Conservation Assessment of *Persoonia oxycoccoides*

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Persoonia oxycoccoides Sieber ex Spreng. (Proteaceae)
Distribution: Endemic to NSW
Current EPBC Act Status: Not listed
Current NSW BC Act Status: Not listed

Proposed change: List on NSW BC Act and EPBC Act as Endangered.

Conservation Advice: *Persoonia oxycoccoides*

Summary of Conservation Assessment

Persoonia oxycoccoides was found to be eligible for listing as Endangered using Criterion B1a,b (i, ii, iii, iv, v); B2a,b (i, ii, iii, iv, v) and C2a(i) of the IUCN Red List Criteria. The main reasons for this species being eligible are that i) it has a highly restricted geographical distribution; ii) there is estimated to be a low number of mature individuals in total (500-1000); iii) subpopulation sizes are very low (<250); iv) the species is considered to be severely fragmented and v) there is continuing decline in Area of Occupancy, Extent of Occurrence, the number of subpopulations, the number of mature individuals and habitat quality due to a range of threats.

In this assessment, the word population is used to refer to the concept of 'subpopulation' in IUCN (2019), in keeping with the terminology used in the Environment Protection and Biodiversity Conservation Act and state/territory environmental legislation and general ecological usage.

Description and Taxonomy

Persoonia oxycoccoides Sieber ex Spreng. is described as a "Prostrate to spreading shrub, young branchlets sparsely to moderately hairy. Leaves narrow- to broad-elliptic to ovate, 0.4–1.1 cm long, 1.5–6 mm wide, flat, with recurved margins, ± discolorous, sparsely to moderately hairy when immature, glabrescent to sparsely so when mature, smooth to slightly scabrous; venation obscure. Inflorescences growing on into a leafy shoot; flowers subtended by reduced leaves or leaves; pedicels 2–5 mm long, erect to spreading, glabrous or rarely very sparsely hairy. Tepals 8–11 mm long, acute to apiculate, glabrous. Ovary glabrous" (PlantNet 2019).

The most prostrate forms seen in natural conditions (not slashed or otherwise mechanically harmed sites) can be <5 cm high. The more erect variants can range to ~100 cm high. Some plants exhibit both characters, with much of the individual having a sprawling to prostrate habit <20 cm high, with a small minority of stems (sometimes only 1) growing erect. The largest plants can spread to at least 250 cm wide and can be mat forming, such that it can be difficult to determine the number of individuals (Douglas pers obs. 2020).

Simpson (2018) notes that "Prior to its reinstatement in 1991, *P. oxycoccoides* was considered part of *P. nutans sens. lat*. (Weston & Johnson 1991). Jacobs & Pickard (1981) incorrectly listed *P. oxycoccoides* as a synonym of *P. nutans* subsp. C, whereas the type of *P. oxycoccoides* is a specimen of the taxon that was at that time treated as *P. nutans* subsp. E (Weston & Johnson 1991). This error perhaps explains the overly large range of *Persoonia oxycoccoides* records within the Atlas of Living Australia (2018) database compared to the taxon circumscribed by Sprengel (1827) and described by Weston & Johnson (1991)."

An assessment of the conservation status of *P. oxycoccoides* for the New South Wales (NSW) Threatened Species Scientific Committee (Simpson 2018) found it to be Data Deficient. However, this

assessment included putative intergrades of *P. oxycoccoides* and *P. acuminata. Persoonia acuminata* occurs on the Boyd Plateau / Bindook Highlands in the southern Blue Mountains (Central Tablelands), at Barrington Tops and in the Ebor district (Northern Tablelands, NSW) (PlantNet 2019). It occurs "in montane heath to wet sclerophyll forest, on granite, metasediments or basic volcanics" (PlantNet 2019). *Persoonia acuminata* occurs on different lithologies from *P. oxycoccoides*, and at higher elevations (mostly 750-1250 m asl), and in sometimes wetter habitats than *P. oxycoccoides*, such as wet sclerophyll forest (Weston and Johnson 1991). The distribution of *P. acuminata* is disjunct from that of *P. oxycoccoides* (Auld *et al.* 2020b).

The putative intergrades of *P. oxycoccoides* and *P. acuminata* are excluded from the current assessment consistent with the recent IUCN status review of *P. oxycoccoides* (Auld *et al.* 2020b) and broadly consistent with the distribution mapped by Weston & Johnson (1991) and the text of Fairley (2004). Bernhardt & Weston (1996) provide data on natural hybridisation and intergradation between all *Persoonia* species in NSW and Victoria and did not report hybrids between *P. oxycoccoides* and *P. acuminata*. Only natural hybrids of *P. oxycoccoides* and *P. levis* are mentioned. Benson & McDougall (2000) report occasional hybridisation between *P. levis* and *P. oxycoccoides* and that *P. oxycoccoides* grows with *P. mollis* and *P. laurina* (without hybridisation being known). In view of this, Auld *et al*. (2020b) determined that the putative intergrades should be treated as variants of *P. acuminata* and should be excluded from any conservation assessment of *P. oxycoccoides*.

The name *P. oxycoccoides* has historically been widely misapplied as evidenced by the mismatch between determinations of specimens in PlantNet, broadly consistent with the approach of Weston & Johnson (1991), and those evident in the Australian Virtual Herbarium (AVH) as of April 2019. Many specimens held by herbaria other than the NSW Herbarium have not been reassigned consistent with the accepted taxonomy of Weston & Johnson (1991). Most of the records in NSW that are assigned to *P. oxycoccoides* in AVH are other species or the putative *P. acuminata* intergrades (Auld *et al*. 2020b).

Distribution & Abundance

This assessment and the IUCN review (Auld *et al*. 2020b) have found the distribution of *P. oxycoccoides* to be centred in Wingecarribee Shire in the south-eastern portion of the Central Tablelands, with the easternmost records in the municipality of Kiama, and a south-western outlier at Tallong in Goulburn-Mulwaree Shire in the Southern Tablelands, NSW. On this basis, the historical northern limit of distribution is at Colo Vale; the eastern limit is at Budderoo National Park (NP) and environs (between Jamberoo and Robertson); and the southern and western limits are at Tallong. All accepted records are within the Sydney Basin Bioregion. The current distribution of *P. oxycoccoides* is almost entirely east of the Hume Highway (Figure 1).

The species is apparently rare and patchily distributed. Since 1980, only five vouchered records of the species have been added to the NSW Herbarium, and 69 sighting-only records of the species have been added to BioNet Atlas within its accepted distribution. Ten records of the species are believed to represent populations that are now thought to be extinct (see Table 1). However, this is likely to significantly under-estimate the loss of habitat and populations due to there being relatively few historic records of the species prior to or concurrent with substantial clearing of its habitat.

There are several records with uncertain georeferencing or location details that cannot be accurately mapped and these are excluded from this assessment. The existence of the species at Tallong is supported by a small number of records. The oldest are from 1892 and 1898 herbarium collections that give the location as "Barber's Creek". This is the watercourse adjoining the railway that was traversed by early collectors who undertook botanical expeditions from Sydney. The next collection from Tallong is a National Herbarium record (CANB 740913.1) from 2004 that gives relatively detailed location notes and states that it derives from a shrub to 50 cm (fruiting) and that it is the "sole patch

recorded in village". *Persoonia oxycoccoides* was confirmed in urban Tallong as an observation of a single plant at the base of an electricity pole on a road verge at an intersection (BioNet Atlas record of Douglas 2014). The adjoining freehold land was at that time proposed for subdivision and urbanisation. As of mid-2019, that use has not occurred, potentially because parts of the site are known to authorities to support the Critically Endangered Tallong Midge Orchid (*Genoplesium plumosum*). Research for this conservation assessment confirmed a large, mature plant of *P. oxycoccoides* not far from the aforementioned record (Douglas pers obs. 2020). The electricity pole had been replaced and the plant had apparently been destroyed with no recruitment evident. However, the newly discovered plant was almost $1m^2$ and contained abundant maturing fruit. Further survey is required to determine the size, location and extent of any remnant Tallong population, especially given increasing urbanisation in the area.

Few records of *P. oxycoccoides* have been reported from vegetation survey plots (OEH, 2017), although these are not considered comprehensive for the habitat of the species. Vegetation surveys within the species' accepted range have been undertaken in projects such as Gray (1993), Benson & Howell (1994), Fisher *et al*. (1995), Black (2000a,b); EcoLogical Australia (2003), Mills (2003; 2004), National Parks and Wildlife Service (NPWS) (2003a; 2003b), DEC (2004), Tozer *et al*. (2010)[1] and Douglas (2011). This list does not include the very large number of unpublished vegetation surveys undertaken by consultants for development assessments in or near the species' range, nor the substantial vegetation survey effort by council staff for works such as roadside maintenance and widening.

Two vegetation surveys within Budderoo NP have been undertaken by Miles *et al.* (2015) and Proust (2001). Whilst these were not targeted surveys for *P. oxycoccoides*, the fact that neither dataset of 34 and 54 full-floristic vegetation plots recorded this species, and that it was also not recorded opportunistically during those surveys, is indicative of the species' rarity, even in a reserve with a relatively high number of records of this species (though most appear to relate to the same sighting). This part of the species' habitat is also relatively well sampled by vegetation survey plots. The most recent records of the species from this area are trail edge sightings by Douglas in 2019 (partly a rediscovery of 2009 records) with a total 4 individuals; and an extension of that population by Demuth and Devereaux (NPWS in 2019) totalling 18 previously unrecorded plants. Notably, two of the plants recorded in this vicinity by Douglas in 2019 are in a flora protection zone for the extremely range-restricted and threatened *Grevillea rivularis*. This is the only known co-occurrence of these species.

Whilst *P. oxycoccoides* has not been subject to targeted survey across its range, its habitat and environs have been subject to substantial survey effort by many botanists, particularly in the last 20 years. Even with a very high level of general vegetation-survey effort, including in some areas of known habitat and existing records, relatively few sightings and very few collections of the species have been added, and only one modern record has very slightly extended the species' previously understood Extent of Occurrence. The species is naturally range-restricted and rare. It is now apparently less common due to a mix of habitat destruction and degradation, including fragmentation.

[1] Note that Tozer et al. (2010) use a broader scope for *P. oxycoccoides*, by including putative intergrades with *P. acuminata*. Consequently, they include references to *P. oxycoccoides* as occurring in Loombah Plateau Heath on Devonian Lambie Group metasediments in the western Blue Mountains. Those occurrences are better treated as *P. acuminata* (Douglas, pers. obs. 2020).

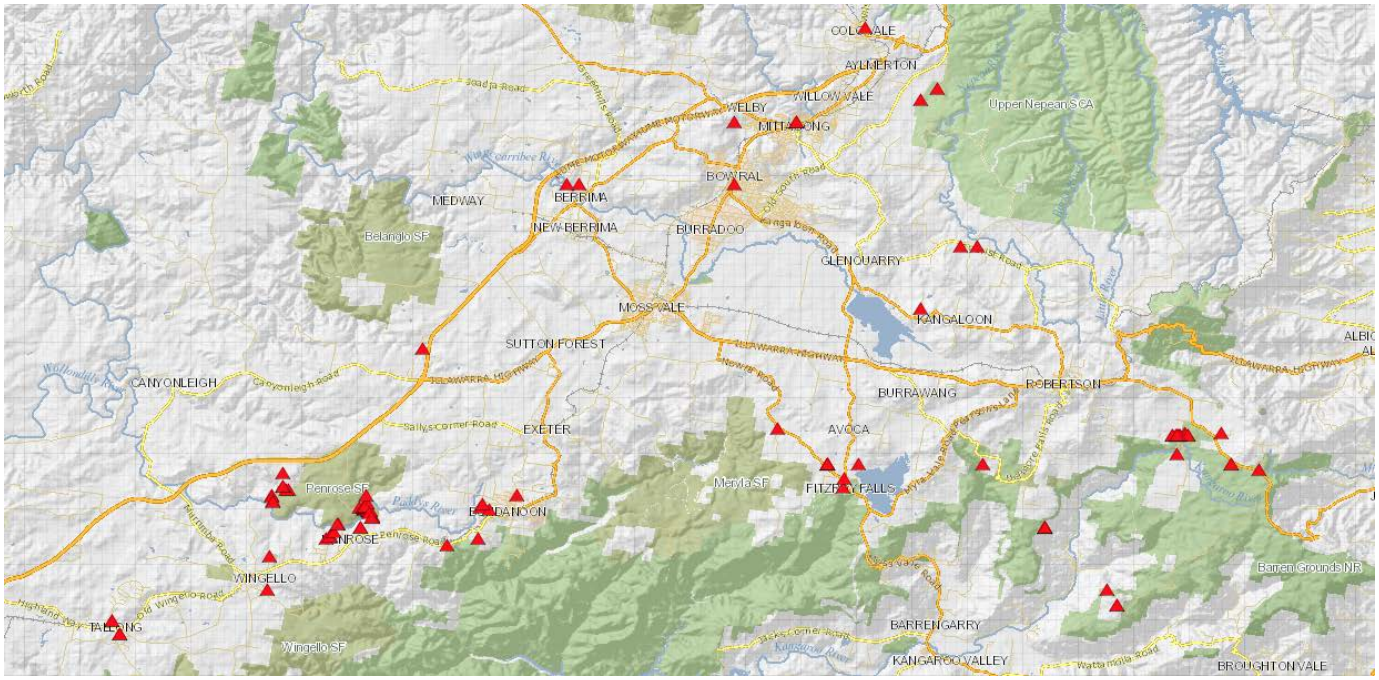

Figure 1. Map of the accepted distribution of BioNet Atlas and NSW Herbarium records as adopted in this assessment as of September 2019. Several of these occurrences are thought to be extinct but the general distribution remains similar. Several records and a small number of sighting locations with erroneous georeferencing were corrected to the most appropriate nearby sighting location in the GeoCat app for calculation of EOO and AOO and for associated calculations of reductions in those values. There are considerably fewer actual sighting locations than the current BioNet Atlas and NSW Herbarium datasets indicate.

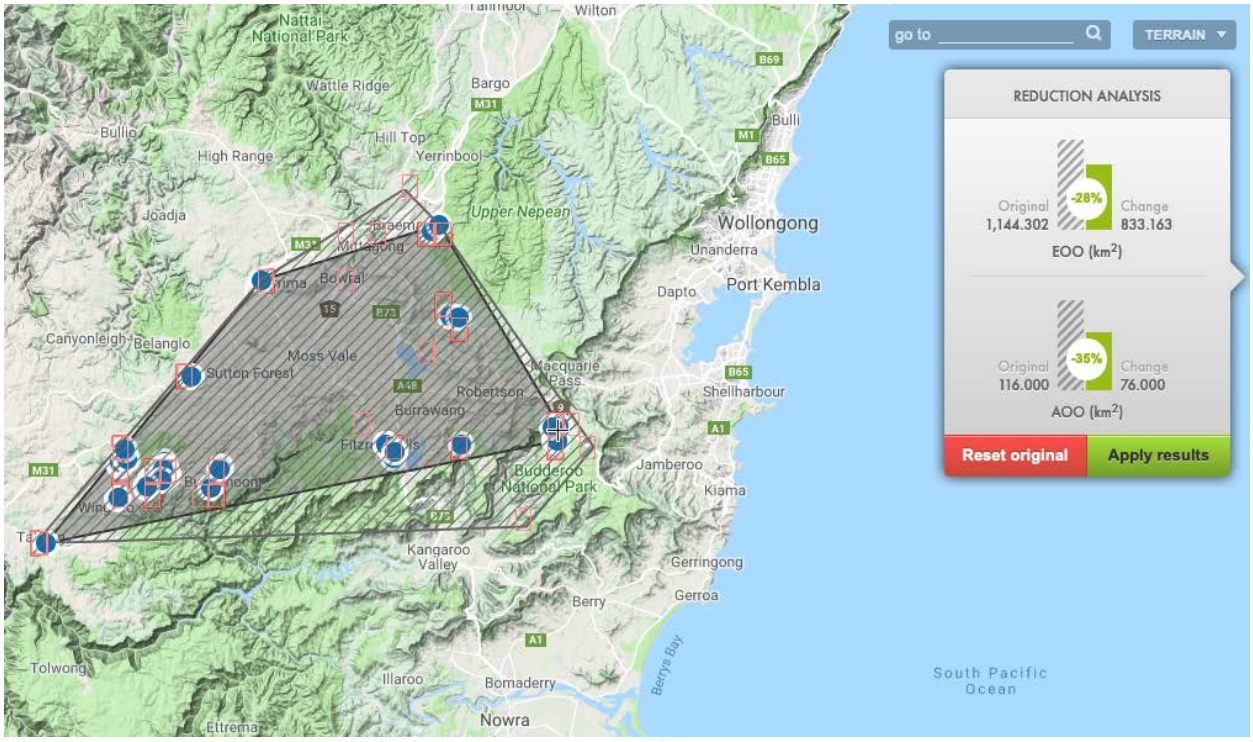

Figure 2. GeoCat map (2020/ http://geocat.kew.org/) showing original EOO and AOO based on historic records (hatched area), and current EOO and AOO based on records known or likely to be extant and that are adequately spatially reliable (hatched AND shaded area). Note that a significant area within the EOO polygon is not suitable habitat for reasons including lithology, terrain, altitude and vegetation type.

Cultural and community significance

The cultural, customary and spiritual significance of species and the ecological communities they form are diverse and varied for Indigenous Australians and their stewardship of Country. This section describes some published examples of this significance but is not intended to be comprehensive, applicable to, or speak for, all Indigenous Australians. Such knowledge may be only held by Indigenous Australians who are the custodians of this knowledge and have the rights to decide how this knowledge is shared and used.

The fruits of *Persoonia* species can form a food source for Indigenous communities (Packer *et al.* 2012). *Persoonia oxycoccoide*s occurs on Tharawal country.

Extent of Occurrence: The current EOO was estimated to be 833 km^2 based on a minimum convex polygon enclosing all mapped occurrences of the species as recommended by IUCN (2019). To be listed as Endangered under Criterion B1, a species must have an EOO of <5000 km^2. *Persoonia oxycoccoide*s meets the EOO threshold for Endangered. The historic EOO was estimated to be 1144 km^2.

Area of Occupancy: The current AOO was estimated to be 76 km^2. This calculation was based on the species occupying 19 (2 x 2 km) grid squares, the spatial scale of assessment recommended by IUCN (2019). To be listed as Endangered under Criterion B2, a species must have an AOO of <500 km^2. *Persoonia oxycoccoides* meets the AOO threshold for Endangered. The historic AOO was estimated to be 116 km^2.

Most records of the species lack population data, but where present, records generally suggest very small to small numbers of individuals with estimates ranging from reports of a single, often very isolated, individual, to a few individuals; very rarely of 10-30 individuals and only a few areas are

estimated to have more than 100 individuals (Table 1). The best available information indicates that the number of mature individuals in the wild is between 415 and 725. Under Criterion C, the threshold for Endangered is <2500 mature individuals. *Persoonia oxycoccoides* is reasonably inferred to meet the threshold for Endangered.

The number of plants above ground versus seeds in the soil seed bank will vary significantly depending on the time since last fire or equivalent disturbance. For example, the presence of two mature individuals on a long-unburnt and long undisturbed site may produce a far larger population after appropriate disturbance such as fire, suitable germination conditions, and sufficient time. Alternatively, the potential population based on seed bank at such a site may be little or no more than the number of observable plants if the habitat has not been disturbed for so long that any seedbank is likely to have decayed AND where the observable plants are not producing viable fruit. This is most likely on a site with a single, isolated individual that is not reproducing due to the lack of nearby plants.

Table 1. Known current and historical sites of *Persoonia oxycoccoides* in New South Wales, Australia. The table also indicates the likely general abundance of individual plants at each of the sites.

Site	Likely general abundance	Approximate plant abundance
Tallong	Apparently very low, only two modern records, one of which is for a single adult. Limited survey effort in the location due in part mostly to prevalence of freehold tenure	1 breeding plant seen in 2019, a 2004 record may represent another plant or plants.
Penrose/Wingello	Relatively high for this species. Ranges from locally rare to locally common across these localities. Mostly seen in Penrose State Forest including Stingray Swamp Flora Reserve.	Estimated 150-250 plants based on review of records plus recent surveys.
Bundanoon	Apparently very small population. Mix of historic and modern records. Two records of one individual each relate to plants that are now dead. One record of 6, others of 1, or no population data. Latest survey added at least 3 very large and fertile plants in northern Morton National Park – 2 in vulnerable trail/easement margins.	Mostly road/trail margin sightings. 10-15 inferred from sighting details. Could reasonably be considered an eastern extension of the Penrose/Wingello population as extant occurrences are sufficiently close to be genetically connected.
Sutton Forest	Very low. Modern record in survey plot at edge of currently known distribution. Only one plant reported. Fenced conservation area of pastoral property.	1-10 inferred.
Fitzroy Falls / Meryla / Yarrawa	Low based on mostly historic records near road or trail margins. One modern sighting of a single plant. Otherwise, no population data.	1-10 plants inferred.
Berrima Riverbend Reserve	Very low. One historic and one modern record. No population data.	1-10 plants inferred.
Colo Vale	Very low. A single 1982 record on the edge of the species' distribution. No population data.	No recent records. Significant on-going habitat loss in vicinity, likely to be now extinct.

Kangaloon (north and south)	Very low. Three modern records. The southernmost is believed extinct. No population data other than 'rare' noted in one record	1-10 inferred near southern Upper Nepean State Conservation Area. Not reported during recent surveys for *P. glaucescens*.
Budderoo Plateau and environs	Whilst some records are in Budderoo National Park, most are on its edges and associated with disturbance margins, so are not necessarily secure. 4 plants on trail edges. Additional 2 recorded in 2019, with three plants seen in 2009 rediscovered. NPWS survey in 2019 indicates 22 plants, mostly on Park boundary / road.	100-150 plants inferred based on historic collections and recent partial observations plus difficulty detecting the species in dense low heath.
Upper Nepean State Conservation Area west	Initially a single, unvouchered and low confidence sighting but occurrence was confirmed during recent fieldwork by Douglas (2019)	150-250 plants inferred from very partial survey (50 counted in a small portion of the habitat).
Mittagong/Welby/Bowral	Very low. Historic records only, with significant habitat loss in potential former habitat. Nearby reserves mostly unsuitable habitat.	Presumed extinct. No modern records despite substantial general survey effort in these areas.

Ecology

The habitat and flowering period of *P. oxycoccoides* is described as follows: "Heath to dry sclerophyll eucalypt forest, at 600 to 700 m altitude, on acid, sandy soils derived from sandstone. Flowering period: December to April" (Weston and Johnson 1991 cited in PlantNet 2019). However, the species can also occur in the margins of montane swamps within wet heath as is evident in and near Stingray Swamp Flora Reserve and parts of Budderoo and northern Morton NPs (Douglas pers. obs. 2020). Importantly, whilst the habitat of the Upper Nepean State Conservation Area (SCA) (west) population can be described as dry sclerophyll forest, rainfall is relatively high, and the site features a clayey subsoil that readily retains moisture as evidenced by the high proportion of sedges in the ground stratum (Douglas pers. obs. 2020).

Not all occurrences are on sandstone-derived soils. When only spatially accurate records of the species are plotted against the best available geological GIS data layers, the associated Triassic lithologies are the Mittagong Formation and the Hawkesbury Group (primarily Hawkesbury Sandstone); with the outlying Tallong records being associated with Permian Tallong Conglomerate. Records in and near Penrose State Forest (SF) and Wingello are associated with Permian Berry Siltstone and adjoining Hawkesbury Sandstone. The disconformity between the Permian and Triassic layers is strongly associated with 'hanging swamps' and groundwater seepage in some parts of this area (Douglas pers. obs. 2020).

Average annual precipitation across the species' currently accepted distribution is estimated to range from ~814 mm at Tallong to ~1764 in part of Budderoo NP (Douglas pers. obs. 2020).

Eastern Australian *Persoonia* have a specialised system of pollination and recruit relatively few of the many genera of native bees as true pollinators (Bernhardt & Weston 1996). Emery & Offord (2019) emphasise that whilst it is accepted that European Honeybees (*Apis mellifera*) are much less effective pollinators of *Persoonia* than native species (primarily *Leioproctus*), their generalist foraging strategy may still lead to some pollination of persoonia flowers. *Persoonia oxycoccoides* is self-incompatible (Weston pers. comm. 2019), and is thought to be pollinated by native bees, primarily from the genus *Leioproctus* subgenus *Cladocerapis*, but also reed bees in *Exoneura* (Bernhardt & Weston 1996).

Many persoonias favour out-crossing (Emery and Offord 2019), meaning that they rarely produce viable fruit without pollen from another plant of the same species. *Persoonia oxycoccoides* is fully self-incompatible (Weston pers. comm. 2019), which has the effect of making this species particularly vulnerable to habitat fragmentation, as plants that are isolated from others are unable to sexually reproduce without a pollinator.

Seed dispersal beyond the maternal plant may be uncommon in some species "but the fleshy *Persoonia* fruits are also likely to be consumed and dispersed by birds and mammals" (Weston 2003; Auld *et al*. 2007 cited in Emery & Offord 2018). Many native bird species consume *Persoonia* fruits (Rose 1973; Lane 1999; McGrath & Bass 1999), but the extent to which this may facilitate dispersal of viable seeds is not known. Cockatoos and other parrots have been observed to eat immature *Persoonia* fruit (Weston 2003; Chia pers. comm. 2016 cited in Emery & Offord 2018). Wallabies are also likely to play a role in dispersal of *P. oxycoccoides* (Auld *et al.* 2007).

Studies of herbarium specimens (Bernhardt & Weston 1991) indicate that *P. oxycoccoides* flowers from December through to April or occasionally through to June. Based on Benson and McDougall (2000) and data from Australian Biological Resources Study Flora of Australia online (https://www.anbg.gov.au/abrs/online-resources/flora/main-query-styles.html, accessed February 2022), flowering predominately occurs from January to April (as reviewed in Emery and Offord 2018)."

Fruits are said to mature into fleshy drupes in late spring (Weston 2003). However, in the relatively westerly and therefore colder sites (Penrose, Bundanoon, western Upper Nepean SCA), advanced, and

some apparently mature fruiting has been seen in late winter and very early spring. (Douglas pers. obs. 2020)"

Persoonia oxycoccoides was not listed as one of several *Persoonia* species that have been studied for breeding system, fruit set and/or seed germination (Emery & Offord 2018). The genus is known to have complex and variable seed dormancy mechanisms, with a hard endocarp that delays germination and can require specific cues that cause it to decay or be weakened to allow the seed to imbibe water, facilitating germination (Emery and Offord 2018). Other variables such as soil moisture, soil temperature, and seasonal factors will also likely influence germination in this species. Some species germinate in response to summer rainfall; some appear triggered by fire and by smoke chemistry; some by seasonally cold temperatures (stratification); and others seem highly dependent on mechanical or microbial damage to the endocarp (see for e.g. Emery & Offord 2018; 2019).

The seed bank longevity of *P. oxycoccoides* is yet to be documented. Available information indicates that soil-buried seed declines rapidly in some *Persoonia* species (half-life of 1-3 years), but less so in others, with variation also noted between populations of the same species (Emery & Offord 2018; 2019), and there is evidence of a persistent seed bank in *Persoonia* species (Auld et al. 2007, Ayre et al. 2009). Relatively short seed bank viability may not be a significant barrier to recruitment success where annual additions to the seed bank are substantial (Emery & Offord 2018). Ayre *et al*. (2009) document that a population of 25 adult plants of *P. mollis* subsp. *nectens* were burnt in a wildfire that resulted in 476 seedlings. These were burnt in a second wildfire four years after the first fire and before they reached maturity. The second fire produced 381 seedlings, suggesting that the population had a large and persistent soil seed bank capable of withstanding a short interval between two fires. Similarly, Auld *et al*. (2007) estimated that the density of seeds in the soil was 6-7 times greater than the density of *P. lanceolata* seedlings that emerged post-fire, and that there was at least 72% of available soil seedbank that did not germinate. This strategy is ecologically effective because if all or most of the soil seedbank were to germinate in a fire, a second fire prior to the new cohort reaching maturity and restoring the seedbank could readily result in local extinction.

Persoonia oxycoccoides has been observed to resprout from a lignotuber post-fire at a site in Budderoo NP (Weston, pers. comm. cited in Benson & McDougall 2000) and is listed as a resprouter in the NSW Fire Response database (OEH 2014). If this is representative of the species across its range, it may help to explain how it is able to persist relatively well in some heavily disturbed sites such as regularly slashed bushfire Asset Protection Zones (APZs) in Penrose SF. Basal resprouting has not been observed in the Penrose population but resprouting on limbs damaged by herbicide spraying was observed. However, in Bundanoon, *P. oxycoccoides* plants that are no longer apparent above ground due to damage from vehicles and road maintenance, have not been seen to resprout in conditions that would otherwise appear favourable for this response (Douglas pers. obs. 2020). Resprouting may only occur under particular conditions. However, many of the mature plants observed across all populations visited during this assessment were seen to have long and relatively thick stems arising from what must be an even thicker and robust rootstock – a form suggestive of basal resprouting ability. These were often in very modified sites with a history of recurrent slashing close to the ground. Whilst there is insufficient information available to be definitive, this assessment treats the species as a facultative resprouter that also recruits from seed.

Persoonia oxycoccoides is often seen in disturbed areas such as road and track edges, slashed bushfire APZs and powerline easements. A similar pattern is known for other rare or threatened *Persoonia* species, including *P. mollis* ssp. *revoluta* (NSW TSSC 2018), *P. hirsuta* (Emery & Offord 2019), *P. acerosa* (Douglas 2014; Friedewald 2015), *P. nutans* (Douglas 2019), and *P. bargoensis* (Weston & Johnson 1991; NSW Scientific Committee 2000; McKenna 2007). Myerscough *et al*. (2000) suggest that soil disturbance might be analogous to the effects (or some effects) of fire, particularly in environments with long inter-fire intervals (see also Emery & Offord 2018).

Field observations suggest that at least five years are required for juveniles to reach reproductive maturity following a fire, but the time to reach an ability to resprout after fire is unknown. In many, but not all of the recently observed occurrences of this species, fire is relatively infrequent for a range of reasons, including that some occurrences are within APZs that are slashed and/or treated with herbicide rather than being burnt, and others are within slashed powerline easements, or on road and trail margins. Yet one of the largest known populations – Upper Nepean SCA (west) - is likely to be burnt relatively often because of its position adjoining rural-residential settlement east, and more-so because it is within the Water NSW potable water catchment area, so is burnt to reduce the likelihood of high intensity wildfire leading to erosion and contamination of water supply reservoirs. That site has exceptionally high diversity of *Persoonia* species, but the size of the oldest plants suggest that it had not burnt for at least 10 years when visited in 2019. DPIE (2019) fire records suggest that it may have been 16 years since the last burn (detailed below).

A review of the species' occurrence records against the fire history database (DPIE 2019) suggest that a number of sites are in areas where fire has not been recorded since the 1964-65 wildfire, although fire history records are not complete outside the NPWS Reserve estate. Sites burnt more recently include Upper Nepean SCA (west), which is within the mapped extent of the 2002-03 wildfire; Upper Nepean SCA (south-west) 1968 wildfire, 1975-76 prescribed burn and 2018-19 prescribed burn (one record) and 1978-79 wildfire (another record but same population); Budderoo NP, where the species' occurrences are within the mapped extent of 1982-83 wildfire (nine records); 1999-2000 prescribed burn (two records), and 2009-10 hazard reduction (six records). Gallagher (2020) and Auld et al. (2020a) estimated that around one third of the distribution of *P. oxycoccoides* was burnt in the 2019–20 fires while around half of the sites that were burnt had the 2019–20 fires burning over areas that were not likely to have fully recovered from a previous fire.

Threats

Catelotti (2015) suggests that *P. oxycoccoides*, like several other *Persoonia* spp. "continue to face risks from ongoing habitat loss, and research into ecological and biological requirements are crucial as part of recovery programs". The major threats to the species are detailed below.

Habitat clearing and fragmentation

The distribution of *P. oxycoccoides* has been fragmented by land clearing for agriculture, plantation forestry, friable sandstone mining, infrastructure, and urban settlements (Auld et al. 2020b) (Figure 1). This trend is continuing due to human population growth and associated intensification of some land uses including expansion of urban and rural-residential areas, and increased mining to supply sand for construction purposes in the greater Sydney region. Urbanisation and/or rural-residential land use in areas of potential habitat and known locations for this species has intensified in recent years across most of the species' range.

Whilst the species occurs within parts of conservation reserves such as Morton and Budderoo NPs, Upper Nepean SCA and Stingray Swamp Flora Reserve, those habitats are generally at or near the species' limit of distribution. They are also small relative to the Extent of Occurrence, are fragmented from each other in most instances, and do not necessarily afford the species full protection due to known or likely conflicts between where it occurs and the need to maintain infrastructure such as roads, trails, utility easements, and APZs.

For geographically restricted species such as *P. oxycoccoides*, habitat destruction has resulted in fragmentation of the landscape and isolation of remaining populations (Rymer et al. 2005), increasing the probability of extinction (Barret & Kohn 1991; Ellstrand & Elam 1993; Young & Brown 1996). Small, isolated populations are expected to have altered pollinator behaviour and movement, as well as decreased pollinator visitation rates (Aizen & Feinsinger 1994; Mustajarvi *et al*. 2001)."

Adverse localised disturbance

Persoonia oxycoccoides shows a similar pattern to several other threatened persoonias in that many sightings and collections are associated with disturbance margins. The strong, but not exclusive, association of the species with disturbance margins may relate to it responding to increased light and reduced competition from shrubs, as well as the seed bank being activated through mechanical disturbance e.g. damage to the hard endocarp that otherwise inhibits germination. Many records in Penrose SF are from trail verges, slashed bushfire APZs, and the margins of pine compartments. A similar pattern is variously known and inferred from Budderoo and Morton NPs and environs but was not seen in Upper Nepean SCA (west) where the habitat was intact. The species is particularly vulnerable to a range of localised threats including slashing and herbicide use, road and track maintenance, recreational vehicle use, and rubbish dumping, all of which may lead to the loss of plants, seed bank decline and reduced habitat suitability.

More than 20 mature *P. oxycoccoides* were killed or harmed following the application of herbicide as a fuel reduction method in Penrose SF in 2019 (Douglas unpubl. data 2020). The residual effects of the herbicide may also prevent or suppress germination of the species from the soil seed bank. Some of the plants not killed by herbicide were showing early signs of resprouting from damaged stems, whilst others appeared too badly contaminated to regrow.

In some situations, particularly urban/bushland interfaces and some APZs, mechanical fuel control is used e.g. flail mowers, turbo mowers, rotary slashers / tritters. That method can destroy adult and juvenile plants and leave a dense cover of mulch that may impede seedling recruitment unless the mulch is first allowed to dry, then burnt to remove the excess (Douglas pers. obs. 2020). This can be difficult to achieve if the fuel is insufficiently aerated, and fire intensity is very likely to be low – potentially too low to break dormancy mechanisms in an adequate proportion of the soil seed bank.

Mechanical slashing can also harm, suppress and potentially kill the species depending on whether plants are crushed by the associated vehicle, and the height and frequency of slashing. Conversely, timely slashing and very selective use of herbicide can advantage this species by suppressing larger shrubs and trees, creating an artificial low heath in which the species has been observed to apparently thrive (Douglas pers. obs. 2020). If slashing is not undertaken with regard for the species' reproductive needs, it can result in reduced or no flowering, fruiting, seed-set and replenishment of the seedbank.

Vehicle use may also adversely impact on plants, e.g. individual plants growing on fire trail margins have apparently been lost to vehicle use and road maintenance. Recruitment or resprouting is not evident at these sites, and any recruits would be at risk from the same or similar threats (Douglas, pers. obs. 2020).

Recreational vehicle misuse poses a threat to *P. oxycoccoides* because this species has some preference for disturbance margins such as road and trail edges, and relatively accessible terrain such as low heathland fringing montane swamps, and APZs. In some situations, private vehicles such as four-wheel drives and trailbikes are driven through APZs, damaging or killing plants, compacting some soils, and promoting erosion of others.

Occurrences on verges of unsealed roads and trails are at risk from dust interfering with pollination and suppressing photosynthesis. This would cause reduced reproduction, potentially reduced recruitment success, and impeded growth in the more severe cases. This can include sites within conservation estate if the roads and trails are subject to frequent use and by vehicles travelling at relatively higher speeds.

Fire regimes that cause biodiversity decline

Persoonia oxycoccoides occurs in different sites that may be exposed to fire either too frequently, or too infrequently. Changes in fire frequency may impact on *P. oxycoccoides* in two ways:

1. High fire frequency may limit successful juvenile recruitment and increase adult plant mortality, although as a resprouter, most adult plants should survive most fires.
2. A relatively long absence of fire may cause plant mortality through competition with other dominant shrubs.

The frequency of severe fire weather events is expected to increase by 2070 (Adapt NSW 2018), increasing the risk of frequent fire in habitats where the species occurs. An estimated 27-36% of the habitat of *P. oxycoccoides* was burnt during the 2019–20 fire season (Gallagher 2020). Both Gallagher (2020) and Auld et al. (2020a) suggest that there is a medium risk to recovery for *P. oxycoccoides* from the 2019–20 fires due to the potential for post-fire impacts of weeds, *Phytophthora cinnamomi* and site disturbance. Auld et al. (2020a) estimated that half of the sites that were burnt in the 2019–20 fires were not likely to have fully recovered from a previous fire within the last 15 years.

Weston (pers. comm. 2019) notes that he searched for historic collection locations of *P. oxycoccoides* in the Fitzroy Falls locality and had great difficulty finding them due to dense shrub cover associated with a prolonged absence of fire. Mesophyll shift (invasion of 'rainforest' plants into sclerophyll communities) has been observed in parts of Budderoo and Morton NPs and Barren Grounds Nature Reserve, including in or near habitats of *P. oxycoccoides*.

The role of other components of the fire regime (particularly fire season and fire severity) on plant recruitment in *Persoonia* remains poorly known.

'High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition' is listed as a Key Threatening Process under the NSW BC Act.

Anthropogenic climate warming

Anthropogenic climate warming may pose a threat to *P. oxycoccoides* through increasing moisture stress during predicted prolonged and intensified drought and/or under higher temperatures, resulting in increased mortality of adults and juveniles, and reduced fruit production (McKenna 2007; Arnolds *et al*. 2015). In the region where *P. oxycocoides* occurs, the number of days over 35˚C is expected to increase by 2030, particularly in summer (Adapt NSW 2018), exacerbating drought impacts on sites with shallow soils. This is likely to further disrupt fire regimes and make fire management more difficult.

Butt & Gallagher (2018) assessed the climate change vulnerability of 24 native plant species listed as threatened under the Commonwealth Environment Protection & Biodiversity Conservation Act. Five threatened *Persoonia* species from the Sydney Basin Bioregion, at least one of which (*P. glaucescens*) is sometimes sympatric with *P. oxycoccoides,* were assessed as having the highest (High) vulnerability. Application of the evaluation criteria used by Butt and Gallagher (2018) indicates that *P. oxycoccoides* would also be assessed as having High vulnerability to climate impacts on reproduction, dispersal capacity, range size and habitat suitability. 'Anthropogenic climate change' is listed as a Key Threatening Process under the NSW BC Act.

Disruption of pollination

Persoonia oxycoccoides is an obligate-outcrossing species (Weston pers. comm. 2019), so is "dependent on reliable pollinators transferring pollen between compatible mates to ensure fruit production" (Richardson *et al*. 2000; Goodwillie 2001 cited in Rymer *et al*. 2005). It is also a rare species with a fragmented and relatively localised distribution. Rymer *et al*. (2005) showed that two rare *Persoonia* species had significantly lower levels of fruit-set than did two common species. Pollen collection from *P. oxycoccoides* flowers is undertaken by native bees (in the genera: *Leioproctus* and *Exoneura*), as well as by *Apis mellifera* (European honeybee) (Bernhardt & Weston 1996). Emery and Offord (2018) note that native bees are likely to be more effective pollinators than *Apis mellifera*. *Apis mellifera* may also reduce effective pollination by excluding native bees. Effective pollination may be

particularly susceptible to the effects of fragmentation. Steffan-Dewenter & Tscharntke 1999 (cited in Rymer *et al*. 2005) note that reductions in population size and increases in population isolation led to decreased visitation rates of pollinators as a result of stochastic processes (unpredictable events that can affect population and community dynamics). An individual plant that becomes functionally isolated from mates will be unable to reproduce. This will cause the soil seed bank to become depleted due to lack of annual additions when combined with natural processes of seed bank decay.

Pest animal species

Grazing and browsing by introduced herbivores (and macropods) can impact on survival and recruitment in plants (Eldridge et al. 2017).

Pest animal species present in known sites that could pose a threat to *P. oxycoccoides* include:

- rabbit and hare (digging – destruction of young plants, death of adult plants);
- deer and pig (trampling and track creation on and through swamp margins, also potentially providing increased opportunity for weed invasion); and
- goat (browsing- affecting plant survival and growth and recruitment).

All of these species are present to varying degrees in *P. oxycoccoides* habitat, including within conservation estate and may pose a threat. Illegal and poorly controlled hunting of some of these species may also be a threat through the misuse of recreational vehicles in *P. oxycoccoides* habitat. This has previously occurred in Stingray Swamp Flora Reserve and included trail bikes and 4WDs being driven through montane swamp and fringing vegetation (Douglas pers. obs 2020).

Competition from Weeds

Weed invasion is not currently known to be a major threat to this species across its range. However, the species' tendency to occur on disturbance margins makes it particularly susceptible to weed invasion and competition. Future threats include African Love Grass (*Eragrostis curvula*), which is present in the vicinity of some extant populations and poses a significant threat by way of competition and suppression of recruitment. Coolatai Grass (*Hyparrhenia hirta*) is also present nearby to known sites for *P. oxycoccoides* and poses a similar future threat. Coolatai Grass has the potential to increase the likelihood of fire of sufficient intensity to kill *P. oxycoccoides*, as the grass seasonally holds a large volume of dry matter that is readily ignited. Whisky Grass (*Andropogon virginicus*) poses a similar future threat and is strongly associated with disturbed areas, particularly slashed or graded utility easements. 'Invasion of native plant communities by exotic perennial grasses' is listed as a Key Threatening Process under the NSW BC Act.

Persoonia oxycoccoides can occur close to areas with infestation of exotic vines and scramblers, such as Blackberry (*Rubus anglocandicans*) and Japanese Honeysuckle (*Lonicera japonica*). Occurrences of *P. oxycoccoides* most threatened by those weeds are present on or near the edges of montane swamps and fringing wet heath, though Blackberry readily extends to drier habitats. 'Invasion and establishment of exotic vines and scramblers' is listed as a Key Threatening Process under the NSW BC Act.

Pine plantings (*Pinus radiata*) and pine wildlings and their control pose a current threat to occurrences of *P. oxycoccoides* in and beyond Penrose SF and northern Morton NP. Wildlings are controlled to some degree by volunteers and contractors, particularly in and near montane swamps. However, *P. oxycoccoides* also occurs on the margins of pine plantations where in general, plantings are maintained for 30 years prior to harvesting, with intervening periods of thinning. Occurrences in those situations are vulnerable to mechanical damage from thinning and harvesting of pines; to herbicide use; and to mechanical slashing of regrowth vegetation, especially along compartment margins and along access roads.

Cinnamon Fungus (*Phytophthora cinnamomi*)

Phytophthora cinnamomi may pose a future threat to *P. oxycoccoides,* with several other *Persoonia* species, some of them sympatric with *P. oxycoccoides*, being known or likely to be at risk from this pathogen (e.g. NSW Scientific Committee 2003). However, the degree of any potential impact on *P. oxycoccoides* is unknown. 'Infection of native plants by *Phytophthora cinnamomi*' is listed as a Key Threatening Process under the NSW BC Act.

Locations

Persoonia oxycoccoides occurs in sclerophyll vegetation that is naturally fire-prone, though to differing degrees based on rainfall, vegetation community (structure), and soil moisture (some habitats adjoin swamps and swampy riparian zones). The major threat is ongoing habitat disturbance/loss in combination with a change fire regime (too frequent or too infrequent fire). Given the highly fragmented and cleared area in which the species is distributed, it is likely that different clusters of sites represent different locations with respect to this threat (*sensu* IUCN 2019). Hence, the minimum estimate for the number of locations is 10. Other widespread threats are a warming climate and disrupted pollination.

Assessment against IUCN Red List criteria

For the purpose of this assessment, it is considered that survey and knowledge of *P. oxycoccoides* is adequate and that there is sufficient scientific evidence to support the listing outcome. This assessment follows the interpretation of *P. oxycoccoides* not including *P. acuminata* intergrades consistent with Auld *et al*. (2020b). Currently not all herbaria collections or sightings are aligned with this interpretation.

Criterion A Population Size reduction

Assessment Outcome: Data Deficient.

Justification:

Generation length is estimated at 20-60 years on the understanding that this species is able to resprout after fire or equivalent disturbance (Weston pers. comm. 2019). The IUCN review of this species by Auld *et al*. (2020b) concluded that it is highly likely to have undergone a large (≥50%) loss of habitat, resulting in a significant reduction in its population size over three generations i.e. 60-180 years. However, confirmed quantitative estimates of change are unavailable and the species is assessed as Data Deficient.

Criterion B Geographic range

Assessment Outcome: Endangered under B1a,b (i, ii, iii, iv, v) and B2a,b (i, ii, iii, iv, v).

Justification:

Persoonia oxycoccoides is endemic to a restricted area in NSW. The current Extent of Occurrence (EOO) of this species is estimated to be 833 km^2 based on a minimum convex polygon enclosing all spatially reliable and likely-extant mapped occurrences of the species as recommended by IUCN (2019). To be listed as Endangered under Criterion B1, a species must have an EOO of <5000 km^2. *Persoonia oxycoccoide*s meets the EOO threshold for Endangered.

The Area of Occupancy (AOO) is estimated to be 76 km^2. This calculation was based on the species occupying 19 (2 x 2 km) grid squares, the spatial scale of assessment recommended by IUCN (2019).

To be listed as Endangered under Criterion B2, a species must have an AOO of <500km^2. *Persoonia oxycoccoides* meets the AOO threshold for Endangered.

In addition to these thresholds, at least two of three other conditions must be met.

a) The population or habitat is observed or inferred to be severely fragmented or there is 1 (CR), ≤5 (EN) or ≤10 (VU) locations.

   Assessment Outcome: Met as Endangered

   Justification: The distribution of *P. oxycoccoides* is considered to be severely fragmented. Given the small size of known populations and the fragmented woodland habitat within a rural landscape matrix, it is very likely that most of the individuals of *Persoonia oxycoccoides* occur in small and relatively isolated habitat patches. Additionally, >50% of the total area of occupancy of the species is in habitat patches that are smaller than would be required to support a viable population. Dispersal of *P. oxycoccoides* seeds is likely to be by frugivorous birds and mammals such as wallabies (Rymer 2006, Auld et al. 2007), however, dispersal distances are generally small as most seeds are dispersed locally and cleared habitat between remnants limits dispersal across cleared areas. Hence, seed dispersal is not sufficient to replace populations or habitat patches that are lost. Consequently the species is therefore considered to be severely fragmented.

   Persoonia oxycoccoides is estimated to be found at ten locations (Table 1) based on the threat of ongoing habitat disturbance and loss. Given the highly fragmentated and cleared area in which the species is distributed, it is likely that different clusters of sites are different locations with respect to this threat.

b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.

   Assessment Outcome: Met for i), ii), iii), iv).

   Justification: A continuing decline is inferred or observed in relation to: i) extent of occurrence (based on ongoing loss of populations due to habitat removal or degradation); (ii) area of occupancy (based on ongoing loss of populations due to habitat removal or degradation); (iii) area, extent and/or quality of habitat (based on ongoing habitat degradation from local disturbances, pest animals and weeds); (iv) number of locations or subpopulations (based on ongoing loss of populations due to habitat removal or degradation) and v) number of mature individuals (due to direct habitat removal, fragmentation causing reduced fecundity, inappropriate fire regimes, local extinctions, herbicide impacts, local disturbances, weeds and pest animals).

c) Extreme fluctuations.

   Assessment Outcome: Not met.

   Justification: As the species is considered to be a resprouter, extreme fluctuations are not likely.

Criterion C Small population size and decline

Assessment Outcome: Endangered under C2a(i).

Justification: The best available information indicates that the number of mature individuals in the wild is between 415 and 725.

Both the lower and upper bound estimates of the species' abundance fall within the range for Endangered (>250 and <2500).

At least one of two additional conditions must be met. These are:

C1. An observed, estimated or projected continuing decline of at least 30 % (up to a max. of 100 years in future).

Assessment Outcome: Data Deficient.

Justification: Ongoing habitat loss, degradation and fragmentation is likely. There is currently no estimate of the rate of future decline in this species.

C2. An observed, estimated, projected or inferred continuing decline in number of mature individuals.

Assessment Outcome: Met.

Justification: There is inferred or observed continuing decline in the number of mature individuals due to direct habitat removal, fragmentation, localised disturbances such as pesticide spraying, road and track use and reduced pollination success leading to reduced seed production.

In addition, at least 1 of the following 3 conditions:

a (i). Number of mature individuals in each subpopulation ≤50 (CR); ≤250 (EN) or ≤1000 (VU).

Assessment Outcome: Met at Endangered.

Justification: The majority of known subpopulations of the species are single plants or small groups such that most apparent subpopulations appear to be ≤50 mature individuals. However, two subpopulations are inferred to be 150-250 (Penrose/Wingello and Upper Nepean SCA), and Budderoo NP is believed by Weston (pers. comm. 2020) to harbour a potential population of 100-150 mature individuals. The best available information indicates that no subpopulation exceeds 250 mature plants.

a (ii). % of mature individuals in one subpopulation is 90-100% (CR); 95-100% (EN) or 100% (VU)

Assessment Outcome: Not met.

Justification: Most or nearly all mature individuals do not occur in one subpopulation.

b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Not met.

Justification: As the species is a resprouter, extreme fluctuations are not likely.

Criterion D Very small or restricted population

Assessment Outcome: Vulnerable

Justification: To be listed as Vulnerable, a species must meet at least one of the two following conditions:

D1. Population size estimated to number fewer than 1,000 mature individuals

Assessment Outcome: Vulnerable

Justification: Auld *et al*. (2020b) estimate the species' population of mature individuals to be 500-1000. This assessment estimates a figure of between 415-715.

D2. Restricted area of occupancy (typically <20 km^2) or number of locations (typically <5) with a plausible future threat that could drive the taxon to CR or EX in a very short time.

Assessment Outcome: Not met.

Justification: The AOO >20 km^2 and the number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time exceeds 5.

Criterion E Quantitative Analysis

Assessment Outcome: Data Deficient.

Justification: No quantitative analysis has been undertaken at this time.

Conservation and Management Actions

There is no National Recovery Plan and no NSW Saving our Species program for this species. The following is derived from the threat information.

Stakeholders

- Inform landowners and managers of sites where there are known populations and consult with these groups regarding options for conservation management and protection of the species.

Habitat loss, disturbance and modification

Prevent further habitat removal, fragmentation and degradation.

- Minimise ongoing fragmentation of habitat that isolates individuals or populations.
- Explore likelihood of providing greater long term protection to sites outside the national reserve estate, e.g. land acquisition, long term covenant agreements.
- Ensure the species is correctly assessed in all works proposals and development assessments that could harm individuals and their habitat. This includes considering the seed bank of the species, rather than only the visible plants. Each site will warrant consideration of the species' particular ecology, including pollination requirements, self-incompatibility, and seedbank dynamics. At present, a particularly precautionary approach is warranted in any assessment of impacts on this species because there is relatively little species-specific information available about some of these key parameters.
- Bushfire Asset Protection Zones (APZs) and some utility easements must be appropriately constructed and maintained. Managers should ensure competent surveys are undertaken for this species, and if it is present, not slash, grade, or otherwise treat the APZ whilst the species is reproducing, unless the process can confidently avoid those plants (e.g. they are marked with flagging tape so that machine operators can drive to avoid them). The species is low-growing, relatively fleshy and of low flammability, so in many cases can simply be avoided during APZ and easement maintenance without undermining the function of those zones.
- The broad-scale use of herbicide in such areas should be avoided in favour of mechanical control methods. Targeted use of herbicide such as to control tree seedlings or saplings or weeds, should be limited to circumstances where spray-drift could not harm threatened species. Direct topical application of herbicide to the target vegetation is preferable *e.g.* 'poison axing' or 'cut and paint' because it avoids the problem of spray-drift.

- At sites where local disturbance is a major issue, take appropriate corrective actions such as erecting vehicle barriers that prevent or reduce the likelihood or severity of recreational vehicle incursions into APZs or managed easements containing this species;

Control European honeybee threat

- To reduce competition from honeybees, where feasible, relocate licensed honeybee hives well-away from at least the more substantial populations of *P. oxycoccoides* on public lands *e.g.* Upper Nepean SCA, Budderoo NP, Penrose SF. Destroy feral honey bee hives. This may also benefit other *Persoonia* species, including the Endangered *P. glaucescens* and *P. hirsuta* and the Vulnerable *P. mollis* ssp. *revoluta*.
- In any development consents, it is preferable to exclude apiaries as a commercial or hobby activity in and near (approx. 1 km) populations of threatened *Persoonia* species.
- Control feral honeybees nests within or near known sites of *P. oxycoccoides*.

Control invasive plant species

- Control and remove weeds such as African Love Grass, Coolatai Grass, Whisky Grass, Blackberry, Japanese Honeysuckle, Italian Lavender (at sites where these are nearby), and Radiata/Monterey Pine (in and beyond Penrose SF and northern Morton NP). Monitor populations of *P. oxycoccoides* for any other weed species and provide appropriate control.

Control risk of Cinnamon Fungus

- At least populations on NPWS estate should be regularly checked to detect Cinnamon Fungus if present, then appropriate phytosanitory guidelines should be developed for these sites. The NPWS and other public land managers such as Water NSW, Forestry Corporation, and local governments could also consider management strategies to reduce the risk of fungal pathogen introduction *e.g.* closing or restricting public access to management and recreational trails in and near *P. oxycoccoides* habitat.

Management of the fire regime

- The optimal fire regime for this species is not well known but too frequent or too infrequent fires should be avoided. Repeated fires at <10 year intervals will likely eliminate recruitment of new *P. oxycoccoides* plants. The species appears able to persist in some situations with infrequent fire, but appropriate use of fire may result in recruitment and may help to suppress competing native mesic species and weeds. Estimating what interval between fires is too infrequent will depend on health of *P. oxycoccoides* and level of invasion of mesic plants and weeds. This may vary between sites but is likely to be >30 years since fire.

Ex situ conservation

- Develop a targeted seed collection program for *ex situ* seed banking and propagation. The species is available in horticulture to a limited extent, so is apparently easier to propagate than some other *Persoonia* species. Note that one variant available commercially is an artificial hybrid of *P. nutans* x *oxycoccoides*.

Research, Survey and Monitoring priorities

- Undertake targeted survey for the species, particularly on public lands and on Land for Wildlife or similar voluntarily conserved sites.
- Determine current population size and demographics.

- Document threats at all sites and include recommendations for remedial actions.
- Monitor for increased habitat degradation and associated threats such as weeds, honeybees, recreational vehicle misuse, and Cinnamon Fungus;
- Undertake regular surveys to determine whether there is a decline in subpopulations;
- Undertake appropriately designed and documented research relating to how to best manage the species in relation to fire regimes and disturbance regimes (the latter relating to APZs and easements plus road verges). This is already in place for some co-occurring threatened species in Penrose SF. Habitat degradation due to insufficiently frequent fire in parts of Budderoo NP warrants inclusion in research and monitoring;
- Determine the extent to which the species is able to resprout post-fire or equivalent disturbance. Examine the factors controlling postfire germination and tag plants to estimate the time it takes recruits to become fire resistant and then mature;
- Detail response of the species to the 2019–20 bushfires and assess impacts of threats on recovery. Where needed, mitigate any adverse threats.
- Monitor to determine the extent to which hybridisation is a concern, if at all.

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Expert Communications / Consultations

Dr Peter Weston (2020), describing co-author of *Persoonia oxycoccoides*; recently retired Curator of Proteaceae at the National Herbarium of NSW; member of the IUCN Proteaceae review panel.

Dr Paul Rymer (2020), Hawkesbury Institute for the Environment, Western Sydney University; author on *Persoonia* ecology.

Dr Nathan Emery (2020), Restoration Biology Officer, The Australian Botanic Garden, Mount Annan (currently researching *Persoonia hirsuta* ecology and threats).

Dr Tony Auld (2020), Senior Principal Research Scientist, NSW DPIE; author on *Persoonia* ecology; member of the IUCN Proteaceae review panel.

Andrew Orme (2020), Identifications Botanist, National Herbarium of NSW.

Dr Stephen Douglas (2020), environmental consultant.

Appendix 1
Assessment against *Biodiversity Conservation Act Regulation 2017* criteria
The Clauses used for assessment are listed below for reference.

Overall Assessment Outcome: Endangered under Clause 4.3 (b) (d) (e i, ii, iii, iv) and Clause 4.4 (b)(e)(i)(ii, AII)

Clause 4.2 – Reduction in population size of species
(Equivalent to IUCN criterion A)
Assessment Outcome: Data Deficient.

(1) - The species has undergone or is likely to undergo within a time frame appropriate to the life cycle and habitat characteristics of the taxon:			
	(a)	for critically endangered species	a very large reduction in population size, or
	(b)	for endangered species	a large reduction in population size, or
	(c)	for vulnerable species	a moderate reduction in population size.
(2) - The determination of that criteria is to be based on any of the following:			
	(a)	direct observation,	
	(b)	an index of abundance appropriate to the taxon,	
	(c)	a decline in the geographic distribution or habitat quality,	
	(d)	the actual or potential levels of exploitation of the species,	
	(e)	the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.	

Clause 4.3 - Restricted geographic distribution of species and other conditions
(Equivalent to IUCN criterion B)
Assessment Outcome: Endangered under Clause 4.3 (b) (d) (e i, ii, iii, iv).

The geographic distribution of the species is:			
	(a)	for critically endangered species	very highly restricted, or
	(b)	for endangered species	highly restricted, or
	(c)	for vulnerable species	moderately restricted,
and at least 2 of the following 3 conditions apply:			
	(d)	the population or habitat of the species is severely fragmented or nearly all the mature individuals of the species occur within a small number of locations,	
	(e)	there is a projected or continuing decline in any of the following:	
		(i)	an index of abundance appropriate to the taxon,
		(ii)	the geographic distribution of the species,
		(iii)	habitat area, extent or quality,
		(iv)	the number of locations in which the species occurs or of populations of the species,
	(f)	extreme fluctuations occur in any of the following:	
		(i)	an index of abundance appropriate to the taxon,
		(ii)	the geographic distribution of the species,
		(iii)	the number of locations in which the species occur or of populations of the species.

Clause 4.4 - Low numbers of mature individuals of species and other conditions
(Equivalent to IUCN criterion C)
Assessment Outcome: Endangered under Clause 4.4 (b)(e)(i)(ii, AII).

The estimated total number of mature individuals of the species is:						
	(a)	for critically endangered species			very low, or	
	(b)	for endangered species			low, or	
	(c)	for vulnerable species			moderately low,	
and either of the following 2 conditions apply:						
	(d)	a continuing decline in the number of mature individuals that is (according to an index of abundance appropriate to the species):				
		(i)	for critically endangered species		very large, or	
		(ii)	for endangered species		large, or	
		(iii)	for vulnerable species		moderate,	
	(e)	both of the following apply:				
		(i)	a continuing decline in the number of mature individuals (according to an index of abundance appropriate to the species), and			
		(ii)	at least one of the following applies:			
			(A)	the number of individuals in each population of the species is:		
				(I)	for critically endangered species	extremely low, or
				(II)	for endangered species	very low, or
				(III)	for vulnerable species	low,
			(B)	all or nearly all mature individuals of the species occur within one population,		
			(C)	extreme fluctuations occur in an index of abundance appropriate to the species.		

Clause 4.5 - Low total numbers of mature individuals of species
(Equivalent to IUCN criterion D)
Assessment Outcome: Vulnerable under Clause 4.5c.

The total number of mature individuals of the species is:			
	(a)	for critically endangered species	extremely low, or
	(b)	for endangered species	very low, or
	(c)	for vulnerable species	low.

Clause 4.6 - Quantitative analysis of extinction probability
(Equivalent to IUCN criterion E)
Assessment Outcome: Data Deficient.

The probability of extinction of the species is estimated to be:			
	(a)	for critically endangered species	extremely high, or
	(b)	for endangered species	very high, or
	(c)	for vulnerable species	high.

Clause 4.7 - Very highly restricted geographic distribution of species–vulnerable species (Equivalent to IUCN criterion D2)
Assessment Outcome: Not met.

For vulnerable species,	the geographic distribution of the species or the number of locations of the species is very highly restricted such that the species is prone to the effects of human activities or stochastic events within a very short time period.