considered here as three generations of key canopy species, up to 60 years). Therefore, the ecological community is **eligible for listing as critically endangered** under this Criterion.

Criterion 3 - Loss or decline of functionally important species

It has been demonstrated that threats have impacted upon functionally important species within the Shale Sandstone Transition Forest ecological community, such as the 'shale birds' and other nomadic nectarivores. The observed loss of mammal species from the ecological community is likely to have had a negative effect on ecological function, through the reduction of pollination, seed dispersal and soil engineering. However, specific data related to the decline of faunal species in this ecological community is limited. 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 has undergone a very severe reduction in its ecological integrity through fragmentation, structural alteration, weed invasion and decline in native species diversity, particularly fauna. The changes to the flora and faunal components of the ecological community are likely to continue in the light of ongoing threats and continuation of existing land use patterns, in particular, the increasing urbanisation of the region. The ecological community is substantially fragmented, which has the capacity to exacerbate the impacts from other disturbance. The ability of the ecological community to regenerate and recover in the near future from these impacts is limited by the length of time taken to recover key structural elements and by the regional patterns of loss of native species. The continuation of damaging land use is also likely to limit recovery. Therefore, the ecological community is **eligible for listing as critically endangered** under this criterion.

Criterion 5 - Rate of continuing detrimental change

The ecological community has experienced a considerable rate of continuing detrimental change in the past, which has continued to the present time. Further declines in geographic distribution are projected to occur across its range, particularly associated with planned urban development. Although there has been continuing detrimental change to the ecological community, data are insufficient to determine an overall rate, as such, there is **insufficient information to determine the eligibility** of the ecological community for listing under any category of Criterion 5.

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.

4 PRIORITY CONSERVATION ACTIONS

4.1 Conservation Objective

To mitigate the risk of extinction of the Shale Sandstone Transition Forest of the Sydney Basin Bioregion, and help recover its biodiversity and function, through the protections provided under the *Environment Protection and Biodiversity Conservation Act 1999* and through the implementation of the following priority conservation actions.

4.2 Research and monitoring priorities

High priority research and monitoring activities that would inform future regional and local actions in relation to the Shale Sandstone Transition Forest include:

- Determination of optimal management regimes (including fire regime) and best practice standards across the ecological community and within different areas.
- Map former and current extent and condition.
- Survey known sites to identify status (including high conservation priority) and key threats and to monitor condition change (including changes in flora and fauna composition.

4.3 Priority recovery and threat abatement actions

The following priority recovery and threat abatement actions should be implemented to support the recovery of the Shale Sandstone Transition Forest:

Habitat Loss, Disturbance and Modification

Highest priorities:

- Avoid further clearance and fragmentation of patches of the ecological community and surrounding native vegetation, including derived grasslands/shrublands.
- Minimise impacts from any developments and activities adjacent to patches that might result in further degradation (for example by applying buffer zones).
- Protect mature trees with hollows and plant native hollow producing species. Ensure that trees are always left to grow to maturity and if necessary place artificial hollows (e.g. nest boxes) in or near to the ecological community and monitor outcomes.
- Retain fallen logs as habitat for fauna (and add logs to areas where they have been removed), noting different log requirements for different species e.g. logs embedded in the soil are necessary for some species and hollow logs are required by other species.
- Retain other native vegetation remnants, derived grasslands or shrublands and paddock trees near patches of the ecological community and create or restore wildlife corridors and linkages.
- Implement appropriate management regimes and best practice standards to maintain the biodiversity, including listed threatened species, of patches of the ecological community on private and public lands.
- Integrate fire and grazing management regimes (see also separate actions below regarding grazing and fire).
- Manage any changes to hydrology or disruptions to water flows that may result in changes to water table levels and/or increased run-off, salinity, sedimentation or pollution.
- Manage any other known, potential or emerging threats such as rural tree dieback.

Other priorities:

- Implement adaptive management actions effectively and monitor the progress of recovery, through estimates of extent and condition assessments of the ecological community.
- Investigate formal conservation arrangements, management agreements and covenants on private land, and for crown and private land investigate inclusion in reserve tenure. This is

particularly important for larger, higher quality patches that are important in a landscape context. For example, areas that link patches and create wildlife corridors.

- Revegetate gullies and stream banks where vegetation has been cleared and widen the strip of riparian vegetation by planting appropriate local native species.

Invasive Species

- Promote knowledge about local weeds and keep non-indigenous invasive plant species controlled at all times.
- Monitor for signs of new disease and identify new weed incursions early and mange for local eradication.
- Control introduced pest animals, including domestic pets, to allow natural regeneration and to manage threats, especially to threatened species.
- Use appropriate hygiene to minimise the introduction or spread of plant diseases and weeds at susceptible sites (e.g. when holding stock in conservation sensitive vegetation, ensure stock are purged of weed seeds; keep vehicles and machinery out of remnants. If vehicles must be taken into remnants ensure vehicles are washed first to remove soil and weed seeds).
- Do not plant potential environmental weeds in nearby gardens or public landscaping, from which they may spread into the remnant, nor dump garden waste beyond the confines of the garden, on private or public land. Promote planning of local native species.

Trampling, Browsing or Grazing

- Ensure that livestock grazing, if it occurs in the area, uses an appropriate management regime and density that does not detrimentally affect this ecological community.
    - Shale Sandstone Transition Forest remnants can be grazed occasionally and this may be beneficial for reducing grass cover, encouraging herb growth and keeping tree and shrub regeneration from becoming too thick. However, if stock could carry noxious weeds into the remnant, then it would be preferable to exclude stock altogether or admit them only at times when none of the weeds are producing seed.
    - Avoid grazing during native plant flowering and seeding times (spring and summer).
    - Short periods of grazing are preferable to leaving stock in for long periods.
- Where appropriate, manage total grazing pressure at important/significant sites through exclusion fencing or other barriers.

Fire

- Implement an appropriate fire management regimes that take into account results from research. This may include:
    - Raking fuel away from the base of old trees prior to burning and extinguishing tree bases during the fire so as not to undermine old trees and hasten their death.
    - Burning in early spring as this is preferable for control of annual weeds, but consider other requirements where threatened species are present.
    - Not burning if soil moisture is very low, or dry conditions are predicted for the coming season, as grass recovery will be too slow and erosion may occur or weeds become established while the ground is bare.
    - For large patches, burning different parts of a remnant in rotation rather than the whole area in any one season.
    - Monitoring the results for increases in native herbs, grasses and forbs or a decrease in weeds.

Communication and Conservation Information

- Promote awareness of the ecological community through liaison with:
  - state and local government planning authorities to ensure that planning takes the protection of remnants into account, with due regard to principles for long-term conservation.
  - state and local government planning and construction industries to minimise threats associated with land development.
  - local councils and state authorities to ensure road widening and maintenance activities (or other infrastructure or development activities) involving substrate or vegetation disturbance do not adversely impact the ecological community. This includes avoiding the introduction or spread of weeds.
  - local fire brigades and agencies to support ecological fire regimes for patches of the ecological community.
  - local communities using a range of media and methods such as information products, signage and field days (e.g. planting, weeding) in conjunction with known industry or community interest groups.
- Maintain engagement with private landholders and land managers where the ecological community occurs and encourage local participation in recovery efforts.
- Develop education programs to discourage the removal of dead timber, dumping of rubbish, and the use of off-road vehicles in environmentally sensitive areas.

4.4 Existing plans/management prescriptions

The following management prescriptions were current at the time of publishing; please refer to the relevant agency's website for any updated versions:

- Department of Environment, Climate Change and Water (NSW) (2011). Cumberland Plain Recovery Plan.

  www.environment.nsw.gov.au/resources/threatenedspecies/20100501CumberlandPlain.pdf

- Department of Environment and Conservation (NSW) (2005). Recovering bushland on the Cumberland Plain: best practice guidelines for the management and restoration of bushland.

  www.environment.nsw.gov.au/resources/nature/RecoveringCumberlandPlain.pdf

- NSW NPWS (2004) Endangered Ecological Community Information: Shale Sandstone Transition Forest.
  www.environment.nsw.gov.au/resources/nature/EECinfoShaleSandstoneTransitionForest.pdf
- Office of Environment and Heritage (NSW). Shale/Sandstone Transition Forest – profile. Available on the internet at: http://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10755.

4.5 Recovery plan recommendation

The Committee considers that a recovery plan is required for the Shale Sandstone Transition Forest ecological community as it has been listed as critically endangered. Preparation of a national recovery plan will promote coordinated recovery actions. Coordinated management actions relevant to the ecological community can be incorporated into the Recovery Plan for the Cumberland Plain and surrounds that is currently in preparation.

APPENDIX A - SPECIES LISTS

Table A1 lists vascular plant species characteristic of Shale Sandstone Transition Forest. It is an indicative rather than comprehensive list of plant species present in the ecological community. 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 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.

Tozer et al. (2010) identify species considered to be particularly distinctive to the ecological community, many of which are included here in bold type. If the total species recorded in a 0.04 ha survey plot contains a high representation of these distinctive species, there is a strong indication that Shale Sandstone Transition Forest is present. This indication is only valid where plots have sufficiently high species richness.[8]

Table A1. Characteristic plant species. Scientific names are as at April 2014.

Species name	**Common name**
Acacia decurrens	**black wattle**
Acacia falcata	
Acacia implexa	
Acacia myrtifolia	
Acacia parramattensis	
Allocasuarina littoralis	**black she-oak**
Allocasuarina torulosa	
Angophora bakeri	
Angophora costata	
Angophora floribunda	rough-barked apple
Aristida ramosa	
Aristida vagans	**three-awned spear grass**
Arthropodium milleflorum	
Astroloma humifusum	
***Rytidosperma* spp. (syn. *Austrodanthonia* spp.)**	
Austrostipa pubescens	**spear grass**
Austrostipa rudis	
Billardiera scandens	
Bossiaea prostrata	
Bothriochloa species	
Breynia oblongifolia	
Brunoniella australis	
Brunoniella pumilio	
Bursaria spinosa	**blackthorn**

[8] The diagnostic test proposed by Tozer, et al. (2010) applied to randomly selected plots with species richness greater than 39 containing more than 26 diagnostic species. Thus, this list of species should be considered as indicative in other circumstances.

Species name	**Common name**
Caesia parviflora	
Calotis dentex	
Carex inversa	
Centella asiatica	
Cheilanthes sieberi* subsp. *sieberi	**poison rock fern**
Corymbia eximia	
Corymbia gummifera	red bloodwood
Corymbia maculata	**spotted gum**
Cyathochaeta diandra	
Cymbopogon refractus	
Cyperus gracilis	
Daviesia ulicifolia	
Desmodium varians	slender tick-trefoil
Dianella caerula	
Dianella longifolia	
Dianella revoluta	**blueberry lily, blue flax-lily**
Dichelachne micrantha	**shorthair plumegrass**
Dichondra repens	**kidney weed**
Digitaria parviflora	**small-flowered finger grass**
Digitaria ramularis	
Dillwynia tenuifolia	
Dodonaea triquetra	**large-leaf hop-bush**
Echinopogon caespitosus	
Echinopogon ovatus	**forest hedgehog grass**
Einadia trigonos	
Entolasia marginata	**borded panic**
Entolasia stricta	**wiry panic**
Epacris purpurascens var. *purpurascens*	
Eragrostis brownii	**Brown's lovegrass**
Eragrostis leptostachya	**paddock lovegrass**
Eucalyptus amplifolia subsp. *amplifolia*	
Eucalyptus beyeriana	
Eucalyptus crebra	**narrow-leaved ironbark**
Eucalyptus eugenioides	**thin-leaved stringybark**
Eucalyptus fibrosa* subsp. *fibrosa	**broad-leaved ironbark**
Eucalyptus globoidea	**white stringybark**
Eucalyptus longifolia	
Eucalyptus maculata	spotted gum
Eucalyptus moluccana	

Species name	Common name
Eucalyptus notabilis	
Eucalyptus paniculata subsp. *paniculata*	
Eucalyptus pilularis	blackbutt
Eucalyptus punctata	**grey gum**
Eucalyptus resinifera* subsp. *resinifera	
Eucalyptus tereticornis* subsp. *tereticornis	**forest red gum**
Euchiton sphaericus	
Exocarpos cupressiformis	
Gahnia aspera	**rough saw-sedge**
Geranium homeanum	
Glycine clandestina	
Glycine microphylla	**small-leaf glycine**
Glycine tabacina	
Gonocarpus tetragynus	
Goodenia hederacea	**forest goodenia, ivy goodenia**
Grevillea parviflora subsp. *parviflora*	**small-flowered Grevillea**
Hakea sericea	needlebush
Hardenbergia violacea	**purple coral pea, false sarsparilla, native wisteria**
Helichrysum scorpioides - Coronidium scorpiodes	button everlasting
Hibbertia aspera	**rough guinea flower**
Hibbertia diffusa	**wedge guinea flower**
Hydrocotyle peduncularis	
Indigofera australis	Australian indigo
Jacksonia scoparia	
Joycea pallida - Rytidosperma pallidum	silvertop wallaby grass, red anther wallaby grass
Kunzea ambigua	**tick bush**
Lagenophora gracilis	
Laxmannia gracilis	**slender wire lily**
Lepidosperma laterale	**saw sedge**
Leucopogon juniperinus	**prickly beard-heath**
Lissanthe strigosa	**peach heath**
Lomandra filiformis* var. *coriacea	
Lomandra filiformis* var. *filiformis	**wattle mat-rush**
Lomandra longifolia	
Lomandra multiflora	**many-flowered mat-rush**
Microlaena stipoides	**weeping grass**
Maytenus silvestris	narrow-leaved orange bark, orange bush, orange bark

Species name	**Common name**
Melaleuca deanei	Deane’s paperbark
Notelaea longifolia	
Olearia microphylla	
Opercularia diphylla	
Opercularia varia	variable stinkweed
Oplismenus aemulus	Australian basket grass, wavy beard grass
Oxalis exilis	
Oxalis perennans	**wood sorrel**
Ozothamnus diosmifolius	**rice flower, sago bush, white dogwood**
Panicum simile	**two-colour panic**
Paspalidium distans	
Persoonia bargoensis	Bargo geebung
Persoonia glaucescens	Mittagong geebung
Persoonia hirsuta	hairy geebung
Persoonia linearis	**narrow-leaved geebung**
Persoonia revolutum	
Phyllanthus hirtellus	
Pimelea curviflora var. *curviflora*	
Pimelea linifolia* subsp. *linifolia	
Plantago debilis	
Poa labillardierei	**tussock grass**
Poa sieberiana	snowgrass
Polyscias sambucifolia	elderberry panax, ornamental ash, elderberry ash
Pomax umbellata	
Poranthera microphylla	
Pratia purpurascens	**white root**
Pseuderanthemum variabile	pasel flower
Pterostylis saxicola	Sydney plains greenhood
Pultenaea pedunculata	matted bush pea
Pultenaea villosa	**hairy bush pea**
Rumex brownii	swamp dock
Solanum prinophyllum	forest nightshade
Syncarpia glomulifera	turpentine
Themeda triandra (syn. *Themeda australis*)	**kangaroo grass**
Vernonia cinerea	
Veronica plebeia	**creeping speedwell**
Wahlenbergia gracilis	Australian bluebell

Table A2 lists fauna that may be part of the ecological community and where applicable, includes threatened status. This is not a comprehensive list of animal species in the ecological community.

Table A2. Fauna species associated with Shale Sandstone Transition Forest. Scientific names are as at April 2014.

Species	Common name	TSC Act	EPBC Act
Birds			
Acanthiza chrysorrhoa	yellow-rumped thornbill		
Acanthiza reguloides	buff-rumped thornbill		
Anthochaera phyrgia	regent honeyeater	CE	E
Callocephalon fimbriatum	gang gang cockatoo	V	
Calyptorhynchus lathami	glossy black cockatoo	V	
Chalcites osculans	black-eared cuckoo		
Climacteris picumnus victoriae	brown treecreeper	V	
Corcorax melanorhamphos	white-winged chough		
Geopelia striata	peaceful dove		
Lalage sueurii	white-winged triller		
Lathamus discolour	swift parrot	E	E
Lichenostomus fuscus	fuscous honeyeater		
Lophoictinia isura	Square-tailed kite	V	
Melanodryas cucullata cucullata	hooded robin	V	
Melithreptus gularis gularis	black-chinned honeyeater	V	
Microeca fascinans	jacky winter		
Myiagra inquieta	restless flycatcher		
Neophema pulchella	turquoise parrot	V	
Pardalotus striatus	striated pardalote		
Petroica boodang	scarlet robin	V	
Petroica goodenovii	red-capped robin		
Petroica phoenicea	flame robbin	V	
Phascolarctos cinereus	koala	V	V
Psephotus haematonotus	red-rumped parrot		
Pyrrholaemus saggitatus	speckled warbler	V	
Smicrornis brevirostris	weebill		
Stagonopleura guttata	diamond firetail	V	
Taeniopygia guttata	zebra finch		
Mammals			
Antechinus stuartii	Brown antechinus		
Cercartetus nanus	eastern pygmy possum		
Dasyurus maculatus maculatus	spotted tail quoll (SE mainland population)	V	E
Petaurus australis	yellow-bellied glider	V	
Pretaurus breviceps	sugar gliders		
Pteropus poliocephalus	grey-headed flying-fox	V	V
Rattus fuscipes	bush rat		
Saccolaimus flaviventris	yellow-bellied sheathtail	V	

Species	Common name	TSC Act	EPBC Act
Scoteanax rueppellii	greater broad-nosed bat	V	
Reptiles and Amphibians			
Pseudophryne australis	red-crowned toadlet	V	
Pseudophryne bibroni	Bibron's or Brown toadlet		
Varanus rosenbergii	Rosenberg's monitor	V	
Invertebrates			
Meridolum corneovirens	Cumberland land snail	E	
Meridolum duralensis	land snail		

Table A3 lists weed species known to occur in the area where the ecological community is present.

Table A3. Weed species associated with Shale Sandstone Transition Forest. Scientific names are as at April 2014.

Species	Common name
Araujia hortorum	moth vine
Cirsium vulgare	spear thistle
Delairea odorata	Cape Ivy
Hyparrhenia hirta	Coolatai grass
Hypochaeris radicata	cat's ear
Lonicera japonica	Japanese honey suckle
Ligustrum lucidum	broad-leafed privet
Ligustrum sinense	small-leafed privet
Myrsiphyllum asparagoides	bridal creeper
Olea europaea subsp. *cuspidata*	African olive
Panicum queenslandicum	Coolabah grass
Plantago lanceolata	plantain
Rubus fruticosus	blackberry
Senecio madagascariensis	fireweed
Setaria gracilis	pigeon grass
Sida rhombifolia	Paddy's lucerne
Sonchus oleraceus	sow thistle

APPENDIX B DETAILED DESCRIPTION OF SHALE SANDSTONE TRANSITION FOREST BIOLOGY AND ECOLOGICAL PROCESSES

Examples of faunal roles and interactions

The relationships between species within the ecological community are important for maintaining ecosystem function. The trees and other plants of Shale Sandstone Transition Forest provide essential resources for many animals. Food is provided both directly (blossom, seed, gum) and indirectly (attract insects that provide food for birds, reptiles and bats). Trees also provide nesting and roosting sites among leaves, on branches and in hollows and create a sheltered microclimate under the canopy by reducing solar radiation and creating a litter layer (leaves, sticks, logs).

The faunal species present in Shale Sandstone Transition Forest differ between the different structural forms of the ecological community (grassy understorey, shrubby understorey, derived grassland). In turn, animals influence the structure and floristics of the vegetation by grazing, browsing, pollination and distribution of seeds.

<u>Food resources</u>

Shale Sandstone Transition Forest is often dominated by ironbark species such as *Eucalyptus crebra* (narrow-leaved ironbark) and *E. fibrosa* subsp. *fibrosa* (broad-leaved ironbark). In winter, when nectar is scarce, these trees, along with *E. tereticornis* subsp. *tereticornis (*forest red gum), *E. globoidea* (white stringybark), *E.punctata* (grey gum) and *Corymbia maculata* (spotted gum) can be significant food sources for a suite of nectarivores. The taxa that benefit include birds such as the migratory and endangered *Anthochaera phrygia* (regent honeyeater) and *Lathamus discolor* (swift parrot); *Melithreptus gularis gularis* (black-chinned honeyeater), as well as mammals such as *Pteropus poliocephalus* (grey-headed flying-fox). Swift parrot is also known to feed on *Corymbia gummifera* (red bloodwood), *Eucalyptus moluccana* (coastal grey box) and *E. pilularis* (blackbutt) (the latter two species for lerps, the former for nectar). Red bloodwood and spotted gum may also be a significant source of nectar and support regional movement of *Pteropus poliocephalus* (grey-headed flying fox), which is listed as vulnerable (NSW TSC Act and EPBC Act).

Shale Sandstone Transition Forest includes several *Eucalyptus* and *Acacia* tree species that are known to or likely to be used as a food source and as potential nesting sites by the vulnerable (NSW TSC Act) *Callocephalon fimbriatum* (gang gang cockatoo), which primarily feeds on eucalypt fruits to obtain the enclosed seeds. Some forms of the ecological community can also include a significant midstorey of black she-oak, which is a food source for the vulnerable (NSW TSC Act) *Calyptorhynchus lathami* (glossy black cockatoo). Grey gum, which can form significant stands in the ecological community, is a preferred feed tree for the vulnerable (NSW TSC Act) *Petaurus australis* (yellow-bellied glider).

Some of the more grassy forms of Shale Sandstone Transition Forest support populations of macropods that browse and graze on the grassy understorey and shrub layer. These populations may significantly influence the floristics and structure of the ecological community and influence fire behaviour, for example, lots of grazers or browsers may favour a more grassy environment, which is relatively flammable, burns quickly with relatively low intensity and flame height relative to shrubby formations. In contrast, the unpalatability of some shrub species has led to increased survival of shrub seedlings (Windsor, 1999).

<u>Other faunal associations and ecosystem interactions</u>

The Shale Sandstone Transition Forest ecological community is also known to support micro-bat species, primarily by providing tree hollows and suitable foraging habitat. Ridgeway (2010) and DECCW (2007) reported that there are at least two vulnerable (NSW TSC) microchiropteran bat species that are strongly associated with the shale-sandstone transition habitat, *Saccolaimus flaviventris* (yellow-bellied sheathtail bat) and *Scoteanax rueppellii* (greater broad-nosed bat).

The ecological community is unlikely to 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 skinks and snakes. For example, the vulnerable (NSW TSC Act) *Varanus rosenbergii* (Rosenberg's monitor) inhabits Shale Sandstone Transition Forest remnants, as it does not require rock outcrops, and is able to use termite mounds for egg incubation.

Frog species known to use Shale Sandstone Transition Forest include *Pseudophryne bibroni* (Bibron's or Brown toadlet), which is regarded as 'at risk' (Thumm & Mahony, 1997) and 'near threatened' on the IUCN Red List (2011) due in part to clearing and degradation of habitat. Additionally, suitable habitat for the vulnerable (NSW TSC Act) *Pseudophryne australis* (red-crowned toadlet) follows the interface of Hawkesbury Sandstone and Wianamatta and Narrabeen Shales, where the ecological community commonly occurs. Individual toadlets are found in the ecological community below sandstone ridges, generally where shale lenses are weathering at the base of cliff lines. This interface is sometimes associated with areas of high groundwater and seepage.

A complex array of ecological interactions occurs between the various components of the ecological community, for example, between soil, vegetation and fauna. Across eastern Australia, a major cause of eucalypt dieback is insect attack. For example, large numbers of *Anoplognathus* species (Christmas beetles) can cause severe and repeated defoliation events of many eucalypt species, and repeated events can lead to the death of affected trees. The shrub, *Bursaria spinosa* (blackthorn), commonly found in the understorey of Shale Sandstone Transition Forest is a significant nectar source for a wasp that parasitises Christmas beetle larvae. They thus control populations of this beetle, which can otherwise boom under suitable climatic and weather conditions. *Bursaria* has often been removed from the ecological community for pasture improvement or by a change in fire regime, resulting in the likelihood that Christmas beetle populations will boom more often, with possible effects on the canopy trees (*sensu* Ridsdill Smith, 1970; Davidson & Davidson, 1992).

Some ground-dwelling native animals such as the common wombat and echidna as well as bandicoot species found, or likely to have been formerly present in the ecological community may have played 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). The loss of these digging 'ecological engineers' may cause reduction in ecological function and disrupt regeneration of the ecological community. In addition, with other modifications and ongoing threats to the ecological community, when soil disturbance now occurs, rather than assisting recruitment of native flora, it often encourages weed invasion.

Fauna also play an important role in pollination and in transfer of seeds – these functions involve a wide range of taxa, including many species of invertebrates and birds. Some mammals such as *Pretaurus breviceps* (sugar gliders), *Antechinus stuartii* (brown antechinus), *Rattus fuscipes* (bush rat) and *Cercartetus nanus* (eastern pygmy possum) also contribute to these functions (Upper Parramatta River Catchment Trust, 1999 after Goldingay and Carthew, 1997).

The Shale Sandstone Transition Forest ecological community contributes to habitat for the 'shale bird' assemblage. These birds correspondingly have an important ecological role consuming large numbers of leaf-eating insects and pasture grubs, and are also important for the pollination and seed dispersal of many plants in the ecological community (Visoiu and Lloyd, 2003).

Role of connectivity and broad landscape context

Connectivity between remnants of the ecological community and with other native vegetation remnants is an important determinant of habitat quality at the landscape scale for native flora and fauna, as well as to the overall condition of the ecological community. For flora, connectivity is important as it increases pollination and spread of propagules. For vertebrate groups, the diversity and abundance of fauna is more correlated with the connectivity of patches to other remnant vegetation than to the size of the patch itself. For example, on the Cumberland Plain both diversity and abundance of micro-bats is significantly correlated with the amount of woodland and forest within a 3 km radius of survey sites (Leary, 2007). This has implications for the long-term conservation of vertebrates in the ecological community given its severe fragmentation. There are also around 30 species of migratory birds (non-shore-birds) that rely on the ecological community and surrounding Cumberland Plain vegetation communities. Most of the migratory species arrive in spring and depart in autumn although a few species are winter migrants. Large numbers of passage migrants move northward through the Greater Sydney region every May and return between August and October (Leary, 2007). This indicates the importance of the ecological community on a scale well beyond its geographic extent.

Remnants of the Shale Sandstone Transition Forest ecological community represent important habitat for fauna and flora in a severely fragmented landscape. Due to historic clearing for agriculture and increasing clearing for urbanisation, few large remnants remain. As such, remnants of Shale Sandstone Transition Forest may form critical refugia. Large patches and smaller patches linking other patches of native vegetation in the landscape are particularly important.

Role of fire

Fire is likely to have played a key role in the development of the ecological community, with fire intensity and interval particularly affecting understorey species composition, and fire management being important for the conservation of the community (*sensu* Keith, 2010). The number of species, and the above ground relative abundance of species will change with time since fire, and may also change in response to changes in fire regime (including changes in fire frequency) (NSW Scientific Committee, 2012). For example, *Themeda triandra* syn. *T. australis* declines in the absence of fire and *Bursaria spinosa* is found in high abundance in low fire frequency sites to the point where the species can dominate much of the landscape (Watson and Morris, 2006). At any one time, above ground individuals of some species may be absent, but the species may be present below ground in the soil seed banks or as dormant structures such as bulbs, corms, rhizomes, rootstock or lignotubers.

APPENDIX C DETAILED DESCRIPTION OF NATIONAL CONTEXT

Distribution

Shale Sandstone Transition Forest occurs on the edges of the extensively cleared Cumberland Plain and the adjoining sandstone-dominated Hornsby, Woronora, and Lower Blue Mountains Plateaux.

The ecological community occurs only in the Sydney Basin Bioregion (IBRA v. 7). It occurs in Local Land Service regions of Greater Sydney and Central West.

Shale Sandstone Transition Forest occurs in the following local government areas: Bankstown, Baulkham Hills, Blue Mountains, Campbelltown, Hawkesbury, Hornsby, Liverpool, Parramatta, Penrith, Wingecarribee and Wollondilly (within the Sydney Basin Bioregion) and may occur elsewhere in the Sydney Basin Bioregion.

Relationships to other vegetation classifications

The ecological community corresponds, entirely or in part, to the following vegetation classifications:

- Tozer et al. (2010)

  - GW p2 - Cumberland Shale Sandstone Transition Forest

- Tozer (2003)

  -Map units 1 and 2

- Tindall et al. (2004)

  -unit GW2

- National Vegetation Information System (NVIS)

  - Major Vegetation Group (MVG)

    MVG 4 - Eucalypt Woodlands

    MVG 3 - Eucalyptus Open Forests

  - Major Vegetation Subgroup (MVS)

    MVS 4 & 5 *Eucalyptus* open forests with a grassy and/or shrubby understorey

    MVS 8 & 9 - *Eucalyptus* open woodlands with a grassy and/or shrubby understorey

If a patch mapped as DSF p146 Sydney Hinterland Transition Woodland (Tozer, 2010) meets the description of the Shale Sandstone Transition Forest, it is considered the ecological community.

Differences to similar or intergrading ecological communities

Shale Sandstone Transition Forest includes vegetation types that are inherently transitional between the relatively well defined, and previously much more common, Wianamatta and Hawkesbury Shale-based vegetation types of the Greater Sydney area, and those of the still extensive sandstone-based vegetation types. Some variants of Shale Sandstone Transition Forest may be relatively distinct from allied shale or sandstone communities, whereas others may be strongly allied to a recognised shale-based, or less often, sandstone-based community. Some variants of Shale Sandstone Transition Forest may share a significant number of species with the following threatened shale and laterised shale-based ecological communities that are listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) and/or EPBC Act:

- Cumberland Shale Plains Woodland (TSC Act)
- Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest (EPBC Act)
- Sydney Turpentine-Ironbark Forest (TSC Act)
- Turpentine-Ironbark Forest in the Sydney Basin Bioregion (EPBC Act)
- Blue Mountains Shale Cap Forest in the Sydney Basin Bioregion (TSC Act)
- Blue Gum High Forest (TSC Act)
- Blue Gum High Forest in the Sydney Basin Bioregion (EPBC Act)
- Southern Highlands Shale Woodlands in the Sydney Basin Bioregion (TSC Act)
- O'Hares Creek Shale Forest (TSC Act)
- Duffys Forest (TSC Act)
- Southern Sydney Sheltered Forest (TSC Act).

Shale Sandstone Transition Forest is distinguished from these communities primarily by its floristic composition being less influenced by shale or secondarily, by having a shale-influenced flora that is not typical of allied shale communities across the canopy, midstorey, and understorey. Some forms of Shale Sandstone Transition Forest may have one or more structural layers with similar or even identical floristics to one or more of the threatened shale-based communities, but will have at least one layer with floristics that are not typical of the associated shale or laterised shale-based community.

Shale Sandstone Transition Forest generally occurs below adjoining Turpentine-Ironbark Forest in the Sydney Basin Bioregion, Blue Gum High Forest, Blue Mountains Shale Cap Forest, and Southern Highlands Shale Woodlands, as most of those communities occur on elevated plateaux. It can occur on ridgetops and plateaux where shale caps have eroded such that the former shale-based communities have altered to become Shale Sandstone Transition Forest. Shale Sandstone Transition Forest generally occurs down-slope of Cumberland Shale Woodlands except where there has been geological uplift as part of the formation of a plateau (e.g. Hornsby, Woronora, Blue Mountains, and where the far southern Cumberland Plain has been uplifted along the Nepean Ramp).

Cumberland Plain Woodland of the Sydney Basin Bioregion (TSC Act) and Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest (EPBC Act) typically occurs on deeper heavy clay soils derived from Wianamatta Shale, and so is not influenced by shallow sandstone substrates as Shale Sandstone Transition Forest. The dominant canopy trees of this ecological community include *Eucalyptus moluccana* (grey box) (which is not typically dominant in Shale Sandstone Transition Forest), in addition to *E. tereticornis* subsp. *tereticornis* (forest red gum), with *E. crebra* (narrow-leaved ironbark), *Corymbia maculata* (spotted gum) and *E.eugenioides* (thin-leaved stringybark) occurring less frequently. The sparse mid canopy is likely to contain small trees not common in Shale Sandstone Transition Forest, including *Exocarpos cupressiformis* (native cherry) and *Melaleuca decora* (paperbark) as well as *Acacia* species. The understory is grassier than that of Shale Sandstone Transition Forest and is dominated by *Bursaria spinosa* (blackthorn) with abundant grasses such as *Themeda triandra* syn. *T. australis* (kangaroo grass) and *Microlaena stipoides* (weeping meadow grass).

Towards the margins of the Cumberland Plain where shale soils become shallower and there is an increased influence from underlying sandstone, Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest grades into Shale Sandstone Transition Forest (low sandstone influence) which lacks grey box as a dominant tree species and may include grey gum, which is not typical of the Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest. The Shale Sandstone Transition Forest may also be distinguished by the likely dominance of *Allocasuarina littoralis* (black she-oak) in the small tree layer (Tozer, 2003).

Turpentine-Ironbark Forest in the Sydney Basin Bioregion occurs close to the shale/sandstone boundary on the more fertile shale influenced soils, in higher rainfall areas on the higher altitude margins of the Cumberland Plain, and on the shale ridge caps of sandstone plateaux, often at a higher altitude. Like Shale Sandstone Transition Forest, this community is also intermediate between Cumberland Plain Shale Woodlands in drier areas and Blue Gum High Forest on adjacent higher rainfall ridges. It can intergrade into Shale Sandstone Transition Forest, but the ecological communities can be distinguished floristically. Sydney Turpentine-Ironbark Forest occurs as open forest, with two of the dominant canopy trees, *Syncarpia glomulifera* subsp. *glomulifera* (turpentine) and *E. saligna* (Sydney blue gum), occurring much less commonly in Shale Sandstone Transition Forest. The shrub stratum is usually sparse and may contain mesic species such as sweet pittosporum, *Pittosporum revolutum* (rough-fruit pittosporum) and *Polyscias sambucifolia* (elderberry panax) which are also not typical of Shale Sandstone Transition Forest.

Blue Gum High Forest in the Sydney Basin Bioregion occurs above adjoining areas of Shale Sandstone Transition Forest where rainfall is higher (above 1100 millimetres per year) and the soils are relatively fertile and derived from Wianamatta shale. In lower rainfall areas, it grades into Sydney Turpentine-Ironbark Forest. Blue Gum High Forest is a moist, tall open forest community, with dominant canopy trees of *Eucalyptus saligna* (Sydney blue gum) and *E. pilularis* (blackbutt). Species adapted to moist habitat such as *Acmena smithii* (lillypilly), *Ficus coronata* (sandpaper fig), *Calochleana dubia* (soft bracken) and *Adiantum aethiopicum* (maiden hair) may also occur. These species are not typical of Shale Sandstone Transition Forest.

Blue Mountains Shale Cap Forest in the Sydney Basin Bioregion occurs on deep fertile soils formed on Wianamatta Shale, on moist sheltered sites at lower to middle altitudes of the Blue Mountains and Wollemi areas. Characteristic tree species of this ecological community differ from those of Shale Sandstone Transition Forest, including *Eucalyptus deanei* (Deane's gum), *E. cypellocarpa* (mountain grey gum) and turpentine.

Southern Highlands Shale Woodlands in the Sydney Basin Bioregion is confined to the Southern Highlands, further south than most occurrences of Shale Sandstone Transition Forest. It occurs roughly within an area bounded by the Illawarra Escarpment in the east, Burrawang and Bundanoon in the south, Canyonleigh in the west and Berrima and Colo Vale in the north. This ecological community is restricted to the clay soils derived from Wianamatta Shale. The dominant canopy species vary across the distribution of the community. Common species throughout much of the community's range are *Eucalyptus cypellocarpa* (mountain grey gum), *E. piperita* subsp. *urceolaris* (Sydney peppermint), *E. ovata* (swamp gum) and *E. radiata* (narrow-leafed peppermint). *Eucalyptus mannifera* (brittle gum), *E. pauciflora* (snow gum), *E. amplifolia* (cabbage gum) and *Angophora floribunda* (rough-barked apple) are more common than in Shale Sandstone Transition Forest. *Eucalyptus macarthurii* (Camden woollybutt) occurs throughout, but appears to be most common in the south-west of the distribution of the community, around Bundanoon.

Duffys Forest is dominated by red bloodwood and *Eucalyptus sieberi* (black ash) but also *Angophora costata* (smooth-barked apple). It is floristically distinct from Shale Sandstone Transition Forest and does not occur adjacent to Wianamatta Shale-based vegetation. Duffys Forest also supports an understorey more typical of laterised shale than shale-proper. This includes the endangered *Grevillea caleyi* (Caley's grevillea) (NSW TSC Act and EPBC Act), which is nearly endemic to the Duffys Forest ecological community. This ecological community has a stronger sandstone influence than Shale Sandstone Transition Forest and occurs on ridge-tops where ironstone mantles occur above sandstone ridges.

O’Hares Creek Shale Forest is floristically distinct from Shale Sandstone Transition Forest, and does not occur adjacent to Wianamatta Shale-based vegetation. O’Hares Creek Shale Forest occurs on small outcrops of Hawkesbury Shale in the Darkes Forest area of the Woronora Plateau and has very high rainfall and a significant coastal influence, with some variants containing substantial stands of *Doryanthes excelsa* (Gymea lily), a species that is not indicative of Shale Sandstone Transition Forest. O'Hares Creek Shale Forest is dominated by *Eucalyptus piperita* (Sydney peppermint), *E. globoidea* (white stringybark) and *Angophora costata* (smooth barked apple).

Southern Sydney sheltered forest on transitional sandstone soils in the Sydney Basin Bioregion is floristically distinct from Shale Sandstone Transition Forest. The dominant trees include *Angophora costata*, *Eucalyptus piperita* and occasionally *Eucalyptus pilularis*. *Corymbia gummifera* occurs frequently within the community, although generally at lower abundance than the other eucalypts. The community occupies a different landscape position to Shale Sandstone Transition Forest being typically associated with sheltered heads and upper slopes of gullies on transitional zones where sandstone outcrops may exist, but where soils are influenced by lateral movement of moisture, nutrients and sediment from more fertile substrates, such as shale/ironstone caps or dolerite dykes, in adjacent areas.

Level of protection in reserves

Transitional vegetation types such as Shale Sandstone Transition Forest in the Cumberland Plain/Greater Sydney region have a very low proportion of their extent in reservation (Tozer et al., 2010), particularly in comparison to surrounding sandstone based vegetation assemblages. It is estimated that approximately 80% of the original extent of the ecological community has been cleared and <1% (420 ha) of the original area is protected in reserves (Tozer et al., 2010).

APPENDIX D DESCRIPTION OF THREATS

The ecological community has suffered substantial damage in the past, largely associated with the direct loss and degradation of vegetation. A range of threats is ongoing, and may interact in complex ways to reduce the integrity and function of the Shale Sandstone Transition Forest ecological community.

Clearing and fragmentation

Clearing of the Shale Sandstone Transition Forest ecological community has been more prevalent than for the adjacent sandstone-based vegetation, but less prevalent than for the Wianamatta Shale-based vegetation in the region. These trends are a result of the more fertile and arable areas in the Sydney Basin being cleared earlier and more extensively.

The pattern of clearing has not been even across the extent of the ecological community, in part because the community was not evenly distributed across its range prior to clearing occurring, but also due to differences in land tenure and use. Nonetheless, overall levels of clearing have been extremely high, with only approximately 20% of the former extent of vegetation remaining (DECCW, 2010).

Clearing continues despite Shale Sandstone Transition Forest being listed as endangered under the EPBC Act in 2001 and NSW *Threatened Species Conservation Act 1995* (NSW TSC Act) in 1998 and changes to State native vegetation management laws since the late 1990s, aimed at preventing broad-scale clearing. These protection measures may have abated some of the threat, however, some of the highest rates of clearing are still occurring on the urban/peri-urban fringe associated with urbanisation on the edges of Cumberland Plain. This includes local government areas (eg. Wollondilly LGA) that contain relatively large portions of the ecological community. It is widely recognised that vegetation loss has been high across many ecological communities in the region. This increases the vulnerability of Shale Sandstone Transition Forest as processes for vegetation regeneration are disrupted (Douglas and James, pers. comm., 2011).

One of the most serious ongoing threats to the ecological community is the fragmentation that has been caused by clearing. Shale Sandstone Transition Forest has been identified as 'among the most fragmented of vegetation types occurring in the Sydney region, with an estimated 1115 km of interface with cleared or degraded land' (NSW Scientific Committee, 2014). With a median patch size of only 2.8 ha, the ecological community is extremely fragmented. Small, isolated fragments are less buffered against disturbances, such as invasion by weeds (Tozer, 2003; Cuneo et al., 2009), or other impacts from surrounding agricultural and urban activities such as spray drift. Fragmentation can also result in increased predator pressure on native fauna such as skinks (Anderson and Burgin, 2002).

Small patches of habitat generally support fewer species and species richness often reduces over time after fragmentation. In the Cumberland Plain Woodland, some species have been lost from smaller remnants. For example, *Melithreptus gularis gularis* (black-chinned honeyeater) is not found in patches smaller than 200 ha while *Pyrrholaemus saggitatus* (speckled warbler) is not found in patches smaller than 100 ha (Leary, 2007). Both of these species are listed as 'vulnerable' in NSW. Further, the simplification of the ecological community's bird assemblage may increase its vulnerability to damage by insect attack.

Inappropriate grazing and mowing regimes

Inappropriate grazing and mowing regimes may prevent regeneration and recruitment of overstorey and understorey species, and can lead to their thinning and ultimate loss. Most remnants of the ecological community are subject to varying degrees of grazing, whether by domestic stock, feral herbivores (e.g. rabbits, hares and goats) or native species (e.g. kangaroos and wallabies). Especially in rural-residential areas, remnants of the ecological community are often mowed, slashed or scrubbed for bushfire fuel reduction, grazing and perceived aesthetics. These activities contribute to the loss of sensitive species (Douglas and James, pers. comms., 2011), which are often replaced by weeds such as the highly invasive African love grass (*Eragrostis curvula*) and fireweed (*Senecio madagascariensis*). Grazing can also lead to hydrological changes, increased soil erosion and compaction, which can make seedling establishment more difficult (DEC, 2005). The removal of the understorey shrubs containing predatory wasps that control Christmas beetle larvae can have the potential flow-on effect of defoliation and die back of canopy Eucalypts (Upper Parramatta River Catchment Trust, 1999).

Increasing urbanisation and the intensive management of rural-residential areas has put more pressure on the remaining grazed areas. Increased grazing by domestic stock, and/or mowing or slashing may also have contributed to a reduction in fire frequency due to reduced fuel loads. This may further alter the structure and floristic composition of the ecological community.

Whilst grazing, mowing and slashing are often ecologically problematic for the conservation of the ecological community, they may be useful as a form of weed suppression, including as an interim measure as part of a longer-term conservation strategy (DEC, 2005). The ground layer of the ecological community is often extensively modified by grazing and mowing but may recover well if these activities cease (Kirkpatrick, 1986; Lunt, 1991; James, 1994; McDonald, 1996; Lewis, 2001; *sensu* DEC, 2005). An exception is 'improved' pastures where fertiliser and/or non-native grasses have been introduced and maintained to a significant degree.

Urbanisation

Urbanisation is of particular relevance to the ecological community because it occurs in and near the extensively and increasingly urbanised region of Greater Sydney, and along much of the Sydney-Goulburn development corridor, which is in turn part of the Sydney-Canberra development corridor.

Continuing decline in the ecological community is now predominately a consequence of dispersed clearing associated with urban development (NSW Scientific Committee and Simpson, 2008). Much of the continuing growth of Sydney to accommodate its growing population will occur on and around the Cumberland Plain, in areas such as the proposed Sydney growth centres to the north-west and south-west of the city. These growth centres cover approximately 27 000 ha and include several remnants of the ecological community. Therefore, these urban development pressures represent a serious and ongoing threat to the ecological community.

The Sydney Growth Centres Strategic Assessment plans for an additional half a million residents over the next 30 years (State of New South Wales, 2010). These growth centres include many patches of the ecological community. The planned North West Growth Centre includes 310 ha of Shale Sandstone Transition Forest, (of which 108 ha has been identified as being in good condition). Through the planned development, up to 251 ha of the ecological community will be cleared, including 66 ha of that in good condition (DSEWPaC, 2011). In addition, there are further urban development pressures that represent an ongoing threat to the ecological community. For example, in Wollondilly Local Government Area, approximately 200 ha of the ecological community is proposed to be cleared across three sites identified as future urban release areas under the NSW Government Metropolitan Growth Strategy.

As well as the direct threats of urban development such as vegetation clearance, the ecological community is also under threat from adjacent urban and rural land uses (Tozer, 2003). Amongst the threats associated with urban and peri-urban land include changes to soil and water quality with increased phosphorous levels and other excessive nutrients from fertilisers, dumped refuse and garden waste; as well as stormwater and sewer discharge and waste from domestic pets (Benson and Howell, 1990; NPWS, 1997). Other impacts include hydrological change and dispersal of weed propagules (Benson and Howell, 1990).

Introduced animals and aggressive native species

The presence of domestic animals such as cats and dogs as well as pest animals such as foxes, rats, house mice and rabbits may be related to agricultural land use, but intensified with urban development. These introduced species have impacts through predation and damage to vegetation and soils and can also compete for resources. For example, the Indian myna competes with native birds for nesting hollows while foxes can occupy wombat burrows (Upper Parramatta River Catchment Trust, 1999). Clearing, mowing and under-scrubbing have also created suitable habitat for a number of large and aggressive native animal species, including *Cacatua galerita* (sulphur-crested cockatoo), *Cracticus tibicen* (Australian magpie) and *Manorina melanocephala* (noisy miner). These species have all increased throughout the extensively cleared landscapes of the Cumberland Plain and now out-compete smaller woodland bird species in areas of fragmented vegetation, contributing to further decline in biodiversity.

Loss of fauna and associated ecological functions

Due to the highly fragmented nature of Shale Sandstone Transition Forest and the fact that it is mostly surrounded by cleared land, the ecological community no longer provides suitable habitat for some native fauna species. The fragmentation of the ecological community, and consequently the habitat for local flora and fauna, has impacted on the ecological processes and the species composition in the fragmented landscape.

Many remnants no longer support a range of fauna due to a loss of large old hollow bearing trees, modifications to the understorey, and isolation and fragmentation of remaining stands (Lindenmayer and Fischer, 2006; Leary, 2007). However, such remnants are still of value to disturbance-tolerant or highly mobile species, particularly as stepping-stone habitat in otherwise cleared or developed landscapes (Doerr et al., 2010).

A 1997 survey by NSW National Parks and Wildlife Service (NPWS) found that of the 62 mammal species known from the western Sydney region at European settlement only 15 of these species had stable populations in the region at the time of this survey. Ten years later, further intensive surveys across the Cumberland Plain found that reserves maintained some fauna but many species had been lost or were in decline. In particular, as in many temperate or arid locations in Australia, the small and medium sized ground dwelling mammals have suffered disproportionate losses. Through the intensive survey effort only one native rodent species, *Rattus fuscipes* (bush rat) and one dasyurid, *Antechinus stuartii* (brown antechinus) were found, in reserves in the area of transition between shale and sandstone substrates. Bandicoots were almost completely absent, with only one *Parameles nasuta* (long-nosed bandicoot) found in the region (Leary, 2007).

The 2007 NPWS survey found that there had been a severe depletion of habitat features needed to support fauna of the region. For example, large hollow-bearing trees were largely absent, while the additional ground habitat provided by these trees as fallen timber has also been reduced. Across the Cumberland Plain survey sites the diameter of trees measured was small (mean 22cm), while fewer than 3% contained hollows or fissures, indicating limited current value in providing nesting habitat for hollow-dependent fauna, such as some bird species, bats and some other arboreal mammals (Leary, 2007). While specific information on hollow development is limited, modelling of grassy box woodland in south west NSW indicates that the lag time for development is likely to have severe implications for species such as *Polytelis swainsonii* (superb parrot), in the absence of immediate intervention (Manning et al., 2013). It seems likely that there would be similar consequences for other threatened species that are dependent on hollows for successful breeding within Shale Sandstone Transition Forest, such as *Calyptorynchus lathami* (glossy black cockatoo).

Leary (2007) also comments on the substantial reduction and modification of ground cover, due to the alteration of fire regimes. Implications of this include the reduction of habitat for small reptiles, invertebrates and mammals.

Hydrological changes

Urbanisation of the often already cleared shale-based landscapes that usually adjoin the ecological community may have significant hydrological effects, especially on components of the ecological community that are dependent on high groundwater and seepage at or below the shale-sandstone interface.

Within the range of Shale Sandstone Transition Forest, dryland salinity is a threat (DEC, 2005) that results from the widespread and intensive removal of deep-rooted perennial vegetation from the naturally salty Wianamatta Shale that dominates the Cumberland Plain and surrounding shale caps. The removal of this vegetation can result in the upward movement of groundwater bearing salts that can retard and ultimately kill most vegetation. The ecological community is likely to be less at risk from soil salinisation than the generally lower-lying communities on the Cumberland Plain-proper, as Shale Sandstone Transition Forest generally occurs at higher elevations within the area at greatest risk. However, there are occurrences of the ecological community in south-western Sydney that may be at significant risk from soil salinisation due to their atypical occurrence down-slope of hills that previously supported extensive areas of Cumberland Woodlands.

Another form of hydrological change occurring adjacent to urban areas is increased runoff from impermeable surfaces, such as roads. This can change stream flow patterns, causing erosion and often penetrates adjacent bushland and carries high nutrient and sediment loads, which can encourage weed invasion (DECCW, 2010).

Invasion by weeds

Weed incursion in the region is associated with grazing and agricultural land uses as well as urbanisation. Weeds can occur in densities that displace native plants and lead to a decline in native species diversity and regenerative capacity (Benson, 1992 cited in DEC, 2005). Weeds that occur in Shale Sandstone Transition Forest include: African olive (*Olea europaea* subsp. *cuspidata*), fireweed (*Senecio madagascariensis*), spear thistle *(Cirsium vulgare*), cat’s ear (*Hypochaeris radicata*), pigeon grass (*Setaria gracilis*), plantain (*Plantago lanceolata*), Paddy’s lucerne (*Sida rhombifolia*), bridal creeper (*Myrsiphyllum asparagoides*) and sow thistle (*Sonchus oleraceus*). Broad-leafed and small-leaf privet (*Ligustrum lucidum* and *L. Sinense)* have also infested wetter riparian areas.

Bridal creeper (*Myrsiphyllum asparagoides*) and African olive have been identified as particularly significant weeds affecting this ecological community as they are highly competitive and appear able to suppress native understorey species (Benson, 1992; Tozer, 2003). Bridal creeper and moth vine (*Araujia hortorum*) are among a suite of exotic vines and scramblers that are listed as a threatening process in NSW and are also considered a specific threat to the ecological community (NSW Scientific Committee, 2006). In addition, bridal creeper is recognised to be a Weed of National Significance given its high ability to invade native vegetation and the difficulty in undertaking long-term management.

African olive is a serious threat to the integrity of the ecological community. It was introduced to historic properties in the region in the 19th century and since the 1970s has been identified as invasive. Frugivorous birds and foxes are the main seed vectors. The damage associated with infestation relates to shading and competition for space and possibly to allelopathic effects as well as changes to fire ecology. By maturity of the stand, most native plant species are suppressed. African olive establishes readily on shale-derived soils and has been mapped as a dense understorey covering 4000ha of the Cumberland Plain in the year 2000, where it is described as a 'major threat to the long term existence of Cumberland Plain Endangered Ecological Communities' (Cuneo and Leishman, 2006, p.548).

Coolatai grass (*Hyparrhenia hirta*) is an emergent threat to the ecological community and has been detected at sites within the ecological community's range (Douglas, pers. comm., 2013). Weed management must also be planned carefully to avoid rapid removal of habitat for fauna (Upper Parramatta River Catchment Trust, 1999) or damage due to herbicides used.

Mining

'Alteration of habitat following subsidence due to longwall mining' is listed as a Key Threatening Process under the NSW TSC Act (NSW Scientific Committee, 2005). The NSW Scientific Committee lists Shale Sandstone Transition Forest, as being threatened by the impacts of longwall mining (NSW Scientific Committee, 2005).

The ecological community may be impacted by the associated infrastructure (e.g. roads, pipelines, clearing of mine sites) of coal seam gas, longwall coal, clay (mainly for bricks), sand and other mining development. The disruption of natural groundwater regimes and discharge patterns associated with mining may have negative impacts on some components of the ecological community. Significant subsidence may also result in dramatic alteration of the land surface and hydrology, causing profound effects on the ecological community. 'Mining subsidence is frequently associated with cracking of valley floors and creeklines, and with subsequent effects on surface and groundwater hydrology' (Booth et al., 1998; Holla & Barclay, 2000; ACARP, 2001, 2002, 2003 cited in NSW Scientific Committee, 2005).

Longwall (subsurface) coal mining occurs and is further proposed under areas supporting the ecological community, including within the Sydney Catchment Authority Upper Nepean and Burragorang Special Areas, the associated State Conservation Areas and near Bargo State Conservation Area. NSW State Conservation Areas do not prohibit surface or subsurface mining.

There is potential for coal seam gas exploration and extraction to occur in areas where the ecological community occurs. Coal seam gas exploration licenses exist across the range of the Shale Sandstone Transition Forest. The introduction of exploration and extraction activities could adversely impact upon the ecological community through changes to hydrology and clearance and consequent loss of habitat connectivity.

Altered fire regimes

Shale Sandstone Transition Forest occurs in and near urban and peri-urban areas. Frequent fire from arson particularly in the bushland remnants of western Sydney has altered the structure and floristic composition of the ecological community (DEC, 2005). Frequent application of fire by authorities with the intent of reducing bushfire risk and/or intensity can also significantly alter remnants of the ecological community near settled areas. This has been documented in the lower Blue Mountains (Chambers, pers. comm., 2011) and is addressed in part by DECCW (2010) and in more detail by Keith (2010) through the formulation of recommended ecologically based fire regimes.

The total exclusion of fire from the ecological community can also have significant negative effects (DEC, 2005). This can be exacerbated by measures to avoid fire in some patches as more residential areas are being built near the ecological community. Guidance on the appropriate fire regimes for the ecological community is provided in the *Priority Conservation Actions*.

Fire associated with military activities, including the use of artillery, potentially threatens the substantial remnants of the ecological community within the Holsworthy Military Area.

Climate Change

Climate change is now understood to pose a serious long-term threat to terrestrial and aquatic ecosystems and to have the potential to change the ecology of these environments, through changed species composition and function (Dunlop et al., 2012). The very fragmented nature of the remnants of Shale Sandstone Transition Forest greatly increases their vulnerability to the effects of rapidly changing climates, as native species movement is restricted. It could also influence the future distribution and extent of the ecological community. Not only does climate change directly threaten species that cannot adapt, it could also exacerbate existing threats, including loss of habitat, altered hydrological regimes, altered fire regimes and invasive species that are not adequately managed at present.

Eco Logical Australia (2010) investigated the vulnerability of various natural and cultural assets in the Hawkesbury-Nepean catchment to climate change. That report did not include the Shale Sandstone Transition Forest ecological community, but did include the related Southern Highlands Shale Woodlands ecological community that directly adjoins some forms of Shale Sandstone Transition Forest. Many of the findings reported for that community can be sensibly extrapolated to this ecological community. In summary, these include:

- Continued clearing, degradation, and fragmentation will limit the ability of the ecological community to adapt and/or migrate in response to climate change;
- Grazing pressure and associated detrimental effects such as depletion of the indigenous understorey, and ringbarking of some tree species (especially stringybarks and woollybutt) may increase under forecast climate change;
- Invasion by non-native plant species is likely to increase in intensity, spread, and diversity, with some such species taking advantage of climate change-induced effects such as periodic depletion of ground cover due to drought and over-grazing. Weeds such as African olive and lantana (*Lantana camara)* are likely to move into areas where they are currently excluded by relatively cold temperatures;
- Remnants containing riparian vegetation may suffer erosion due to intensification of rainfall events, and this increased disturbance may facilitate or worsen weed invasion;
- Altered native plant species mix;
- Altered structural composition of remnants may include an increase in shrub cover, a decrease in grass cover, and variable changes to tree cover;
- Altered structure and/or floristics may change fauna composition in and between remnants, and may alter the behaviour of migratory species, including some that perform significant ecosystem functions;
- Increased risk of ecological instability through asynchrony of events such as emergence of insect prey and arrival of migratory bird predators; and
- Altered fire regimes due to changed climate and weather, and due to changed vegetation structure and composition.

While the ecological community is likely to be vulnerable to the impacts of climate change, at a regional level it may still play an important role in supporting ecological adaptation. With other woodlands and forests on the coastal slopes of the Great Dividing Range it may provide refuge for threatened lowland specialists such as regent honeyeaters and swift parrots in an increasingly dry climate further inland.

Vegetation is also important in the landscape as a means of mitigating extreme temperatures in the local area through its evaporative and cooling influences, mitigating the ‘urban heat island effect’ shown to be operating in western Sydney (Beshara, 2008). The alteration of local microclimates may however affect remnants of the ecological community within and adjacent to urban developments. This process operates separately to any temperature rise due to global climate change.

APPENDIX E - ELIGIBILITY FOR LISTING AGAINST THE EPBC ACT CRITERIA

Criterion 1 - Decline in geographic distribution

The Shale Sandstone Transition Forest ecological community is estimated to have undergone declines ranging from 70% - 80% of its original pre-European extent (Table E1).

The estimates may include low quality remnants that do not meet the condition thresholds for the national ecological community. Thus, the current extent remaining in good condition is likely to be less than that shown. The decline in the area of occupancy of the ecological community is due largely to clearing and degradation of remaining patches mostly by agriculture, urban development and invasive species.

Table E1. Estimates of decline and extent for Shale Sandstone Transition Forest based on vegetation units that correspond with the ecological community.

Vegetation Community	Estimated area pre-clearing (ha)	Estimated area extant (ha)	% original extent	Estimated area reserved (ha)	% of current extent reserved
a) Cumberland SSTF Map unit p2 (Tozer et al., 2010)		9600	20-40[9]	240	<2
b) Map unit GW04 (DECCW, 2009)	24 000-48 000	9600	20-40	240	<2
c) DEC, 2005	43 990	9 950	22.6%	283.6	0.6
d) DECCW, 2010	45 355	9 642[10]	21	420[11]	4
e) Map units 1 and 2 (Tozer, 2003)	45355	9 960[12]	23		

a) 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.

b) DECCW (2009). The native vegetation of the Sydney Metropolitan Catchment Management Authority Region. Department of Environment, Climate Change & Water, Hurstville, NSW.

c) DEC (2005). Recovering Bushland on the Cumberland Plain: Best practice guidelines for the management and restoration of bushland. Department of Environment and Conservation (NSW), Sydney.

d) DECCW (2010). Cumberland Plain Recovery Plan. Department of Environment, Climate Change, and Water (NSW), Sydney.

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

Taking into account the information in Table E1 and given the estimate bounds by DECCW (2009), the Committee considers that the degree of loss of the ecological community is likely to be 70-80%. Based on this estimate and ongoing clearance in the Sydney Basin Bioregion since 2010, the ecological community has undergone a ‘severe’ decline (> 70%) in its geographic extent and is therefore **eligible** for listing as **endangered** under this criterion.

[9] Approximate generic bounds of +/- 10% were estimated for all map units in the study.
[10] In condition classes A, B, C identified in NPWS (2002) as having a relatively intact tree canopy.
[11] On DECCW estate in condition classes A, B, C.
[12] Estimated extent in 1997.

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 in distribution 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; area of occupancy, total extent of occurrence and patch size (indicative of fragmentation). If any of the three measures is demonstrated to apply to the ecological community it is considered to have a limited geographic distribution.

Maps of the ecological community from DECCW (2009) and Tozer et al. (2010) indicate that the present geographic distribution of the ecological community is 'restricted' with the total extent of occupancy < 10,000 ha.

The ecological community is also highly fragmented with a mean patch size of approximately 9.6 ha and median size of 2.8 ha, also considered to be 'very restricted' (analysis of data from Tozer et al., 2010). Almost all patches (81%) have a size of less than 10 ha (Table E2). Gaps between patches are likely to limit regeneration opportunities as some key species have restricted distribution of seeds. For example, the seed of narrow-leafed ironbark, a common dominant in the canopy, is wind dispersed over only 20 m (Benson and McDougall, 1998).

Table E2. Patch size distribution (based on Tozer et al., 2010)

Thresholds		Size range (ha)	No. patches	% patches	Cumulative %	
Restricted	Very Restricted	0.5 - 10	802	81	81	99
		> 10-100	176	18		
		> 100	10	1		
		Total	988	100		

As detailed in *Description of Threats*, the Shale Sandstone Transition Forest ecological community is subject to a range of ongoing demonstrable threats, several of which interact. Key threats include the impacts associated with clearance and fragmentation of remnants as well as weed invasion and change in fire regimes. The loss of area and condition can have compounding impacts through the loss of fauna that play important ecological roles. The loss of mammal species has been noted across the Cumberland Plain region, removing their functions as soil engineers and dispersers of pollen and seeds. Similarly, the bird assemblage has been simplified by vegetation loss and fragmentation, limiting pollination, seed dispersal and control of invertebrate populations.

The loss, fragmentation and degradation of vegetation is increasingly associated with rural residential and urban developments. This pressure is ongoing, with the expectation that the Sydney North West and South West Growth Centres will accommodate up to half a million additional people in the next 30 years (State of NSW, 2010). The development planned for the North West Growth Centre is expected to result in the clearance of up to 251 ha of the ecological community, including 66 ha of that in good condition (DSEWPaC, 2011). In addition to direct loss through clearance of vegetation, threats associated with urbanisation include predation and competition by domestic and pest animals, spread of weeds and changes to hydrology.

Climate change is expected to cause increasing damage to the ecological community, through changed temperature and rainfall patterns. In addition to direct stress on plants and animals, this is likely to result in changed habitat features and food availability, as well as being expected to compound other threats such as inappropriate fire regimes.

In addition, mining is a threat to the ecological community, particularly in the Macarthur and upper Nepean regions (Douglas, pers. comm., 2013). These threats are unlikely to diminish in the foreseeable future.

Regeneration is limited by a range of threats, combined with the slow growth and long regeneration times of some key species, for example, the dominant canopy species of narrow-leafed ironbark, grey gum and broad-leafed ironbark each live for more than 100 years (Benson and McDougall, 1998). The time for saplings to reach maturity can also be substantial, for example, 15 years for narrow-leafed ironbark, and 20 years for other canopy species such as forest red gum (Royal Botanic Gardens and Domain Trust, undated).

The ecological community is considered to be 'very restricted' and the fragmented nature of its distribution makes it likely that the action of threatening processes could cause it to be lost in the immediate future (considered here as three generations of key canopy species, up to 60 years). Therefore, the ecological community is **eligible** for listing as **critically endangered** under this criterion.

Criterion 3 - Loss or decline of functionally important species

Although studies specific to functional species in Shale Sandstone Transition Forest are not available, the relationship between various species is important for maintaining ecosystem function.

Vegetative components of the ecological community are important as they provide food and habitat for faunal components of the ecological community. Notably, they provide food for nomadic nectarivores during winter (Leary, 2007). However, the ability of the ecological community to provide these resources is diminished if the ecological community is in poor condition or regrowth. For example, large old trees often contain hollows that provide habitat for fauna, but surveys in the ecological community have found the mean tree diameter to be small and occurrence of hollows infrequent due to past clearance (Leary, 2007). The long delay in creation of new hollows limits the capacity to recover within the foreseeable future.

The fragmentation of the ecological community has reduced its ability to support a natural and complete assemblage of birds such as the 'shale birds' and other nomadic nectarivores. The majority of eucalypt dieback in eastern Australia is caused by insect attack. In some locations a healthy bird community has been observed to remove 50-70% of leaf-feeding insects, thus playing an important role in maintaining the canopy of the ecological community.

The observed loss of mammal species from the ecological community (Leary, 2007) is likely to have had a negative effect on ecological function, through the reduction of pollination, seed dispersal and soil engineering.

Additionally, fundamental changes in nutrient inputs and hydrology associated with land clearing and agriculture have caused physical, chemical and biological changes to woodland soils, driving reductions in the abundance of soil and litter dwelling invertebrates, which are a major food source for many woodland birds (Watson, 2011).

Therefore it is likely that threats have impacted upon functionally important species within the Shale Sandstone Transition Forest ecological community; however, specific data related to the decline of faunal species in this ecological community is limited. 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

This ecological community occurs in or on the edges of the extensively cleared shale-based landscapes of Greater Sydney, and so the primary cause of loss of integrity has been by clearing. The remaining area is severely fragmented and many remnants have been and remain subject to grazing by domestic stock and invasion by weeds. As in other ecological communities in the region, the faunal assemblage is depauperate. While little specific information is available on the roles played by species formerly present, it is likely that the ecological function of Shale Sandstone Transition Forest has been compromised by the loss of many of its soil engineers, pollinators and seed dispersers. Further damage to integrity is evident through the change in vegetation structure and loss of key habitat features such as tree hollows, necessary to support breeding of resident fauna. The very long lag time to recover vegetation structure, with adequate representation of large old trees, likely to contain features such as hollows suggests that recovery is unlikely in the immediate future. The intractability of other problems, such as the regional loss of fauna further reduces the likelihood of recovery.

Reduction in integrity through clearing and fragmentation

The ecological community has been extensively cleared across its range, severely compromising its integrity. The total area, estimated to have formerly been approximately 45 000 ha is now less than 10 000 ha (a loss of up to 80%). This steep decline to such a limited distribution is likely to have caused a fundamental change in function both within the boundaries of the community as well as in the role it plays in the wider landscape. The loss through land clearing is expected to be ongoing, as indicated by the planned clearing of the ecological community for at least the next 30 years (growth plan).

Those remnants that remain are generally small and isolated, with 81% of patches being less than 10 ha in size (analysis of data from Tozer et al., 2010) with a total interface of 1115 km with degraded or cleared land (NSW Scientific Committee, 2014). This fragmentation is likely to reduce rates of survival and dispersal by individuals, interrupt population processes such as genetic exchange as well as other ecological processes that sustain the ecological community. Fragmentation also increases the proportion of the remaining area of the ecological community subject to threats from predation, changed microclimates and weed incursion, for example, by African olives and bridal creeper. In contrast, the limited dispersal ability of the dominant canopy Eucalypt species restricts their ability to support regeneration of the ecological community where the gaps between fragments are wide.

Reduction in integrity through urbanisation

In addition to the direct threats of urban development such as vegetation clearance, the ecological community is also under threat from urban and peri-urban activities on adjacent land. Associated damage occurs through increased soil phosphorous levels from fertiliser use, dumped refuse and garden waste, stormwater and sewer discharges. Severe damage to native fauna populations is also caused by predation on native fauna by domestic pets and other introduced animals adapted to urban environments (as recognised through key threatening processes listed under the EPBC Act including Predation by European Red Fox' and 'Predation by feral cats'). As previously described, this pressure is likely to increase in coming decades. Inappropriate recreation activities, for example, trail bike use in quality bushland, is also impacting the ecological community.

Reduction in integrity through weed invasion

A number of weeds pose a serious threat to the ecological community, with many remnants affected and the likelihood of further infestation increased by fragmentation. Amongst the most serious threats are African olive, fireweed and bridal creeper. As described in *Description of Threats*, African olive has the potential to prevent regeneration of almost all native plant species, once a canopy is established.

Reduction in integrity through inappropriate fire and grazing regimes

The ground layer of the ecological community is often extensively modified by grazing and mowing contributing to the loss of grazing-sensitive palatable species and those that are intolerant of relatively frequent and/or intensive mowing (Douglas and James, pers. comms., 2011). In many cases these plant species have been replaced by weeds.

Grazing can also lead to hydrological changes, and increased soil erosion. Soil compaction is a common result of grazing and leads to reduced water infiltration and increased runoff. Compaction and erosion can make seedling establishment more difficult (DEC, 2005). Overgrazing can create areas of bare soil that are readily colonised by weeds.

The effects of grazing and mowing are likely to have a complex relationship with fire regimes. Other influences on the frequency and intensity of fire in the ecological community include suppression for asset protection, change in floristic composition (for example, with the introduction of weeds such as African olive) and climate change.

Reduction in integrity due to change in vegetation structure and loss of key habitat elements.

With other damage, such as grazing and tree removal, the structure of vegetation across the ecological community has been compromised. In particular, few large old trees now exist, limiting their value as habitat, especially through the provision of specific features such as hollows. The loss of these features is likely to continue and compromise the ecological community's capacity to support hollow-nesting fauna such as parrots and gliders.

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 to the community of *Eucalyptus* dieback associated with defoliation by insects, while other services such as pollination and seed dispersal may also be compromised. While the ecological community still supports populations of the 'shale bird' assemblage, many of these species are now threatened. The loss of many species of mammals formerly found throughout the region has reduced the integrity of the ecological community directly, through the loss of an element of its original character. In addition, the roles that these mammals may have played as soil engineers, pollinators and seed dispersers have also been compromised.

Reduction in integrity through climate change

As described in *Description of Threats*, climate change is likely to compromise the integrity of the community both directly and by altering the survival rates of constituent species. It is also likely to interact with other threats, such as changed fire regimes or the invasion of weeds. The long generation time and limited dispersal ability of some key species, such as the canopy eucalypts is likely to limit adaptation through range shift.

Restorability of the ecological community

The ground layer of the ecological community will often recover if grazing and mowing activities are ceased (Kirkpatrick, 1986; Lunt, 1991; James, 1994; McDonald, 1996; Lewis, 2001; *sensu* DEC, 2005) with the exception of improved pastures where fertilisers and/or non-native grasses have been introduced and maintained to a significant degree. However, in general, the likelihood of recovery in the immediate future is negligible due to the severity of damage that has occurred. Foremost, the reduction in total area of the community is substantial, with much of the former extent replaced by other land uses (which is planned to continue). Even with substantial commitment to re-vegetation, the unavailability of this land greatly limits its scope. In areas where land is zoned for urban or industrial land uses, the expense in acquiring these for conservation purposes can be prohibitive (DECCW, 2010). Fragmentation of the ecological community is also intractable for similar reasons, with urban areas and roads dividing remnant vegetation. This fragmentation is likely to result in ongoing loss of species that cannot persist in small patches. Natural regeneration is limited by the short distance that tree canopy seeds are dispersed, as well as the overall pattern of clearing across the region, limiting sources of genetic material. Competition for light and nutrients due to the spread of weeds such as African olives limits the survival and regeneration of understorey species while adequate controls are not in place.

Even with active management such as tree planting, the recovery of canopy layers is likely to take a substantial length of time, given the slow rates of growth of these species and the long delay for production of structural habitat features such as tree hollows. The loss of fauna is also region-wide, making their recovery within the ecological community unlikely. The associated loss of services provided by this fauna also compromises the regeneration of the native vegetation.

The specific effects of climate change on recovery are difficult to quantify. Nonetheless, the likely change in temperature and precipitation, as well as influences on the fire regime and the competitive relationships between species limit the likelihood of the ecological community recovering its former nature.

While a recovery plan has been developed by the NSW State Government (DECCW, 2010), this document emphasises that the priority actions described will be insufficient for the ecological community to recover its former integrity. Other challenges to organising recovery efforts discussed include the uncertain desire and ability of landholders to be involved and the inadequacy of funds available to support these efforts.

<u>Summary</u>

Substantial clearing, severe fragmentation, urbanisation, weed invasion, inappropriate fire and grazing regimes, and associated changes to vegetation structure and loss of faunal components have substantially reduced the integrity of the ecological community. These losses are compounded by climate change, and together with a range of ecological characteristics of the community, as well as the nature of the ongoing threats severely limit the likelihood of recovery.

The change in integrity experienced by the ecological community is **very severe** and regeneration is unlikely in the immediate future. Therefore, the ecological community is **eligible** for listing as **critically endangered** under this criterion.

Criterion 5 - Rate of continuing detrimental change

Remnants have visibly declined over the past 20 years (Douglas, pers. comm., 2013) with the increase in weeds such as fireweed, African lovegrass, African Olive and Coolatai grass.

In addition, inappropriate fire and grazing regimes that alter the species composition of the vegetation in the ecological community and urban and peri-urban development continue to be detrimental to the ecological community.

Although there has been continuing detrimental change to the ecological community, data are insufficient to determine an overall rate. As such there is **insufficient information to determine the eligibility** of the ecological community for listing under any category of Criterion 5.

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.

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