

Conservation Assessment of *Diuris arenaria* D.L.Jones (Orchidaceae)

NSW Threatened Species Scientific Committee, 7th March, 2026.



Photo: *Diuris arenaria* from Tomaree National Park. Credit: Lachlan Copeland © (used with permission).

***Diuris arenaria* D.L.Jones (Orchidaceae)**

Distribution: Endemic to NSW

Current EPBC Act Status: Not listed

Current NSW BC Act Status: Endangered

Proposed listing on NSW BC Act and EPBC Act: Endangered

The NSW Threatened Species Scientific Committee published a notice of final determination for *Diuris arenaria* in 2002 (NSW Scientific Committee 2002). This Conservation Assessment report has found that there is no change to the listing status of this taxon on the schedules of the *Biodiversity Conservation Act 2016*. This report provides an updated assessment for the risk of extinction for the taxon against the criteria in the *Biodiversity Conservation Regulation 2017* using the Common Assessment Method. The Common Assessment Method is the agreed method for assessing the extinction risk of species by the Australian Government and all state and territory governments. This document should be read in conjunction with the 2002 final determination.

Summary of Conservation Assessment

Diuris arenaria was found to be eligible for listing as Endangered under IUCN Criteria B1ab(i,ii,iii)+2ab(i,ii,iii). The main reasons for this species being eligible are: (1) it has a highly restricted geographic distribution with an estimated Area of Occupancy (AOO)

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of 72 km² and Extent of Occurrence (EOO) of 161 km²; (2) it occurs across four threat-defined locations; and (3) it is experiencing observed continuing decline in EOO, AOO, and the area, extent and quality of habitat, due to the threats of habitat clearing, adverse fire regimes, road/easement maintenance activities, increased frequency of drought due to climate change, weeds and recreational activities.

Description and Taxonomy

Diuris arenaria (Sand Doubletail) is a conventionally accepted species (CHAH 2018, PlantNET 2024a) in the Orchidaceae family, within *Diuris*, subgenus *Diuris*, section *Purpureo-albae* (Indsto *et al.* 2009). *Diuris arenaria* was described by Jones (1999) as “a tuberous terrestrial herb growing singly or in loose groups. Leaves basal, semi-erect to lax, conduplicate, usually two, linear to linear-lanceolate, 15–50 cm long, 2–6 mm wide, green, base sheathing, apex acuminate. Scape 15–50 cm tall, slender, green, 1–9 flowered. Sterile bracts closely sheathing, usually two, narrowly lanceolate, 20–70 mm long, 4–8 mm wide, acute to acuminate. Fertile bracts closely sheathing, narrowly lanceolate, 12–45 mm long, 3–5 mm wide, acute to acuminate. Pedicels 10–35 mm long, very slender, straight. Ovaries obovoid, 3–7 mm long, 2–4 mm wide. Flowers porrect, 20–30 mm diameter, mauve to light purple, labellum darker, callus area yellowish, lateral sepals purplish brown. Dorsal sepal porrect in the proximal third, then obliquely erect to erect, ovate to ovate-lanceolate, 10–18 mm long, 7–11 mm wide, apex broadly obtuse to nearly truncate. Lateral sepals obliquely deflexed, parallel or crossed, ensiform to narrowly lanceolate, 15–40 mm long, 1.6–3 mm wide; margins involute; apex asymmetrically acute to acuminate. Petals obliquely erect to recurved, lamina ovate, elliptic or obovate, 10–17 mm long, 6–10 mm wide, apex broadly obtuse, claw 3–6 mm long, blackish, widest near the apex, tapered to the base, curved. Labellum 10–14 mm long, obliquely decurved, 3-lobed, lateral lobes narrowly oblong to oblong, 2.5–5 mm long, 1–2 mm wide, erect and closely flanking the column, outer margins entire to irregular, mid-lobe ovate-cuneate, 8–12 mm long, 7–11 mm wide, margins entire to shallowly crenate, apex obtuse to acute. Labellum callus consisting of two divergent purple ridges extending into the base of the mid-lobe, incurved apically, a yellow patch between them. Column porrect from the end of the ovary, 4.5–5 mm long, 2.5–3 mm wide. Column wings lanceolate, c. 5 mm long, c. 1.8 mm wide at the base, white with a prominent yellow, convolute basal flange, distal margins irregularly erose. Anther narrowly ovate, c. 4 mm long, c. 2 mm wide, purplish brown. Pollinarium c. 2.5 mm long, c. 1.5 mm wide; viscidium elliptic, c. 0.7 mm long; pollinia clavate, 2.2 mm long, white, mealy. Stigma elliptic, c. 3 mm long, c. 2.5 mm wide. Capsules obovoid, 15–20 mm long, 6–8 mm wide, ribbed.”

Diuris arenaria was previously known as *Diuris* sp. aff. *punctata* (Nelson Bay) (Bishop 1996).

Preliminary whole genome sequencing data based on single nucleotide polymorphisms (SNP) suggests *Diuris arenaria* is very closely related to *Diuris alba* (T. Hopley pers. comm. April 2024). The two species can be distinguished primarily by their flower colour and leaf characteristics (PlantNET 2024a; 2024b). *Diuris arenaria* produces mauve to light purple flowers with purplish brown lateral sepals, while *D. alba* has white flowers with lilac or purple markings. *Diuris arenaria* typically has two leaves that are 15–50 cm long and 2–6 mm wide, whereas *D. alba* produces 1–3 leaves that are shorter (10–30 cm long) and narrower (2–3 mm wide).

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Distribution and Abundance

The NSW Scientific Committee (2000a) state that *Diuris arenaria* occurs only on the Tomaree Peninsula near Newcastle in the North Coast botanical subdivision of New South Wales, in the NSW North Coast Bioregion (DAWE 2021).

The species is currently known to occur across four subpopulations (as per the IUCN (2022) definition): Heatherbrae, Tomaree, Worimi, and Tilleringy. The Tomaree subpopulation is divided into three sites managed under the Saving Our Species (SoS) program, but it is likely that all sites are part of the same subpopulation, with current gaps between database records (the largest distance between records is 1.2 km) likely reflective of low survey effort or a lack of recent fire that would prompt flowering of the species in these areas (N. Hunter pers. comm. May 2024). The distance between records within the Tilleringy subpopulation is 1.8 km across contiguous native vegetation which is also likely to be under-surveyed suitable habitat, and thus these records are considered to represent a single Tilleringy subpopulation. However, the Worimi and Tilleringy subpopulations are separated by a distance of 2 km of unsuitable habitat (cleared farmland, a creek and a town), and are therefore considered to be different subpopulations with little genetic exchange likely to occur between them (N. Hunter pers. comm. May 2024).

The majority of the Tomaree and Worimi subpopulations are located within national parks (Tomaree National Park (NP) and Worimi NP), and part of the Tilleringy subpopulation is within the Tilleringy State Conservation Area. The Heatherbrae subpopulation is located on land owned by the Hunter Water Corporation (Transport for NSW 2021).

The total population size of *Diuris arenaria* is estimated at a minimum of 8,733 plants, based on the maximum counts from the last five years for the Worimi (4000 plants), Tilleringy (16 plants) and Tomaree (4,635 plants) subpopulations, and the most recent count from the Heatherbrae subpopulation (82 plants), which has suffered a large decline in recent years due to land clearing (Table 1).

However, monitoring data for this species only records flowering individuals, and the number of flowering individuals fluctuates from year to year based on a range of environmental and other factors (N. Hunter pers. comm. May 2024). Therefore, this figure is likely to be a significant underestimate. For example, surveys for the Heatherbrae bypass recorded 1,447 plants in September 2016, and 329 plants in September 2018, attributed to lower rainfall in 2018 (Transport for NSW 2021). The actual number of plants of *Diuris arenaria* may be larger than the number of flowering plants as a significant number remain dormant or emerge but don't flower in any given year (N. Hunter pers. comm. May 2024). However, no data are available on the number of non-flowering plants, nor on the proportion of plants that flower relative to non-flowering plants. Therefore, this assessment uses the number of flowering plants as a minimum estimate of the species' population size.

Table 1. *Diuris arenaria* subpopulation information

Subpopulation	Number of flowering plants (Year)	Source
Heatherbrae	82 (2021) 329 (2018) 1,447 (2016) 603 (2011)	DCCEEW 2024a DCCEEW 2024a Transport for NSW 2021 DCCEEW 2024a

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Worimi	~4000 (2020) 767 (2018) 2437 (2017) 1445 (2005)		N. Hunter [#] DCCEEW 2024a
Tillingerry	16* (2011 and 2022 records combined)		DCCEEW 2024a
Tomaree	North Tomaree SoS	South Tomaree SoS	N. Hunter [#] N. Hunter [#] DCCEEW 2024a DCCEEW 2024a DCCEEW 2024a
	~1600 (2023)	167 (2023)	
	~1600 (2022)	272 (2020)	
	4363 (2018)	128 (2018)	
	3393 (2017)	216 (2017)	
	1040 (2005)	354 (2005)	DCCEEW 2024a

*Inferred from number of BioNet records (which lack count data), assuming each record represents one individual (DCCEEW 2024a). [#] N. Hunter pers. comm. May 2024.

Area of Occupancy and Extent of Occurrence

The Extent of Occurrence (EOO) is estimated to be 161 km² and is based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2022). The Area of Occupancy (AOO) of *Diuris arenaria* is estimated to be 72 km² based on 2 x 2 km grid cells, the scale recommended by IUCN (2022). Both EOO and AOO were calculated using QGIS (QGIS 2024), enclosing all likely extant survey records and cleaned spatial datasets. Cleaning removed five records with inaccurate location data (SDMPI0118668 and SDMPI0118647 from Salamander Bay; NSW451671, NSW508841 and SDMPI0097151 from Nelson Bay) and 126 records at the Heatherbrae subpopulation occurring in areas now destroyed by the Heatherbrae Bypass project, leaving 7,093 clean records used in the assessment (some records contained count data of multiple plants resulting in a population estimate higher than the number of records). Based on these estimates, *D. arenaria* has a highly restricted AOO and EOO.

Number of Locations

Diuris arenaria is found at four threat-defined locations when considering the most serious plausible threats of habitat clearing and damage from road or easement maintenance activities. The potential of this threat to cause the effective elimination of entire subpopulations is illustrated by Heatherbrae Bypass project, which recently caused the near-complete loss of the Heatherbrae subpopulation with the majority of the plants being cleared (Transport for NSW 2021), and the subpopulation is now largely destroyed (N. Hunter pers. comm. May 2024). Other subpopulations occur partially inside conservation reserves (although only one of the 16 records from the Tillingerry subpopulation is reserved). However, the proposed Fingal Bay Link Road project, could result in the loss of part of the Tomaree subpopulation within Tomaree NP if the project restarts. This project has three possible alignment options, two of which run through Tomaree NP (Transport for NSW 2020b). Port Stephens Council has already acquired part of Tomaree NP for one of the possible alignments, and a second alignment proposes a new acquisition of a separate part of the Park (Transport for NSW 2020b). Therefore, even subpopulations ostensibly protected within a National Park cannot be considered protected from the threat of clearing, and thus, the entirety of all subpopulations are considered possibly at risk from this threat. Additionally, most of the BioNet records for *D. arenaria* are located along easements and road verges. Although most of these areas are currently well managed

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(particularly within the NPWS estate), a change or error in management regime (e.g., a switch from slashing to herbicide application) could plausibly result in the loss of the majority of records in the Tomaree, Worimi and Tillungerry subpopulations in a very short space of time.

Ecology

Habitat

Diuris arenaria occurs in coastal heath and dry grassy eucalypt forest on sandy flats with deep white or grey sand and in gently undulating country in eucalypt forest with a grassy or heathy understorey on clay soil (DCCEEW 2024b). Associated species can include *Angophora costata*, *Corymbia gummifera*, *Eucalyptus pilularis*, *Banksia serrata*, *Monotoca scoparia*, *Leucopogon lanceolatus*, *Themeda triandra*, *Pteridium esculentum*, *Dodonaea triquetra*, *Epacris pulchella*, *Hibbertia vestita*, *Pomax umbellata*, *Andropogon virginicus*, *Cynodon dactylon*, and *Imperata cylindrica* (AVH 2024).

The species frequently occurs in semi-disturbed slashed road verges, easements or management trails, and some authors suggest that *Diuris arenaria* favours a microhabitat of cleared firebreaks and service tracks (Transport for NSW 2021). However, this may not be the case because *D. arenaria* does occur in undisturbed vegetation, but usually only flowers after fire in such habitat (DCCEEW 2024a; N. Hunter pers. comm. May 2024). The large number of records from slashed road verges and easements is likely influenced by the relative ease of access and detectability in such areas, combined with the stimulatory effect on flowering of periodic slashing during the orchid's dormant season (M. Freestone pers. obs.).

Life History

Diuris arenaria flowers from August to September, with most BioNet records from mid-September (DCCEEW 2024a, 2024c). Flowering is reduced in dry years, when many individuals likely persist as non-flowering or dormant plants (Transport for NSW 2021). While *Diuris arenaria* possesses a tuber and can persist in a dormant state during unfavourable conditions, long periods of dormancy are associated with increased mortality of adult plants in other Australian terrestrial orchids (Coates *et al.* 2006) and this is likely to also be the case for *D. arenaria*.

Subpopulations appear positively responsive to disturbance (such as slashing or fire) during the dormant season (likely November–March/April), which can stimulate flowering, with *Diuris arenaria* displaying a strong post-fire flowering response (N. Hunter pers. comm. May 2024). However, fire during the growing season can be detrimental to the persistence of Australian terrestrial orchids (Jasinge *et al.* 2018). Tubers at this time may have insufficient resources to sustain a second flush of leaf production, resulting in tuber mortality and consequently plant senescence (Jasinge *et al.* 2018). Seedlings generally do not develop tubers until spring, and they are likely to be located at a very shallow depth, suggesting fires during the non-dormant season are likely to cause high seedling mortality (M. Freestone pers. obs. 2024).

Reproductive Ecology

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Specific information on pollinators of *Diuris arenaria* is lacking. However, *Diuris* species are thought to be pollinated mainly by native bees in the genus *Exoneura*. Other Hymenoptera including the sawfly *Eurys pulcher* Benson, 1934 and a potter wasp (*Paralastor* species) were reported visiting flowers of the closely-related *Diuris alba* (Indsto *et al.* 2007). Many *Diuris* species have flowers that resemble those of Fabaceae and are thought to use food deceptive guild mimicry to deceive pollinators (Beardsell *et al.* 1986; Indsto *et al.* 2006; Scaccabarozzi *et al.* 2020). *Diuris alba* produces small amounts of nectar and has relatively high rates of fruit set that are higher in subpopulations growing with *Dillwynia retorta* (Fabaceae) than in those where this species is lacking (Indsto *et al.* 2007). *Exoneura* bees show some preference for the flowers of *Dillwynia retorta*, but are more generalist foragers than bee species known to pollinate other *Diuris* species (Indsto *et al.* 2007). This suggests that the pollination mechanism of *D. alba* (and by inference *Diuris arenaria*) is partial Fabaceae guild-mimicry with food reward (Indsto *et al.* 2007).

Diuris species take around three years to reach maturity in cultivation (M. Freestone pers. obs. 2024). It is not known what the maturity and generation length is in the wild, and the clonality of this species makes generation length difficult to estimate.

Seed Ecology

Diuris species reproduce via seed, and each plant has a single underground tuber, replaced annually, that allows it to persist underground for long periods. Orchid seeds are generally minuscule in size and wind-dispersed and are not known to form a persistent soil seedbank (Batty *et al.* 2000). *Diuris* species, like all orchids, require a fungal symbiont for germination and nutrient uptake. *Diuris arenaria* associates with the fungus *Tulasnella calospora* (Sommerville *et al.* 2008). *Ex situ* trials have shown that the seed and fungus of *D. arenaria* can be stored together in long-term storage encapsulated in alginate beads (Sommerville *et al.* 2008). However, when not frozen in long-term storage, *Tulasnella* fungi lose their ability to germinate orchid seed rapidly with increasing time following their isolation from adult plants (Reiter *et al.* 2023).

Cultural significance

Diuris arenaria occurs on the traditional lands of the Worimi First Nations people and in the Worimi Local Aboriginal Land Council (NPWS 2015). It is a culturally significant species for the Worimi First Nations people, with a cultural dance and song celebrating the species (NSW Government 2024).

This assessment is not intended to be comprehensive of the traditional ecological knowledge that exists for *Diuris arenaria*, or to speak for Aboriginal people. Aboriginal people have a long history of biocultural knowledge, which comes from observing and being on Country, and evolves as it is tested, validated, and passed through generations (Woodward *et al.* (Eds.) 2020). Aboriginal peoples have cared for Country for tens of thousands of years (Bowler *et al.* 2003; Clarkson *et al.* 2017). There is traditional ecological knowledge for all plants, animals and fungi connected within the kinship system (Woodward *et al.* (Eds.) 2020). Traditional ecological knowledge referenced in this assessment belongs to the relevant knowledge custodian and has been referenced in line with the principals of the NSW Indigenous Cultural and Intellectual Property protocol (ICIP) (Janke and Company 2023).

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Threats

Diuris arenaria is threatened by clearing, disturbance and fragmentation of habitat, damage during road management activities, increased frequency of drought due to climate change, adverse fire regimes, weed invasion and recreational activities. Of the threats listed by DCCEEW (2024c), illegal rubbish dumping although not currently a major issue (S. Bell pers. comm. April 2024; N. Hunter pers. Comm. May 2024) may be a significant future threat to the species.

Clearing, disturbance and fragmentation of habitat

Habitat clearance has been observed and threatens every *Diuris arenaria* subpopulation, including subpopulations located outside and inside the conservation estate. Parts of all subpopulations have likely been destroyed in the past.

An estimated 721 plants in the Heatherbrae subpopulation were recently destroyed during the construction of the Heatherbrae Bypass (Transport for NSW 2021), encompassing the majority of BioNet records from this subpopulation (DCCEEW 2024a). Of the 721 plants within the footprint of the Heatherbrae Bypass, 560 plants occurred in an area covered by a previous industrial development approval (Transport for NSW 2021). Clearing of 25 ha of native vegetation for the industrial development occurred in 2014 but work then stopped. The site was then re-cleared in 2023–2024 for the construction of the bypass, and all 560 plants are inferred to have been destroyed, along with an additional 121 plants in the remainder of the project footprint (Transport for NSW 2021). The Heatherbrae Bypass project destroyed an estimated 63.5 ha of potential habitat for *D. arenaria* (Transport for NSW 2021).

An additional project that has recently resulted in the loss of *Diuris arenaria* plants and habitat at Worimi is the Nelson Bay Road Upgrade (an estimated 18 plants lost; Transport for NSW 2020a). The proposed Fingal Bay Link Road will affect the Tomaree subpopulation, and includes proposals to acquire and fragment part of Tomaree NP (Transport for NSW 2020b). This project is currently on hold (Transport for NSW 2024), but it remains a threat if the project is restarted in future. It is possible that additional infrastructure or other development projects that affect *D. arenaria* may be proposed in the future.

Sand mining is a major threat to the species' habitat, particularly around Salt Ash on the periphery of Worimi NP (Worimi Conservation Lands). Recent records occur in and around this area of sand mining, suggesting that the destruction of the species' habitat in this area has likely resulted in the loss of *Diuris arenaria* plants.

Urban or industrial development is a significant threat to the habitat of *Diuris arenaria*. Industrial development destroyed 25 ha of the species' habitat and an unknown number of plants at Heatherbrae in 2014. A proposal to undertake a property development at the former Gan Gan Army Base has the potential to destroy the species' habitat (Port Stephens Examiner 2020; N. Hunter pers. comm. May 2024).

'Clearing of native vegetation' is listed as a Key Threatening Process under the NSW *Biodiversity Conservation Act 2016* (NSW Scientific Committee 2001) and 'land clearance' is listed as a Key Threatening Process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (TSSC 2001a).

Accidental damage whilst maintaining the road verge, slashing and spraying of easements

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Diuris arenaria frequently occurs in slashed vegetation along road verges, easements and management trails (DCCEEW 2024a). Slashing likely stimulates flowering of the species by reducing competition from canopy trees and mid-storey shrubs, as has been observed for other terrestrial orchids from heathy vegetation communities (Duncan *et al.* 2005). However, slashing regimes must be timed so they occur during the orchid's dormant or non-flowering period (likely November–May). Slashing outside of this time likely removes any chance of recruitment and may cause mortality resulting in population declines, especially if sustained over a number of years. Spraying orchids with herbicide at any time of year is likely to have negative consequences, either by directly killing the orchids or through indirect effects on their mycorrhizal fungi (Jusaitis 2017). However, the threats posed by slashing and herbicide use are currently managed in the NPWS estate through liaison with the management authorities (including AusGrid and Hunter Water), and the risk posed by this threat has been reduced as a result (N. Hunter pers. comm. May 2024).

Adverse fire regimes

The mechanisms by which fire can affect species are diverse and can be direct or indirect. Fire seasonality is perhaps the most likely threat to *Diuris arenaria*, inferred from other terrestrial orchid species (Jasinge *et al.* 2018). *Diuris arenaria* may be threatened by out-of-season fires during the non-dormant phase (likely approximately April–October). When fire occurs out of season there are a number of mechanisms that lead to recruitment failure and reduce the recovery potential of species following fire (DAWE 2022). These include seedling mortality due to desiccation as a consequence of the interaction between out of season fires and fire-hydrological interactions (Miller *et al.* 2019); low rate of seed production due to sub-optimal flowering cues, particularly by species that rely on seasonal pollinators or specific flowering conditions (Brown *et al.* 2017); and disruption to processes that facilitate post-fire recovery and limit dispersal (Jasinge *et al.* 2018; Keith *et al.* 2020), particularly for species with seasonal growing conditions such as orchids. If fires occur soon after leaf emergence, the tubers may store insufficient resources to sustain a second flush of leaf production, resulting in tuber mortality (Jasinge *et al.* 2018). Out of season fire can also affect mycorrhizal fungal communities (Jasinge *et al.* 2018) or pollinator communities (Brown *et al.* 2017). Prescribed burns are likely to be the main source of out-of-season fire, given the species occurs close to urban environments. However, the threat of out-of-season fire may interact with climate change threats, particularly the projected decrease in winter rainfall (threat detailed below), to increase the risk of out-of-season bushfires. Dry conditions during the orchid's winter growing season may increase the risk of winter bushfires, with likely negative consequences for *D. arenaria*.

Long-term fire exclusion (low fire frequency) may also be a threat. *Diuris arenaria* occurs in naturally fire-prone vegetation, located in proximity to human habitation. The species appears to be fire-stimulated, with flowering events occurring following fires in the Worimi subpopulation (N. Hunter pers. comm. May 2024). Plants in non-disturbed (e.g., unslashed) vegetation seldom flower in the absence of fire, and therefore the long-term exclusion of fire in these subpopulations is a suspected threat to *D. arenaria*. Parts of Tomaree NP have recently been burnt, and follow-up surveys for *D. arenaria* may provide information on the species' response to such fire events (N. Hunter pers. comm. May 2024). Very high fire frequency (e.g., every 1–2 years) may also threaten the species and its habitat (S. Bell pers. comm. April 2024) by reducing the capacity

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for the species to recruit during inter-fire periods, particularly if it affects pollinators (Brown *et al.* 2017). Maximum and minimum tolerable fire intervals are unknown for this species. 'High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition' is listing as a Key Threatening Process under the NSW *Biodiversity Conservation Act 2016* (NSW Scientific Committee 2000b), while 'Fire regimes that cause declines in biodiversity' is a listed Key Threatening Process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (DAWE 2022).

Increased frequency of drought due to climate change

Climate change projections by CSIRO (Grose *et al.* 2015) for the subregion encompassing the range of *Diuris arenaria* project with very high confidence that average temperatures will continue to increase in all seasons, with more hot days and warm spells. Fewer frosts, increasing intensity of extreme rainfall events and a harsher fire-weather climate is projected in the future with high confidence, while decreases in winter rainfall and increases in time spent in drought are projected with medium confidence (CSIRO and BOM 2022). Flowering of *Diuris arenaria* appears to be reduced in dry years (Transport for NSW 2021), when the species likely persists as non-flowering or dormant plants. While *D. arenaria* possesses a tuber and can persist in a dormant state during unfavourable conditions, long periods of dormancy are associated with increased mortality of adult plants in other Australian terrestrial orchids (Coates *et al.* 2006). Therefore, decreases in winter rainfall are likely to have an adverse effect on this species, which is likely dependent on adequate soil moisture during the winter growing season for reproduction (Janissen *et al.* 2021). Drought may cause increased adult mortality (Pfeifer *et al.* 2006) and alter site hydrology leading to the habitat becoming unsuitable for the species. Therefore, it is plausible that climate change represents a real threat to the long-term survival of the species, particularly through increased adult mortality and decreased recruitment, although additional research is needed to confirm the severity of this threat. 'Anthropogenic Climate Change' is listed as a Key Threatening Process under the NSW *Biodiversity Conservation Act 2016* (NSW Scientific Committee 2000c), while 'Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases' is listed as a Key Threatening Process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (TSSC 2001b).

Competition for resources by Bitou bush (Chrysanthemoides monilifera) and other weeds

Bitou bush and several grassy weeds occur in parts of the species' subpopulations and are a minor threat (N. Hunter pers. comm. May 2024). These invasive weed species are likely to compete with *Diuris arenaria* for resources and may degrade habitat quality. However, the threat from invasive weeds such as bitou bush may increase if weed management works cease for extended periods of time. Heavy weed infestations may prevent germination of *D. arenaria*, thereby reducing recruitment – although research is required to better understand these interactions. 'Invasion of native plant communities by Bitou bush and boneseed' is listed as a Key Threatening Process under the NSW *Biodiversity Conservation Act 2016* (NSW Scientific Committee 1999) and 'Novel biota and their impact on biodiversity' is listed as a Key Threatening Process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (TSSC 2013).

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Recreational activities causing accidental damage to the species

Offroad motorbikes are a localised threat to some subpopulations, particularly in Tomaree NP (N. Hunter pers. comm. May 2024). Bikes can cause soil disturbance and introduce weeds and pathogens, which may negatively affect the orchid and its habitat. The threat of bikes appears to have increased in recent years (N. Hunter pers. comm. May 2024).

Assessment against IUCN Red List criteria

For this assessment it is considered that the survey of *Diuris arenaria* has been adequate and there is sufficient scientific evidence to support the listing outcome.

Criterion A Population Size reduction

Assessment Outcome: Data deficient

Justification: Monitoring data from *Diuris arenaria* subpopulations is heavily influenced by environmental conditions, such that no inferences can be drawn from variable monitoring data at the Worimi, Tomaree or Tillingerry subpopulations, which are assumed to be stable. The Heatherbrae subpopulation has declined due to vegetation clearing (it is estimated that the loss of individuals from vegetation clearing is 739 plants with 721 plants lost from the Heatherbrae Bypass and 18 individuals lost from the Nelson Bay Road Upgrade, equating to approximately 8.5% of the total *Diuris arenaria* population). However, it is unclear how often such losses might occur over a 3-generation period, and as such, projecting rates of ongoing population decline is inappropriate. Although additional declines of the species' population are likely, due to planned and proposed future development projects, the quantity of plants likely to be lost and the timing of these losses are uncertain and variable. Therefore, there are insufficient data to assess the decline of *D. arenaria* under Criterion A.

Criterion B Geographic range

Assessment Outcome: Endangered under Criterion B1ab(i,ii,iii)+2ab(i,ii,iii)

Justification: *Diuris arenaria* is endemic to a small area on the Tomago Sandbeds on the NSW Central Coast and has a highly restricted geographic distribution. The Area of Occupancy (AOO) is estimated to be 72 km², meeting the threshold for Endangered. The Extent of Occurrence (EOO) is estimated at 161 km², also meeting the threshold for Endangered.

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

- 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 for Endangered, due to the species having ≤5 threat-defined locations.

Justification: *Diuris arenaria* is found at four threat-defined locations when considering the most serious plausible threats of habitat clearing and damage from road or easement maintenance activities. The potential of this threat to cause the effective elimination of entire subpopulations is illustrated by Heatherbrae Bypass project, which recently caused the near-complete

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loss of the Heatherbrae subpopulation. Other subpopulations are threatened by proposed future projects, even those ostensibly protected within a National Park, and thus, the entirety of all subpopulations are considered possibly at risk from this threat. Additionally, most of the BioNet records for *D. arenaria* are located along easements and road verges and are threatened by changes to management regimes.

The species is not found in small subpopulations that are likely to be unviable, although likely applicable minimum viable population sizes for this species are unknown. Therefore, there are insufficient data to determine if the species is severely fragmented according to IUCN (2022).

- 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 continuing decline, observed for (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and quality of habitat.

Justification: There is continuing decline in the extent and quality of habitat of *Diuris arenaria*. Clearing for road infrastructure projects has resulted in an observed loss of habitat and individuals, which has caused a reduction in EOO of 9 km² and a reduction in AOO of 12 km² due to the spatial location of the losses (on the western end of the species' range). Declines in EOO and AOO are inferred due to industrial development and sand mining. Adverse fire regimes, road/easement maintenance activities, climate change, weed invasion, and recreational activities threaten the species' subpopulations and the quality of the species' habitat is inferred to be declining as a result.

- c) Extreme fluctuations.

Assessment Outcome: Data deficient

Justification: The number of flowering individuals of *Diuris arenaria* can vary depending on recent rainfall and management conditions. However, this does not suggest a fluctuation in the number of mature individuals, as many individuals likely persist as dormant or non-flowering plants during such years.

Criterion C Small population size and decline

Assessment Outcome: Data deficient

Justification: The minimum estimated number of mature individuals of *Diuris arenaria* is 8,733 plants, meeting the threshold for Vulnerable.

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

- C1. An observed, estimated or projected continuing decline of at least: 25% in 3 years or 1 generation (whichever is longer) (CR); 20% in 5 years or 2 generations (whichever is longer) (EN); or 10% in 10 years or 3 generations (whichever is longer) (VU).

Assessment Outcome: Data deficient

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Justification: The Heatherbrae subpopulation has declined due to vegetation clearing, with the Heatherbrae Bypass project observed to have caused the loss of 8.3% of the total *Diuris arenaria* population (721 plants) when the footprint was cleared in 2023–2024 (Transport for NSW 2021). The Nelson Bay Road Upgrade is projected to cause the loss of an additional 0.2% of the species' population (18 plants) in the near future (Transport for NSW 2020a). However, not all populations are declining, and the number of individuals in each population is highly variable through time (Table 1). Thus, there is insufficient data to determine whether the species is suffering a continuing decline that will meet the required thresholds for criterion C1.

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

Assessment Outcome: Not met

Justification: There is insufficient data to confirm a continuing decline in the number of mature individuals of *Diuris arenaria* and the species does not meet the thresholds of the subcriteria below, and therefore, does not meet the threshold for C2.

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: Not met

Justification: The largest subpopulation of *Diuris arenaria* (Worimi) has an estimated ~4000 mature individuals.

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

Assessment Outcome: Not met

Justification: The largest subpopulation (Worimi) contains an estimated 46% of the total population of mature individuals.

- b. Extreme fluctuations in the number of mature individuals

Assessment Outcome: Data deficient

Justification: Extreme fluctuations in the number of mature individuals is not known for this species.

Criterion D *Very small or restricted population*

Assessment Outcome: Not met

Justification: The species' minimum number of mature individuals is estimated at 8,733 plants and its AOO is estimated at 72 km².

To be listed as Vulnerable under D, 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: Not met

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Justification: The species' number of mature individuals is estimated at 8,733 plants.

D2. Restricted area of occupancy (typically <20 km²) 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 species' AOO is estimated at 72 km² and it is found at four threat-defined locations. It is plausible that threats to this species, particularly land clearing, could result in the rapid elimination of each subpopulation individually (*i.e.*, sufficient to justify each subpopulation as a separate location, see discussion under Criterion B above; IUCN 2024). However, given the site-based nature of land clearing, it is unlikely that such events would occur at all subpopulations within a very short period of time (*e.g.*, within one or two generations, 9–18 years; IUCN 2024). Therefore, it is considered that *D. arenaria* does not meet the threshold for D2.

Criterion E Quantitative Analysis

Assessment Outcome: Data deficient

Justification: A quantitative analysis of extinction probability is not currently available for this species.

Conservation and Management Actions

Diuris arenaria is currently listed on the NSW *Biodiversity Conservation Act 2016* and a conservation project has been developed by the NSW Department of Planning and Environment under the Saving our Species program. The conservation project identifies priority locations, critical threats and required management actions to ensure the species is extant in the wild in 100 years. *Diuris arenaria* sits within the site-managed management stream of the SoS program. There is no National Recovery Plan for this species. These conservation and management actions have been based on the species' Conservation Action Plan (DPE 2022).

Habitat loss, disturbance and modification

- Do not permit the species or its habitat to be cleared.
- Ensure surveys for this species are undertaken at an appropriate time of year, with appropriate survey effort, during years of average or above average autumn–winter rainfall, and following an appropriate disturbance (*e.g.* fire, slashing), which is necessary to stimulate flowering plants especially in undisturbed vegetation. Results from surveys that do not meet these conditions should be considered to provide provisional information only, particularly in the case of undisturbed vegetation that has not been subject to recent fire, because the species is unlikely to be detectable under such conditions.
- Continue regular slashing maintenance regimes of road verges, easements and management tracks throughout the species' range. Where possible, avoid slashing from June–October inclusive.

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- Do not use herbicide in a non-targeted way on road verges, easements or management tracks within the range of *Diuris arenaria*.
- Consider physically marking the extent of *Diuris arenaria* subpopulations along road verges or easements to avoid accidental damage.
- Legally protect the surviving part of the *Diuris arenaria* subpopulation at Heatherbrae (e.g. by incorporation into the conservation reserve estate).
- Implement a fire management regime that avoids out-of-season fire during the orchid's growing season (likely April/May to October).
- Ensure all records of the species are uploaded to BioNet promptly so that land managers are aware of newly discovered plants/subpopulations.

Invasive species

- Continue the control of Bitou Bush and other weeds where necessary.

Ex situ conservation

- Undertake targeted seed and mycorrhizal fungal collection for ex situ seed banking and propagation. Seed/tissue collection and storage should be conducted in accordance with best practice guidelines and procedures (Martyn Yenson *et al.* 2021 or Commander 2018). Collect seed from all subpopulations to maximise genetic diversity of ex-situ collections. Fungal collections of *Tulasnella* (e.g., from *Diuris*) rapidly lose the ability to germinate seed and should be cryogenically stored immediately following isolation (Reiter *et al.* 2023).

Stakeholders

- Liaise with managers of road verges and easements where *Diuris arenaria* occurs, to ensure that maintenance activities do not threaten the species.
- Engage cultural knowledge custodians in conservation actions, including the implementation of Indigenous fire management and other survey, monitoring and management actions. Enable the sharing of knowledge, while ensuring the processes and protocols to record, store, and share any knowledge are agreed and appropriately resourced. Information on the application of integrated Caring for Country practices to protect and enhance habitat is of critical importance.
- Engage local residents to participate in surveys, monitoring or other conservation actions for the species.

Survey and Monitoring priorities

- Conduct further targeted surveys in areas of suitable habitat, particularly following fire.
- Continue monitoring of flowering individuals at SoS sites.
- Consider undertaking a detailed monitoring research project on a representative sample of the species' population, to document all individual plants (i.e. that are accurately located and tagged), recording leaf emergence,

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flowering and pollination data (e.g. number of pollinated flowers), which could help answer questions about the species ecology. This would be particularly useful if undertaken before and after fire, and when monitored over a number of years, which could provide information on the number of non-flowering individuals, and their response to fire and climatic cues.

- Monitor threats at all subpopulations.

Information and Research priorities

- Identify the pollinator/s of *Diuris arenaria* and conduct research into their ecology.
- Conduct research into the ecology of *Diuris arenaria*, including estimating the number of non-flowering mature individuals, fire response and tolerable fire intervals, emergence and flowering cues (e.g., slashing/fire requirements; rainfall timing and amount), pollination rates, recruitment, fire ecology, etc.
- Correct records with inaccurate location data from the Tomaree subpopulation (BioNet DCCEEW 2024a).

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APPENDIX 1

Assessment against *Biodiversity Conservation Regulation 2017* criteria

The Clauses used for assessment are listed below for reference.

Overall Assessment Outcome:

Diuris arenaria was found to be Endangered under Clause 4.3(b)(d)(e ii,iii)

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 ii,iii)

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:	

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	(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: Data deficient.

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.

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Clause 4.5 - Low total numbers of mature individuals of species

(Equivalent to IUCN criterion D)

Assessment Outcome: Not met

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.
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