***Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (s266B)**

Approved Conservation Advice (including listing advice) for Southern Highlands Shale Forest and Woodland of the Sydney Basin Bioregion (EC62)

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 *Southern Highlands Shale Forest and Woodland of the Sydney Basin Bioregion* ecological community to the Minister as a draft of this approved conservation advice. In 2015, the Minister accepted the Committee's advice, adopting this document as the approved conservation advice.
3. The Minister amended the list of threatened ecological communities under section 184 of the EPBC Act to include the *Southern Highlands Shale Forest and Woodland of the Sydney Basin Bioregion* ecological community in the **critically endangered** category. This ecological community encompasses the *Southern Highlands Shale Woodlands in the Sydney Basin Bioregion* which is listed as threatened under the New South Wales *Threatened Species Conservation Act 1995*.
4. A draft description and likely conservation status for this ecological community was made available for expert and public comment for a minimum of 30 business days. The Committee and Minister had regard to all public and expert comment that was relevant to the consideration of the ecological community.
5. This approved conservation advice has been developed based on the best available information at the time it was approved; this includes scientific literature, advice from consultations, existing plans, records or management prescriptions for this ecological community.

1 DESCRIPTION OF THE ECOLOGICAL COMMUNITY

The Southern Highlands Shale Forest and Woodland of the Sydney Basin Bioregion ecological community is dominated by eucalypt trees and typically has a herbaceous understorey, but is variable in vegetation structure, ranging from a tall wet sclerophyll forest to more open, grassy woodland. It occurs in the New South Wales Southern Highlands region and is associated with soils derived from Wianamatta Shale.

1.1 Name of the ecological community

The Southern Highlands Shale Forest and Woodland of the Sydney Basin Bioregion ecological community (hereafter referred to as the 'Southern Highlands Shale Forest and Woodland' or 'the ecological community') encompasses the similarly named ecological community 'Southern Highlands Shale Woodlands in the Sydney Basin Bioregion' that is listed under the New South Wales *Threatened Species Conservation Act 1995*[1].

1.2 Location and physical environment

The Southern Highlands Shale Forest and Woodland is endemic to New South Wales, occurring within the southern part of the Sydney Basin IBRA bioregion[2].

The ecological community occurs on the Southern Highlands plateau and is associated with clay soils derived from Wianamatta Group shales. The Southern Highlands Shale Forest and Woodland occurs in the Wingecarribee Shire (boundary as defined July 2015), although outliers may occur in adjacent local government areas. The eastern limit of the ecological community is the Illawarra escarpment where Wianamatta Shale is replaced by other geologies (younger basalts and older sedimentary geologies of the Hawkesbury, Narrabeen and Illawarra Groups) near the towns of Kangaloon, Robertson and Fitzroy Falls; the southern limit is in the vicinity of the town of Penrose; it is currently known to extend north to near Braemar and Alymerton; and west to near Canyonleigh, High Range, Berrima and Medway.

The Southern Highlands Shale Forest and Woodland generally occurs in areas receiving an annual rainfall of between 1400mm (in the east) to 900mm (in the western parts of its range). Typically it occurs at elevations of between 470m to approximately 830m above sea level (ASL).

1.3 Vegetation

The Southern Highlands Shale Forest and Woodland has a tree canopy dominated by eucalypts and a typically herbaceous understorey. It shows some variation in structure and composition in different locations due to differences in: rainfall, topographic shelter, exposure, the influence of cold air drainage and ponding; and the influences of groundwater and proximate geologies across the distribution of the ecological community. In addition, extensive clearing, grazing, logging, weed invasion, altered fire regimes and changed hydrological patterns have also resulted in variation in form. Reflecting this variation, three 'forms' of the ecological community are recognised: 'typical', 'tall wet' and 'short dry'.

[1] Information regarding the NSW listed ecological community is available at: http://www.environment.nsw.gov.au/determinations/SouthernHighlandsShaleWoodlandsSydneyEndComListing.htm

[2] Interim Biogeographic Regionalisation of Australia Version 7. IBRA regions are large geographically distinct areas of similar climate, geology, landform, vegetation and animal communities. Further information regarding IBRA, including maps, is available at: http://www.environment.gov.au/topics/land/nrs/science-maps-and-data/australias-bioregions-ibra

The '**typical**' form occurs in areas of more moderate rainfall and can be further differentiated into three variants: Penrose; Braemar; and Bundanoon ridges and exposed slopes. The '**tall wet**' form typically occurs in areas with higher rainfall, soil moisture and fertility, and in areas of sheltered topography. In areas of lower rainfall, more frost and, in some cases more exposed locations, a '**short dry**' form of the ecological community occurs.

Canopy

Characteristic canopy species (Table 1) of the Southern Highlands Shale Forest and Woodland that may be found in all forms of the ecological community include: *Eucalyptus globoidea* (white stringybark), *E. piperita* (Sydney peppermint) and *E. radiata* (narrow-leaved peppermint).

In addition to the aforementioned species, the ecological community may be dominated by one or more of the following canopy species:

- In the **'typical'** form - by *Eucalyptus macarthurii* (Paddy's River box). *Eucalyptus pauciflora* (snow gum) may also be present but not as a dominant species. *Eucalyptus amplifolia* (cabbage gum) and/or *E. tereticornis* (forest red gum) often occur. *Eucalyptus ovata* (swamp gum) is often present at poorly drained sites.

  In addition, a **Penrose variant** is dominated by *Eucalyptus blaxlandii* (Blaxland's stringybark); a **Bundanoon variant** often includes *Angophora floribunda* (rough barked apple); and a **Braemar variant** is often dominated by *E. fibrosa* (red ironbark) and *E. punctata* (grey gum), reflecting a stronger sandstone influence.

- In the **'tall wet'** form - by *Eucalyptus cypellocarpa* (mountain grey gum), *E. elata* (river peppermint), *E. obliqua* (stringybark), *E. ovata* (swamp gum), *E. quadrangulata* (white-topped box), *E. smithii* (gully peppermint, blackbutt peppermint) and/or *E. viminalis* (manna gum, ribbon gum).

- In the **'short dry'** form - by *Eucalyptus cinerea* (Argyle apple, silver leaved stringybark), *E. dives* (broad leaved peppermint), *E. mannifera* (brittle gum), *E. rubida* (candlebark, ribbon gum). *Eucalyptus pauciflora* may also occur, and while not a dominant species, its frequency in this form reflects the increased exposure to frost and lower rainfall.

In all forms of the ecological community, the presence of *Eucalyptus agglomerata* (blue-leaved stringybark), *E. eugenioides* (thin-leaved stringybark), *E. fibrosa* (red ironbark), *E. punctata* (grey gum), or *Syncarpia glomulifera* (turpentine) typically reflects that the patch is near the edge of a shale substrate.

Understorey

Where present, the shrub layer is typically sparse, although it may be dense in some parts of a patch. *Bursaria spinosa* typically occurs in all forms of the ecological community. The ground layer is typically dense, dominated by grasses and herbs. Ground layer species typically occurring in all forms include: *Dichondra* spp.; *Hardenbergia violacea; Lomandra longifolia;* and *Poa labillardierei*.

The typical form has a more evident grass and sclerophyll sub-shrub layer. A tall shrub layer may be present where disturbance has favoured large Acacias such as *Acacia mearnsii* and *A. melanoxylon*. Typical mid layer species include: *Daviesia ulicifolia*; *Olearia viscidula*; *Oxylobium ilicifolium*. Typical ground layer species include: *Xerochrysum bracteatum*; *Coronidium scorpioides*; *Hypericum gramineum*; *Poranthera microphylla*; *Pteridium esculentum*; *Themeda triandra*.

The tall wet form can have rainforest understorey components, significant wetland components and can be a swamp forest with lots of sedges, rushes, graminoids and areas that are wetland at a small

scale. Typical mid layer species in the tall wet form include: *Goodenia ovata*; *Leptospermum polygalifolium*; *Melaleuca linariifolia*; *Pittosporum undulatum*; and *Rubus parvifolius*. Common ground layer species include: *Blechnum cartilagineum*; *Eustrephus latifolius*; *Hibbertia scandens*; and *Viola betonicifolia*.

The dry form has a predominantly grassy understorey. *Rytidosperma pallidum* (syn. *Joycea pallida*) is typically present in the dry form and largely absent from the tall wet and typical forms. *Olearia microphylla* is a common mid storey species.

Further information on understorey plant species is available in Appendix A.

Contra-indicative flora

The following are considered contra-indicative of the ecological community:

- Presence in the canopy of *Eucalyptus sieberi* (silvertop ash); *E. sclerophylla* (scribbly gum) (and related variants *E. racemosa* and *E. haemastoma*); *E. stellulata* (black sallee) and/or *Angophora costata* (smooth-barked apple, Sydney redgum); and/or
- A mid-layer dominated by Proteaceae and Myrtaceae species.

Table 1 Characteristic canopy species of the three forms of Southern Highlands Shale Forest and Woodland ecological community. Source: Douglas, pers. comm., 2015; Tozer et al., 2010. Scientific names are as at June 2015.

✓= canopy species characteristic of the form

Species	**Common name**	**Typical**	**Tall wet**	**Short dry**
Angophora floribunda	rough-barked apple	✓		
Eucalyptus amplifolia	cabbage gum	✓		
Eucalyptus blaxlandii	Blaxland's stringybark	✓		
Eucalyptus cinerea	Argyle apple, silver leaved stringybark			✓
Eucalyptus cypellocarpa	mountain grey gum		✓	
Eucalyptus dives	broad leaved peppermint			✓
Eucalyptus elata	river peppermint		✓	
Eucalyptus fibrosa	red ironbark	✓		
Eucalyptus globoidea	white stringybark	✓	✓	✓
Eucalyptus macarthurii	Paddy's River box	✓		
Eucalyptus mannifera	brittle gum			✓
Eucalyptus obliqua	stringybark		✓	
Eucalyptus ovata	swamp gum	✓ (poorly drained sites)	✓	
Eucalyptus pauciflora	snow gum	✓		✓
Eucalyptus piperita	Sydney peppermint	✓	✓	✓
Eucalyptus punctata	grey gum	✓		
Eucalyptus quadrangulata	white topped box		✓	
Eucalyptus radiata	narrow leaved peppermint	✓	✓	✓
Eucalyptus rubida	candlebark, ribbon gum			✓
Eucalyptus smithii	gully peppermint		✓	
Eucalyptus tereticornis	forest red gum	✓		
Eucalyptus viminalis	manna gum		✓	

Fauna

Although there are no fauna species confined only to the Southern Highlands Shale Forest and Woodland, the ecological community supports a diverse range of fauna providing essential resources such as shelter (e.g. hollows, nesting materials, roosting) and food (e.g. nectar from flowers or invertebrate prey). Some fauna may be transient through the ecological community; for instance pollinating birds such as honeyeaters are likely to visit during the flowering season, and other animals may use patches of the ecological community as stepping stones to more preferred habitats.

Many insectivorous bats frequent the ecological community including: *Vespadelus* spp. (vesper bats); *Chalinolobus* spp. (wattled bats); and *Nyctophilus* spp. (long-eared bats). Other mammal species such *Trichosurus vulpecula* (common brushtail possum), *Petaurus breviceps* (sugar glider), *Petaurus australis* (yellow-bellied glider), *Cercartetus nanus* (eastern pygmy possum) and *Pteropus poliocephalus* (grey-headed flying fox) are also found in the ecological community (NSW Bionet, 2014). The vulnerable (EPBC Act; NSW *Threatened Species Conservation Act* (TSC Act)) *Potorous tridactylus tridactylus* (long-nosed potoroo) and *Phascolarctos cinereus* (koala) have been recorded in the ecological community. Species utilising the grassy/shrubby understorey include: *Macropus* and *Wallabia* spp. (kangaroos and wallabies); *Vombatus ursinus* (bare-nosed or common wombat); *Tachyglossus aculeatus* (echidna); and *Rattus fuscipes* (bush rat) (NSW Bionet, 2014).

Typical woodland birds found in the ecological community include *Acanthiza* spp. (thornbills) and *Eopsaltria australis* (eastern yellow robin). Woodland bird species across eastern Australia are declining due to loss, fragmentation and degradation of habitat (Ford, 2011) and as a result many are now identified as threatened under NSW and/or national environmental legislation. Those found in this ecological community include *Petroica boodang* (scarlet robin), *Ninox strenua* (powerful owl) and *Anthochaera phrygia* (regent honeyeater).

Reptiles including skinks, dragons and snakes; and a range of frog species including toadlets and tree frogs (NSW Bionet, 2014) are typically found in the ecological community. These include threatened species such as *Heleioporus australiacus* (giant burrowing frog) (EPBC, TSC Acts) and *Varanus rosenbergi* (Rosenberg's goanna, heath goanna) (TSC Act).

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

1.4 Key diagnostic characteristics and condition thresholds

National listing focuses legal protection on patches of the ecological community that are most functional, relatively natural (see the 'Description') and in comparatively good condition.

Key diagnostic characteristics and condition thresholds assist: in identifying a patch of native vegetation as being the threatened ecological community; determining whether the EPBC Act is likely to apply to a patch; and to distinguishing between patches of different quality.

The key diagnostic characteristics summarise the main features of the ecological community. Because the ecological community exhibits various degrees of disturbance and degradation, condition classes and thresholds have been developed. These provide guidance on whether a patch of a threatened ecological community retains sufficient conservation values to be considered as a Matter of National Environmental Significant (MNES), as defined under the EPBC Act. This enables the referral, assessment and compliance provisions of the EPBC Act to be focussed on the most valuable elements of the ecological community. Very degraded patches which do not meet the minimum condition thresholds will be largely excluded from national protection.

Although very degraded or 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.

To be considered a Matter of National Environmental Significance under the EPBC Act, areas of the ecological community must meet:

- the *Key diagnostic characteristics* (in Section 1.5.1); AND
- at least the minimum *Condition thresholds* for Moderate quality (i.e. class B1 or B2, in Section 1.5.3).

1.4.1 *Key diagnostic characteristics*

The key diagnostic characteristics of this ecological community are:

- Is an open forest or woodland[3] with a canopy dominated by one or more eucalypt species listed in Table 1.
- Has a ground layer including native grasses and/or other herbs (although it may vary in development and composition, refer Appendix A, Tables A1 and A2).
- Occurs in the Southern Highlands in the Sydney Basin Bioregion (IBRA v7).
- Occurs at elevations between 470 m – 830 m ASL on clay soils derived from Wianamatta shale.

1.4.2 *Other diagnostic considerations*

- The ecological community may contain fauna species listed in Appendix A, Table A3.

1.4.3 *Condition thresholds*

The condition thresholds (refer to Table 2) apply to patches of forest or woodland that meet the key diagnostic features above, and identify them as patches of the ecological community.

The Southern Highlands Shale Forest and Woodland occurs in an area that has been intensively cleared, where much of the native vegetation that remains occurs amongst a heavily modified landscape. The patches that remain are typically small, highly fragmented and have been disturbed to some extent. It is intended that the condition thresholds will exclude the more highly degraded patches on farms and other properties. For instance, those patches that now exist as isolated paddock trees or small, narrow stands of trees over exotic pastures. The condition thresholds also exclude degraded roadside remnants that are small or narrow, or where the native understorey has effectively become lost, and/or the tree canopy is patchy and discontinuous (i.e. <10% cover).

For Southern Highland Shale Forest and Woodland, categories B1 and B2 are considered to be moderate quality condition (moderate condition class) and the minimum thresholds for a patch of the

[3] For this ecological community, forest or woodland means a patch has a minimum projected foliage cover of canopy trees of 10% or more; or the trees have a density of at least 10 native tree stems per 0.5 ha (=20 stems/ha) that are at least 1 m in height, as evidence of potential natural regeneration of native tree species.

ecological community to be subject to the referral, assessment and compliance provisions of the EPBC Act. Categories A1 and A2 are considered the minimum thresholds for a patch of Southern Highlands Shale Forest and Woodland to be regarded as an example of high quality condition (high condition class). The condition categories, classes and thresholds for the Southern Highlands Shale Forest and Woodland are outlined in Table 2.

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

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

1.4.4.1 Defining a patch

A patch is defined as a discrete and mostly continuous area of the ecological community[4]. Permanent man-made structures, such as roads and buildings, are typically excluded from a patch. Patches may include small-scale disturbances, such as tracks or breaks, watercourses or small-scale variations in vegetation that do not significantly alter the overall functionality of the ecological community. (processes such as the movement of wildlife and pollinators, the dispersal of plant propagules, activities of seed and plant predators and many others).

Where native grassland/shrubland (natural or derived) connects discrete patches of the ecological community that are in close proximity (up to 100m apart), this should be considered a single patch of the ecological community rather than individual patches.

1.4.4.2 Buffer zone

A buffer zone is an area contiguous with 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. For instance, 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), weed invasion and other damage.

The buffer zone is not part of the ecological community and hence the buffer zone itself is not formally protected as a matter of national environmental significance. However, a buffer zone is strongly recommended. For EPBC Act approval, changes in use of the land falling within the buffer zone must not have a significant impact on the ecological community. If the use of an area that directly adjoins a patch of the ecological community is going to be intensified, approval under EPBC Act may also be required to avoid adverse impacts, but there are exemptions for continuing use (e.g. cropping, grazing or maintaining existing fire breaks). The buffer zone may also be a focus for revegetation initiatives where practical.

The recommended minimum buffer zone is 50 metres from the outer edge of the patch as this distance accounts for the maximum height of the vegetation and likely influences upon the root zone. A larger buffer zone should be applied, where practical, to protect patches that are of very high

[4] The 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.

conservation value or if patches are located down slope of drainage lines or a source of eutrophication.

Table 2 Condition categories, classes and thresholds for the Southern Highlands Shale Forest and Woodland

Category and Rationale	Thresholds		
A1. High condition class A larger patch with good quality native understorey	Patch size ≥ 2 ha **And** ≥ 50% of the perennial understorey vegetation cover* is made up of native species **Or** ≥ 30 native understorey species per ha		
A2. High condition class A patch with very good quality native understorey	Patch size ≥ 0.5 ha **And** ≥ 70% of the perennial understorey vegetation cover is made up of native species		
B1. Moderate condition class A patch with good quality native understorey	Patch size ≥ 0.5 ha **And** ≥ 50% of the perennial understorey vegetation cover is made up of native species **Or** ≥ 15 native understorey species per 0.5 ha		
B2. Moderate condition class A moderate sized patch with connectivity to a native vegetation area; or a mature tree; or a tree with hollows	Patch size ≥ 0.5ha **And** ≥ 30% of the perennial understorey vegetation cover is made up of native species **And**		
	The patch is contiguous** with another type of native vegetation remnant (i.e. any native vegetation where cover in each layer present is dominated by native species) ≥1 ha in area	**Or**	The patch has at least one tree with hollows per 0.5 ha or at least one large locally indigenous tree (>60cm dbh) per 0.5 ha

dbh is diameter at breast height.

**Perennial understorey vegetation cover* includes vascular plant species of the ground and shrub layers (where present) with a lifecycle of more than two growing seasons. The ground layer includes herbs (i.e. graminoids, forbs, and low shrubs [woody plants ≤0.5m high]). 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.

1.4.4.3 Sampling protocols

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.

The number of plots/records (if using a liner/transact method) 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 0.04 ha (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.

1.4.4.4 Seasonal variation and timing of surveys

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 held in 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, slashing or grazing, so surveys should be planned to occur after an adequate time for some recovery (for example, at least 18 months post fire).

1.4.4.5 Surrounding environment, landscape context and other significant considerations

The Southern Highlands Shale Forest and Woodland is highly fragmented, sitting within a patchwork of cleared land and native vegetation between the northernmost portion of the Shoalhaven River catchment dominated by Morton National Park, and the southern Hawkesbury-Nepean River catchment featuring Nattai National Park to the northwest, and Upper Nepean State Conservation Area to the north and northeast. Much of those reserves are declared Sydney Catchment Authority Special Areas[5]. At the far northern end of the ecological community's range, in the vicinity of the Highway and railway based settlements, are the southernmost remnants of vegetation associated with the Cumberland Plain, an area heavily impacted by the on-going expansion of Greater Western Sydney. As such, the habitat of Southern Highlands Shale Forest and Woodland serves as a northwest/southeast corridor across the Southern Highlands/Robertson Plateau, and a north/south corridor between the lower rainfall/lower altitude grassy woodland of the Cumberland Plain, and the vegetation of the Highlands, and further south, the Southern Tablelands. These corridors still accommodate the movement of fauna and plant genetic material between these habitats and catchment areas.

Actions that may have 'significant impacts[6]' on any patches of Southern Highlands Shale Forest and Woodland meeting the condition thresholds require approval under the EPBC Act. The ecological

[5] The Sydney Catchment Authority and the Office of Environment and Heritage jointly manage Special Areas, declared under the *Sydney Water Catchment Management Act 1998* for their value in protecting the quality of the raw water used to provide drinking water to Sydney, the Illawarra and the Blue Mountains, and for their ecological integrity. Further information is available at: http://www.sca.nsw.gov.au/science-and-education/education/learn/special-areas

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

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 Southern Highlands Shale Forest and Woodland 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 (e.g. 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 (i.e. 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 Southern Highlands Shale Forest and Woodland 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 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, diverse smaller patches or isolated patches that occur in areas where the 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, connectivity 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, watercourses, natural rock outcrops or diversity of plants.
- High native species richness, possibly including many understorey plant species or native fauna species.
- Presence of nationally or state listed threatened species or patches that contain a unique combination of species and/or rare or important species in the context of the particular ecological community or local region (e.g. a variant of the patch with unique fauna and/or understorey flora composition; or a patch that contains flora or fauna that has largely declined in the ecological community or region).
- Areas with minimal weeds and feral animals, or where these threats can be efficiently managed.
- Presence of cryptogams, soil crust and leaf litter on the soil surface indicating low recent disturbance and potential for good functional attributes such as nutrient cycling.
- Proximity to derived native grasslands and shrublands that were formerly the ecological community. These can be important to the survival of the ecological community in a fragmented, modified landscape.

- Connectivity to other native vegetation remnants or restoration works (e.g. native plantings in particular), a patch in an important position between (or linking) other patches in the landscape. This can contribute to movement of fauna and transfer of pollen and seeds.
- Linear road reserves often contain remnant native vegetation in good to moderate condition, representing a diverse range of upper storey, mid-storey and perennial understorey species. These areas also act as important corridor links to larger patches of nearby vegetation. In many instances linear road reserves can represent the only remnant native vegetation occurring in an area where adjacent land has largely been cleared.

1.4.4.6 Area critical to the survival of the ecological community

Areas that meet the minimum condition thresholds (i.e. moderate condition class) 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, buffers for higher condition areas, and should also be considered as part of the surrounding environment, landscape context and other significant considerations.

1.4.4.7 Geographic extent and patch size distribution

The Southern Highlands Shale Forest and Woodland is endemic to New South Wales, and limited to the Sydney Basin Bioregion. It is known to occur in the Wingecarribee Local Government Area (as defined at March 2015), but may occur elsewhere in the Sydney Basin Bioregion.

The ecological community has been subject to extensive clearing and degradation and now exists in a highly fragmented state. It has undergone a decline estimated between 75-90% of its original pre-European extent, with less than 6000 ha remaining. Remnants consist mostly of small isolated pockets some of which may be low quality that do not meet the condition thresholds for the national ecological community and hence potentially less than 1000 ha remains. It has a mean patch size of approximately 4 ha and a median patch size of 0.94 ha which is considered to be ‘very restricted’ (Tozer et al., 2010). Almost all patches (93%) are less than 10 ha in size. Details of the calculation of values given in the section are in Appendix E (tables E1 and E2).

1.5 National context and other protection

The Southern Highlands Shale Forest and Woodland is endemic to New South Wales, occurring within the southern part of the Sydney Basin IBRA Bioregion. This ecological community is included in the broad vegetation class ‘Southern Tableland Wet Sclerophyll Forests’ (Keith, 2004).

Relationship to State-listed ecological communities

The ‘Southern Highlands Shale Woodlands in the Sydney Basin Bioregion’ ecological community was listed in 2001 under the NSW *Threatened Species Conservation Act 1995* as an endangered ecological community. The state listed ecological community is encompassed by the national ecological community.

Listed threatened species

The Southern Highlands Shale Forest and Woodland supports 24 state and/or nationally listed threatened species (refer Table 3).

Level of protection in reserves

The Southern Highlands Shale Forest and Woodland is vastly under-represented in formal conservation estate, with less than 1% (Tozer et al., 2010) of the pre-European extent conserved. Remnants still exist within a range of other public lands but these do not necessarily afford adequate protection. Most examples on public land occur in small, urban Council-managed reserves where the primary land use is not nature conservation. One relatively large example is known from a formal conservation reserve (Upper Nepean State Conservation Area). One small example is known from reserved State Forest (Meryla) which although not subject to managed logging, has been degraded by earlier land use and is under severe threat from inappropriate recreational use. Another example is known from Morton National Park but this occurrence is relatively small, narrow and transitional. In addition, very small areas of shale margin with extant native vegetation cover are reserved on boundaries of Nattai and Budderoo National Park. Only one occurrence is known from a Nature Reserve, and this example is highly altered due to earlier agricultural and pastoral use, and changed hydrology. Whilst it contains some remnant vegetation, including the threatened species *Eucalyptus macarthurii* (Paddy's River gum), it is primarily a reconstruction through plantings.

Further details on national context can be found at Appendix C.

Table 3 Threatened species associated with Southern Highlands Shale Forest and Woodland (as at July 2015).

Scientific name	Common name	TSC	EPBC
Flora			
Eucalyptus macarthurii	Paddy's River box	E	-
Pterostylis gibbosa	Illawarra greenhood	E	E
Fauna			
Amphibians			
Heleioporus australiacus	giant burrowing frog	V	V
Reptiles			
Varanus rosenbergi	Rosenberg's goanna, heath goanna	V	-
Birds			
Anthochaera phrygia	regent honeyeater	CE	CE
Callocephalon fimbriatum	gang gang cockatoo	V	-
Calyptorhynchus lathami	glossy black cockatoo	V	-
Climacteris picumnus victoriae	brown treecreeper (south eastern)	V	-
Daphoenositta chrysoptera	varied sittella	V	-
Melanodryas cucullata cucullata	hooded robin (south eastern)	V	-
Neophema pulchella	turquoise parrot	V	-
Ninox strenua	powerful owl	V	-
Petroica boodang	scarlet robin	V	-
Mammals			
Cercartetus nanus	eastern pygmy possum	V	-
Chalinolobus dwyeri	large-eared pied bat	V	V
Dasyurus maculatus maculatus	spotted-tailed quoll (SE mainland population)	V	E
Falsistrellus tasmaniensis	great pipistrelle	V	-
Miniopterus orianae oceanensis	eastern bentwing bat	V	-
Myotis macropus	southern myotis	V	-
Petaurus australis	yellow-bellied glider	V	-
Phascolarctos cinereus	koala (combined populations of Qld, NSW and the ACT)	V	V
Potorous tridactylus tridactylus	long-nosed potoroo (SE mainland)	V	V
Pteropus poliocephalus	grey-headed flying-fox	V	V
Scoteanax rueppellii	greater broad-nosed bat	V	-

V= vulnerable, E= endangered, CE= critically endangered
TSC = NSW *Threatened Species Conservation Act 1995*
EPBC = *Environment Protection and Biodiversity Conservation Act 1999*

2 SUMMARY OF THREATS

The ecological community occurs on rich clay soils, often on relatively flat land which, historically, has led to it being extensively cleared for agriculture and forestry and, more recently urban development, leaving relatively few small remnants, many of which are in poor condition. Key threats currently affecting the ecological community are:

- Vegetation clearing and landscape fragmentation (previously due to agriculture and forestry; currently due to residential and commercial development)
- Inappropriate grazing, mowing and slashing regimes
- Removal of fallen timber and dead standing trees
- Invasion by weeds
- Invasion by introduced animals and aggressive native species
- Loss of fauna and associated ecological functions
- Inappropriate fire regimes
- Climate change.

2.1 Key Threatening Processes

Key threatening processes listed under the NSW TSC Act and EPBC Act that are affecting the Southern Highlands Shale Forest and Woodland are:

- Land clearance (EPBC Act); Clearing of native vegetation (TSC Act)
- Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants (TSC Act, EPBC Act); Invasion of native plant communities by exotic perennial grasses (TSC Act); Invasion of native plant communities by African olive (TSC Act) ; Invasion and establishment of exotic vines and scramblers (TSC Act); Invasion and establishment of Scotch broom (*Cytisus scoparius*) (TSC Act)
- High frequency fire resulting in the disruption of life cycle processes in plants and animals and a loss of vegetation structure and composition (TSC Act)
- Loss of hollow-bearing trees (TSC Act)
- Removal of dead wood and dead trees (TSC Act)
- Competition and land degradation by rabbits (EPBC Act); Competition and grazing by the feral European Rabbit, *Oryctolagus cuniculus* (TSC Act)
- Herbivory and environmental degradation caused by feral deer (TSC Act)
- Competition from feral honeybees (TSC Act)
- Aggressive exclusion of birds from potential woodland and forest habitat by over-abundant noisy miners (*Manorina melanocephala*) (EPBC Act); Aggressive exclusion of birds by noisy minors (*Manorina melanocephala*) (TSC Act)Predation by European red fox (EPBC Act); Predation by the European red fox (*Vulpes vulpes*) (TSC Act)
- Predation by feral cats (EPBC Act); Predation by the feral cat (*Felis catus*) (TSC Act)
- Predation, habitat degradation, competition and disease transmission by feral pigs (*Sus scrofa*) (EPBC Act)
- Loss of terrestrial climatic habitat caused by anthropogenic emissions of greenhouse gases (EPBC Act); Anthropogenic climate change (TSC Act)

Further details about 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 Southern Highlands Shale Forest and Woodland is estimated to have undergone a decline ranging between 75-90% of its original pre-European extent (Tozer et al., 2010). The estimated decline in geographic distribution is a result of past and ongoing clearing and degradation of remaining patches due to rural, residential and commercial development, clearance for agriculture and infrastructure.

Based on estimates of current extent, the ecological community is considered to have undergone at least a 'severe' decline (≥ 70%) in geographic distribution and is therefore considered to be **eligible** for listing as **endangered** under this criterion.

Criterion 2 – Limited geographic distribution coupled with demonstrable threat

The present geographic distribution of the ecological community is 'restricted' with a total extent of occupancy < 10 000 ha. The ecological community is also highly fragmented with a mean patch size of 4 ha and a median patch size of 0.94 ha and therefore is considered to be 'very restricted' (analysis of data from Tozer et al., 2010).

The ecological community is subject to a range of ongoing threats including clearing, fragmentation and other damage associated with rural residential development; loss of ecological services associated with populations of fauna that have been lost or reduced; weed invasion; and inappropriate fire and grazing regimes. Climate change is likely to increase the severity of many current threats, as well as introducing new pressures on the 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. As such, the ecological community is **eligible** for listing as **critically endangered** under this criterion.

Criterion 3 – Loss or decline of functionally important species

The loss of fauna 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 relating to the decline of functionally important species is not available. As such, there is **insufficient information to determine the eligibility** of the ecological community for listing under this criterion.

Criterion 4 – Reduction in community integrity

The ecological community has undergone a very severe reduction in ecological integrity as a result of clearing, fragmentation, structural alteration, weed invasion and decline in faunal components. The changes to the flora and fauna components of the ecological community are likely to be on-going due to the continuation of existing land use patterns. The ecological community is substantially fragmented, which will exacerbate 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 detrimental change in the past, which has continued to the present time. Further declines in geographic distribution are likely to occur due to pressures from on-going rural residential and commercial development.

Although there has been continuing detrimental change to the ecological community, data are not available to determine an overall rate. As such, there is **insufficient information to determine the eligibility** of the ecological community for listing under this criterion.

Criterion 6 – Quantitative analysis showing probability of extinction

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

Further details about eligibility against listing criteria can be found at Appendix E.

4 PRIORITY CONSERVATION ACTIONS

4.1 Conservation objective

To mitigate the risk of extinction of the Southern Highlands Shale Forest and Woodland, 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 and research 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 Southern Highlands Shale Forest and Woodland include:

- Determine optimal management regimes including integrated fire, grazing and revegetation and best practice management standards for each of the three main forms of the ecological community.
- Survey known sites to identify sites of high conservation priority and better improve understanding of the variation across the ecological community.
- Determine the most appropriate restoration techniques to improve the quality and diversity of the undertorey and regularly monitor condition change (e.g. increases in native grasses and forbs or a decrease in weeds) and evaluate the success of different restoration techniques.
- Determine the total extent of the ecological community meeting at least the minimum condition threshold.

4.3 Priority recovery and threat abatement actions

The following priority recovery and threat abatement actions should be implemented by all levels of government, regional NRM groups, private landholders and other organisations to support the recovery of the Southern Highlands Shale Forest and Woodland. Assessments of activities that inovolve likely significant impacts to the ecological community should incorporate relevant actions below when determining any recommendations.

Habitat loss, disturbance and modification

High priorities:

- Avoid further clearance and fragmentation of patches of the ecological community that meet the condition thresholds and surrounding native vegetation.
    - Individual patches more than 10 ha in size must be retained and patches should not be reduced to below 2 ha.
    - Overall, the extent of the ecological community meeting at least minimum condition thresholds should not be reduced below a critical viability threshold (e.g. 800 ha)
- Minimise impacts from any developments and activities in and adjacent to patches that might result in further degradation (for example, by avoiding disturbances to native vegetation and soil, applying recommended buffer zones around the ecological community, controlling run-off and avoiding significant hydrological changes and eutrophication).
- The highest priority and most cost effective habitat measure is to protect mature trees with hollows and a range of age cohorts in each patch (including ensuring that trees are left to grow to maturity). In addition, plant hollow-producing locally native species and supplement retention of habitat trees by planting artificial hollows (e.g. nest boxes) in or near to the ecological community and monitor outcomes.
- Retain fallen logs and habitat for fauna, 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). Supplement with re-introducing logs to degraded patches.
- Retain other native vegetation remnants, derived native grasslands or shrublands and paddock trees near patches of the ecological community, particularly patches of the community less than 5 ha. Increase the size and condition of patches by promoting regeneration of and replanting canopy trees and a diversity of understorey species. As part of this create or restore appropriate wildlife corridors and linkages, including stepping stones.
- 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).

Other priorities:

- Manage any other known, potential or emerging threats such as rural tree dieback.
- Promote formal conservation arrangements, management agreements and covenants on private land, and for Crown and private land promote inclusion in reserve tenure if possible. In particular, ensure that patches of high quality or importance in a landscape context are considered for inclusion in formal reserve tenure or other land tenure for biodiversity conservation purposes.
- Promote awareness of the ecological community through liaison with:
    - state and local government planning authorities to ensure that land zoning and other 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, state authorities and corporations (e.g. telecommunications) to ensure road widening and maintenance activities (or other infrastructure or development activities) involving substrate or vegetation disturbance in areas where the Southern Highlands Shale Forest and Woodland occurs do not adversely impact the ecological community. This includes avoiding the introduction or spread of weeds.
- Enforce local regulations to avoid rubbish dumping (particularly garden waste), collection of firewood and unauthorised access by motor vehicles.

Invasive species

- Promote knowledge about local weeds and keep invasive plant species controlled at all times.
- Control introduced pest animals, including limiting access by domestic pets, to avoid vegetation damage and allow natural regeneration and to manage threats especially to threatened species.
- Use appropriate hygiene and management protocols to prevent contain weed incursions and aim to eradicate them.
- Keep vehicles and machinery out of remnants. If vehicles must be taken into remnants, ensure they are washed first to remove soil and weed seeds.
- Do not plant potential environmental weeds in gardens and other landscaping from which they may spread into the remnant, nor dump garden waste beyond the confines of the garden on private or public land.
- Manage weeds before and after ecological burns, and during revegetation works to maximise success of restoration.
- Support local projects to remove weeds and rubbish using best practice (e.g. low impact and cost effective) techniques.

Trampling, browsing or grazing

- Ensure that livestock grazing, if it occurs in the ecological community, uses an appropriate management regime and density that does not detrimentally affect the ecological community.
    - if stock could carry weeds into the remnant, then it is preferable to exclude stock altogether or admit them only at times when none of the weeds are producing viable seed.
    - If moving stock to patches of the ecological community, ensure stock are purged of weed seeds.
    - avoid grazing during native plant flowering and seeding times (late spring and summer).
    - grazing at peak reproduction time of exotic grasses (early to mid-spring) may help to suppress these species in favour of native plants.
    - short periods of intense grazing are preferable to leaving stock in for long periods.
- Where appropriate, manage total grazing pressure at important/significant sites and to allow canopy trees to reach maturity through exclusion fencing or other barriers.

Fire

- Implement an appropriate fire management regime.
    - 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.
    - 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.

Conservation information

- Raise awareness and 'ownership' of the Southern Highlands Shale Forest and Woodland within the local community using a range of media and methods such as fact sheets, information brochures and field days in conjunction with known industry or community interest groups.
- Develop education programs, information products and signage to help the public recognise the presence and importance of the ecological community (and their responsibilities under state and local regulations and the EPBC Act).
- Maintain engagement with private landholders and land managers where the ecological community occurs and encourage local participation in recovery efforts.
- Support opportunities for traditional owners to manage the ecological community.

4.4 Existing plans/management prescriptions

- Wingecarribee Shire Council Private Land Biodiversity Conservation Strategic Plan (2014- 2019)
- Wingecarribee Biodiversity Strategy Phase 1: 2003
- Wingecarribee Environment Strategy 2010 – 2015
- Wingecarribee Local Environmental Plan 2010
- Saving our Species program (SOS) – NSW Office of Environment and Heritage
- Cecil Hoskins Nature Reserve: Plan of Management 1999
- Throsby Park Historic Site and Cecil Hoskins Nature Reserve: Fire Management Strategy 2007

4.5 Recovery plan recommendation

Although there is no specific state recovery plan for the Southern Highlands Shale Forest and Woodland, there are a number of existing local planning documents for conservation and threat abatement that align with the ecological community. Taking into account the benefits listing the ecological community and implementation of the recovery and threat abatement priorities and actions specified in this conservation advice, a recovery plan for the ecological community is not required at this time.

APPENDIX A – SPECIES LISTS

Table A1 Mid layer species of the Southern Highlands Shale Forest and Woodland ecological community. This is not a comprehensive list. Source: Douglas, pers. comm., 2015; Tozer et al., 2010; NSW Scientific Committee, 2011. Scientific names are as at July 2015.

Species	**Common name**
Acacia binervata	two-veined hickory
Acacia decurrens	black wattle
Acacia falciformis	mountain hickory
Acacia implexa	hickory wattle
Acacia longifolia	Sydney golden wattle
Acacia mearnsii	black wattle
Acacia melanoxylon	blackwood, black wattle
Acacia parramattensis	Parramatta wattle
Acacia rubida	red-stem wattle
Acacia stricta	hop wattle
Amperea xiphoclada	broom spurge
Billardiera scandens	appleberry
Bursaria spinosa	blackthorn
Cassinia aculeata	dogwood
Clematis aristata	common clematis
Daviesia ulicifolia	gorse bitter-pea
Dillwynia ramosissima	-
Exocarpos cupressiformis	native cherry
Goodenia ovata	hop goodenia
Indigofera australis	native indigo
Leptospermum polygalifolium	yellow tea-tree
Leucopogon juniperinus	-
Leucopogon lanceolatus	lance beard heath
Pittosporum undulatum	sweet pittosporum
Melaleuca linariifolia	tea-tree; flax leaved paperbark
Melaleuca thymifolia	thyme honeymyrtle
Olearia microphylla	-
Olearia viscidula	daisy bush
Oxylobium ilicifolium	prickly oxylobium
Ozothamnus diosmifolius	-
Persoonia linearis	narrow-leaved geebung
Plectanthus parviflorus	-
Pultenaea blakelyi	Blakely's bush-pea
Pultenaea flexilis	bush-pea
Rubus parvifolius	native raspberry
Zieria smithii	sandfly zieria

Table A2 Ground layer species of the Southern Highlands Shale Forest and Woodland ecological community. This is not a comprehensive list. Source: Douglas, pers. comm., 2015; Tozer et al., 2010; NSW Scientific Committee, 2011. Scientific names are as at July 2015.

Species	**Common name**
Asperula conferta	common woodruff
Blechnum cartilagineum	gristle fern
Xerochrysum bracteatum	golden everlasting
Brachyscome graminea	daisy
Calochlaena dubia	common ground fern
Coronidium elatum	daisy
Coronidium scorpioides	button everlasting
Dichondra spp.	kidney weed
Dichelachne crinita	plume-grass
Echinopogon caespitosus	tufted hedgehog grass
Einadia nutans	climbing saltbush
Eustrephus latifolius	wombat berry
Geranium homeanum	native geranium
Geranium solanderi	native geranium
Gonocarpus tetragynus	-
Hardenbergia violacea	native lilac
Hibbertia empetrifolia	-
Hibbertia scandens	guinea flower
Hypericum gramineum	small St Johns wort
Imperata cylindrica	blady grass
Lomandra longifolia	spiny mat rush
Lomandra multiflora	mat rush
Microlaena stipoides var. *stipoides*	weeping grass
Opercularia diphylla	stinkweed
Patersonia glabrata	native iris
Poa labillardierei	river tussock grass
Poa sieberiana	fine leaved tussock grass
Poranthera microphylla	small-leaved poranthera
Pratia purpurascens (syn. *Lobelia purpurascens*)	whiteroot
Pteridium esculentum	common bracken
Pterostylis gibbosa	Illawarra greenhood
Rytidosperma (syn. *Austrodanthonia*) spp.	wallaby grass
Rytidosperma pallidum (syn. *Joycea pallida*)	red-anther wallaby grass
Schoenus melanostachys	black bog rush
Senecio hispidulus	hill fireweed
Senecio minimus	fireweed
Stackhousia monogyna	creamy candles
Stackhousia viminea	stackhousia
Themeda triandra	kangaroo grass
Tricoryne simplex	-
Veronica plebeia	trailing speedwell
Viola betonicifolia	showy violet
Viola hederacea	native violet

Table A3 Fauna species that may occur in the Southern Highlands Shale Forest and Woodland, including threatened status. This is not a comprehensive list. Source: NSW Bionet. Scientific names are as at July 2014.

Species	Common name	TSC	EPBC
Birds			
Aegotheles cristatus	Australian owlet nightjar	-	-
Anthochaera phrygia	regent honeyeater	CE	CE
Acanthiza chrysorrhoa	yellow-rumped thornbill	-	-
Acanthiza lineata	striated thornbill	-	-
Acanthiza pusilla	brown thornbill	-	-
Acanthorhynchus tenuirostris	eastern spinebill	-	-
Cacatua galerita	sulphur-crested cockatoo	-	-
Caligavis chrysops	yellow-faced honeyeater	-	-
Callocephalon fimbriatum	gang gang cockatoo	V	-
Calyptorhynchus lathami	glossy black cockatoo	V	-
Calyptorhynchus funereus	yellow-tailed black cockatoo	-	-
Climacteris picumnus victoriae	brown treecreeper (south eastern)	V	-
Colluricincla harmonica	grey shrike-thrush	-	-
Cracticus tibicen	Australian magpie	-	-
Dacelo novaeguineae	laughing kookaburra	-	-
Daphoenositta chrysoptera	varied sittella	V	-
Eopsaltria australis	eastern yellow robin	-	-
Manorina melanocephala	noisy miner	-	-
Melanodryas cucullata cucullata	hooded robin (south eastern)	V	-
Microeca fascinans	jacky winter	-	-
Neophema pulchella	turquoise parrot	V	-
Ninox strenua	powerful owl	V	-
Ninox novaeseelandiae	southern boobook	-	-
Pardalotus striatus	striated pardalote	-	-
Petroica boodang	scarlet robin	V	-
Platycercus eximius	eastern rosella	-	-
Podargus strigoides	tawny frogmouth	-	-
Rhipidura albiscapa	grey fantail	-	-
Sericornis frontalis	white-browed scrub-wren	-	-
Strepera graculina	pied currawong	-	-
Reptiles			
Ctenotus taeniolatus	copper-tailed skink	-	-
Drysdalia coronoides	white-lipped snake	-	-
Varanus rosenbergi	Rosenberg's goanna, heath goanna	V	-
Amphibians			
Crinia signifera	eastern froglet	-	-
Heleioporus australiacus	giant burrowing frog	V	V
Mammals			
Antechinus stuartii	brown antechinus	-	-
Cercartetus nanus	eastern pygmy possum	V	-
Chalinolobus dwyeri	large-eared pied bat	V	V
Dasyurus maculatus maculatus	spotted-tailed quoll (SE mainland popn)	V	E
Falsistrellus tasmaniensis	great pipistrelle	V	-
Macropus giganteus	eastern grey kangaroo	-	-
Miniopterus orianae oceanensis	eastern bentwing bat	V	-
Myotis macropus	southern myotis	V	-

Species	Common name	TSC	EPBC
Mammals cont.			
Nyctophilus geoffroyi	lesser long-eared bat	-	-
Petaurus australis	yellow-bellied glider	V	-
Petaurus breviceps	sugar glider	-	-
Phascolarctos cinereus	koala (combined populations of Qld, NSW and the ACT)	V	V
Potorous tridactylus tridactylus	long-nosed potoroo (SE mainland)	V	V
Pteropus poliocephalus	grey-headed flying-fox	V	V
Rattus fuscipes	bush rat	-	-
Scoteanax rueppellii	greater broad-nosed bat	V	-
Tachyglossus aculeatus	short beaked echidna	-	-
Trichosurus vulpecula	brush-tailed possum	-	-
Vespadelus darlingtoni	large forest bat	-	-
Vespadelus regulus	southern forest bat	-	-
Vombatus ursinus	common or bare-nosed wombat	-	-
Wallabia bicolor	swamp wallaby	-	-

V= vulnerable, E= endangered, CE= critically endangered
TSC = NSW *Threatened Species Conservation Act 1995*
EPBC = *Environment Protection and Biodiversity Conservation Act 1999*

Table A4 Weed species found in the Wingecarribee Shire that may impact the Southern Highlands Shale Forest and Woodland. Source: Douglas, pers. comm., 2015; WSC, 2013. Scientific names are as at March 2015.

Species	Common name
Araujia sericifera	moth vine
Berberis vulgaris	barberry
Asparagus asparagoides	bridal veil creeper
Cotoneaster spp.	contoneaster
Crataegus spp.	hawthorn
Delairea odorata	cape ivy
Cytisus scoparius	Scotch broom
Eragrostis curvula	African love grass
Genista monspessulana	montpellier broom
Hedera helix	English ivy
Ligustrum spp.	privet
Nassella trichotoma	serrated tussock
Olea europaea ssp. *cuspidata*	African olive (emerging threat)
Pittosporum undulatum	sweet pittosporum (native sp.)
Prunus laurocerasus	cherry or common laurel
Rubus fruticosus agg.	blackberry
Salix spp.	willows
Tradescantia fluminensis	wandering jew
Ulex europaeus	gorse

As at July 2015, further information on environmental and noxious weeds in the Southern Highlands can be found at: http://www.wsc.nsw.gov.au/services/environment/environmental-information/flora-fauna/environmental-weeds

APPENDIX B – FURTHER INFORMATION ON 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 the Southern Highlands Shale Forest and Woodland are an essential resource for many animals. The plants provide food directly (leaves, blossom, seed, sap) and indirectly through insects, spiders and mites. They also provide nesting and roosting sites among leaves, on branches, fissures in bark and in hollows, and create a sheltered microclimate under the canopy by reducing solar radiation and creating a litter layer. In turn, animals influence the structure and floristics of the vegetation through selective grazing, pollination and dispersal of seed, as well as providing nutrients, keeping soil healthy and regulating other animals that can impact on vegetation (e.g. controlling insect numbers).

The Southern Highlands Shale Forest and Woodland supports a variety of fauna that have diminished but still have a broad range of functional roles within the ecological community. These include kangaroos, wallabies and wombats, smaller ground dwelling mammals (e.g. echidnas, potoroos), arboreal mammals (e.g. possums, bats), reptiles, birds and invertebrates.

Woodland birds across eastern Australia are declining due to loss, fragmentation and degradation of their habitat (Ford, 2011). A diversity of small woodland birds is important for regulating insect populations, including the suite of phytophagous[7] insects associated with rural tree dieback (Landsberg, 1990). Insectivorous bats and small arboreal species such as sugar gliders also contribute to the control of insect numbers. Defoliated trees can change understorey composition and are less likely to flower, subsequently impacting nectar-feeding fauna; habitat patches are more exposed to weather effects, potentially making foraging more difficult; and shelter is reduced, leaving individuals more at risk from predation and exposure (Ford and Bell, 1982; Ford et al., 2001). The decline of insectivorous birds, bats and small arboreal mammals in the ecological community has implications for the quality of habitat for a range of woodland flora and fauna.

Soil disturbance by digging mammals (e.g. wombat, echidna, potoroo) contributes significantly to ecosystem function. The process of bioturbation[8] alters soil processes through increasing soil turnover and altering structural and chemical properties (Flemming et al., 2014). Diggings capture organic matter, provide habitat for microscopic and macroscopic organisms, create suitable sites for fungal growth and increase seedling recruitment, with the overall effect of increasing biodiversity and resilience (Flemming et al., 2014). The disruption of biological processes associated with the decline of digging fauna in this ecological community contributes to a reduction in ecological function.

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), found in the understorey of this ecological community and surrounding native vegetation 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 native vegetation patches 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).

[7] Leaf eating.
[8] Bioturbation is the reworking of soils and sediments by animals or plants.

The shrub layer of the Southern Highlands Shale Forest and Woodland is generally open, allowing animals to graze on the grassy ground layer. Populations of grazers may significantly influence the floristics and structure of the ecological community and consequently, fire behaviour. The severity and frequency of fire, grazing or fertilizer regimes affects appearance, species composition and functionality in the ground layer. These regimes influence the density and diversity of native grasses, herbs and wildflowers and the capacity of the canopy layer to regenerate. Land management practices such as grazing or burning can alter floristic composition by eliminating species which are most sensitive to a particular regime, especially if the grazing is heavy or continuous or burning occurs frequently. Therefore, regimes that maintain or restore diversity in the understorey and allow for regeneration of the overstorey are best for the persistence of the ecological community, and those that decrease diversity should be avoided.

Role of connectivity and broader landscape context

Woodland forms of the ecological community occur naturally as mosaics amongst the forests and wetlands that once dominated the Southern Highlands plateau. The distribution of the woodland and forest forms of the ecological community is influenced by factors such as topography, geology, climate and disturbance regimes. Clearing and land-use changes have created further complexity. Remnants of the Southern Highlands Shale Forest and Woodland now primarily exist as patches, linear strips and scattered trees along roadsides and on farmland. Only a very small number of remnants occur within conservation reserves of any kind, and only one large remnant is known to persist. Due to the highly fragmented nature of this ecological community, and the fact that it is largely surrounded by cleared land, the habitat provided for many native fauna species has diminished. However, despite fragmentation and decline in quality, remnants of habitat that remain are still of value to highly mobile species or to those that are tolerant of disturbance, particularly as stepping stones to other areas (Doerr et al., 2010).

Connectivity between remnants of the Southern Highlands Shale Forest and Woodland and 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 fauna, diversity and abundance is more correlated with the connectivity of the patches to other remnant vegetation than to the size of the patch itself. The Southern Highlands Shale Forest and Woodland sits within a patchwork of cleared land and intact native vegetation connecting Morton National Park to Nattai National Park and to the Upper Nepean State Conservation Area. It also occurs between the grassy woodlands and forests of the Southern Tablelands and the Cumberland Plain. These corridors are likely to be important for the movement of fauna including nationally and regionally threatened species such as the koala, regent honeyeater, glossy black cockatoo and the gang gang cockatoo (DECCW, 2007).

Given the highly fragmented state of the Southern Highlands Shale Forest and Woodland, the long-term conservation of fauna associated with the ecological community is also dependent on the connectivity between the ecological community and surrounding native vegetation.

APPENDIX C – DETAILED DESCRIPTION OF NATIONAL CONTEXT

Distribution

Southern Highlands Shale Forest and Woodland occurs on clay soils derived from Wianamatta Shale, on the extensively cleared Southern Highlands/Robertson plateau. The ecological community is limited to the Sydney Basin Bioregion (IBRA v.7).

The ecological community occurs in New South Wales, in the Local Land Services South East region. It is found in the Wingecarribee Local Government Area (as defined at July 2015), with potential for some outliers in adjacent shires.

Relationships to other vegetation classifications

The Southern Highlands Shale Forest and Woodland corresponds entirely or in part to the following vegetation classifications:

- Tozer et al. (2010) WSF p268 – Southern Highlands Shale Woodlands, as identified by Tindall et al. (2004)
- Tozer et al. (2010) WSFp168 – Shale-Basalt Sheltered Forest
- Pidgeon (1941) *Eucalyptus radiata – E. cypellocarpa* (syn. *Eucalyptus goniocalyx*) – *E. eugenioides* forest type
- Benson and Howell (1994) Open Forest (*E. radiata – E. macarthurii*)
- Fischer et al. (1995) Open Forest (*E. cypellocarpa – E. quadrangulata – E. globoidea*).

Differences to similar or intergrading ecological communities

Soils within the Wingecarribee Shire Local Government Area are typically derived from either shale, basalt or sandstone. Some patches of Southern Highlands Shale Forest and Woodland adjoin forest occurring on similarly fertile soils of basaltic origin making the boundary between this ecological community and basalt vegetation communities sometimes difficult to distinguish as they may share a number of species. Further, other patches of Southern Highlands Shale Forest and Woodland may include a suite of species which reflect a stronger sandstone influence from the upper Mittagong Formation, which is a transitional member between the Wianamatta Group and the Hawkesbury Group. This is evident around Braemar and Alymerton.

Some forms/variants of Southern Highlands Shale Forest and Woodland may share a number of species with the following threatened basalt-based and shale/sandstone-based ecological communities occurring within the Southern Highlands that are listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act) and/or EPBC Act:

- Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion (EPBC Act)
- Robertson Basalt Tall Open Forest in the Sydney Basin Bioregion (TSC Act)
- Mount Gibraltar Forest in the Sydney Basin Bioregion (TSC Act)
- Shale Sandstone Transition Forest of the Sydney Basin Bioregion (EPBC and TSC Acts)
- Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest (EPBC Act)
- Cumberland Plain Woodland in the Sydney Basin Bioregion (TSC Act)
- Sydney Turpentine-Ironbark Forest in the Sydney Basin Bioregion (EPBC and TSC Acts)

- Tablelands Snow Gum, Candlebark and Kangaroo Grass Grassy Woodland in the NSW South Western Slopes, South East Corner, South Eastern Highlands and the Sydney Basin Bioregions (TSC Act)
- Tablelands Basalt Forest in the Sydney Basin Bioregion and South Eastern Highlands Bioregion (TSC Act)

Southern Highlands Shale Forest and Woodland is distinguished from these communities by its floristic composition being primarily influenced by clay soils derived from Wianamatta shale; location (occurring only on the Southern Highlands in the Sydney Basin Bioregion); and position in the landscape (typically occurring on flat or undulating terrain at elevations between 470 m-830 m ASL). Other differences are detailed below.

The nationally listed **Upland Basalt Eucalypt Forest** encompasses the state-listed **Mount Gibraltar Forest** and the **Robertson Basalt Tall Open Forest**. Patches of Upland Basalt Eucalypt Forest are found in the central, southern and eastern parts of the Southern Highlands (around Robertson, Kangaloon, Mount Murray, Moss Vale, Bowral, Exeter and Bundanoon). Upland Basalt Eucalypt Forest and Southern Highlands Shale Forest and Woodland share a number of canopy eucalypt species. However, canopy species such as *Doryphora sassafras* (sassafras) and *Eucalyptus fastigata* (brown barrel) which can be indicative of Upland Basalt Eucalypt Forest, do not typically occur in Southern Highlands Shale Forest and Woodland.

The northern boundary of Southern Highlands Shale Forest and Woodland to overlaps with the southern limit of **Shale Sandstone Transition Forest of the Sydney Basin Bioregion** (EPBC and TSC Acts). The Southern Highlands Shale Forest and Woodland may adjoin the Shale Sandstone Transition Forest, however, they have relatively few canopy species in common. While Shale Sandstone Transition Forest is found on soils that are primarily derived from Wianamatta Shale, it also occurs on part of the Mittagong Formation, including on soils with some influence from weathered sandstone.

In the central, west and south of the Southern Highlands plateau, Southern Highlands Shale Forest and Woodland may intergrade with **Tablelands Snow Gum, Candlebark and Kangaroo Grass Grassy Woodland in the NSW South Western Slopes, South East Corner, South Eastern Highlands and the Sydney Basin Bioregions** (TSC Act). The area of potential overlap is small and the two communities comprise different species assemblages with relatively few species in common. The Tablelands community is distinguished in this region by the dominance of *Eucalyptus pauciflora* (snow gum) as a grassy woodland occurring in sites with significant cold air drainage and ponding. *Eucalyptus rubida* (Candlebark) is relatively common in that community, but is very rare in the Southern Highlands Shale Forest and Woodland (with the exception of the most westerly, drier and colder remnants). *Eucalyptus stellulata* (black Sallee) may be associated with *Eucalyptus pauciflora* in the Tablelands community but is absent from Southern Highlands Shale Forest and Woodland. Examples of where these communities intergrade include the western quarter of Sally's Corner Road in Exeter/Sutton Forest; and along Golden Vale Road in Sutton Forest.

In some parts of the Wingecarribee Shire **Tableland Basalt Forest in the Sydney Basin and South Eastern Highlands Bioregions** may intergrade with Southern Highlands Shale Forest and Woodland. Examples of such sites include eastern Canyonleigh, Sutton Forest and Bowral, where basalt-based forests on either Robertson Basalt, Sutton Forest Basalt, or Mt Gibraltar Microsyenite, occur in a wider matrix of shale-based forests. Tableland Basalt Forest examples in the Highlands may be related to Upland Basalt Eucalypt Forests and Robertson Basalt Tall Open Forest but occur in areas of lower rainfall, less coastal climatic influence, more exposure to drying winds, and more frost. Such Tableland Basalt Forest examples tend to have little or no rainforest understorey, and lack rainforest sub-canopy except in rare riparian situations.

APPENDIX D – DESCRIPTION OF THREATS

The Southern Highlands Shale Forest and Woodland has suffered substantial damage in the past, largely associated with the direct loss and degradation of vegetation, primarily for agriculture, particularly pastoralism. Continuing urban and rural development, along with the construction and maintenance of public infrastructure, have resulted in further clearing, degradation and modification of large areas of the community. Such activities and associated invasive species continue to impact the ecological community, reducing its integrity and resilience to any future impacts.

Vegetation clearing and landscape fragmentation

European settlement in the Southern Highlands began around 1821, when a government settlement was established at Bong Bong. In 1867 the Southern railway line opened, facilitating growth in the region. During this period land use was primarily for sheep and cattle grazing and timber harvesting. Today the region remains largely rural, with urban areas in a number of towns and villages. Grazing is still the primary land use with some timber production (primarily pine plantations), fruit and vegetable growing, mining and viticulture.

Historically, levels of clearing of the Southern Highlands Shale Forest and Woodland have been very high. Only one relatively large remnant of the ecological community is known from a formal conservation area (Upper Nepean State Conservation Area).

Despite much of the ecological community being listed as threatened under the NSW *Threatened Species Conservation Act 1995* and changes to state native vegetation management laws since the late 1990s, aimed at preventing broad-scale clearing, the ecological community continues to be cleared.

One of the most serious ongoing threats to the Southern Highlands Shale Forest and Woodland is fragmentation as a result of earlier and on-going clearing. The ecological community is extremely fragmented with almost all patches (93%) less than 10 ha in size (median patch size is 0.94 ha). As a consequence, it has a large ratio of boundary to area. The negative impacts of edges on the abundance and diversity of native and endemic species are well documented (e.g. Anderson and Burgin, 2001; Davies et al., 2001; Hannah et al., 2007). Small patches of habitat generally have fewer species which are often further reduced over time. Small and isolated fragments are less buffered against disturbances such as weed invasion (Cuneo and Leishman, 2013), or other impacts from surrounding agricultural and residential activities. Isolated paddock trees and small remnant copses are relatively vulnerable to storm damage/windthrow by way of their high exposure. As trees blow down and/or die of disease and age, they are frequently not replaced, and livestock grazing continues to further erode what remains of the forest and woodland. Such slow, incremental loss or attrition of paddock trees and small remnants has a very significant cumulative effect over the medium-term.

Residential and commercial development

The Wingecarribee Shire forms part of the Sydney-Canberra-Melbourne transport corridor on the Southern rail line and the Hume Highway. This, coupled with the expansion and growth of south west Sydney and the Illawarra, is resulting in significant development pressure in the region as migration from these areas increases to the Southern Highlands region. This includes subdivision for residential and lifestyle purposes, infrastructure, industry and more intensive agriculture. The Sydney-Canberra Corridor Regional Strategy (State of NSW, 2008) calculates that projected population growth in the Wingecarribee Shire will equate to a demand for an additional 8700 dwellings by 2031. The towns of Bowral, Mittagong and Moss Vale will be under increasing

pressure to develop in order to accommodate future growth. The majority of greenfield development[9] will be located central to the ecological community, around Mittagong and Moss Vale, with 1000 lots and 1400 lots respectively planned in the short to medium term future (State of NSW, 2008).

This development is likely to exert additional pressures on the natural environment, including the ecological community, through further clearing for the construction of homes and supporting infrastructure. It may also lead to changes in soil and water quality from increased nutrient levels. Proximity to urban areas also leads to damaging activities such as rubbish dumping, off-road vehicle trails, fire wood collection and incursions by domestic pets or garden plants.

Inappropriate grazing, mowing and slashing regimes

If not appropriately managed, livestock grazing can be detrimental to the Southern Highlands Shale Forest and Woodland. The structure and composition of flora components of the ecological community may be altered through selective grazing of more palatable species. Subsequent changes in native plant species composition and diversity in remnant patches may reduce habitat values for fauna.

Most remnants of the ecological community are subjected to varying degrees of grazing by domestic stock, feral herbivores (e.g. rabbits, hares) or native animals (e.g. kangaroos, wallabies, wombats) (NSW Scientific Committee, 2011; 2014, Tozer et al., 2010). In rural residential areas, patches of the ecological community are mowed or slashed for bushfire fuel reduction or for grazing (promoting fresh new growth). These activities may prevent the regeneration and recruitment of overstorey and understorey species, leading to thinning and ultimately loss. Often these species are replaced by weeds or pasture species. Grazing can also lead to increased soil compaction or erosion, which may make native seedling establishment less likely.

However, while grazing, mowing and slashing are often problematic for the conservation of the ecological community, they may be useful for weed suppression, including as an interim measure as part of a longer-term conservation strategy (DEC, 2005). Priority research activities (see Section 4 – Priority Conservation Actions) seek to clarify best practice management standards for the preservation and restoration of the ecological community, including grazing.

Removal of fallen timber and dead standing trees

Dead standing trees and fallen timber provide habitat and feeding substrates for a wide range of woodland birds, mammals, reptiles, amphibians and invertebrates within the ecological community. The collection of firewood from forest and woodland remnants significantly reduces the habitat values of these areas.

'Tidying up' is a common activity in the increasingly park-like Southern Highlands, and generally involves the removal of dead trees, fallen logs and branches, rock and leaf litter from forest and woodland areas. It is an activity which is often mistakenly considered to be part of good land management (ANZECC, 2001) and is sometimes carried out for fire hazard reduction purposes. The collection of firewood may also be undertaken. However, the removal of these elements from an ecosystem significantly reduces habitat values for many species. These elements are also essential for maintaining nutrient cycling within woodland ecosystems since they provide the raw materials and habitat for the many organisms (insects, fungi and micro-organisms) which break down this material into soil.

[9] Agricultural or amenity properties being considered for urban development.

Invasion by weeds and pathogens/diseases

Weed incursion in the Southern Highlands region is associated with grazing and agricultural land uses as well as residential development. Clearing and intensive grazing over many years has altered ground cover, diminished perennial native grasses and herbs, and changed water dynamics in the landscape. This has made the ecological community vulnerable to invasive weed species.

Weeds compete with locally indigenous flora species for available resources (water, light, nutrients) and often lead to a decline in the diversity and regenerative capacity of a native ecosystem. This in turn, impacts on habitat values for woodland fauna by affecting the type and availability of resources such as food (e.g. nectar, seeds and fruit), shelter from predators or weather, and nesting sites.

Further, the use of herbicides and pesticides to control weeds and other agricultural insect pests can kill native flora and disrupt natural food webs, hence also impact many fauna.

There are 48 plant species currently classified as environmental weeds in the Wingecarribee Shire (WSC, 2012), although there may be many more. A number of these have the potential to invade the ecological community (refer Table B3). Examples of invasive weeds likely to pose a significant threat to the Southern Highlands Shale Forest and Woodland include blackberry (*Rubus fruticosus* agg.), gorse (*Ulex europaeus*) and hawthorn (*Crataegus* spp.).

Blackberry is a Weed of National Significance (WoNS) and is regarded as one of the worst weeds in Australia because of its invasiveness and potential for spread. It degrades natural environments such as this ecological community by displacing native plants and potentially reducing habitat values for native species, although it may also provide seasonal food by way of berries (contributing to further spread of the weed). Blackberry also reduces agricultural values. For example, available land for grazing as most livestock find blackberry unpalatable; or productivity through shading out pastures and crops, and competing for soil moisture and nutrients (NSW DPI, 2012). It also exacerbates rabbit impacts by providing them shelter.

Gorse has also been declared a WoNS. It is a small shrub, which like blackberry, can invade natural ecosystems such as this ecological community, with heavy infestations smothering native vegetation (or pastures). Infestations can spread rapidly. Seed production is prolific, with mature infestations producing up to 6 million seeds per ha each year (DoE, 2011a). Seeds can remain dormant in the soil for up to 30 years (CRC, 2003, cited in DoE, 2011a), allowing a large seed bank to establish.

Hawthorn is a low tree or tall shrub that forms dense thickets along roadsides, in grasslands, open woodlands and pastures in and around this ecological community. It can displace native plants, reduce native understorey regeneration and may therefore have long term impacts on native plant community structure. Hawthorn produces a large amount of seed, which is readily dispersed by birds and mammals which eat the fruit (DoE, 2011b).

Introduced animals and aggressive native species

The presence of domestic animals e.g. cattle, cats and dogs as well as pest animals such as foxes (*Vulpes vulpes*), feral cats (*Felis catus*), rabbits (*Oryctolagus cuniculus*), brown hares (*Lepus capensis*), deer (*Cervus* spp.) and mice (*Mus musculus*) in the ecological community are associated with agricultural land use, and can also increase with residential development. These animals can impact through predation of species and damage to native vegetation and soils. Moderate to heavy grazing by livestock and/or rabbits results in the decline and disappearance of palatable plant species, including shrubs and herbs, and compaction and erosion of topsoil, making re-establishment of a diverse native understorey problematic. The effects of overgrazing may be exacerbated under drought conditions. Habitat degradation associated with overgrazing and erosion contributes to a large reduction in ecological function of the community.

Introduced animals can also compete with native wildlife for resources. For example, the common or Indian myna bird (*Acridotheres tristis*), which appears to be increasing in the Wingecarribee Shire (WSC, 2012), compete with native birds and hollow-dwelling animals. During 2011-12, 150 mynas were captured by residents as part of the Shire's Indian Myna Program (WSC, 2012). Indian mynas are identified by the IUCN[10] Invasive Species Specialist Group as one of the world's 100 worst invasive species (Lowe et al., 2000). Vegetation clearing can also create more suitable habitat for a number of other aggressive native species including the sulphur-crested cockatoo (*Cacatua galerita*), magpie (*Cracticus tibicen*), red wattlebird (*Anthochaera carunculata*), pied currawong (*Strepera graculina*) and noisy miner (*Manorina melanocephala*). All of these species have spread throughout the largely cleared landscapes of south eastern New South Wales, including this ecological community, and now out compete or aggressively exclude woodland bird species in areas of fragmented vegetation, further contributing to a decline in biodiversity.

The introduced honey bee (*Apis mellifera*) is another feral species that competes with native fauna for habitat resources (tree hollows) and food (pollen). Breeding colonies of bees occupy large tree hollows, making them unavailable for birds (e.g. cockatoos and other parrots) and arboreal mammals (e.g. possums, gliders, microbats). In addition, honeybees, feral and managed, frequent blossoms and often remove 80% or more of the floral resources produced (Paton, 1996, 2000, cited in NSW SC, 2011). This can result in competitive displacement of native fauna that use these resources, including honeyeaters (Paton 1993, cited in NSW SC, 2011), native bees (Paton, 1996, cited in NSW SC, 2011) and possums.

The spread of sweet pittosporum is a major threat to many of the wetter and more sheltered or riparian remnants of the community, especially in and near urban areas (Douglas, pers. comms., 2015). It rapidly invades bushland, alters fire ecology in a manner that favours it and many non-native woody weeds, chemically and physically suppresses other native plants, and changes the floristics, structure and faunal composition of remnants over time (Douglas, 2014). Further, the spread of woody weeds such as pittosporum leads to declining numbers of those woodland birds that favour more open habitat. Frugivorus birds feed on the pittosporum, contributing to its spread, effectively pushing the vegetation to a 'weedy rainforest', changing floristic and avifaunal diversity and composition over time (Douglas, pers. comms., 2015).

Loss of fauna and associated ecological functions

Many remnants no longer support a range of fauna due to the loss of large hollow bearing trees, modifications to the understorey, and isolation and fragmentation of remaining patches (Lindenmayer and Fischer, 2006).

The highly fragmented nature of the ecological community and the fact that patches are largely surrounded by cleared land means the Southern Highlands Shale Forest and Woodland no longer provides suitable habitat for some native fauna species. The consequential loss of local flora and fauna has impacted on the natural ecological processes and ecological community composition in the fragmented landscape.

However, remnants provide vital habitat to fauna species, for example as stepping stone habitat in otherwise cleared or modified landscapes particularly for those fauna which are disturbance tolerant or highly mobile (Doerr et al., 2010).

[10] International Union for Conservation of Nature

Inappropriate fire regimes

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

Known occurrences of the Southern Highlands Shale Forest and Woodland are now less connected and surrounded by open areas; hence fires impacting the ecological community are likely to be mostly localised. The size and shape of patches may not be sufficient to develop fuel loads that generate a hot fire within a given patch. Consequently, fires in smaller patches may not be sufficiently hot to stimulate effective regeneration of the full suite of plant biodiversity from the seed bank. However, in cases where a hot fire does develop, fragmentation makes it more likely for the entire patch to be burnt (and potentially destroyed) in a single event. Furthermore, insufficiently hot fires and/or very infrequent fires promote a mesophyll shift in floristics which can further promote this situation by making the ecological community more rainforest like. In many cases, this situation is also associated with and sometimes co-driven by weed invasion, including sweet pittosporum (Douglas, pers. comms., 2015).

Further, the frequent application of fire to reduce bushfire risk and/or intensity in order to protect residential areas and infrastructure may impact on this ecological community, particularly on species that are more reliant on unburnt sites. Conversely, the exclusion of fire for long periods can also have a detrimental impact on the ecological community, particularly through loss of understorey plant diversity.

Climate change

Climate change poses a serious long-term threat to terrestrial and aquatic ecosystems with the potential to change the ecology of these environments through changes to species composition and function (Dunlop et al., 2012). The extremely fragmented nature of the ecological community greatly increases its vulnerability to the effects of a changing climate. For example, movement of native species is limited. In addition to threatening species that cannot adapt, climate change could also exacerbate existing threats such as habitat loss, altered fire regimes and the spread of invasive species.

Eco Logical Australia (2010) investigated the vulnerability of various natural and cultural assets in the Hawkesbury-Nepean catchment to climate change. The Southern Highlands Shale Woodland (NSW ecological community) was included in the study as some occurrences occur within the catchment area. Findings of the report applicable to the ecological community 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 may increase under forecast climate change.
- Invasion by non-native plant species is likely to increase in intensity, spread, and diversity, with some species taking advantage of climate-change induced effects such as periodic depletion of ground cover due to drought and over-grazing.
- 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 nomadic species, including some that perform important ecosystem functions.
- Increased risk of ecological instability through asynchrony of events such as emergence of insect prey and arrival of migratory bird predators.
- Altered fire regimes due to changed climate and weather, and due to changed vegetation structure and composition.

Whilst the ecological community will be negatively impacted by the effects of climate change, in a regional context it is still likely to play an important role in supporting ecological adaptation by providing refuge for species displaced from their preferred habitat. Along with other woodlands and forests on the coastal slopes of the Great Dividing Range it may provide refuge for threatened species such as regent honeyeaters and glossy black cockatoos.

Vegetation such as this ecological community is also important in mitigating extreme temperatures in local areas through shading, evaporative cooling and other attenuating processes.

APPENDIX E – ELIGIBILITY FOR LISTING AGAINST EPBC ACT CRITERIA

Criterion 1 – Decline in geographic distribution

The Southern Highlands Shale Forest and Woodland ecological community is estimated to have undergone declines ranging between 75% - 90% of its original pre-European extent (Table F1).

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 moderate condition is likely to be less than that shown in Table F1, and potentially less than 1000 ha (Douglas, pers. comms., 2015). The decline in area of the ecological community is due to past and ongoing clearing and degradation of remaining patches for rural residential and commercial development and infrastructure.

Table E1 Estimates of extent and decline for Southern Highlands Shale Forest and Woodland (Tozer et al. 2010).

Vegetation community	**Estimated area pre-clearing (ha)**	**Estimated area extant (ha)**	**Estimated decline (%)**
Southern Highlands Shale Woodland - Map unit WSF p268 (Tozer et al. 2010)	21 600 - 54 000	5374	75 - 90
Shale Basalt Sheltered Forest – Map unit WSF p168 (Tozer et al. 2010)	1642 - 2875	575 (a)^	65 - 80
Total	**23 242 – 56 875**	**5949**	**75 - 90**

a) It is estimated that 50% of the extent of map unit p168 occurring north east of Robertson between 470 – 830m ASL may correspond to the Southern Highlands Shale Forest and Woodland ecological community.

^ Survey data is not available, therefore the estimated area of extent is indicative only.

In conclusion, the Southern Highlands Shale Forest and Woodland has undergone at least 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

This criterion aims to identify ecological communities that are geographically restricted to some extent. Three indicative measures apply:

1) extent of occurrence, an estimate of the total geographic range over which the ecological community occurs;

2) area of occupancy, an estimate of the area actually occupied by the ecological community (which generally equates with its present extent); and

3) patch size distribution, an indicator of the degree of fragmentation of the ecological community.

It is recognised that an ecological community with a distribution that is limited, either naturally or that has become so through modification, has an intrinsically higher risk of extinction if it continues to be subjected to ongoing threats.

It is estimated that the extent of occurrence of the Southern Highlands Shale Forest and Woodland is approximately 310 000 ha (Tozer et al., 2010) which is considered to be 'limited'; and the area of occupancy is less than 6000 ha (and potentially less than 1000 ha (Douglas, pers.comm., 2015)), considered to be 'restricted'.

The ecological community is also highly fragmented, with a mean patch size of approximately 4 ha and a median patch size of 0.94 ha which is considered to be 'very restricted' (Tozer et al., 2010). Almost all patches (93%) are less than 10 ha in size (Table F2). It is likely that many of these small patches are in poor condition, existing primarily as remnant stands of trees. Gaps between patches are likely to limit regeneration opportunities as eucalypt seed is poorly dispersed, and regeneration is almost always within 30 m of the adult tree (Benson and Howell, 1990).

Table E2 Patch size distribution for the Southern Highlands Shale Forest and Woodland* (Tozer et al., 2010)

Thresholds		Size range (ha)	No. patches	% patches	Cumulative %	
restricted	**very restricted**	**<0.5 - 10**	**1250**	**93**	**93**	**99**
		>10 – 100	**85**	**6**		
		>100	**8**	**1**		
		Total	**1343**	**100**		

* Analysis is based on data for Southern Highlands Shale Woodlands Map Unit WSF p268 (Tozer et al., 2010). Survey data for the ecological community is not available for Map Unit WSF p168. As WSF p268 encompasses the majority of the ecological community, the analysis is taken to be representative of the ecological community as a whole.

As detailed in *Description of Threats* (Appendix D), the Southern Highlands Shale Forest and Woodland is subject to a number of ongoing demonstrable threats. Loss, fragmentation and degradation of vegetation associated with rural residential and commercial development and invasive species invasion are continuing. In addition to direct loss through clearing, associated threats include predation and competition by domestic and feral animals and the incursion of weeds. Climate change

is expected to cause increasing pressure on the ecological community through changes in temperature and rainfall patterns. Combined with a range of threats, and the slow growth and long regeneration times of some key canopy species, regeneration of the ecological community will be limited. For example, common canopy species of white stringybark, narrow-leaved peppermint and Sydney peppermint each live for more than 100 years (Benson and McDougall, 1998). Additionally, the time for *Eucalyptus* saplings to reach maturity can also be substantial (typically between 10-15 years) (Royal Botanic Gardens and Domain Trust, undated).

In conclusion, the ecological community is considered to be 'very restricted' and its highly fragmented nature makes it more likely that threatening processes could cause it to be lost in the immediate future (considered here to be three generations of key canopy species i.e. 30-45 years). Therefore the ecological community is **eligible** for listing as **critically endangered** under this criterion.

Criterion 3 – Loss or decline of functionally important species

Although studies specific to the functional species in the Southern Highlands Shale Forest and Woodland are not available, it is known that the relationship between 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 community. Notably, they provide food for nomadic nectarivores during winter. Fragmentation of the ecological community has reduced its ability to support a natural and complete assemblage of birds. 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 loss of mammal species from an ecological community such as the Southern Highlands Shale Forest and Woodland is likely to have 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 cause physical, chemical and biological changes to woodland soils, leading to reductions in the abundance of soil and litter dwelling invertebrates, which are a major food source for many woodlands birds (Watson, 2011) and small mammals.

Although it can be demonstrated that threats have impacted upon the composition of the ecological community, data to support decline of particular functionally important species is not available. As such, there is **insufficient information to determine the eligibility** of the ecological community for listing under any category of this criterion.

Criterion 4 – Reduction in community integrity

This criterion recognises that an ecological community can be threatened with 'functional' extinction through on-going modifications across the full range that do not necessarily lead to total destruction of all elements of the community. The severity of the reduction in community integrity is assessed by considering the changes being such that restoration is unlikely within the immediate, near or medium-term future.

This ecological community occurs in extensively cleared landscapes. The remaining areas of native vegetation are severely fragmented and subject to further rural residential development, weed invasion and continuing decline of faunal assemblages. While little specific information is available on the roles played by species formerly present, it is likely that ecological function has been compromised by the decline or loss of many soil engineers, pollinators and seed dispersers. Further damage to integrity is evident through change in vegetation structure and loss of key habitat features such as tree hollows necessary to support breeding of some resident fauna. The long time to recover vegetation structure (as discussed in criterion 2), 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.

<u>Reduction in integrity through clearing and fragmentation</u>

The ecological community has been extensively cleared across its range, severely compromising its integrity. The total extant area of the ecological community is estimated to be less than 6000 ha (representing a decline of between 75-90%). Many of the remaining patches are very small and in poor condition. Such a severe decline is likely to have caused fundamental changes in function, both within the boundaries of the community and in the role it plays in the wider landscape.

The ecological community is also extremely fragmented. Almost all patches (93%) have a size of less than 10 ha, with an estimated median patch size of 0.94 ha. The high degree of fragmentation is likely to reduce rates of survival and dispersal, interrupt population processes such as genetic exchange, as well as disrupting other ecological processes that sustain the community. Fragmentation also increases the proportion of the remaining patches susceptible to threats from predation, changed microclimates and weed incursion; for example, invasion by blackberry and gorse. Further, the limited dispersal ability of eucalypt species (Benson and Howell, 1990) restricts their ability to support regeneration of the ecological community where gaps between fragments are wide.

<u>Reduction in integrity through weed invasion</u>

A number of weeds pose a serious threat to the ecological community, with the likelihood of infestation increased by fragmentation, particularly as patches occur amongst a mosaic of agriculture and urban land use. Amongst the most serious threats are blackberry and gorse, both of which are considered to be Weeds of National Significance. As described in *Appendix D - Description of Threats*, these weeds, along with other invasive species, can prevent regeneration of native species once established.

<u>Reduction in integrity though inappropriate fire and grazing regimes</u>

The ground layer of the ecological community is often extensively modified by grazing (NSW Scientific Committee, 2014, Tozer et al. 2010), leading to the loss of grazing-sensitive, palatable species. This can create bare areas that are readily colonised by weeds. Grazing can also lead to hydrological changes and increased soil erosion. Soil compaction is a common result of heavy grazing that leads to reduced water infiltration and increased run-off. Compaction and erosion can make seedling establishment more difficult.

Reduction in integrity due to change in vegetation structure and loss of key habitat elements
With damage from heavy grazing, tree removal and invasive species, the structure of vegetation across the ecological community has been compromised. For example the loss of large, old trees reduces habitat value, particularly 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 possums.

Reduction in integrity through decline in faunal components
Loss of total area and severe fragmentation of the remaining 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 rural tree dieback associated with defoliation by insects, while other services such as pollination and seed dispersal may also be compromised. The decline of many species of mammals throughout the region has reduced the integrity of the ecological community directly, through changes to 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
Climate change is likely to compromise the integrity of the ecological community both directly and by altering the survival rates of species. It is also likely to interact with other threats, such as changed fire regimes or invasion by weeds. The long generation time and limited dispersal ability of eucalypts (refer criterion 2), are likely to limit adaptation through range shift.

Restorability of the ecological community
The ground layer of an ecological community will often recover if grazing and mowing activities are reduced (Kirkpatrick, 1986; Lunt, 1991) with the exception of improved pastures where fertilizers 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. The reduction in total area of the community is substantial, with much of the former extent replaced by other land uses. Fragmentation is likely to result in further losses 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 blackberry and gorse limits the regeneration of understorey species while adequate controls are not in place.

Even with active management such as tree planting, the recovery of functional canopy layers takes 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 (hollows suitable for vertebrate animals generally do not form in trees younger than 120 years old, and larger hollows until 220 years old (NSW NPWS, 1999; Mackowski, 1984; Gibbons and Lindenmayer, 2001; cited in Keith, 2004;)). The loss of fauna is also region-wide, making their recovery within the ecological community difficult. The associated loss of ecosystem services provided by this fauna also compromises the regeneration of native vegetation.

The specific effects of climate change on recovery are difficult to quantify. Nevertheless changes in temperature and precipitation, as well as influences on the fire regime and the competitive relationships between species, may further limit the recovery of the ecological community.

Summary

Substantial clearing, severe fragmentation, 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 across its distribution. These losses are compounded by climate change, and together with the ecological characteristics of the Southern Highlands Shale Forest and Woodland, as well as the nature of the ongoing threats, severely limit the likelihood of recovery of the ecological community.

In conclusion, 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

A continuing change refers to a recent, current or projected future change whose causes may be either known, not known, or not adequately controlled, so is liable to continue unless remedial measures are taken.

The Southern Highlands Shale Forest and Woodland is subject to a number of on-going demonstrable threats. These include inappropriate grazing and fire regimes that alter the species composition (vegetation and faunal) and rural residential development leading to further clearing and degradation of remaining remnants.

Although there has been continuing detrimental change to the ecological community, data are not currently available 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 this criterion.

Criterion 6 – Quantitative analysis showing probability of extinction

There is 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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